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Posted Date: 23 August 2024

doi: 10.20944/preprints202408.1741.v1

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 doi:10.20944/preprints202408.1741.v1

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Emerging Trends in Sustainable Digital Transformation Strategies Across Higher Education Institutions: A Systematic Review

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Abstract: The technological revolution has contributed significantly to environmental and social issues worldwide. In higher education institutions, there is a theoretical gap in systematic reviews on the integration of digital transformation into sustainability. This systematic review of the literature aims to address this gap by exploring how digital transformation improves sustainability in higher education institutions, identifying emerging trends and best practices for effective strategies. Using the PRISMA guidelines, the study conducted a comprehensive search in the Scopus database, producing 1,686 publications from 2019 to 2024. The findings reveal a widespread awareness of digital technology integration but highlight a lack of consensus on sustainable integration strategies. Furthermore, the results demonstrate that educational achievements can be enhanced through tools and methodologies that align with the Sustainable Development Goals of the United Nations. The analysis identifies three primary domains: sustainability capabilities enabled by digital transformation, innovative sustainable approaches, and the conceptualisation of sustainability in higher education. The incorporation of digital tools, such as AI chatbots, institutions foster innovation and achieves sustainability objectives, thus transforming teaching and learning approaches. This review contributes significantly to understanding the role of digital transformation in promoting a sustainable and digitally enabled future in higher education.

Keywords: sustainability; sustainable development; digital transformation; higher education; technology; innovation

1. Introduction

Rapid advances in digital technologies have led to a new era of unprecedented change, transforming various aspects of our lives, including the way we approach Sustainable Development (SD). This study identified the existence of digital transformation (DT) as the ability to improve efficiency, optimise resource utilisation, and drive innovation which have become a crucial component in the pursuit of sustainability.

Sustainable development and digitalisation are emerging as intertwined megatrends, leading to paradigm shifts in economic and social systems [1,2]. Government agencies and leading companies have recognised the importance of integrating environmental sustainability into the digital revolution, but this integration remains a complex and multifaceted challenge that requires further exploration and innovation [3,4].

The literature suggests that DT has both positive and negative impacts on environmental sustainability [5,6]. On the one hand, the application of modern digital technologies such as artificial intelligence (AI), cloud computing (CC), big data (BD) analytics, Internet of Things (IoT), and blockchain contributes to sustainable urban development, efficient resource management, and effective pollution control [7,8]. However, the energy-intensive nature of data centres and the production of electronic waste pose significant challenges that must be addressed [1].

 doi:10.20944/preprints202408.1741.v1

Rapid advances in technology have transformed in various industries and the field of higher education (HE) is no exception. As a result, higher education institutions (HEIs) are now faced with the imperative to adapt to the dynamic demands and tools of the digital age, a process often referred to as "digital transformation" [6]. Therefore, it is significant to understand that transformation is not only a matter of technological change but also necessitates a cultural shift within institutions [9,10]. However, DT in HE encompasses a wide range of initiatives, from the modernisation of educational services through digital tools and techniques to the redefinition of the student experience. Thus, it will allow the HEIs to undergo a transformation of critical operations, including their product portfolio, delivery methods, integration, and organisational structure [11]. For this purpose, this process requires a combination of technical and cultural change, presenting institutions with the challenge of guiding the transition to a digital-centric culture.

Moreover, the strategic perspective focused more on DT strategies in HE are aimed at increasing revenue, enhancing productivity, generating value through innovative practices, and developing a strong brand reputation and novelty [12,13]. As the trendy and tech-savvy generation of students demands greater access to digital education services. Therefore, it remains the responsibility of HEIs to respond on adopting a wide range of digital tools and techniques, transforming everything from the learning process to institutional management to achieve positive outcomes. Nevertheless, the effective integration of DT in higher education is not devoid of obstacles. To promote creativity and innovation, institutions should focus on developing the ability to establish a new corporate culture that allows professionals to interact effectively. This can be achieved by implementing strategies recommended by Miglionico [14], Bokolo [15] and Guo, Geng, and Yao [16]. The objective of this study is to identify the current patterns and developments related to SDT techniques in HEIs. This study provides a thorough examination of the existing literature on the status of DT in higher education.

1.1. Higher Education and Sustainable Digital Transformation

A significant portion of the current literature on SDT strategies highlights trends that are highly relevant to DT strategies within HEIs. Key topics including information technologies, DT itself, innovation, and sustainability are frequently discussed in this context. Given the focus on sustainability within HEIs, understanding these broader trends and implications of DT in the post-pandemic era informs strategic decisions [13,17,18]. The intersection of sustainability and DT promotes green industries such as smart manufacturing, sustainable production, and smart farming that can contribute to the sustainability of the planet by efficiently using resources [19].

Sustainability undoubtedly is seen to be amongst the fastest growing areas of focus, however, there is a gap in understanding how to effectively apply this knowledge to the use of digital technologies [20,21]. For the most part of it, there is a research gap in specific discussions on DT strategies within HEIs, distinct from broader trends in the implementation of Industry 4.0 and Society 5.0 implementation [22,23]. Similarly, limited research exists on environmental management initiatives in HEIs, particularly in regions where such initiatives may be entirely absent [24,25].

