From Outbreak to Uptake: The Explosive Growth of Digitalization Research in the Pandemic

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ABSTRACT

Keywords:

COVID-19; Interdisciplinary; Thematic analysis; Implications; Innovation

The COVID-19 pandemic has triggered a surge in research on digitalization across various domains, necessitating a comprehensive analysis of its multifaceted implications. The latest understanding highlights the urgent need for innovative solutions and strategies to address challenges brought by the pandemic. This study aimed to systematically analyse the landscape of digitalization research during the COVID-19 pandemic, elucidating its themes, trends, and implications. Employing a bibliometric approach, we conducted an extensive analysis of scholarly publications between 2020 and 2023. The study involved quantitative assessment, citation analysis, and thematic exploration to comprehend the multidisciplinary dimensions of digital transformation. Our findings showcase a remarkable increase in scholarly activity, evidenced by high publication numbers and robust citation rates. Digitalization's pervasive impact extends across disciplines, including Social Sciences, Computer Science, and Environmental Science. Notable themes emerged, such as digital transformation in sectors like healthcare, education, and the economy, underscoring the complexity of the field. This study provides valuable insights into the dynamic interplay between digitalization and the pandemic. The thematic diversity underscores the need for cross-disciplinary collaboration, innovative strategies, and sustainable practices. Our research contributes to a comprehensive understanding of digitalization's role during global challenges, setting the stage for future exploration and real-world application.

1. Introduction

The COVID-19 pandemic has caused widespread illness, death, and disruption since it was first identified in late 2019 [1]. Governments around the world have implemented measures to contain the spread of the virus, including lockdowns and social distancing guidelines, which have had significant social and economic consequences. The pandemic has overwhelmed healthcare systems and disrupted global supply chains, leading to shortages of medical equipment and essential goods. The economic impact of the pandemic has been significant, with many businesses forced to close

and people losing their jobs. The pandemic has also had a significant impact on mental health, with increased levels of anxiety and depression reported [2]. The long-term consequences of the pandemic are still unclear, but it has highlighted existing inequalities and vulnerabilities in societies around the world. It is important that governments and communities work together to address the social, economic, and health challenges presented by the pandemic.

Digitalization has played a crucial role in managing the COVID-19 pandemic. With lockdowns and social distancing measures in place, digital technologies have allowed people to continue working, studying, and accessing healthcare remotely [3]. Digital tools such as video conferencing, online collaboration platforms, and telemedicine have enabled people to stay connected and access essential services without leaving their homes. Moreover, digitalization has facilitated contact tracing efforts, which have been critical in controlling the spread of the virus. Mobile apps and other digital tools have been used to track the movements and interactions of infected individuals, identify potential exposure risks, and notify people who may have been in contact with infected individuals.

The use of digital technologies has also enabled researchers to collaborate more effectively on developing treatments and vaccines for the virus. Digital tools have facilitated data sharing and collaboration across geographical and institutional boundaries, allowing scientists to work together more efficiently. Bibliometric analysis is a quantitative method used to analyse and measure the characteristics of published literature, such as the number of publications, authors, citations, and keywords. This article will use bibliometric analysis to examine research trends in digitalization during the pandemic. By conducting a bibliometric analysis of the literature on digitalization during the pandemic, researchers can gain insights into the key themes, trends, and gaps in the research. This information can be used to identify areas where more research is needed, to inform policy decisions, and to guide future research agendas. In specific, the study endeavours to answer the following research questions:

i. What is the current state of research concerning digitalization in the context of the COVID-19 pandemic?
ii. What emerging trends are discernible within publications related to digitalization and COVID-19?
iii. Which key players, such as institutions and countries, are driving advancements in research on digitalization and COVID-19?
iv. Which journals and publications serve as the focal points for seminal studies on digitalization in the COVID-19 era?
v. What landmark papers have significantly influenced the discourse and direction of digitalization and COVID-19 research?
vi. What critical research themes underpin the ongoing evolution and expansion of the field, focusing on digitalization and the COVID-19 pandemic?

2. Literature Review

Digitalization involves the use of digital tools and platforms to enable new forms of communication, collaboration, and innovation. The COVID-19 pandemic has highlighted the importance of digitalization in enabling remote work, online learning, and telemedicine, among other things. Several studies have examined the importance of digitalization during the pandemic. For example, a study by Kumar & Singh [3] highlighted the role of digital technology in containing the COVID-19 pandemic. The study argued that digital technologies such as mobile apps,

telemedicine, and remote work tools have enabled people to stay connected and access essential services during the pandemic. The authors also noted that digital tools have facilitated contact tracing efforts, supported research and development of treatments and vaccines, and enabled collaboration across geographical and institutional boundaries. The literature on digitalization during the pandemic emphasizes the importance of digital technologies in enabling continuity of work and services during the pandemic, facilitating contact tracing efforts, and supporting research and development of treatments and vaccines.

2.1 Digitalization During Pandemic

The COVID-19 pandemic has prompted a surge in research on the role of digitalization in various aspects of society. Numerous studies have examined the impact of digital technologies on healthcare, education, business, and government during the pandemic. For example, a study by Koo *et al.*, [4] examined the use of telemedicine during the pandemic. The study found that telemedicine has enabled patients to access healthcare services remotely, reducing the risk of exposure to the virus. We are aware that telemedicine has increased the efficiency of healthcare delivery and improved patient outcomes.

Another study by Saberi *et al.,* [5] examined the use of digital tools in contact tracing efforts. The study found that digital tools such as mobile apps and GPS tracking have enabled more effective and efficient contact tracing, allowing public health officials to quickly identify and isolate individuals who have been exposed to the virus.

Other studies have examined the impact of digitalization on remote work and online learning during the pandemic. For example, a study by Veletsianos and Houlden [6] found that digital technologies have enabled educators to continue delivering educational content remotely. There are challenges associated with remote learning, digital technologies have enabled educators to provide more flexible and personalized learning experiences.

