

Digital Transformation: A Bibliometric Analysis

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ABSTRACT

This paper aims to provide an overview of academic research within the field of digital transformation. The authors conduct a bibliometric analysis using VOSviewer, Harzing's Publish or Perish, and SciMAT to evaluate and visualize the bibliographic materials. The analysis focuses on journals, papers, researchers, institutions, and countries, using bibliometric indicators such as productivity, citations, H-index values, and TLS values. Graphical analyses illustrate co-authorship, co-occurrence of keywords, evolution of research topics, and network of influential researchers within digital transformation. The results complement each other and show that Germany, the United States, and the Russian Federation are the most influential countries in digital transformation research. Additionally, the results suggest that collaboration within this field is still weak, and many research topics are just beginning to emerge. This research provides a summary of most of the key aspects in digital transformation research and helps lay the groundwork to shape the future of this growing field.

KEYWORDS

Bibliometric Analysis, Bibliometric Mapping, Bibliometrics, Digital Transformation, H-Index, Harzing's Publish or Perish, Literature Review, SciMAT, VOSviewer

INTRODUCTION

Digital transformation is a recognized research field that has emerged as digital technologies have been widely adopted in society, industries, and organizational management (Nadkarni & Prügl, 2021; Verhoef et al., 2021; Vial, 2019; Zaoui & Souissi, 2018). It is known that digital transformation arises at the intersection of products, services, and mediums based on digital technologies and processes of value transformation and creation (Schallmo & Williams, 2018). Since its inception, digital transformation has been characterized as a field of research that has continuous changes associated with the area in which it is relevant (Roth, 2019). Integrating extant literature, Vial (2019, p. 118) defined digital transformation as “a process that aims to improve an entity by triggering significant

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changes to its properties through combinations of information, computing, communication, and connectivity technologies.”

Given the outbreak of COVID-19 and the pandemic’s spread across the globe, digital transformation research has gained an increasingly established position of recognition among researchers associated with reliance on the use of digital technologies in socioeconomic activities. The field has attracted hundreds of researchers from diverse areas of the social sciences, including management (e.g., Daradkeh, 2021; Hensellek, 2020; Salman et al., 2022; Sigari et al., 2021), marketing (e.g., Kumbhojkar & Menon, 2022; Xiao et al., 2022), economics (e.g., Anttiroiko, 2021; Maji & Laha, 2020), technology (e.g., Lichtenthaler, 2021; Mydyti & Kadriu, 2021), education (e.g., Coral & Bernuy, 2022; Erskine et al., 2022), and society (e.g., Fan, 2018; Kazim, 2021; Mossberger & Tolbert, 2021; Tebepah, 2020). This has led to a widespread body of literature.

Researchers generally emphasize the importance of classifying the literature of a research area based on main trends. Bibliometrics is one of the most used techniques for this purpose. Bibliometric mapping, or science mapping, is an important research stream in bibliometrics. It monitors a scientific field, delimits its cognitive structure and evolution, and serves as a spatial representation of how disciplines, fields, researchers, and individual documents are related (Cobo et al., 2012). Despite the value of uncovering key elements in a specific field of interest, bibliometric studies in the field of digital transformation are scarce. Therefore, the aim of this article is to provide an overview of digital transformation research based on bibliometric mapping.

To accomplish this task, the authors conducted bibliographic mapping in this field using VOSviewer, Harzing’s Publish or Perish, and SciMAT for relevant evaluation and visualization of the bibliographic materials. The analysis focuses on researchers, research topics, publications, journals, countries, and institutions. The work uses a series of bibliometric indicators like productivity, citations, H-index values, and total link strength (TLS) values. The graphical analysis conveys coauthorship, cooccurrence of keywords, evolution of the research topics, and network of influential researchers.

The current study seeks answers to the following questions in the field of digital transformation:

1. What is the status of collaboration among researchers?
2. What is the distribution and trend of keywords?
3. Who are the most influential researchers?
4. Which are the most influential publications?
5. Which are the most influential journals?
6. Which are the most influential countries and institutions?

This article is structured as follows. First, the article describes the methodology used in the current study. Next, the article offers a presentation of the results of bibliometric analyses and mapping. Finally, the main conclusions are discussed.

METHOD

Research Design

Bibliometrics is a statistical method commonly used in academic literature review to quantify the assessment of scientific output (e.g., Baier-Fuentes et al., 2019; Goksu, 2021; Liu et al., 2020). This article follows five steps to examine networks, evolutionary tendencies, and the most influential units (i.e., researchers, keywords, publications, journals, institutions, and countries) in the field of digital transformation. The first step, the data retrieval step, uses the Scopus database for the breadth of information. In addition to being the biggest database in the world, Scopus provides more detailed information about publications as compared to other databases. This information includes full article titles, exact journal names, and a more complete list of researcher names (i.e., the names of the first

author to the eighth author). Thus, Scopus will help form a more accurate and broader network of cooperation between researchers. It can reveal more details about digital transformation trends than if the network had been built using information obtained from other databases.

In the data preprocessing step, the authors removed duplicated data and error information before beginning the third step, the analysis. The authors explored the following aspects of the data:

1. Coauthorship analysis to explore the relationship among researchers and countries.
2. Cooccurrence analysis to identify hot topics in the field of digital transformation and a longitudinal analysis to present how the field changed over time and predict future research trends.
3. Comparison of the values of TLS and the H-index of each unit to identify the most influential units of the field, including researchers, publications, journals, countries, and universities.

The visualization step used diagrams like network, evolution map, and strategic diagram to allow readers to better understand the results. Finally, the interpretation step presented results of the figures and tables. It also combined the analysis results with relevant literature for further discussion.