The broader trends, which encompasses the impact of digitalisation on business practices, manufacturing, agriculture, transportation, and energy within the context of DT [26,27]. Subsequent to that, the study highlights the interdisciplinary nature of many sustainability initiatives in HEIs. Understanding different levels of engagement with sustainability is crucial for developing effective strategies [28]. Noted in the study too, the effort of HEIs to strive on making educational resources accessible to diverse audiences while minimising environmental impact, underscoring the relevance of this study's findings to the broader goals of HEIs [29]. Equally important, the understanding of emerging research themes and trends, HEIs could guide the development of curricula and research agendas related to SDT strategies.

Sustainable Development is being promoted worldwide across all sectors, with a focus on addressing sector-specific challenges that arise when human activities transition into the digital realm. These two notable social trends are the focus of this research [20,30]. In 2000, the General Assembly of the United Nations issued its Millennium Declaration which identified and set goals to

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achieve eight Millennium Development Goals by 2015 [31]. The Millennium Development Goals focused primarily on eradicating extreme and absolute poverty and hunger for the poorest populations in low-income countries, achieving universal primary education, promoting gender equality, protecting the environment, and building global partnerships for development [32]. Recognising the ongoing challenges and the critical role of sustainability in society, the 2030 Agenda of the United Nations expanded these goals to 17 comprehensive Sustainable Development Goals (SDGs). The 17 Sustainable Development Goals aim to address a broader range of global issues and promote long-term sustainable development [33,34].

1.2. The Need for a SLR on SDT Strategies in HEIs

As early as 2002, researchers envisioned the potential of digital technology to boost economic growth while reducing environmental burdens [35,36]. This potential extends to knowledge dissemination, improved management practices, and increased accessibility, impacting not only businesses, but also broader institutions [29,37,38]. In recent years, the increase in the integration of digital technologies within HEI governance highlights the crucial role that HEIs play in promoting and achieving the SDGs through education, research, and community engagement [39–41]. Based on the 2030 Agenda, the SDGs offer a comprehensive framework that critically aids in achieving sustainability within HEIs. However, considering additional frameworks and institutional goals can further enhance the realisation of these objectives. Guo and Zeng [42] highlight student satisfaction as a key factor in evaluating the effectiveness of DT strategies.

This study brings an understanding towards the complexities of digitalisation and sustainability, and it remains possible to examine how HEIs leverage this knowledge. The importance of this study in that systematic review focused on HEIs is necessary considering the growing interest in digital sustainability, particularly its intersection with global development goals [43–45]. For an example, the Massive Open Online Courses (MOOCs) underscore the importance of upfront sustainability planning within HEIs, even if such strategies might not be directly adaptable [46]. Therefore, the alignment must be based on a broader discussion on digital sustainability, as highlighted by a special issue of First Monday exploring its sociological aspects and its role in establishing a sustainable world [32].

Education infused with the values of SD encourages stakeholders to act responsibly, guaranteeing environmental resilience, economic viability, and the creation of a safe environment for current and future generations [44]. Noted in the study too is that HEIs remains to be the cornerstones of knowledge production and dissemination, in response to a changing society and the rise of digital technologies, are now undergoing significant changes. The once calm waters of traditional education are now being disrupted by powerful currents of change [47–49]. However, our focus remains specifically on HEIs and their efforts toward SDT strategies. Narrowing the scope, this Systematic Literature Review (SLR) aims at evaluating the effectiveness of DT initiatives within the context of HE and considering the implications for sustainability practices and outcomes. Previous studies suggests that digitalisation promotes equity, inclusivity and sustainability in education systems [50,51].

1.3. The Research Questions

Although several research examined distinct aspects of DT in education, a gap exists in HEI research on how digital technologies can be leveraged to contribute to sustainability [52–56]. This review aims to:

- **Map trends:** understanding the development of publications on SDT strategies in HEIs over time and in terms of geographic distribution, authorship, and publication patterns.
- **Characterise existing research:** understand the characteristics of studies on SDT strategies, indirectly contributing to evaluating their effectiveness by identifying what approaches and frameworks are being used in achieving environmental, social, and economic sustainability goals.

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- **Identify Opportunities and Risks:** to identify best practices associated with SDT in HEIs, thus synthesising key findings for the review.

This study incorporates relevant research both indirectly and directly related to understanding how HEIs can leverage digital technologies to achieve a sustainable future. In efforts to create a well-rounded systematic review that considers the broader landscape as well as specific findings within HE. This study adopts recent methods of reviewing the literature that have been more thorough by applying systematic or structural approaches. The Preferred Reporting Items for Systematic Literature Reviews the PRISMA guidelines were used to review the literature of articles published in the past five (5) years in Elsevier's Scopus database [57].

The results presented are based on research questions that guide the search and analysis of the information. The results will provide the research agenda and strategies for researchers seeking to fulfil the multi-pronged goals of SD through digital technology transformation.

Research Question: What are the emerging trends associated with sustainable digital transformation strategies in higher education institutions?

PICO FRAMEWORK

The PICO framework is a widely recognised approach in conducting systematic literature reviews [58]. This study considers the use of the PICO framework to explore the emerging trends associated with SDT strategies in HEIs.

The research question "**What are the emerging trends associated with sustainable digital transformation strategies in Higher Education Institutions?**" relatively satisfies the PICO framework for an SLR. As it focuses on the population of HEIs, the intervention of DT strategies, and the desired outcome of identifying emerging trends.