2.2 Bibliometric Analysis

Bibliometric analysis is a research method that involves the quantitative analysis of bibliographic data to study patterns and trends in scholarly literature. This technique has been increasingly used in academic research to gain insights into the structure and dynamics of research fields, as well as to evaluate the impact and influence of research outputs. Bibliometric analysis typically involves the collection and analysis of various types of bibliographic data, including publication counts, citation counts, co-authorship networks, and keyword co-occurrence networks. This data is then used to identify key research areas, influential authors and institutions, and emerging trends in a given field. Bibliometric analysis has been used in a variety of research fields, including science and technology studies, library and information science, and social sciences. For example, a bibliometric analysis by Li and colleagues [7] examined the research trends in disaster health management. The authors used bibliometric analysis to identify key research themes and trends, as well as to evaluate the impact and influence of research outputs in the field.

3. Methods

This study draws on data procured from the Scopus database as of August 20, 2023. The selection of Scopus as the primary data source represented a strategic methodological choice grounded in its distinguished position as one of the most expansive and comprehensive abstract

and citation databases of peer-reviewed literature. The acquired data embraced diverse dimensions, such as document type, source type, languages, subject areas, publication trends, institutional contributions, geographical distribution of publications, and prevalent keywords, among other essential attributes.

3.1 Search Strategy

The search aimed to pinpoint documents pertinent to digitalization and COVID-19, utilizing an amalgamation of synonyms and associated keywords. This array encompassed terms like digitalization, digital adaptation, digitization, digital transformation, digital integration, and digital conversion, along with phrases tied to COVID-19, such as pandemic, covid, coronavirus, or Sars. The primary field for the search was the article title, chosen to yield precise and pertinent results concerning the study's thematic focus. Consequently, the following query was executed: TITLE(digitalization OR "digital adapt*" OR digitization OR "digital trans*" OR "digital intergra*" OR "digital conver*" AND pandemic OR covid OR coronavirus OR Sars). The query returned 654 documents, constituting an extensive array of articles delving into the multifaceted subjects of digitalization and the COVID-19 pandemic. This comprehensive dataset lays the groundwork for our systematic review, fostering an unerring depiction of the field's current state and the recognition of burgeoning trends and challenges within this domain.

The dataset underwent a scrupulous examination to detect duplicates or off-topic documents, none of which were found. The study encompassed all documents, sources, and languages, ensuring a broad and representative collection. The complete set of 654 articles was utilized to evaluate the landscape of digitalization and COVID-19 research, pinpointing significant trends, hurdles, and prospects within the discipline. This methodical approach ascertained that the analysis was anchored in primary sources, encapsulating contemporary and pertinent discoveries within this rapidly evolving field. The research protocols deployed in this study and a visual representation of the methodological framework are elucidated in Figure 1.
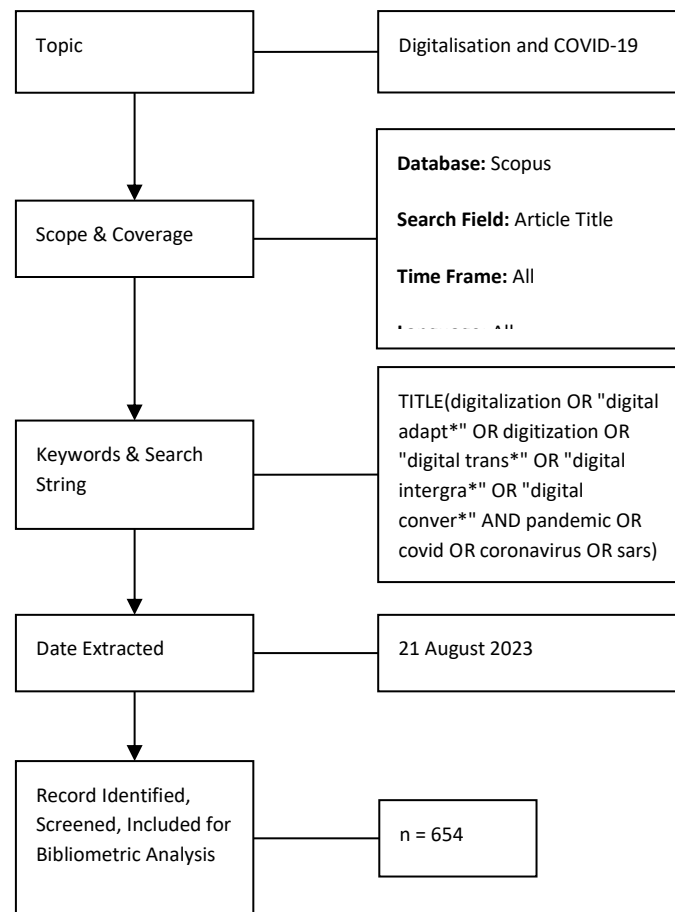
Fig. 1. Study search and selection process

3.2 Data Cleaning and Standardization

This study emphasizes the significance of data cleaning and harmonization in bibliometric analysis for ensuring accurate and reliable outcomes. OpenRefine and biblioMagika by Ahmi [8] were utilized to clean and harmonize diverse data aspects, like author names, affiliations, and keywords. These tools effectively managed the challenges posed by varying research outputs and data inconsistencies. The Scopus data in .csv format was cleaned using OpenRefine, which standardized and improved data accuracy. BiblioMagika was employed for comprehensive bibliometric measurements and detecting missing data, enhancing data quality. Post-initial cleaning, keywords were manually verified, and multivalued cells were consolidated for consistency. Cleaned data was then returned to its original format for further analysis. The use of these tools enhanced the study's analytical validity and result reliability, while also refining the dataset's granularity and clarity for exploring the intricate domain of green manufacturing.

3.3 Data Analysis and Tools

The data analysis was structured to address the research questions set in the introduction. Our approach involved documenting the current state of green manufacturing research in terms of document types, sources, languages, subject areas, and citations. The findings are presented based on different criteria, including yearly paper publication rates, most prolific authors, institutions, countries, and source titles. This reveals significant contributors and prevailing trends. Bibliometric measures such as total publications, cited paper count, total citations, citations per paper, citations

per cited paper, h-index, g-index, m-index, and citation sum within the h-core were also used to comprehensively gauge the impact and relevance of identified publications. Additionally, to highlight major themes and concepts, we employed co-occurrence network analysis, thematic mapping, and factorial analysis to visualize author keywords. These visualizations unveiled topic clusters, latent patterns, and connections among research subdomains. Various tools were used for an exhaustive bibliometric analysis. Microsoft Excel aided in initial data cleaning and organization, while BiblioMagika streamlined author, affiliation, and country data cleaning. OpenRefine was applied to refine author keyword data. With prepared data, VOSviewer Van Eck & Waltman [9] created insightful visual summaries of our results. The combined use of these tools and techniques facilitated a meticulous and robust exploration of the green manufacturing field.

