Digital Transformation: Towards New Research Themes and Collaborations Yet To Be Explored

Abstract

This study aimed at providing an overview of research themes and collaborations in the digital transformation scholarship. The methods of co-word analysis, co-author analysis, and network analysis were employed to network-analyze the keywords, countries, and institutions of 2820 research articles published on the digital transformation topic and indexed by the Web of Science database. Our main results indicated that researchers have mostly focused on three aspects of the digital transformation phenomenon including *Technological and Industrial View*, *Organizational and Managerial View*, and *Global and Social View*. Also, it was realized that *Technology*, *Sustainability*, *Big Data*, *Information and Communications Technology*, *Innovation*, *Industry 4.0*, *Artificial Intelligence*, *Business Model*, *Social Media*, and *Digitization* are the most recurring themes in this field of research. Besides, *Small and Medium-Sized Enterprises*, *Blockchain*, *Machine Learning*, *Knowledge Management*, and *Sustainable Development* were respectively identified as the five hottest issues in the digital transformation scholarship. The contribution of our study highlights that European countries and specially the institutions of northern Europe have had better performance in the research collaborations in digital transformation.

Keywords: digital transformation, research themes, research collaborations, co-word analysis, co-author analysis, network analysis.

Introduction

Due to the advent of novel digital technologies like SMACIT (social, mobile, analytics, cloud, and internet of things [IoT]) technologies (Sebastian et al., 2017) and their acknowledged value (Huarng and Rey-Martí, 2019; Hajiheydari et al., 2019a), a strong academic and practical interest in digital transformation (DT) has emerged in the past few years (White, 2012). In fact, researchers have increasingly published a plethora of scholarly articles on this topic. In this regard, Figure 1 reports the number of English journal articles on the DT topic indexed in the

Web of Science research platform during the last two decades. Also, most of executives and managers across various industries have embraced achieving DT as a crucial issue to their organizations (Fitzgerald et al., 2014). Vial (2019) introduces DT as "a process where digital technologies create disruptions triggering strategic responses from organizations that seek to alter their value creation paths while managing the structural changes and organizational barriers that affect the positive and negative outcomes of this process". Based on the dynamic capabilities perspective (Teece et al., 1997), the DT process can be formulated as sensing the digital opportunities and threats, seizing the sensed digital opportunities, and digitally reconfiguring the existing resources of organization for building organizational digital capabilities especially dynamic digital capabilities in response to environmental digital changes (Talafidaryani, 2020).

Notwithstanding the aforesaid undeniable significance of the DT topic from both academic and practical points of view, there is a remarkable lack in providing a holistic understanding of this subject (Gray and Rumpe, 2017; Matt et al., 2015; Vial, 2019). In other words, recent literature has only contributed to provide insights about some specific aspects of the DT phenomenon (Vial, 2019). Therefore, a comprehensive investigation is required to address this gap. Accordingly, the current study has been designed to render a global picture of the intellectual structure of the DT scholarship. To this end, the following research questions (RQs) are answered based on the methods of co-word analysis, co-author analysis, and network analysis in the next sections. To the best of our knowledge, this is the first attempt to provide a holistic understanding of the most important research themes and collaborations on the DT topic.

RQ_1. What is the most recurring DT research themes and their respective sub-themes?

RQ_2. What are the main research collaborations and central actors in the DT field of research?

Method

Figure 2 shows an overview of the research process. Following the suggestions from Henriette et al. (2015), Reis et al. (2018), and Vial (2019), "digital transformation", digitalization, and "digital disruption" were used as search terms. Also, Web of Science was utilized as search database because this platform is generally considered the most inclusive database for scholarly works (Dahlander and Gann, 2010). By anchoring on this research platform, all English journal articles dated to the beginning of 2020 and contained at least one of the search terms in their

topic (i.e., title, abstract, or keywords) were retrieved. Among different types of documents, journal articles were only included due to the fact that journal articles are those scholarly publications which successfully have gained the approval of fellow researchers through the journals' peer-review process and accordingly, can be seen as "certified knowledge" (Ramos-Rodríguez and Ruíz-Navarro, 2004). Eventually, 2820 research articles on the DT topic were extracted as the research corpus. Some of the bibliographical attributes of this corpus, i.e., keywords, years, countries, and institutions, were utilized for the data analyses.