The "P" in the PICO framework represents the population. The population aspect of the PICO framework typically refers to the group of individuals or entities being studied. In this case, the population is clearly defined as HEIs. The "I" stands for the intervention. The intervention aspect of the PICO framework involves a specific action or intervention being studied [58]. "Sustainable digital transformation strategies" defines the intervention of interest. The "C" represents the comparator, which is not applicable for this type of research question as it is not comparing interventions. Lastly, the "O" describes the outcomes that this study is exploring. In this context would be the "Emerging trends" associated with SDT strategies (58].

This research question allows this study to gather existing knowledge and identify key areas of focus and potential roadblocks related to SDT in HEIs.

More specifically, this systematic review addresses the following sub-questions:

i. What have publications on SDT strategies in HEIs developed over time in terms of (a) geographic distribution of studies, (b) authorship, and (c) publication patterns?
ii. What characteristics are found in studies conducted on SDT strategies in HEIs regarding: a) theoretical frameworks and methods applied (study characteristics)? b) Institutional type, technological environment of the institution, socioeconomic factors, pedagogical factors, environmental factors (contextual characteristics)?
iii. What opportunities have emerged regarding the use of technology for teaching, learning, and research in HEIs as a result of DT initiatives?

2. Research Methodology

This section provides a detailed account of the systematic methodology employed in this SLR. This article adopts a structured and transparent methodology to identify, select and analyse relevant literature. The systematic review of the literature concentrates on a specific research question, unlike the bibliometric strategy or a scoping review that adopts a broader scope [59]. The SLR ensures evidence-based reviews that are thorough and replicable [60]. The reproducibility of a search is determined by its ability to be replicated using the same methods within a specific search system. When identical query yields the same search results, the search is deemed reproducible [60]. The Methodology section is structured into five subsections, each focussing on a crucial aspect of the process. Section 2.1 Search strategy clarifies the search terms used to identify relevant literature, the

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chosen sources of literature, and describes the methodology employed for conducting the literature search. Section 2.2 Study selection provides details on the criteria rigorously applied for including or excluding studies during the final selection process. Section 2.3 Data extraction explains the process of documenting and ensuring the quality of the studies included in the review. Section 2.4 Systematic review execution, this subsection provides a summary of the entire review process, an overview of the search execution, data collection, and data selection processes. Finally, in Section 2.5 Quality assessment phase provides details on the evaluation of full-text articles against inclusion criteria and assessing quality using Microsoft Excel, with the results summarised in a PRISMA flow diagram. The results of the entire study execution are presented in Section 3 Results and findings.

2.1. Search Strategy Phase

This section elaborates on the chosen literature source and the specific procedures followed during the literature search. To extract relevant literature from the selected database, a search term or string is built and applied through identifying keywords with the maximum possible alternatives. To achieve the objective of the paper, a systematic review of the scientific literature containing references to the keywords identified includes titles, abstracts, and keywords. This search strategy was tailored to one database. For the benefit of this study, the research adopted the use of Elsevier's Scopus database, as it indexes only the most respected academic journals on an international scale [44].

Researchers have found that Elsevier's Scopus offers broader journal coverage compared to Web of Science (WoS), and Elsevier's Scopus indexes nearly all articles found in WoS [61]. This comprehensive coverage minimises the risk of overlooking relevant articles, thus enhancing the completeness of data analysis. Additionally, Elsevier's Scopus is widely recognised as a premier database for bibliometric studies, providing more extensive and reliable bibliographic information than alternatives such as Google Scholar [62,63]. Given these advantages, Elsevier's Scopus is selected as the main database for searching and extracting data for this study.

Table 1 lists the search terms used, which are the following: "Sustainab*" AND "Digital Transformation" OR "Digital technologies" OR "Digital*" or "Educational technologies" AND "Educat*" OR "University" OR "College" OR "Faculty" OR "Insti*" OR "Scholar*" OR "Teach*" OR "Learn*" OR "Research*". As (64) states, the asterisk after 'digital' allows access to a wider cohort of research, derived from the word 'digital' (e.g. digitalised, digitally) and including English and American spelling (e.g. digitalisation or digitalisation). The type of documents for this review were restricted to those published in peer-reviewed journals and only final publications in English. All searches spanned from the past five years 2019 to 2024, and from numerous countries.

Table 1. Initial Search String.

Topic and Cluster	**Search Terms**
Sustainable	"Sustainab*"
AND	
Digital Transformation	"Digital Transformation" OR "Digital technologies" OR "Educational technologies"
AND	
Educational Context	"Educat*" OR "University" OR "College" OR "Faculty" OR "Insti*" OR "Scholar*" OR "Teach*" OR "Learn*" OR "Research*"

2.2. Selection Criteria Phase

The selection criteria were based on the PRISMA statement [57]. The inclusion and exclusion process followed the guidelines outlined in the PRISMA extension for scoping reviews [57]. Initially, articles were selected based on their titles and abstracts, followed by a thorough examination of the full articles. The search mainly focused on mapping existing literature on SDT strategies in HEIs limited to the fields of social sciences, environmental sciences, computer science, business,

 doi:10.20944/preprints202408.1741.v1

management and accounting, and economics, econometrics and finance. Due to research being multi-disciplinary or transdisciplinary (Tripple bottom line). The search span was from year 2019 to 2024. All articles before 2019 were excluded from the search. The search included publications from a wide range of countries; no geographical restrictions were imposed. There were 1,686 records that were extracted at this stage.