4. Results

The following section delves into a rigorous and multifaceted analysis of the digitalization research landscape during the COVID-19 pandemic. By aligning our examination with the research questions in the introduction, we strive to unearth a comprehensive and nuanced understanding of this emerging field. These research questions, focusing on the current landscape, emerging trends, key players, pivotal publications, and underlying themes in digitalization research, guide our investigation and enable us to synthesize data from various angles. The objective of this analysis is not merely to present statistical findings but to interpret them within the broader context. In doing so, we aim to offer a vital academic contribution that bridges theory and practice, facilitating valuable insights for researchers, practitioners, policymakers, and all those invested in the interplay between digitalization and the pandemic. By orchestrating our insights around these targeted research questions, we hope to create a roadmap that articulates the past, elucidates the present, and anticipates the future of digitalization within the unique context of the COVID-19 era. Through this meticulous exploration, we aspire to contribute to the scholarly conversation and offer practical implications that resonate across sectors and disciplines. The detailed findings, tables, and following discussions are crafted to shed light on the complexity and potential of this burgeoning study area, enhancing our collective understanding and guiding future endeavours.

4.1 Main Information

Table 1 reveals an impressive surge in research activity, with 654 publications between 2020 and 2023. The high total citations of 5,749 and an average of 8.79 citations per paper bear testimony to the broader impact and importance of this research within the academic community. The presence of 1,995 contributing authors and an average of 3.05 authors per paper indicate a collaborative and multi-expertise research environment. The bibliometric indices, including an h-index of 35, emphasize this research area's robustness and substantial contributions to knowledge. This vital information underscores the burgeoning interest in digitalization during the pandemic and guides future research, policy, and technological innovation for scholars, businesses, and governments.

Table 1
Main Information

Main Information	Data
Publication Years	2020 - 2023
Total Publications	654
Citable Year	4
Number of Contributing Authors	1995
Number of Cited Papers	374
Total Citations	5,749
Citation per Paper	8.79
Citation per Cited Paper	15.37
Citation per Year	1916.33
Citation per Author	2.88
Author per Paper	3.05
Citation sum within h-Core	4,318
h-index	35
g-index	66
m-index	8.75

Table 2 illustrates the interdisciplinary nature of digitalization and COVID-19 research. With disciplines ranging from Social Sciences (44.95%) to Computer Science (31.19%), Business, Management, and Accounting (28.13%), and including Medicine, Engineering, Environmental Science, among others, the research extends across diverse sectors. This diversity emphasizes that digitalization transcends technology and interfaces with societal, economic, medical, and environmental domains. Policymakers and industry leaders can leverage these findings to formulate targeted strategies, weaving digitalization into various facets of pandemic preparedness and response.

Table 2
Subject Area

Subject Area	Total Publication	Percentage
Social Sciences	294	44.95%
Computer Science	204	31.19%
Business, Management and Accounting	184	28.13%
Economics, Econometrics and Finance	112	17.13%
Engineering	111	16.97%
Medicine	64	9.79%
Decision Sciences	63	9.63%
Environmental Science	58	8.87%
Energy	46	7.03%
Arts and Humanities	37	5.66%
Mathematics	27	4.13%
Psychology	21	3.21%
Earth and Planetary Sciences	15	2.29%
Health Professions	13	1.99%
Physics and Astronomy	12	1.83%
Materials Science	8	1.22%
Multidisciplinary	7	1.07%
Agricultural and Biological Sciences	6	0.92%
Biochemistry, Genetics and Molecular Biology	6	0.92%
Nursing	6	0.92%
Pharmacology, Toxicology and Pharmaceutics	6	0.92%
Chemistry	5	0.76%

Chemical Engineering	4	0.61%
Neuroscience	3	0.46%
Immunology and Microbiology	2	0.31%

Table 3 categorizes the distribution of research into different formats, with the majority found in articles (55.20%), and followed by conference papers (19.57%) and book chapters (14.98%). The prevalence of journals (63.15%) as the predominant source type reflects the centrality of peer-reviewed literature in the field. Understanding these document and source types is instrumental for researchers, librarians, and academics in accessing the most relevant materials and comprehending the dissemination of knowledge in this area.

Table 3
Document and Source Type

Document Type	TP	%	Source Type	TP	%
Article	361	55.20%	Journal	413	63.15%
Conference Paper	128	19.57%	Conference Proceeding	94	14.37%
Book Chapter	98	14.98%	Book Series	72	11.01%
Review	30	4.59%	Book	69	10.55%
Editorial	11	1.68%	Trade Journal	6	0.92%
Note	11	1.68%			
Book	6	0.92%			
Conference Review	3	0.46%			
Letter	2	0.31%			
Short Survey	2	0.31%			
Data Paper	1	0.15%			
Erratum	1	0.15%			

Table 4 shows the predominance of English (88.23%) in publications, followed by languages such as German, Spanish, and Russian. The dominance of English points to the discourse's accessibility primarily to English-speaking academia and professionals, potentially hindering non-English speakers from accessing this vital research. Initiatives to translate or summarize these key findings in various languages could democratize access and widen the reach of insights into digitalization during the COVID-19 era.

Table 4
Language

Language	Total Publications	Percentage
English	577	88.23%
German	29	4.43%
Spanish	27	4.13%
Russian	16	2.45%
Portuguese	4	0.61%
French	3	0.46%
Italian	2	0.31%
Chinese	1	0.15%
Dutch	1	0.15%
Hungarian	1	0.15%
Slovak	1	0.15%
Turkish	1	0.15%

Collectively, these sections paint a comprehensive picture of the vibrant and multidisciplinary research landscape on digitalization in the context of the COVID-19 pandemic. They hold significant

implications for scholars, businesses, and policymakers, contributing to the broader discourse on this subject. By offering an evidence-based foundation, these findings act as a compass for future research and action in the ever-evolving and increasingly vital field of digitalization.