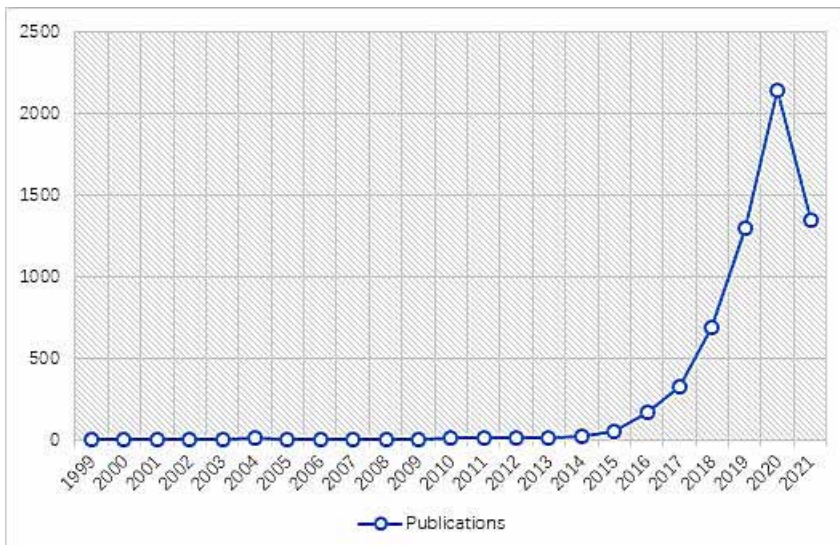
Obtaining the Metadata Set

Inspired by previous review work on academic research (e.g., Zheng et al., 2018), the authors conducted a systemic search of the database from January 1999 to August 2021. They used the keyword “digital transform*,” restricting the search to English-language literature. The search extracted 6,813 metadata sets, including articles, book chapters, conference papers, reviews, and books. The data contained article title, publication year, journal, author, abstract, keywords, and citation count.

To determine which of these data was valid for further analysis, the authors went through the metadata sets to remove data with missing or duplicated information. The final data set included a total of 4,853 publications. It covered 306 countries, 8,306 organizations, and 12,083 authors identified by the VOSviewer’s citation function.

Figure 1 shows the distribution of the data by publication year. The first four articles on digital transformation appeared in 1999. They covered evaluation of digital libraries (Shim & Kantor, 1999), educational software packages (Magdziarz et al., 1999), the digital learning process (Saga, 1999),

Figure 1. Distribution of digital transformation research by publication year



and the digital bandpass filter (Djuric & Stancic, 1999). In other words, digital transformation was explored by researchers in terms of how it was applied in education. Publications in this field slowed until 2015, after which many disciplines were involved and the number of publications increased.

Data Analysis

Three bibliographic analysis tools were used to visualize outstanding factors and the evolution of research in the field of digital transformation. Specifically, VOSviewer was used to visualize a network formed by the outstanding factors (Van Eck & Waltman, 2010). Harzing's Publish or Perish was used to evaluate the H-index of the researchers, journals, countries, and universities. SciMAT was applied to illustrate how the focal points changed (Cobo et al., 2012).

The current study used VOSviewer to analyze the number of publications, citations, and TLS values for the data. The results were used to form the following three networks:

1. **Coauthorship Analysis:** Examined the partnership of authors who collaborated on digital transformation research.
2. **Cooccurrence Analysis:** Keywords were selected and classified to display the most popular topics and their connections.
3. **Citation Analysis:** Identified the most popular researchers, journals, countries, and universities in the field of digital transformation.

Harzing's Publish or Perish software provides a more accurate method to determine the academic achievement of researchers and journals using H-index ratings. H stands for "high citations." The value of the H-index of a researcher or a journal means that, at most, h papers have been cited h times (Rao & Govardhan, 2016). A higher H-index indicates that a person's or journal's paper has greater influence over the field of digital transformation. The information that can be learned from H-index ratings is an important supplement to the result of TLS as generated by VOSviewer. In this study, TLS value and H-index were used together to identify the most influential units in the field of digital transformation research.

A strategy diagram and evolution map created by SciMAT complement the understanding on the development of the field of digital transformation research. The strategic diagram presents density and centrality of researchers' interests. The evolution map reveals the most important keywords over time and the relationships between and dynamics of the keywords during the development of the field.

To ensure accurate results, synonymous keywords were merged into a single group. For example, by using the word-grouping function of SciMAT, the phrases "smart technology" and "smart technologies" were categorized into the same group. Finally, the authors filtered out the outlier data to yield a clearer map. In the results obtained using SciMAT and VOSviewer, the size of nodes in the network visualization reflects how publications performed. The distance between two nodes indicates the closeness of their relationship. For example, a larger node means that the factor has more publications, more citations, or a higher TLS value. The closer together the nodes, the higher probability they emerged at the same time.

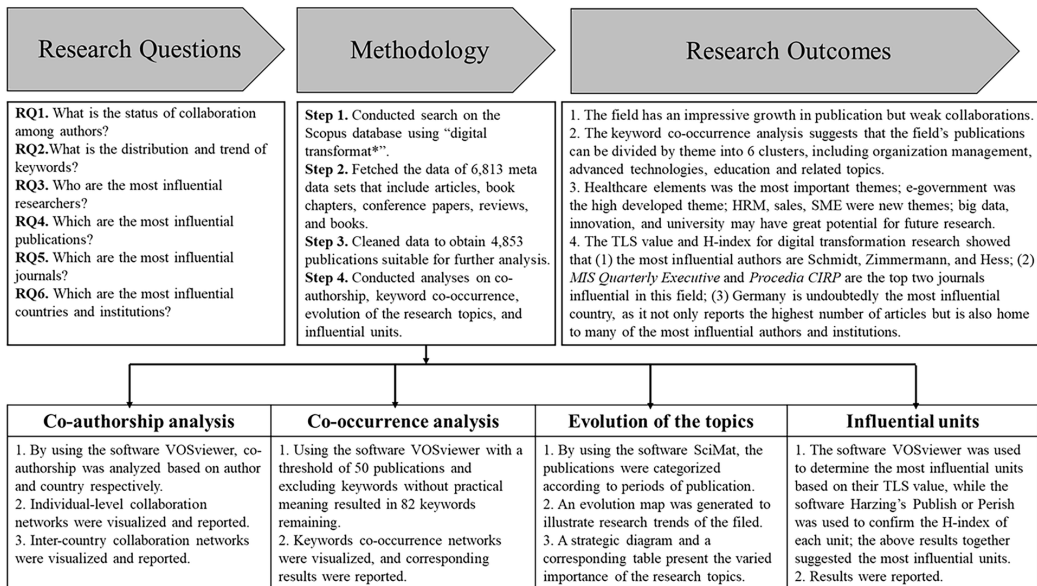
In short, to answer the research questions, the authors retrieved the raw data set from Scopus. Then, they used the three visualization tools according to the research design shown in Figure 2.