A well-defined inclusion/exclusion criterion was established to ensure quality assurance and follow four filtering stages.

1) INCLUSION CRITERIA

I-1. Publications containing topics related to Sustainability and Education, broad search: The use of wildcards (" ") in "Sustainab" and "Educat*" allows for capturing various terms.

I-2. Publications containing Multiple Related Terms: Including "Digital transformation," "Digital technologies," and "Educational technologies" increases the search coverage.

I-3. Publications focussing on Educational Institutions Terms like "university," "college," "faculty," "institute," etc. ensure that the search focusses on educational settings.

I-4. Publications containing Educational Activities: Words like "Scholar *," "Teach *," "Learn *" and "Research*" capture the educational activities impacted by DT.

2) EXCLUSION CRITERIA

E-1. Studies between the year 2019 and the year 2024.

E-2. Remove duplicate papers.

E-3. Papers not focussing on sustainability or DT in HEIs.

E-4. Multidimensional papers & papers not in the English language.

2.3. Data Extraction

The entire search process has been thoroughly documented using the Zotero reference manager software and the Microsoft Excel database. When conducting a SLR, the quality assessment of the sources is crucial to ensure the reliability and validity of the findings. Zotero, a widely used reference management tool, helps organise and assess the quality of the collected literature. When systematically using Zotero for quality evaluation, researchers ensure that their SLR is based on robust and reliable evidence, ultimately leading to more credible and impactful findings. Throughout the data extraction process, meticulous annotations were made to comply with the inclusion and exclusion criteria for each selected study. Full texts of selected studies were recovered, and for each selected paper the information was extracted.

2.4. Systematic Review Execution

This section outlines the process of conducting the SLR, including the search strategy, execution, and selection of the research data. Executing the search string within Elsevier's Scopus database in Table 1 of Section 2.1, focussing on publications between January 2019 and April 2024 (E1 criteria). This initial search yielded 1,686 documents. Duplicate removal (E2 criteria) eliminated 75 records, bringing the total to 1,611. Applying further filters for multidimensional focus (E3 criteria) and language (E4 criteria - English only) resulted in the exclusion of 1,490 additional papers. Ultimately, 1,490 articles were eliminated, leaving 121 articles selected for inclusion in this study.

2.5. Quality Assessment Phase

The study was based solely on original research articles retrieved from the Scopus database between January 2019 and May 2024. To ensure data quality, all duplicates were meticulously removed. A single reviewer conducted the screening process based on predefined inclusion and exclusion criteria, involving a thorough examination of titles and abstracts. Subsequently, full-text articles from potentially eligible studies were evaluated against the inclusion criteria. Data extraction was performed using a standardised form and the quality of the included studies was assessed using the Microsoft Excel database. Figure 1 presents a PRISMA flow diagram that describes the systematic review process.

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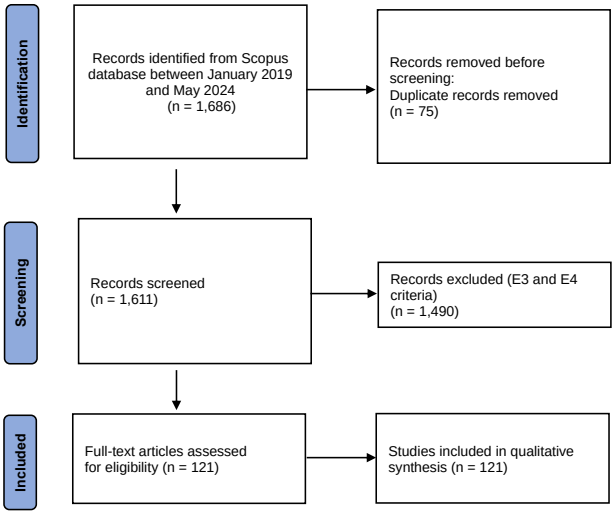

Figure 1. The process of selecting the final articles.

3. Results and Findings

This section presents the results of the SLR research questions raised in Section 1.3. The result of each research question has been extracted and elaborated separately.

- **Map Trends:** understanding the development of publications on SDT strategies in HEIs over time and in terms of geographic distribution, authorship, and publication patterns.
- **Characterise Existing Research:** to understand the characteristics of studies on SDT strategies, indirectly contributing to evaluating their effectiveness by identifying which approaches and frameworks are being used in achieving environmental, social, and economic sustainability goals.
- **Identify Opportunities and Risks:** to identify best practices associated with SDT in HEIs, thus synthesising key findings for the review.

For the analysis of the search results, the list was exported to SciVal. SciVal was used for the benchmarking analysis of the publications.

Table 2 displays the top five regions through scholarly output. China leads in scholarly output with 21 publications, significantly surpassing other regions. The United Kingdom followed with 16, closely followed by Germany and Italy with 12 and 11 respectively. Finally, Australia completes the top five countries with 10 publications.

Table 2. Top five regions by scholarly output.

Regions	2019	2020	2021	2022	2023	2024	Total per Country
China	0	2	2	5	7	5	21
United Kingdom	2	0	1	9	3	1	16
Germany	1	1	0	7	2	1	12
Italy	1	2	0	2	5	1	11
Australia	1	0	1	3	3	2	10
Total per year	**5**	**5**	**4**	**26**	**20**	**10**	**70**

Out of the 70 scholarly outputs ranging within the top five regions, in Table 2. It is revealed that 26 outputs were executed in the year 2022, followed by 20 in 2023. Notably, for 2024, the top five regions have 10 outputs thus far. The year 2021 had the lowest output with only four publications,

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whereas both 2019 and 2020 each had five scholarly outputs. The top five regions account for a significant portion of the total scholarly output, suggesting potential research concentration in these areas. Furthermore, there is considerable fluctuation in output among regions from year to year, indicating potential factors influencing research productivity.