4.2 Emerging Trends and Growth

Figure 2 offers a profound look at the trends and growth patterns within digitalization research during the COVID-19 pandemic. The trend analysis begins with the year 2020, the onset of the pandemic, where a modest number of 70 publications were released, garnering a substantial 2,898 citations. This remarkable number of citations in the initial year indicates the immediate recognition and high relevance of digitalization within the context of the pandemic. Moving into 2021, the total publications tripled to 207, reflecting a growing awareness and urgency in understanding digitalization as the pandemic continued to unfold. However, a noticeable decrease in total citations to 2,009 signifies an increase in the volume of literature with a varied impact, possibly due to diversification in research focus and methodology.
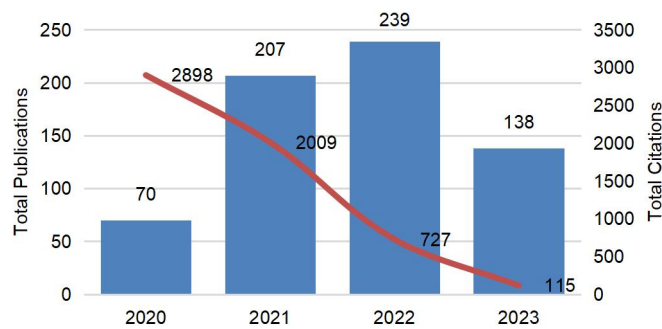

Fig. 2. Total Publication and Total Citations by Year

The year 2022 marked the peak in total publications, with 239 papers contributing to the academic discourse. The drastic decline in citations to 727 may be interpreted as a normalization in the research field, with more diverse contributions leading to more specific and targeted impacts. As the pandemic evolved, the subjects within digitalization likely became more nuanced, requiring specialized understanding and thus resulting in fewer overall citations. The decline in total publications in 2023 to 138, alongside the sharply reduced citations to 115, might suggest a maturation or stabilization in the field. Given that the data was collected as of August 2023, it may also reflect a partial year's output. These figures may demonstrate a shifting research focus, possible saturation in certain research areas, or the beginning of a consolidation phase where research emphasis may be shifting from quantity to quality.

This chronological analysis paints a vivid picture of a rapidly evolving field, one that has responded with agility to the global crisis. The trend shows an initial explosion of interest, leading to extensive investigation and followed by a period of stabilization and possible consolidation. The fluctuations in publications and citations across these years reflect the field's dynamism, underlining its responsiveness to real-world challenges and opportunities. These findings hold critical implications for researchers, guiding them towards emerging research gaps and opportunities, and helping policymakers and practitioners to appreciate the evolution of digitalization within the pandemic. In essence, this trend analysis serves as a mirror to the academia's pulse, mapping the ebbs and flows of a field in constant dialogue with a world in flux.

4.3 Publication by Institutions and Countries

The COVID-19 pandemic has catalysed a surge in research on digitalization across various aspects of society, prompting an in-depth analysis of the major contributors to this field. This section examines the key institutions and countries leading this scholarly wave, providing a comprehensive overview of the landscape. The analysis of the most productive institutions (Table 5) reveals intricate patterns in publication volume and impact. The Russian State Social University, despite leading with seven publications, demonstrates a relatively moderate influence, evidenced by an h-index of 2 and an average of 1.43 citations per publication. Conversely, Malmö University, with six publications, has exhibited substantial impact, registering a remarkable citation per paper ratio of 6.17.

Table 5
Most Productive Institutions with a Minimum of Four Publications

Institution	TP	NCP	TC	C/P	C/CP	h	g	m
Russian State Social University	7	10	4	1.43	2.50	2	2	0.67
Malmö University	6	37	3	6.17	12.33	3	1	1.00
Peter the Great Saint Petersburg Polytechnic University	5	0	0	0.00	0.00	0	2	0.00
University of Johannesburg	5	168	4	33.60	42.00	2	1	0.50
Osnabrück University	5	9	3	1.80	3.00	2	1	0.67
Lviv Polytechnic National University	4	20	3	5.00	6.67	3	1	0.75
Universitat de València	4	14	3	3.50	4.67	2	1	0.67
Universiti Malaya	4	1	1	0.25	1.00	1	2	1.00
Bucharest University of Economic Studies	4	45	4	11.25	11.25	3	1	1.00
Financial University under the Government of the Russian Federation	4	1	1	0.25	1.00	1	2	0.50
University of Craiova	4	9	3	2.25	3.00	2	1	1.00

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=index

Other institutions such as Peter the Great Saint Petersburg Polytechnic University, despite equal publication volume, exhibit significant variations in citation metrics, indicating the heterogeneity in scholarly contributions. The high citation rate per publication from the University of Johannesburg, coupled with Osnabrück University's modest impact, underscores the diversity within the academic community. Institutions like Lviv Polytechnic National University, Universitat de València, and Universiti Malaya further embellish this diversity with their unique contributions.

The scrutiny of the most productive countries (Table 6) yields insightful observations regarding international contributions. The Russian Federation leads in publication volume, with 64 papers, balanced by an average citation rate of 2.67 per publication. Germany follows closely with 56 publications, distinguished by an impressive average citation rate of 12.79 per paper. Spain's significant impact is evident from its 44 publications and a commendable citation per publication average of 19.34. Meanwhile, the United States, with 40 publications and an average of 12.93 citations per paper, continues to reinforce its longstanding academic tradition. Countries like the United Kingdom, Italy, China, Australia, and the United Arab Emirates, among others, collectively represent a global, multifaceted response to the challenges of digitalization amidst the pandemic.