RESULTS

Coauthorship Status

The coauthorship analysis included researchers with at least three publications (fractional counting) regarding digital transformation. Among the 12,083 researchers in the initial data set, 450 met this threshold and were selected for network analysis. Among these 450 researchers, only 21 of them

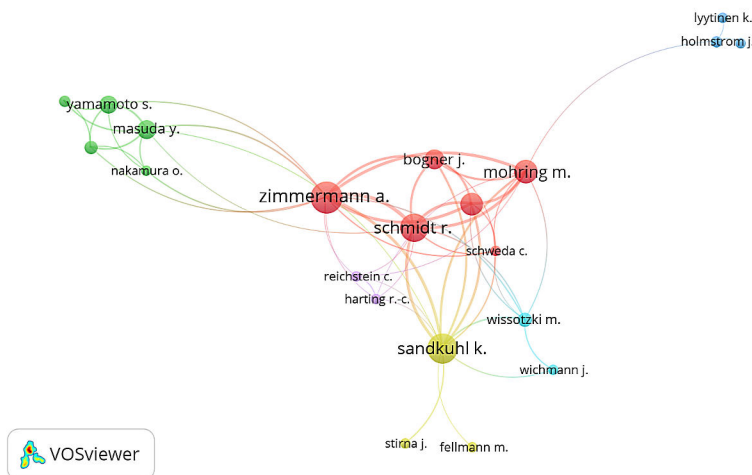
Figure 2. Research design of the study



collaborated directly or indirectly. The authors separated these 21 researchers into six clusters to form a network of coauthorship. As shown in Figure 3, the sizes of most nodes in the red cluster and yellow cluster are bigger than in other clusters. This visualization indicates that most of the selected researchers in these clusters have published more articles than other researchers. The distance between the nodes shows partnerships among the red, yellow, blue, and purple clusters (they are closer together as compared to the other two clusters). Of all these clusters, the red cluster is at the center.

Specifically, six researchers are classified in the red cluster. Of these, the researcher Zimmermann A. has the most articles. Five researchers are in the green cluster, including Masuda Y. with the

Figure 3. Coauthorship network in the digital transformation field



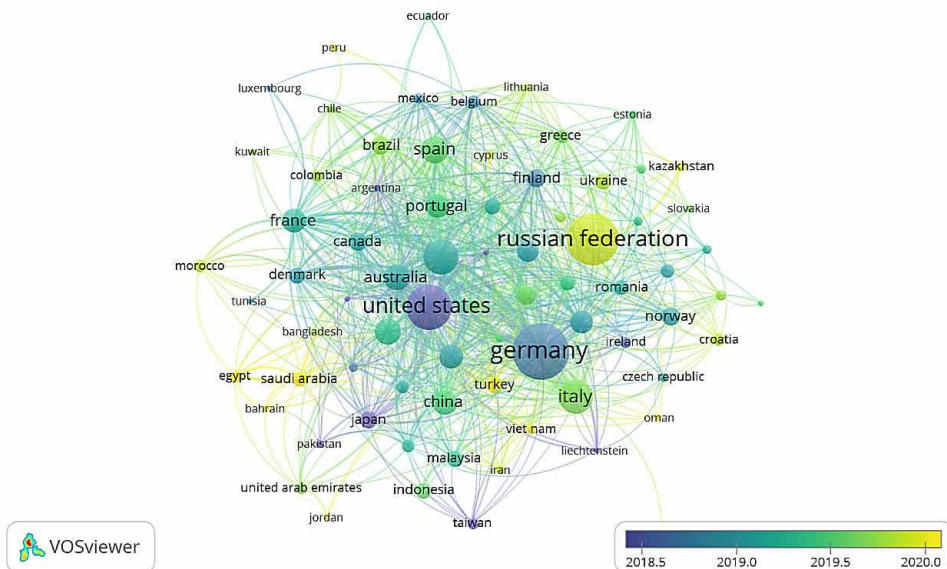
highest number of publications in that cluster. The yellow cluster includes three researchers, led by Sandkuhl H. The dark blue cluster also includes three researchers. Holmstrom J. published the most articles and linked the dark blue and red clusters. No leading researchers are in the remaining two clusters. Furthermore, the researchers in the red, yellow, purple, and sky-blue clusters are from German institutions. The researchers in the green cluster are from Japanese institutions. Thus, it can be inferred that cross-border collaboration in the field of digital transformation research is still weak.

The authors analyzed the titles of the researchers' publications. The results reveal that the selected researchers have focused on management of digital transformation. The researchers in the red cluster published the most articles on architecting, including digital products and services (Zimmermann, Schmidt, Sandkuhl, Jugel et al., 2021), digital platforms, intelligent digital systems (Zimmermann, Schmidt, Sandkuhl, El-Sheikh et al., 2021), digital enterprises (Zimmermann et al., 2016), and decision management (Zimmermann et al., 2018). They also explored the impact of digital transformation in the context of banking, insurance, and libraries. The researchers in the green cluster published the most articles on digital platform architecture (Masuda et al., 2021), risk management (Masuda et al., 2017), and e-health management (Masuda et al., 2018; Yamamoto, 2021). In the yellow cluster, publications concentrated on enterprise modeling, specifically in product and service modeling (Sandkuhl et al., 2020). In the sky-blue cluster, the most popular publication topic was digital innovation and transformation, including its application in public sectors (Wichmann et al., 2021) and zoological institutions (Wichmann et al., 2020; Wißotzki & Wichmann, 2019).

The study further analyzed collaboration among researchers by country in the field of digital transformation. Among the 306 countries, 76 countries satisfied the criterion of at least five publications. These were included in further analysis, as shown in Figure 4. In this visualization map, the larger nodes indicate the more publications a country has produced. The map's lighter color nodes indicate more recent publications.