Author(s) contribution

Table 3 shows the top 11 authors in this set of publications, presenting information about various authors and their academic contributions. This table shows an evaluation of the academic influence and visibility of these authors based on their academic output, citation counts, and the relative impact of their citations in their respective fields, Field-Weighted Citation Impact (FWCI). Of the 424 authors of the 121 synthesised publications, no author has more than two publications. With only eleven authors having two and the remaining 413 only having one Scholarly output. This indicates a relatively low level of author productivity in this field. Furthermore, the FWCI varies significantly between authors, indicating differences in research influence. However, a key finding is geographic diversity, with authors affiliated with institutions in various countries, demonstrating international collaboration.

It is deducible that collaboration opportunities exist through identifying co-authorship patterns among the 11 authors with two publications. Analysing the research focus and topics of the leading authors may help HEI identify emerging trends and research gaps.

Table 3. The top authors in this publication set, through scholarly output.

	Author	Affiliation	Region	Scholarly output	FWCI	Citation Count
1.	Beier, Grischa	Helmholtz Centre Potsdam - German Research Centre for Geosciences	Germany	2	3.35	64
2.	Gašević, Dragan	Monash University	Australia	2	3.94	75
3.	Korneeva, Elena Nikolaevna	Financial Academy of the Russian Federation Government	Russian Federation	2	1.4	14
4.	Lichtenthaler, Ulrich	International School of Management	Germany	2	0.81	10
5.	Martínez-Pérez, Sandra	University of Seville	Spain	2	2.96	70
6.	Matthess, Marcel	Helmholtz Centre Potsdam - German Research Centre for Geosciences	Germany	2	3.35	64
7.	Parida, Vinit	Luleå University of Technology	Sweden	2	3.52	46
8.	Sá, Maria José	Centro de Investigação de Políticas do Ensino Superior, Portugal	-	2	6.09	162
9.	Serpa, Sandro	University of the Azores	Portugal	2	6.09	162

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10.	Strielkowski, Wadim	Czech University of Life Sciences Prague	Czech Republic	2	1.4	14
11.	Xue, Bing	CAS - Shenyang Institute of Applied Ecology	China	2	3.35	64

Institution(s) contribution

The top 10 institutions in this set of publications are displayed in Table 4, through scholarly output. A small number of institutions contribute significantly to the overall Scholarly output. Monash University's high FWCI indicates a strong research influence compared to global standards. There is potential for collaboration between top performing institutions to enhance research impact. The analysis is based solely on Scholarly output and citation impact, without considering other factors like research quality or societal impact.

Table 4. The top 10 institutions in this publication set through scholarly output per region.

	Institution	**Region**	**Scholarly output**	**FWCI**
1.	Monash University	Australia	4	9.49
2.	Korea Advanced Institute of Science and Technology	South Korea	3	2.81
3.	Tianjin University	China	3	4.67
4.	Beijing Normal University	China	2	1.04
5.	CAS - Shenyang Institute of Applied Ecology	China	2	3.35
6.	Chinese Academy of Sciences	China	2	3.35
7.	Czech University of Life Sciences Prague	Czech Republic	2	1.4
8.	European Commission Joint Research Centre Institute	Belgium	2	0.72
9.	Financial Academy of the Russian Federation Government	Russian Federation	2	1.4
10.	Helmholtz Centre Potsdam - German Research Centre for Geosciences	Germany	2	3.35

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Of the 83 Scopus sources the top 9 journals have over one more journal than the remaining 74 which all have only one publication each. Regarding the most productive journals on the topic, as shown in Table 5, Sustainability is the leader, with 30 publications and 1051 citations. The Journal of Cleaner Production followed, with three publications and 64 citations. The British Journal of Educational Technology (2), and others.

Table 5. Top 10 Scopus sources by scholarly output.

	Scopus Source	Scholarly Output	Views Count	FWCI	Citation Count
1.	Sustainability (Switzerland)	30	4505	2.92	1051
2.	Journal of Cleaner Production	3	435	15.31	64
3.	British Journal of Educational Technology	2	356	6.98	123
4.	Business Strategy and the Environment	2	512	9.83	129
5.	Computers and Industrial Engineering	2	289	9.26	29
6.	Frontiers in Education	2	222	1.78	14
7.	International Journal of Environmental Research and Public Health	2	141	1.36	19
8.	Journal of Business Research	2	572	4.27	89
9.	Mathematics	2	83	7.92	27
10.	Others	1	-	-	-

Research Fields

The study methodology, involving keyword co-occurrence analysis, is applicable in bibliometric analyses within the field of HE to anticipate future research thematic orientations. This approach assists researchers and institutions to stay informed about emerging trends and research priorities.

Table 6 lists the top five key phrases by relevance, based on 121 publications. The most frequently mentioned key phrase is ‘Digital Transformation’, appearing 46 times. "Digitisation" ranks second with 39 mentions, followed by ‘Sustainable Development Goals’ with 20 mentions. The topics ‘Educational Technology’ and ‘Digital Education’ have 10 and 9 mentions, respectively. The number of publications that feature specific key phrases varies significantly from year to year, indicating evolving research trends. The increasing frequency of "Sustainable Development Goals" highlights the growing interest in the intersection of technology and sustainability.