Table 6
Most Productive Countries with a Minimum of Ten Publications

Country	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Russian Federation	64	171	32	2.67	5.34	6	7	1.50
Germany	56	716	41	12.79	17.46	11	6	2.75
Spain	44	851	35	19.34	24.31	15	4	3.75
United States	40	517	23	12.93	22.48	9	5	2.25
United Kingdom	38	533	27	14.03	19.74	10	4	2.50
Italy	32	258	22	8.06	11.73	8	4	2.00
China	30	396	20	13.20	19.80	8	4	2.00
India	26	164	17	6.31	9.65	7	4	1.75
Turkey	21	95	8	4.52	11.88	5	3	1.67
Indonesia	21	313	12	14.90	26.08	4	4	1.00
Canada	19	318	12	16.74	26.50	6	3	1.50
Ukraine	17	54	10	3.18	5.40	5	3	1.25
Poland	17	120	8	7.06	15.00	5	3	1.25
Brazil	15	123	7	8.20	17.57	2	3	0.50
Viet Nam	15	71	9	4.73	7.89	4	3	1.33
Greece	15	54	8	3.60	6.75	5	3	1.25
Malaysia	14	21	6	1.50	3.50	2	3	0.67
Romania	12	128	10	10.67	12.80	4	2	1.00
Sweden	12	41	5	3.42	8.20	3	3	1.00
France	12	68	7	5.67	9.71	5	2	1.67
Portugal	11	205	5	18.64	41.00	4	2	1.00
Saudi Arabia	11	148	7	13.45	21.14	5	2	1.25
South Africa	10	175	7	17.50	25.00	3	2	0.75
Pakistan	10	170	5	17.00	34.00	3	2	0.75
Australia	10	51	8	5.10	6.38	4	2	1.33
United Arab Emirates	10	46	5	4.60	9.20	3	2	1.00

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=index

In response to Research Question 3, this section elucidates the major academic institutions and countries driving research on digitalization during the COVID-19 pandemic. The presented tables provide a comprehensive insight into the complex interplay of publication volume and impact, highlighting the diversity and breadth of the academic landscape. The findings illustrate a global collaborative effort, where varying contributions from different institutions and nations contribute to the collective understanding of digitalization's role during a worldwide crisis.

4.4 Publication by Source Titles

In response to Research Question 4, the study sought to identify the journals and publications that serve as the focal points for seminal studies on digitalization in the COVID-19 era. The findings reveal intricate patterns in the scholarly publishing landscape, with each source contributing uniquely to the field's growth. Leading the list, "Lecture Notes in Networks and Systems" has emerged as a crucial platform with 22 total publications. The total number of cited publications stands at 11, with total citations of 30, translating to an average citation per publication (C/P) of 1.36 and an average citation per cited publication (C/CP) of 2.73. The h-index, g-index, and m-index

further solidify its central position in network systems discussions during the pandemic. Another significant contributor is "Sustainability (Switzerland)," with 20 total publications. The journal's focus on integrating digitalization with sustainable practices during the pandemic is evident from its 172 total citations and an average C/P of 8.60. Its scholarly impact is also reflected in its higher h, g, and m indices (Table 7).

The "ACM International Conference Proceeding Series," encompassing nine publications, offers a platform for real-time insights into the evolution of digital technologies. Though the citation impact is more modest, with a C/P of 1.00 and a C/CP of 1.50, its role in fostering interdisciplinary dialogue cannot be understated. Other notable source titles like "sub\urban," "International Journal of Environmental Research and Public Health," and "Studies in Systems, Decision and Control" make unique contributions, ranging from urban development considerations to public health and system-based decisions. They each represent a distinct facet of digitalization studies during the COVID-19 era. Emerging and specialized sources such as "E3S Web of Conferences," "Instruments of Public Law: Digital Transformation during the Pandemic," and "Smart Innovation, Systems and Technologies" hold their own places in the landscape. Whether emerging platforms or specialized forums, they offer focused discussions on specific thematic areas.

The presence of journals like "Frontiers in Psychology" and "BMC Medical Education" emphasizes the interdisciplinary reach of digitalization research. These sources extend the dialogue into disciplines such as psychology and medical education, enriching the discourse. The investigation into RQ4 has illuminated a rich and diverse landscape of source titles that have shaped the discourse on digitalization in the COVID-19 era. The variety in citation metrics among these sources reflects the multifaceted impact and recognition within this evolving field. The findings collectively underscore the complexity and breadth of scholarly engagement with this critical subject during a time of global challenge.

Table 7
Most Productive Source Titles with a Minimum of Five Publications

Source Title	TP	NCP	TC	C/P	C/CP	*h*	*g*	*m*
Lecture Notes in Networks and Systems	22	11	30	1.36	2.73	3	4	1.00
Sustainability (Switzerland)	20	20	172	8.60	8.60	7	12	2.33
ACM International Conference Proceeding Series	9	6	9	1.00	1.50	2	2	0.50
sub\urban	8	8	24	3.00	3.00	2	4	0.67
International Journal of Environmental Research and Public Health	8	6	248	31.00	41.33	5	8	1.25
Studies in Systems, Decision and Control	7	3	43	6.14	14.33	3	6	1.00
E3S Web of Conferences	5	2	5	1.00	2.50	2	2	0.50
Instruments of Public Law: Digital Transformation during the Pandemic	5	0	0	0.00	0.00	0	0	0.00
Springer Proceedings in Business and Economics	5	1	2	0.40	2.00	1	1	0.33
Smart Innovation, Systems and Technologies	5	1	1	0.20	1.00	1	1	0.33
Frontiers in Psychology	5	3	9	1.80	3.00	2	3	0.67
BMC Medical Education	5	4	13	2.60	3.25	3	3	1.50

Notes: TP=total number of publications; NCP=number of cited publications; TC=total citations; C/P=average citations per publication; C/CP=average citations per cited publication; h=h-index; g=g-index; m=index

4.5 Highly Cited Articles

The examination of the top-20 highly cited articles in the field of digitalization and COVID-19 provides critical insights into the landmark papers that have shaped the discourse (Table 8). These influential studies offer profound implications for various sectors including education, business,

healthcare, public policy, and technological innovation. Leading the charge is Iivari *et al.,* [10] seminal work on the digital transformation of basic education for the younger generation during the pandemic, published in the International Journal of Information Management. With a total of 408 citations and an average of 102 citations per year (C/Y), this study underscores the urgency of information management in the education sector, casting a spotlight on the transformative effects of digitalization. The second and third most cited works, by Priyono *et al.,* [11] and Amankwah-Amoah *et al.,* [12], with 211 and 188 total citations respectively, focus on business aspects. Priyono *et al.,* identify digital transformation paths in SMEs, emphasizing adaptability during the pandemic. Amankwah-Amoah *et al.,* discuss the accelerated pace of digitalization in business, reflecting the broader trend in organizational responses to COVID-19.