Comparing node size, the countries with the greatest quantity of digital transformation research are Germany, the Russian Federation, and the United States. The color bar at the bottom right corner of the map shows at what point researchers in each country developed interest in this field. The map

Figure 4. Collaboration among researchers from different countries in the field of digital transformation



shows that researchers in the U.S. were the first groups to explore the field, followed by Germany. Researchers in the Russian Federation were the latest to enter the field.

Keyword Analysis and Trend Topics in Digital Transformation

A total of 19,447 keywords was used in the selected 4,853 publications. To clear the map, the authors only considered keywords labeled in at least 50 publications. This resulted in 91 keywords. The keyword “digital transformation” was excluded because it was used in the query. Other keywords were excluded because they did not hold practical meaning. These included “article,” “human,” and “survey” and so on. Ultimately, 82 keywords were moved to the next step of analysis.

As shown in Figure 5, the keywords are classified into six clusters. In the red cluster, the keywords are separated into the following topics of emerging technologies: AI, IOT (i.e., Internet of things); automation; big data; blockchain; security; cyber security; and risk management. Green cluster keywords describe the use of digital technologies in information management and decision making. In the dark blue cluster, keywords mainly relate to digitalization in education, including e-learning, engineering education, higher education, students, etc. In the yellow cluster, the focus shifts to industry topics like industry 4.0 (industrial management and industrial revolutions) and smart manufacturing. In the purple cluster, research themes focus on socioeconomic development, including public management (public administration and e-government), economic development (digital economy, economic, and sustainable development), and agriculture. The light blue cluster focuses on business factors, with keywords like commerce, competitive advantage, and ecosystems. From the range of these subjects, it can be inferred that digital transformation has been discussed and applied widely in various topics at different levels.

In addition, SciMAT was used to present the longitudinal framework of digital transformation. It traced the important topics discussed in each period (see Figure 6). The H-index was used to benchmark the importance of each keyword. According to the trends of an increasing number of publications, the authors found that the field of digital transformation research had little development and was, in fact, almost static in the early stage. However, it has exploded in recent years.

Figure 5. Network visualization of cooccurrence of keywords

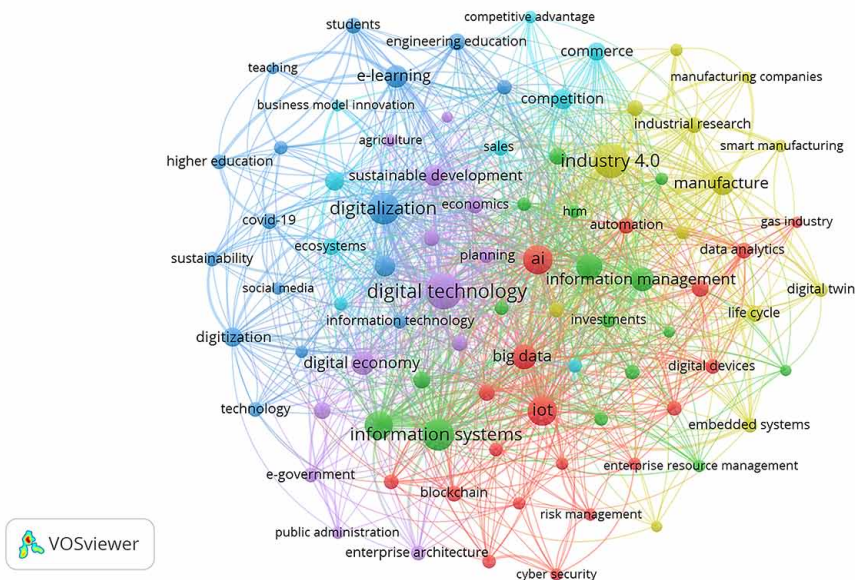
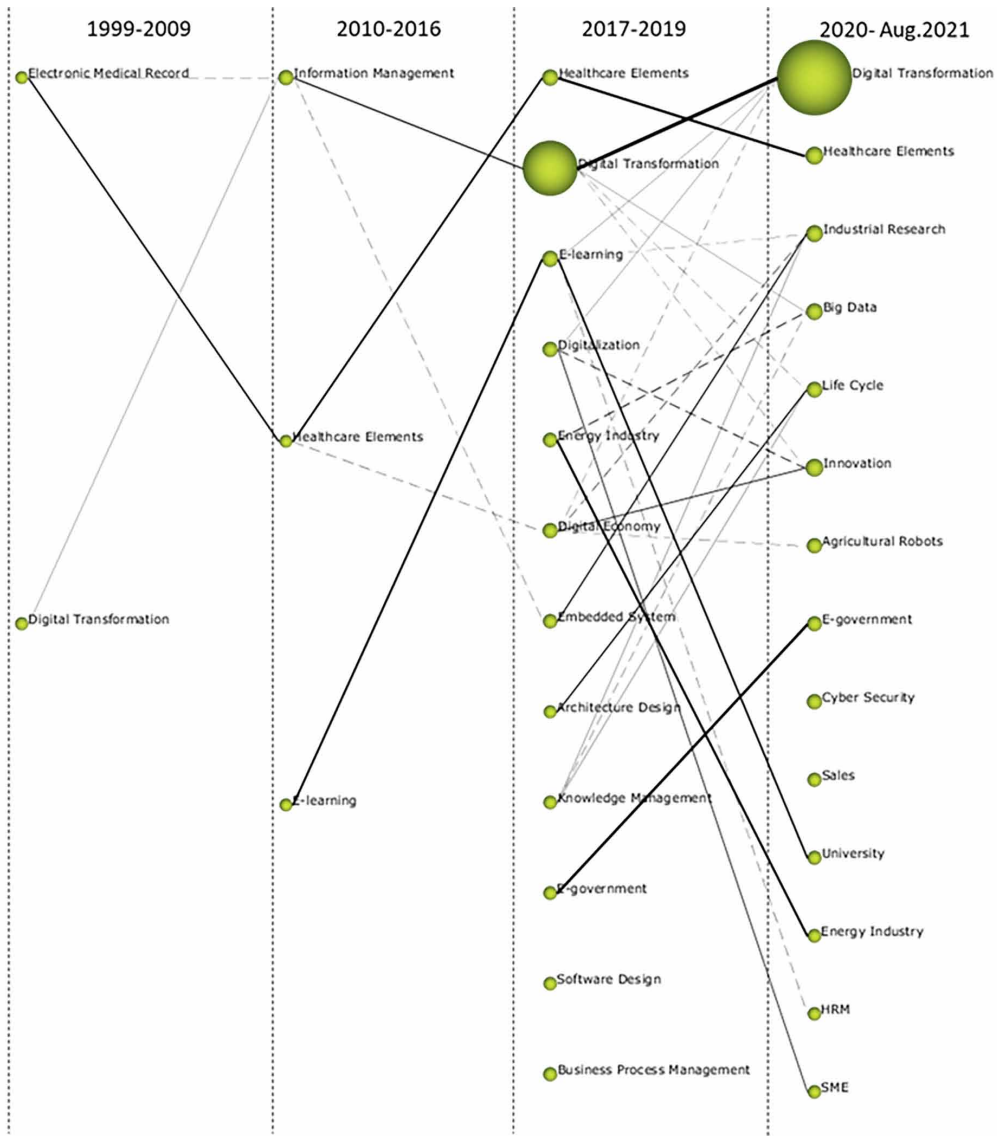