The data in Figure 2 suggest a strong emphasis on the role of digital technologies in education and social development. Figure 2 displays the key phrases by Word cloud of the top 50 key phrases by relevance, based on 121 publications. The key phrase ‘Digital Transformation’ is the most prevalent, indicating a strong focus on this topic within the analysed publications. Terms like ‘Digitization’, ‘Educational Technology’ and ‘Digital Education’ are closely associated with ‘Digital Transformation’, suggesting a cohesive research area. Surprisingly, the increased status of ‘Innovation Management’ and ‘Human Resource Management’ over key phrases such as ‘Digital Platform’, ‘Massive Open Online Course' and 'Service System' is increasing.

 doi:10.20944/preprints202408.1741.v1

Table 6. Top five key phrases by relevance, based on 121 publications. Source (own).

Key phrases	2019	2020	2021	2022	2023	2024	2019 to 2024
Digital Transformation	1	8	1	12	19	5	**46**
Digitization	3	3	3	11	13	6	**39**
Sustainable Development Goals	1	3	1	6	4	5	**20**
Educational Technology	2	3	0	2	3	0	**10**
Digital Education	0	2	0	1	4	2	**9**
Total	**7**	**19**	**5**	**32**	**43**	**18**	**124**

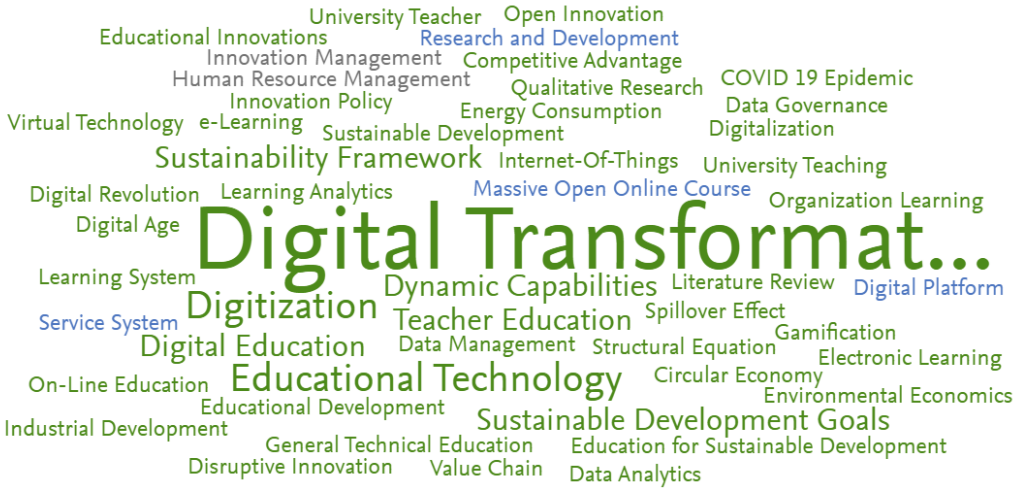

Figure 2. Key phrases by Word Cloud: Top 50 key phrases by relevance, based on 121 publications. Source (own).

The systematic review of the literature on emerging trends in SDT strategies in HEIs reveals a strong research focus on the role of digital technologies in education and social development, particularly focussing on the management and strategic aspects of DT. The increasing prominence of terms like "Sustainable Development Goals" indicates a potential shift towards more sustainable and responsible digital initiatives in the field of HE. This shift aligns with the growing global attention to sustainability and the need for academic institutions to integrate digital technologies in a sustainable way.

However, the relatively low frequency of terms such as "Digital Platform," "Massive Open Online Course," and "Service System" suggests potential research gaps in these areas. This finding highlights the need for further investigation into the specific applications and platforms that facilitate SDT in HEIs. Additionally, the emergence of "Innovation Management" and "Human Resource Management" as prominent terms suggests a growing interest in the intersection of technology, management, and human capital in the context of HE. This interdisciplinary approach underscores

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the importance of considering organisational and human factors in the successful implementation of SDT strategies.

All Key phrases - Top contributors

For the top contributors to the publication set for all key phrases, analysing the publication patterns using the most frequent key phrases to identify influential works. Four out of the five institutions are located in Asia, indicating that Asian institutions are heavily contributing to the scholarly output in the key phrases being analysed. The Korea Advanced Institute of Science and Technology and Tianjin University both have 3 outputs, which is close to Monash University's 4. This suggests a competitive landscape in terms of research productivity. Beijing Normal University and Nanjing Normal University are slightly behind with 2 outputs each, indicating they are also significant but not leading contributors. Monash University leads with 4 scholarly outputs. Monash University seems to have a strong presence or specialisation in the key areas being measured. This indicates a higher level of research activity or expertise in those areas compared to the other institutions listed.

From Table 7, China's leadership in scholarly output suggests a robust research environment, possibly driven by significant investments in research and development, as well as a strong emphasis on higher education and innovation. The regions represented span multiple continents (Asia, Europe, and Oceania), indicating that the key phrases attract global research interest. This geographical diversity also suggests that the topics being studied have broad relevance and appeal across different regions.