Soto-Acosta's [13] examination of the pandemic's role in shifting digital transformation into a higher gear also merits attention, with 179 citations. This work emphasizes the imperative of agility in information systems management, epitomizing the dynamism of digital transitions in the crisis context. Further, studies like Almeida *et al.,* [14] and Dannenberg *et al.*, [15] explore the challenges and opportunities in company digitalization and online retail transformation, respectively. With 171 and 168 citations, they capture the complex interplay of hurdles and prospects that the pandemic has unveiled. In the educational domain, papers by García-Peñalvo & Corell [16], Mhlanga & Moloi [17], and Skulmowski & Rey [18] contribute to an enriched understanding of digital transformation in teaching, higher education, and hybrid campus models. These works collectively reflect a shift in pedagogical paradigms, driven by the exigencies of the pandemic.

The interface between healthcare and technology is eloquently captured in Khan *et al.*, [19] exploration of robotics in global COVID-19 management, cited 149 times. This work emphasizes the novel utilization of digital technologies in healthcare, signalling a new frontier in medical innovation. Further down the list, works on leadership during the pandemic [20], digital responses of SMEs [21,22], and digital transformation in public service delivery [23] expand the discourse into diverse arenas. These papers underscore the multifaceted nature of digital transformation, reflecting its pervasive impact across various spheres of life.

The analysis of RQ5 elucidates a constellation of landmark papers that have significantly steered the narrative of digitalization in the COVID-19 era. These studies, with their distinct thematic focus and empirical insights, contribute to a nuanced understanding of the phenomenon. They collectively embody the multiplicity of responses, challenges, and innovations triggered by the pandemic, thus forming an invaluable corpus of knowledge for scholars, policymakers, and practitioners navigating the complex terrain of digital transformation in these unprecedented times.

Table 8
Top-20 Highly Cited Articles

No.	Author(s)	Title	Source Title	TC	C/Y
1	Iivari N.; Sharma S.; Ventä-Olkkonen L. [10]	Digital transformation of everyday life – How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?	International Journal of Information Management	408	102.00
2	Priyono A.; Moin A.; Putri V.N.A.O. [11]	Identifying digital transformation paths in the business model of SMEs during the COVID-19 pandemic	Journal of Open Innovation: Technology, Market, and Complexity	211	52.75
3	Amankwah-Amoah J.; Khan Z.; Wood G.; Knight G. [12]	COVID-19 and digitalization: The great acceleration	Journal of Business Research	188	62.67
4	Soto-Acosta P. [13]	COVID-19 Pandemic: Shifting digital transformation to a high-speed gear	Information Systems Management	179	44.75

5	Almeida F.; Duarte Santos J.; Augusto Monteiro J. [14]	The challenges and opportunities in the digitalization of companies in a post-COVID-19 World	IEEE Engineering Management Review	171	42.75
6	Dannenberg P.; Fuchs M.; Riedler T.; Wiedemann C. [15]	Digital transition by COVID-19 pandemic? The german food online retail	Tijdschrift voor Economische en Sociale Geografie	168	42.00
7	García-Peñalvo F.J.; Corell A. [16]	The COVID-19: The enzyme of the digital transformation of teaching or the reflection of a methodological and competence crisis in higher education?	Campus Virtuales	156	39.00
8	Mhlanga D.; Moloi T. [17]	COVID-19 and the digital transformation of education: What are we learning on 4ir in South Africa?	Education Sciences	155	38.75
9	Khan Z.H.; Siddique A.; Lee C.W. [19]	Robotics utilization for healthcare digitization in global COVID-19 management	International Journal of Environmental Research and Public Health	149	37.25
10	Bartsch S.; Weber E.; Büttgen M.; Huber A. [20]	Leadership matters in crisis-induced digital transformation: how to lead service employees effectively during the COVID-19 pandemic	Journal of Service Management	139	46.33
11	Guo H.; Yang Z.; Huang R.; Guo A. [21]	The digitalization and public crisis responses of small and medium enterprises: Implications from a COVID-19 survey	Frontiers of Business Research in China	136	34.00
12	Savić D. [24]	COVID-19 and work from home: Digital transformation of the workforce	Grey Journal	112	28.00
13	Nagel L. [25]	The influence of the COVID-19 pandemic on the digital transformation of work	International Journal of Sociology and Social Policy	110	27.50
14	Klein V.B.; Todesco J.L. [22]	COVID-19 crisis and SMEs responses: The role of digital transformation	Knowledge and Process Management	106	35.33
15	Papagiannidis S.; Harris J.; Morton D. [26]	WHO led the digital transformation of your company? A reflection of IT related challenges during the pandemic	International Journal of Information Management	104	26.00
16	Skulmowski A.; Rey G.D. [18]	COVID-19 as an accelerator for digitalization at a German university: Establishing hybrid campuses in times of crisis	Human Behaviour and Emerging Technologies	102	25.50
17	Bai C.; Quayson M.; Sarkis J. [27]	COVID-19 pandemic digitization lessons for sustainable development of micro-and small-enterprises	Sustainable Production and Consumption	92	30.67
18	Agostino D.; Arnaboldi M.; Lema M.D. [23]	New development: COVID-19 as an accelerator of digital transformation in public service delivery	Public Money and Management	85	21.25
19	Winarsih; Indriastuti M.; Fuad K. [28]	Impact of covid-19 on digital transformation and sustainability in small and medium enterprises (SMEs): a conceptual framework	Advances in Intelligent Systems and Computing	72	24.00
20	García-Peñalvo F.J. [29]	Digital transformation in the universities: Implications of the COVID-19 pandemic	Education in the Knowledge Society	71	23.67

Notes: TC=total citations; C/Y=average citations per year

4.6 Keywords Analysis

In addressing RQ6, we endeavour to unravel the critical research themes that underpin the ongoing evolution and expansion of the field, with a particular focus on digitalization and the implications arising from the COVID-19 pandemic. This intricate analysis necessitates a robust

methodological approach, leveraging the interconnections and patterns that emerge from the authors' keywords.