Figure 6. Evolution of research themes in the digital transformation field(1999-2009; 2010-2016; 2017-2019; 2020-August 2021)



The selected publications were sliced into four periods. In the period 1999 to 2009, only a few articles were published in each year. In the period 2010 to 2016, the number of publications increased every year. In the period 2017 to 2019, the number of publications grew exponentially. The year 2020 had explosive growth.

Next, the authors conducted an evolution analysis by detecting key research themes in each period, discovering shared terms, and identifying how they evolved. A solid line connecting themes means that the linked cluster shares the main item. A dotted line means that the themes share elements that are not the main item (Cobo et al., 2012).

Figure 6 presents the standout topics for each period. Specifically, before 2010, the most discussed applications in the field were “electronic medical records” and “digital transformation.” In the period 2010 to 2016, three key themes were discussed, including “information management” (derived from

the “digital transformation” theme in the last period). These themes are, therefore, connected with a solid line. “Electronic medical records” in the period before 2010 and “healthcare elements” in the period 2010 to 2016 are different names for the same concept. Therefore, they are linked with a strong solid line. “E-learning” was a theme that emerged in the period 2010 to 2016. In the period 2017 to 2019, in addition to the three themes of the previous period, many topics emerged, including “digitalization,” “energy industry,” “digital economy,” “embedded systems,” “architecture design,” “knowledge management,” “e-government,” “software design,” and “business process management.” In the period 2020 to August 2021, the themes of “digital transformation,” “healthcare elements,” “energy industry,” and “e-government” still existed; however, scholars’ research interests expanded to include industrial topics like “big data,” “life cycle,” “innovation,” “agricultural robots,” “cyber security,” “sales,” “university,” “HRM,” and “SME” (i.e., small and medium enterprise). Of the themes in this period, only “cyber security” and “sales” were new; all others derived from the research topics in the previous period. The evolution map shows that “healthcare elements” and “e-learning” are the two most common topics that were covered and have evolved.

The evolution of topics confirms what has been found in previous literature. It shows that digital transformation generates a strong socioeconomic impact on various fields (e.g., Caputo et al., 2021; Evangelista et al., 2014). Furthermore, the evolution of popular topics across periods supports that:

it is necessary to consider the digital transformation, outside sectoral limitations, as an economic development model by identifying all the conceptual components that can directly or indirectly impact digitalization. (Zaoui & Souissi, 2018, p. 1)

Specifically, the emergence of topics along the timeline reflects how different domains advance with innovation and diffusion of digital technologies in a broad process of socioeconomic development.

Next, the authors used the density index and centrality index to generate a strategic diagram tool to illustrate the importance of emerging topics (see Figure 7). The density index represents the link strength between keywords in a single topic. Higher density topics have greater maturity. The centrality index represents link strength among topics. The more central a topic, the more closely it relates to other topics.

There are four categories in a strategic diagram. Quadrant 1, motor themes, contains themes with strong centrality and high density. These themes can be regarded as cornerstones that help develop and structure the field of digital transformation research. Quadrant 2, highly developed and isolated themes, contains themes that have developed into a highly mature state. However, these themes are less connected to others. Quadrant 3, emerging or declining themes, contains themes that present low density and low centrality. They are either emerging or declining in the field of digital transformation research. Quadrant 4, basic and transversal themes, refers to themes that are characterized by high centrality and low maturity (Cobo et al., 2011; Viedma et al., 2020).

Table 1 summarizes the main research themes in the field of digital transformation research. It measures their performance by number of publications, citations achieved, and H-index from 1999 to August 2021. First, in the period of 1999 to 2009, “electronic medical records” and “digital transformation” were the key themes. Still, their poor performance indicates that the field of digital transformation research was in its introduction stage. Second, among the three themes that emerged in the period of 2010 to 2016, “information system” was the most prevalent. This can be inferred from the theme’s performance in publication, citations, and H-index, as well as its belongingness to motor themes (Quadrant 1). In the 2010 to 2016 period, “healthcare elements” was the transverse and general basic theme. It was closely connected to other themes and appeared frequently (but not in depth). The poor performance of “e-learning” implies that research on e-learning was relatively isolated. Third, in the period of 2017 to 2019, 12 themes can be classified into the four Quadrant categories. To be more specific, motor themes (Quadrant 1) included “digital transformation,” “e-learning,” and “energy industry,” suggesting that these themes formed the base for the development and structure

Table 1. Principal research themes related to digital transformation

Electronic medical record	Q1(9 70 3)			
Digital transformation	Q1(15 118 4)		Q1(938 6,642 35)	Q1(1,382 3,015 23)
Information system		Q1(59 902 15)		
Healthcare elements		Q4(10 142 6)	Q2(83 682 14)	Q1(120 350 10)
E-learning		Q2(8 31 2)	Q1(84 393 10)	
Digitalization			Q4(63 890 13)	
Energy industry			Q1(47 92 5)	Q2(26 16 2)
Digital economy			Q4(64 334 10)	
Embedded system			Q4(44 285 8)	
Architecture design			Q2(17 207 8)	
Knowledge management			Q3(30 101 5)	
E-government			Q3(25 107 5)	Q2(54 64 5)
Software design			Q2(24 145 7)	
Business process management			Q2(32 113 6)	
Industrial research				Q1(94 215 7)
Big data				Q4(89 258 8)
Life cycle				Q1(75 80 5)
Innovation				Q4(120 553 11)
Agricultural robots				Q1(62 58 3)
Cyber security				Q2(63 22 3)
Sales				Q3(32 53 3)
University				Q4(34 45 3)
HRM				Q3(19 10 2)
SME				Q3(18 104 4)