Table 7. Top five regions by scholarly output for all key phrases.

Regions	Scholarly Output
China	19
United Kingdom	14
Germany	12
Australia	10
Italy	10

All top five authors by scholarly output for all key phrases. Beier, Gašević, Lichtenthaler, Parida, and Strielkowski have an equal scholarly output of 2. The equal output might indicate that these authors are leaders or emerging figures within their respective areas of expertise. With 26 scholarly outputs, "Sustainability (Switzerland)" is by far the most prolific journal in this list. This suggests a significant focus on sustainability-related research within the key phrases being analysed. The overwhelming output in this journal indicates its central role in disseminating research related to sustainability. The variety of journals indicates that the key phrases span multiple disciplines, from business strategy to industrial engineering, all connected by the common theme, sustainability.

Subject areas

The mapping of existing literature on SDT strategies in HEIs is limited to the subject areas of social sciences, environmental sciences, computer science, business, management and accounting, energy, engineering and economics, econometrics, and finance. The pie chart displayed in Figure 3 of subject areas are shown through segment size representing relative publication share per subject area. With a publication being mapped to multiple subject areas. The subject area of social sciences has the greatest contribution with 62%, followed by environmental sciences 43% and computer science 38.8%. Subsequently followed by energy 31.4% business, management, and accounting 29.8%. Engineering 21.5%. Finally, economics, econometrics and finance have a share of 9.9%.

 doi:10.20944/preprints202408.1741.v1

Geographical collaboration overview

Geographical collaboration in SciVal indicates the extent to which an entity's publications have international, national, or institutional co-authorship, and single authorship.

Table 8 shows the overall geographical collaboration. Each publication is assigned to 1 of 4 mutually exclusive geographical collaboration types, based on its affiliation information: international, national, institutional, or single authorship. A single publication may, of course, display each of international, national and institutional collaboration in its affiliation information, but a single geographical collaboration type is assigned to ensure that the sum of an entity's publications in the four categories adds up to 100% of the publications with the necessary affiliation information. International collaboration is the most prevalent, accounting for 38% of the output and demonstrating the highest impact on citations. Although national and institutional collaborations also contribute significantly, they exhibit lower citation metrics compared to international collaborations. Single authorship constitutes the smallest proportion of output. These metrics highlight that international collaboration tends to result in higher citations and impact, as indicated by the FWCI.

Table 8. The general geographical collaboration.

Geographical collaboration types	Metric	Scholarly Output	Citations	Citations per Publication	FWCI
International collaboration	38.0%	46	1655	36	5.64
Only national collaboration	25.6%	31	496	16	2.82
Only institutional collaboration	23.1%	28	731	26.1	2.27
Single authorship (no collaboration)	13.2%	16	193	12.1	3.02

4. Discussion

In research discussing barriers to successful implementation of e-learning, various critical success factors (CSFs) were identified alongside barriers [65]. E-learning is a digital technology used in the educational setting of HEIs [66]. Naveed et al. [65] uses the Analytic Hierarchy Process-Group Decision Making (AHP-GDM) methodology, adding rigour to assessing barriers and CSFs. This structured methodological approach provides a systematic way to evaluate and prioritise factors, offering valuable insights for decision-makers in HEIs. The identified barriers, such as those related to institutional management, infrastructure, students, and instructors, are directly relevant to DT efforts in HE. Addressing these barriers is crucial to ensuring the effectiveness and sustainability of digital initiatives, including the implementation of e-learning. To promote creativity and innovation, institutions must develop the ability to establish a new corporate culture that allows professionals to interact effectively [14–16].

DT plays a crucial role in HE, leading to the development of sustainable curriculums, enhancing student performance and innovation, and improving accessibility to education [31,50,67]. From a case study of PSU (Prince Sultan University) based on the best national and international practices, a framework proposal is made that aims to create a SDT environment in HEIs in the Kingdom of Saudi Arabia [67]. Emphasising the significance of adopting SDT strategies to ensure that HEIs can effectively fulfil their roles in providing high-quality education and contributing to societal development.

Along with technological advances in the digital age, changes in consumer behaviours and emerging generations of Z can lead to changes in market needs, which requires the innovation of business models. Therefore, innovation in the business model is increasingly recognised as one of the

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most important challenges facing organisations in the digital age. Due to rapid environmental changes, if organisations want to take advantage of past competitive advantages, they cannot compete with leading organisations, so they must create and maintain dynamic capabilities [68]. Vandevenne et al. [69] directly addresses the intersection of DT and environmental sustainability in organisations. A critical gap is highlighted in embedding environmental sustainability into DT and proposes a Green Enterprise Architecture (GREAN) as a method to bridge it. This research contributes to understanding the environmental implications of DT and underscores the necessity of sustainable strategies. Effective project management is crucial for HEIs undertaking complex DT initiatives. For an example of the importance of research in the challenges and complexities of implementing DT strategies in HEIs. Slavinski, Todorović and Obradović [70] discusses how research themes in project management, including those related to DT, have evolved over time.

Understanding the evolution of research themes provides insights into how DT strategies have been studied and implemented in various contexts, including HEIs. The study highlights future trends in project management research, including challenges related to Industry 4.0, DT, and the SDGs. These future trends are highly relevant for HEIs as they navigate changes in technology and strive to achieve sustainability objectives. The findings of Slavinski, Todorović and Obradović [70] may assist researchers and educators in HEIs to define the thematic orientation of their studies and programs. Understanding emerging research themes and trends can guide the development of curricula and research agendas related to SDT strategies.