To facilitate a comprehensive understanding of these interconnected themes, Figure 3 presents a Network Visualization of the Co-occurrences of Author's Keywords. This visualization serves as a graphical map, highlighting the predominant clusters and connections among various keywords, thereby illuminating the multidisciplinary landscape of the research area. The analysis of Figure 3 enables us to delineate several significant themes, forging a holistic understanding of the digitalization trends and pandemic responses in the academic literature. The ensuing sections will further elaborate on these themes, drawing insights from the network visualization and articulating their implications for the broader field. The data represents critical research themes that underpin the ongoing evolution and expansion of the field, with a focus on digitalization and the COVID-19 pandemic.
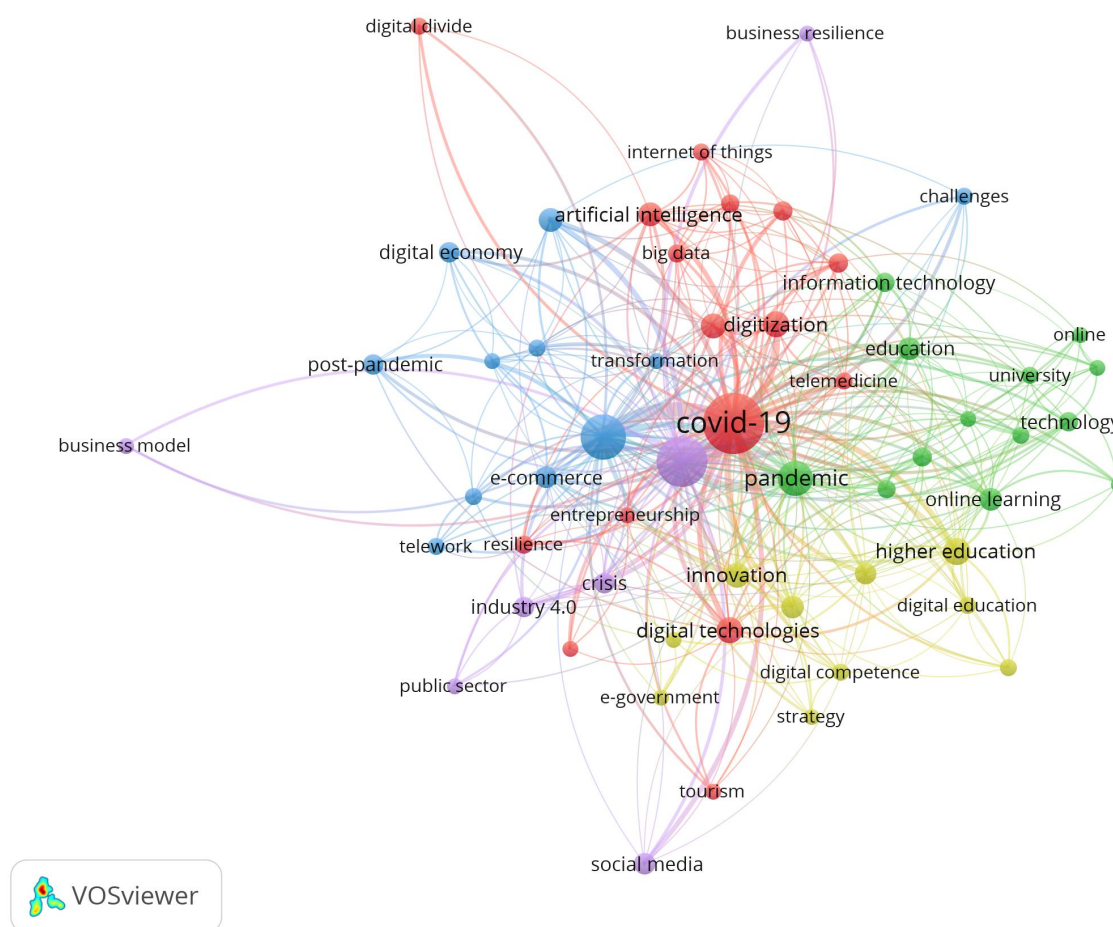

Fig. 3. Network Visualisation of the Co-occurrences of Author's Keywords

Digital Transformation and Integration: The network visualization identifies a prominent cluster around the digital transformation theme. This includes terms such as "digitalization" (47 links), "digital economy" (9 links), "digital technologies" (20 links), "industry 4.0" (11 links), and "information technology" (13 links). The significant weight of occurrences and citations in this cluster underlines the rapid transformation and integration of digital technologies into various sectors, reflecting an evolution driven by technological innovation. It also highlights the pervasive nature of digitalization, impacting multiple facets of society, including business, education, healthcare, and government.

Education and Learning in the Digital Age: The theme of digital education is prominently featured, comprising terms such as "online learning" (16 links), "e-learning" (17 links), "distance education" (6 links), "higher education" (20 links), and "blended learning" (10 links). This cluster reflects the accelerated shift to online and blended learning models in response to the COVID-19 pandemic. The links between these terms underline the interconnectedness and complementary nature of different digital education approaches, shaping a new paradigm for teaching and learning.

Healthcare Transformation during the Pandemic: Another significant theme revolves around healthcare transformation during the COVID-19 pandemic, featuring terms like "coronavirus" (17 links), "covid-19" (56 links), "telemedicine" (12 links), and "e-health" (10 links). This cluster underscores the pandemic's role in catalysing technological advancements in healthcare, promoting telemedicine, remote patient monitoring, and digital health solutions. The strong linkage between these terms emphasizes the interconnectedness of healthcare and technology during a global health crisis.

Business Resilience and Strategy: Business-related terms like "business resilience" (4 links), "business model" (3 links), "strategy" (6 links), and "entrepreneurship" (10 links) reflect the theme of business resilience and strategy. This cluster underscores the need for organizations to develop innovative strategies and resilient business models to adapt to the challenges posed by the pandemic and digitalization. It signifies the importance of agility, innovation, and strategic planning in the contemporary business landscape. Sustainability and Social Impact: Terms like "sustainability" (13 links), "sustainable development" (13 links), and "social media" (8 links) form a theme that emphasizes the increasing importance of sustainability and social impact in the digital era. This cluster reflects a growing awareness of environmental, social, and economic responsibilities within digital transformation efforts, aligning with global sustainable development goals.