Note: Q1, Q2, Q3, and Q4 are short for Quadrant 1, Quadrant 2, Quadrant 3, and Quadrant 4 (illustrated in Figure 7). The three numbers after Q1, Q2, Q3, and Q4 are publication, citations, and H-index of the corresponding theme, respectively.

of the field of digital transformation research in this period. Highly developed and isolated themes (Quadrant 2) included “healthcare elements,” “architecture design,” “software design,” and “business process management.” As reflected in their performance in this period, as well as the fact that they appeared in the next period, the theme of “healthcare elements” was better developed than the other three themes in this period. Emerging or declining themes (Quadrant 3) included emerging topics like “knowledge management” and “e-government.” Basic and transversal themes (Quadrant 4) included “digitalization,” “digital economy,” and “embedded systems.”

Finally, 14 themes were identified in the latest period in this study (2020 to August 2021). Specifically, themes of “digital transformation,” “healthcare elements,” “industrial research,” “life cycle,” and “agricultural robots” were identified as motor themes (Quadrant 1), indicating that they were the most important themes in the field of digital transformation research at this time. Highly developed and isolated themes (Quadrant 2) included “energy industry,” “e-government,” and “cyber security.” Compared to the previous period, the theme of “energy industry” lost its centrality. More publications were focused on “e-government.” “Cyber security” was an isolated theme. Emerging or declining themes (Quadrant 3) included “HRM,” “sales,” and “SME” (all new themes). Basic and

transversal themes (Quadrant 4) included “big data,” “innovation,” and “university,” implying that they may have great potential for future research in the field of digital transformation research. To have a clear view of the latest research development on digital transformation, the authors generated a strategic diagram jointly considering the density index and centrality index for the period from 2020 to August 2021 (see Figure 7).

Note: Motor themes (Quadrant 1); Highly developed and isolated themes (Quadrant 2); Emerging or declining themes (Quadrant 3); Basic and transversal themes (Quadrant 4).

Most Influential Researchers

The top 10 influential researchers were analyzed as follows. First, the authors used VOSviewer to identify the top 10 researchers according to their TLS values. This indicated the researchers’ frequency and range of collaboration. Thus, the top 10 researchers were those with the top 10 TLS values. Second, the number of publications, number of citations, and H-index of the top 10 researchers were extracted from Harzing’s Publish or Perish. To ensure that the most influential researchers were identified, the authors conducted additional assessments (see Table 2). Among the 10 most influential researchers, seven were from Germany and three were from Japan. The researchers with the highest TLS scores were Zimmermann A., Hess T., and Schmidt R. The researchers with the best H-index ratings were Schmidt R., Yamamoto S., and Zimmermann A. The researchers with the most citations were Schmidt R., Yamamoto S., and Hess T. Accordingly, Schmidt R., Zimmermann A., Hess T., and Yamamoto S. were the most influential researchers.

Figure 7. Strategic diagram for window period 2020 to August 2021

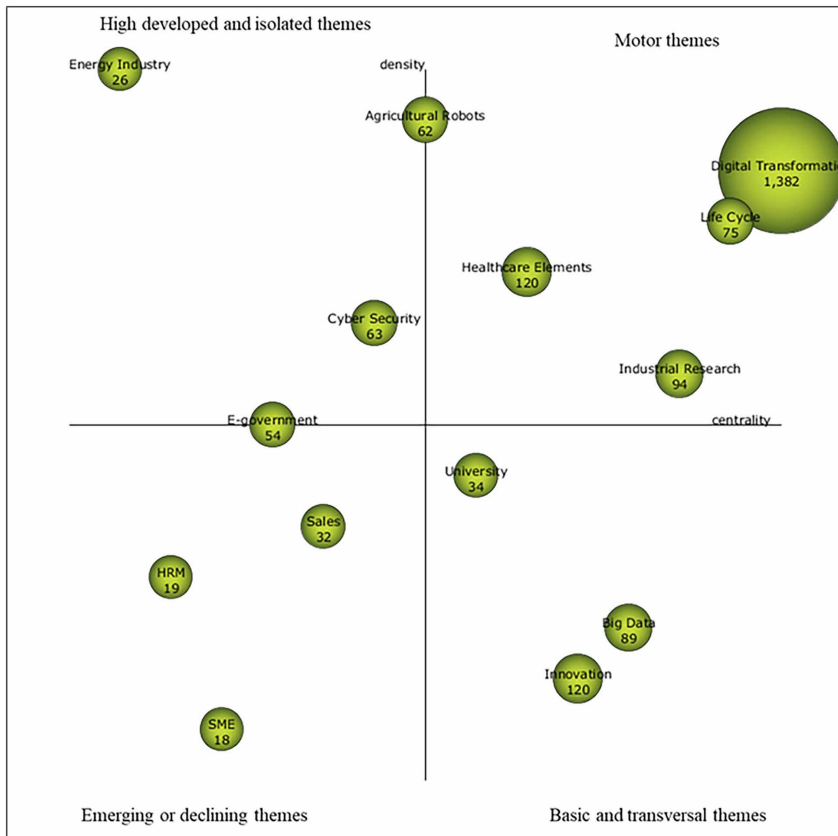


Table 2. Most influential researchers of digital transformation

No.	Researcher	University	CNT	Pub	Pub Time	Citations	C/P	H-index	TLS
1	Zimmermann A.	Reutlingen University	GER	206	1995-2021	3861	148.5	33	61
2	Hess T.	Munich University	GER	174	1996-2021	6989	279.56	32	54
3	Schmidt R.	Munich University	GER	456	1965-2022	25666	458.32	60	43
4	Sandkuhl K.	University of Rostock	GER	103	1996-2021	835	33.4	13	37
5	Masuda Y.	Keio University/ Carnegie Mellon University	JPN	115	1973-2021	5171	107.73	23	34
6	Jugel D.	Hochschule Reutlingen	GER	36	2014-2021	412	58.86	10	29
7	Mohring M.	Munich University	GER	40	2004-2021	1421	35.53	12	29
8	Yamamoto S.	Nagoya University	JPN	364	1966-2021	10043	2510.75	49	28
9	Shirasaka S.	Keio University	JPN	17	2014-2021	159	22.71	7	26
10	Bogner J.	University Stuttgart	GER	25	1993-2021	388	15.52	9	21

Note: The authors used VOSviewer to obtain the TLS value and Harzing's Publish or Perish for the publications, citations, and H-index evaluation. CNT = Country, Pub = number of publications, Pub Time = publication period, C/P = citation/paper, GER = Germany, and JPN = Japan.