Beier et al. [3] Beier et al. (2022) examined the impact of digital technologies on environmental sustainability across industrial sectors in Brazil, China, and Germany. Their findings offer valuable insights for HEIs formulating DT strategies with a focus on environmental sustainability. Their study explored the potential of Industry 4.0 for environmental sustainability within industrial production, highlighting the importance of supporting measures to achieve this goal. HEIs that implement DT strategies can benefit from similar considerations. A critical evaluation is necessary to ensure that these strategies contribute to broader sustainability objectives.

Similarly, Kunkel et al. [71] explored the role of digitalisation, particularly in the context of Industry 4.0, in supply chain management, which is a crucial aspect of DT strategies. The study specifically focusses on environmental sustainability aspects within supply chain collaboration (SCC), how firms collaborate on sustainability in the supply chain. The study by Kunkel et al. [71] employs qualitative methods, including 18 interviews with industry representatives from international electronics buying firms and Chinese suppliers. Kunkel et al. [71] provides policy and managerial levers to enhance the socio-ecological performance of the supply chain, which informs decision-making and strategy development in HEIs aiming to improve sustainability through DT. According to Guo and Zeng (42) a key factor in the evaluation of DT strategies is the importance of stakeholder satisfaction in the effectiveness of these strategies. As an example of DT for sustainable education practices, specifically focussing on online learning. Guo and Zeng (42) discuss the promotion of green and low-carbon transformation in education, particularly in the context of online foreign language education. This aligns with the broader theme of SDT.

Understanding different levels of engagement with sustainability is crucial to develop effective strategies [72]. Pasi and Misuraca [72] introduce four scenarios based on levels of sustainability and engagement, providing valuable insights into how DT strategies in HEIs may be effectively implemented and sustained over time. Recognising the interconnectedness of various societal systems, including education, welfare, and digital technologies. The researchers discuss the impact of digital technologies on the welfare state and societal structures in Europe. While the focus is on the welfare state, a broader discussion on the impact of DT is highly relevant to understanding DT strategies in HEIs. The study highlights the implications of different scenarios for European policies and suggests further research directions. This broader perspective informs the discussions and decision-making processes related to DT strategies in HEIs, considering their alignment with national, regional, and local policies. The interdisciplinary nature of DT strategies requires collaboration across departments and fields, emphasising the need for a holistic approach to

 doi:10.20944/preprints202408.1741.v1

education within Industry 4.0. The review primarily features contributions from European and Asian researchers.

5. Conclusions

The synthesis of the current literature emphasises the crucial role of digital technologies in education and social development, particularly focussing on the management and strategic aspects of DT. As the importance of SDGs continues to increase, there is a noticeable shift towards more sustainable and responsible digital initiatives within HEIs. The findings indicate that understanding the broader trends and implications of DT in the post-pandemic era is essential for informing strategic decisions related to sustainability in HEIs.

The implications of this research extend to students, educators, and policymakers within HEIs, highlighting both potential advantages and disadvantages of various learning practices. Fully understanding these implications, institutions can develop SDT strategies that align technological integration with educational goals, thus enhancing student learning outcomes. However, the literature also reveals significant research gaps, particularly in areas such as digital platforms, MOOCs, and service systems, underscoring the need for further investigation into the intersection of DT and sustainability transitions relevant to HEIs.

Additionally, the study suggests further analysis of the factors contributing to China's dominance in academic output, noting that a small number of institutions significantly influence overall research productivity. This raises questions about specific research areas driving growth in scholarly output and the implications of these trends for research collaboration and knowledge exchange.

To effectively deliver high-quality education and foster positive social change, HEIs must embrace SDT strategies [23,73]. These strategies are vital to navigate the complexities of the digital age while contributing to the SDGs. Through integrating quality education with technology, students can accelerate their knowledge acquisition, develop essential skills, and cultivate collaborative problem-solving mindsets to address global challenges. The interdisciplinary nature of DT strategies often necessitates collaboration across various departments and fields, highlighting the need for a cohesive approach to education in the context of Industry 4.0. Emerging technologies present challenges and opportunities that require individuals, businesses, and governments to remain agile and responsive. Consequently, policy initiatives should focus on diversifying productivity through strategic investments in HE, ensuring that institutions are well equipped to meet the demands of an evolving educational landscape. This synthesis offers a blueprint for developing a future workforce equipped with the technical skills, critical thinking, and ethical compass necessary to thrive in the Human-centred innovation Society 5.0 and Industry 5.0 era. Collaborative action among educational stakeholders is essential to transform this potential into reality. A significant portion of the current literature on SDT strategies highlights trends that are highly relevant to DT strategies within HEIs. These key topics include information technologies, digital transformation itself, innovation, and, of course, sustainability. Sustainability is a core focus for HEIs, and understanding the broader trends and implications of DT in the post-pandemic era informs strategic decisions in this regard [18,74,75].

Author Contributions: Conceptualization, methodology, writing—review and editing: B.N., M.P. and L.M.; investigation, validation, formal analysis, writing—original draft preparation: B.N. and B.M.; data curation, project administration: B.N.; supervision, M.P. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created. Data are available through the referenced sources.

Conflicts of Interest: The authors declare no conflicts of interest.

 doi:10.20944/preprints202408.1741.v1

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