The network visualization reveals multifaceted themes within the context of digitalization and the COVID-19 pandemic. The interplay between technology, education, healthcare, business resilience, and sustainability paint a complex picture of a society in transition. This analysis offers valuable insights into emerging research directions, underscoring the critical role of digital transformation as a driving force shaping various domains of contemporary life. It also emphasizes the urgent need for innovative solutions and strategies to address the challenges and opportunities presented by this unprecedented era of digital evolution.

Building upon the insights from Figure 3, Figure 4 presents an Overlay Visualization of the Co-occurrences of Author's Keywords, adding a sophisticated layer of analysis that uncovers temporal dynamics and hierarchical relationships among identified themes. The overlay in Figure 4 highlights the chronological progression of the identified themes, revealing how they have evolved and interacted over time. This is exemplified in the marked prominence of concepts like "digital transformation" in recent years, reflecting technological advancements. In contrast, the emergence of themes such as "e-learning" and "distance education" in earlier periods illustrates the historical trajectory of remote educational strategies. The visualization further explicates the interconnectedness of various clusters. For example, the interconnection between "artificial intelligence" and "big data" suggests a synergistic relationship between these technological facets. Likewise, the linkage between "business resilience" and "coronavirus" underscores the nexus between organizational adaptability and global challenges.

An important observation from Figure 4 is the elucidation of the profound impact of the COVID-19 pandemic on the thematic landscape. Themes related to "telework," "emergency remote teaching," and "online learning" have significantly intensified, reflecting societal and organizational responses to unprecedented circumstances. The Overlay Visualization also provides a means to

identify central and peripheral themes within the network. Themes like "digital economy" occupy a central position, representing core foci, while peripheral themes such as "tourism" denote complementary or emergent areas contributing to a broader comprehension of digitalization. Finally, Figure 4 offers insight into the relative impact and influence of the various themes. The high average citations associated with keywords such as "business model" and "sustainability" indicate their seminal nature in shaping discourse around digitalization and pandemic responses.

Figure 4, when interpreted in tandem with Figure 3, affords a multifaceted perspective of the complex and evolving research themes. By visualizing co-occurrences and overlaying them with additional contextual layers, it elucidates the interplay, chronological emergence, and significance of various concepts within the context of digital transformation and global crises. This synthesis contributes to a robust foundation for further exploration, offering a comprehensive understanding of the dynamism and intricacies of the research landscape.

Fig. 4. Overlay Visualisation of the Co-occurrences of Author's Keywords

5. Discussion

The COVID-19 pandemic has precipitated a significant shift in research attention towards the subject of digitalization, highlighting its multifaceted implications across various spheres of human activity. This comprehensive bibliometric study provides a rich and systematic analysis of the digitalization research landscape during this critical period. The period between 2020 and 2023 has witnessed a substantial surge in scholarly activity within the field of digitalization, as evident from the high number of publications and robust citation rates. Such metrics underscore the academic

rigor and significance of this research area, emphasizing the urgency and relevance of digitalization in addressing the COVID-19 pandemic. The digitalization research's considerable growth and impact set the stage for continued scholarly investigation. Digitalization transcends the bounds of technology to intersect with a wide array of disciplines, including Social Sciences, Computer Science, and Environmental Science. This interplay stresses the diverse applications of digitalization, especially pertinent to a global health crisis, and lays a foundation for integrating digitalization across various sectors.

The study elucidates the distribution of research across various formats and highlights the importance of quality and academic merit. At the same time, it poses vital questions regarding accessibility and global inclusivity, considering the dominance of English in publications. This aspect signals the need for broader reach and democratization of access. The insights gathered offer a nuanced understanding of the digitalization research landscape during the COVID-19 era. Themes such as digital transformation in sectors like healthcare, education, and the economy; business resilience; and sustainability reflect the field's complexity. These findings furnish crucial directions for scholars, businesses, policymakers, and practitioners, constituting a roadmap for future research and strategic endeavours. Furthermore, they herald potential future trajectories, challenges, and opportunities within digitalization research

Our study's findings present a substantial academic contribution that connects theory with practice, fostering further exploration and innovation within the realm of digitalization. By exploring this burgeoning field's multifaceted aspects, this study illuminate's pathways for continued growth, collaboration, and real-world impact amid unprecedented global disruptions. The variation in total publications, citations, and indices illustrates the rich interplay between diverse themes and digitalization's multifaceted roles during the pandemic. This diversity not only enriches academic discourse but also facilitates a nuanced understanding of digitalization as a complex phenomenon. The analyses contribute to a holistic view, guiding future researchers in navigating the robust landscape of sources.

6. Conclusion

This study serves as a vital reference for researchers, practitioners, policymakers, and academics striving to comprehend the contours of digitalization research during the COVID-19 pandemic. The detailed analysis provides a guide for navigating this intricate field, engaging with current scholarship, and inspiring future exploration. Emphasizing digitalization's critical role as both a tool and a subject of study during these unique global challenges underscores its potential in shaping a resilient and innovative future. The paper's unique contributions lie in its intricate methodological approach, multidisciplinary perspectives, and integration of the COVID-19 pandemic's impact. By visualizing the interconnections, chronological emergence, and relative significance of various concepts, it provides a comprehensive picture of the research landscape. The insights obtained from this study will be pivotal in shaping discourse, policy, and practice as we traverse this unprecedented era of digital evolution. The findings of this research position it as a valuable addition to the scholarly field, meriting publication for its significant contributions to understanding digital transformation, particularly during a globally defining period such as the COVID-19 pandemic.

Despite its comprehensive nature, certain limitations in this study warrant acknowledgment. Future research could further deepen this investigation, considering qualitative aspects and long-term impacts, and extending the exploration of digitalization beyond the pandemic. Such endeavours will continue to refine our understanding of this dynamic and vital field.

Acknowledgement

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