A network map helps illustrate influential researchers' status in their collaboration networks. The authors generated a network map based on the following procedure. Researchers were only considered if they had at least 50 citations. Eighty-six researchers met the criteria; however, only 39 of those researchers had connections with each other. As shown in Figure 8, the authors divided the selected researchers into two sections. The right section included the green and light blue clusters. The left section included the red, yellow, dark blue, and purple clusters. The map shows that the researchers in the right section had larger nodes, indicating that these researchers had more publications than those in the left section. In the left section, only Hess T. and Krcmar H. are shown to have prominent work.

Most Influential Publications

Of the 4,853 articles on digital transformation found through citation analysis, the 10 publications with the most citations are listed in Table 3. The most cited article, *The Digital Transformation of Healthcare: Current Status and the Road Ahead*, provides an overview of the status of health information technology. It identifies three research gaps in applying digital technologies in the healthcare domain.

Most Influential Journals

The authors used the citation analysis provided by VOSviewer to identify journals with the strongest link strength. They obtained their H-index values using Harzing's Publish or Perish. Of the full 1,826 sources of publications, 61 journals published at least 10 studies on digital transformation. Table 4 lists the 10 most influential journals in the field of digital transformation research as ranked by TLS value. Among these leading journals, *MIS Quarterly Executive*, *Procedia CIRP*, *Advances in Intelligent Systems and Computing*, and *Procedia Manufacturing* have the highest link strength values.

Figure 8. Network visualization of the most influential authors

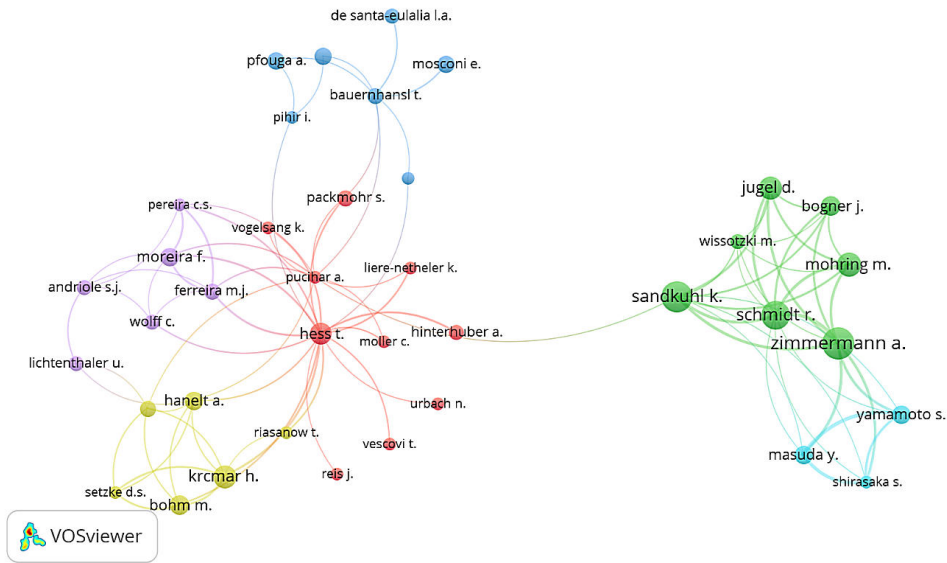


Table 3. Ten publications on digital transformation with the most citations

Rank	Year	First Author	Article Title	Scopus Citations
1	2010	Agarwal R.	The digital transformation of healthcare: Current status and the road ahead	444
2	2019	Frank A.G.	Industry 4.0 technologies: Implementation patterns in manufacturing companies	374
3	2006	Zhu K.	Innovation diffusion in global contexts: Determinants of post-adoption digital transformation of European companies	351
4	2019	Vial G.	Understanding digital transformation: A review and a research agenda	345
5	2016	Hess T.	Options for formulating a digital transformation strategy	340
6	2016	Dimitrov D.V.	Medical Internet of things and big data in healthcare	328
7	2018	Kritzinger W.	Digital twin in manufacturing: A categorical literature review and classification	324
8	2012	Berman S.J.	Digital transformation: Opportunities to create new business model	246
9	2008	Bailenson J.N.	The use of immersive virtual reality in the learning sciences: Digital transformations of teachers, students, and social context	245
10	2017	Sebastian I.M.	How big old companies navigate digital transformation?	180

Table 4. 10 most influential journals in digital transformation

Rank	Journal	Articles	Citations	H-index	TLS
1	<i>MIS Quarterly Executive</i>	13	1025	38	155
2	<i>Procedia CIRP</i>	32	292	56	30
3	<i>Advances in Intelligent Systems and Computing</i>	122	356	5	28
4	<i>Procedia Manufacturing</i>	28	483	44	28
5	<i>Sustainability (Switzerland)</i>	65	532	1	27
6	<i>Journal of Business Research</i>	27	193	83	26
7	<i>Communications in Computer and Information Science</i>	57	157	4	22
8	<i>Technological Forecasting and Social Change</i>	23	271	109	15
9	<i>Procedia Computer Science</i>	31	137	54	12
10	<i>International Journal of Information Management</i>	14	328	99	10

Technological Forecasting and Social Change, *International Journal of Information Management*, *Journal of Business Research*, and *Procedia CIRP* have the greatest H-index values.

Most Influential Countries and Universities

There are 306 countries and 8,306 institutions included in the data set of publications on digital transformation. As with previous categories, the authors used TLS value to identify leading universities and countries in the field of digital transformation research. Table 5 shows the 10 leading countries; Table 6 lists the top 10 universities, respectively.

As can be seen in Table 5, Germany has the highest TLS value and most publications related to digital transformation. This is followed by the U.S. and United Kingdom. The table also reveals that the 10 most influential countries in the field of digital transformation research are developed economies.

To limit the data to universities with repeated focus on digital transformation, the authors applied the criterion that each university must have produced at least five publications in this field. This

Table 5. Top 10 countries in the field of digital transformation research

Rank	Countries	Articles	Citations	TLS
1	Germany	794	5,552	1,550
2	United States	516	6,877	1,272
3	United Kingdom	305	2,487	767
4	Canada	87	1,022	680
5	Italy	290	1,548	579
6	France	146	1,321	572
7	Austria	127	1,309	445
8	Spain	183	1,209	440
9	Australia	171	939	427
10	Finland	89	708	413

Table 6. Top 10 universities in the field of digital transformation research

Rank	Universities	Articles	Citations	TLS
1	Munich University (Germany)	17	146	18
2	Reutlingen University (Germany)	15	339	12
3	Financial University under the Government of the Russian Federation (Russia)	14	18	5
4	State University of Management (Russia)	45	15	5
5	Samara State University of Economics (Russia)	28	35	4
6	Al-farabi Kazakh National University (Kazakhstan)	5	70	2
7	Plekhanov Russia University of Economics (Russia)	13	29	2
8	Peter the Great St. Petersburg Polytechnic University (Russia)	10	9	2
9	Stavropol State Agrarian University (Russia)	5	8	1
10	Universidade do Minho (Portugal)	5	4	1
	University of Rostock (Germany)	5	4	1

effort narrowed the number of universities for analysis to 35. Table 6 shows that, according to the number of citations, the top two universities are Munich University and Reutlingen University (both German institutions). Additionally, there are six Russian universities in the list, accounting for more than half of the top 10 list.

DISCUSSION AND CONCLUSION

These results show that research of digital transformation has emerged and attracted considerable attention. Scholars in different fields have explored its influence from varying perspectives of their academic and professional areas of interest. As a result, a great number of research papers on digital transformation have been published. However, the results of coauthorship analysis suggest that collaboration in the field remains weak; therefore, the field needs further development.

The analysis of coauthorship status shows that only 21 researchers out of 12,083 researchers have collaborated extensively with others in the field. Most researchers with considerable collaboration are from German and Japanese institutions. Researchers like Zimmermann A., Masuda Y., and Sandkuhl H. are the leading authors. Analyzing coauthorship within the field of digital transformation uncovers many examples of intercountry collaboration, although the countries that collaborate may have entered this field in different periods. The U.S., Germany, and the Russian Federation are the most influential countries in the field of digital transformation research. The Russian Federation is the most recently emerging country in this field. The relatively large number of publications achieved by researchers from these three countries show that a potential monopoly trend is taking shape in the field of digital transformation research.

The result of this study's keyword analysis shows that digital transformation has been studied in a variety of practical domains. In particular, the analysis of keyword cooccurrence suggests that the selected publications cover various themes at different levels, including emerging technologies (e.g., AI, big data, blockchain, cloud computing), security and risk management, information management (e.g., data handling, decision making, information management, and information systems), digitalization in education (e.g., e-learning, engineering education, higher education, and learning systems), industry 4.0 (e.g., smart manufacturing and industrial revolutions), public management and socioeconomic development (e.g., public administration and e-government), and organizational factors

like business model and digital platforms. Moreover, the increasing number of publications implies that the field of digital transformation research has moved into the rapid growth stage as of 2017.

The evolution map of periods illustrates that the field of digital transformation research has an increasing diversity of practical domains. The research topics regarding digital transformation have evolved from macrolevel topics (concerning socioeconomic development) to microlevel topics (concerning specific industries).

The results of the analysis of how research themes' centrality and density have evolved further demonstrate changes to research hotspots in the field of digital transformation research. While some research themes like healthcare elements, e-government, and e-learning have become increasingly important (reflected in the themes' centrality and density), the status of other themes like the energy industry have fallen. The rise and fall of themes enrich our understanding of how the broad field of digital transformation research has developed.

The analysis result about influential researchers, based primarily on TLS values, reveals that the top 10 researchers are either from Germany or Japan. This uncovers the active role played by these countries' researchers in conducting research and collaborating with others in the field of digital transformation research. This finding confirms and supplements the result of the coauthorship analysis stated above.

The 10 publications with the most citations in the field of digital transformation research mainly discuss how digital transformation has been applied in the healthcare sector, manufacturing sector, education sector, and domain of business and organizational development. This coincides with the results of the authors' keyword analysis.

The 10 most influential journals that published articles on digital transformation research targeted scholars and practitioners interested in the management of manufacturing and business associated with information technology innovations. This echoes the results of the authors' analyses of keywords and evolutionary trends in the field of digital transformation research.

Identifying the top 10 countries that contribute to digital transformation research sheds light on the leading role played by developed economies, especially Germany, the U.S., and the U.K. Moreover, as many of the top 10 universities are in Germany and Russia, it is apparent that these countries are also playing a considerable role in digital transformation research. These results further supplement the results of the intercountry collaboration analysis.

Taken together, the results of analyzing researchers and their collaboration, distribution and trends of keywords, influential publications and journals, and leading countries and universities within digital transformation research not only confirm but also complement each other. In addition, these results show a trend toward monopolies of influence in the field of digital transformation research. In brief, the list of 10 most influential researchers overlaps with the researchers who have the greatest amount of coauthorship; most of the influential researchers are from institutions in the same two countries: Germany and Japan; the country with the greatest number of articles in the field of digital transformation, Germany, is home to many of the most influential researchers and institutions. Further analysis may investigate potential pitfalls of this monopoly within the field.

This study analyzed and discussed the network of coauthorship, trending topics, influential researchers, journals, publications, countries, and institutions within the field of digital transformation research. By mapping the research output of this field in a bibliometric sense, the authors hope to have discovered future research directions for others to explore in this field.

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