Following the suggestions from Hajiheydari et al. (2019b), Jalali and Park (2018), Talafidaryani et al. (2020), Talafidaryani et al. (2018), and Zong et al. (2013), the method of co-word analysis was used to reveal the research themes of the DT scholarship. The selection of co-word analysis was due to the fact that this method has a great potential to identify research themes and trends in technical discourse based on the association strengths of words representing the relevant articles of a scholarly filed (Monarch, 2000). The co-word analysis rests on this tenet that the revealed patterns of representative word associations are maps of the knowledge structure or conceptual network of a scientific field and that a series of such maps creates a fairly minute overview of the thematic matters of a discipline (Monarch, 2000). In this research, the co-word analysis was conducted based on the keywords of retrieved articles because keywords are the most important research elements in this method (Zong et al., 2013).

Moreover, following the suggestions from Jalali and Park (2018), Kwon et al. (2012), Otte and Rousseau (2002), Park and Leydesdorff (2010), and Park and Leydesdorff (2013), the method of co-author analysis was employed to reveal the research collaborations among countries and institutions in the DT field of research. The selection of co-author analysis was due to the fact that the prevalent measure of collaboration in scholarly research is co-authorship (Savanur and Srikanth, 2010). Like the co-word analysis, the main methodological idea behind the co-author analysis rests on the logic of co-occurrence. That is, the co-author analysis works based on this assumption that the patterns of author associations are maps of the collaboration structure or network of a scientific field and that a series of such maps creates a fairly detailed overview of the collaborative matters of a discipline.

Both of the co-word and co-author analyses were performed by using the VOSviewer open-source software (Van Eck and Waltman, 2010). This software generally conducts three main tasks including normalization, mapping, and clustering to create a clustered bibliometric network such as keywords co-occurrence network, countries co-authorship network, or

institutions co-authorship network. First, VOSviewer does the association strength normalization thoroughly described by Van Eck and Waltman (2009) to normalize the high differences between nodes in the number of links they have. Second, this software maps normalized network based on a distance-based approach in a two-dimensional space. That is, the distance between two nodes represents the similarity or relatedness of them. For this aim, VOSviewer employs the VOS mapping technique extensively discussed by Van Eck et al. (2010). Finally, this software clusters the nodes in the mapped network in such a way that a cluster includes a group of closely related nodes without any overlap with any other cluster. The VOS clustering technique has been completely explained by Waltman et al. (2010). For more explanations of the technical procedures of VOS mapping and clustering approach, see Van Eck and Waltman (2014).

After generating the keywords co-occurrence network, countries co-authorship network, and institutions co-authorship network, following the suggestions from Feicheng and Yating (2014), Jalali and Park (2018), Otte and Rousseau (2002), Park and Leydesdorff (2013), and Zong et al. (2013), the method of network analysis was recruited to identify the most central or influential nodes of each network. In this regard, the standardized degree centrality measure was utilized to accomplish the network analysis task. According to Otte and Rousseau (2002), the standardized degree centrality can be calculated by the Eq. 1 in which c_i^d is the standardized degree centrality of ith node, d_i is the number of edges attached to the node, and n is the number of nodes in the network.

$$c_i^d = \frac{d_i}{n-1} \quad \textbf{1)}$$

Results

RQ$_1$. The thematic network of keywords

Figure 3 shows the keywords' co-occurrence network in which the size of a circle represents the number of articles indexed by the respective keyword, and the link between two keywords indicates their co-presence in an article. The more co-presence, the thicker link and the closer locations in the network. In this network, 50 keywords have been grouped into 10 colored

clusters based on their co-occurrence relationships in the DT field of research. In what follows, clusters are mentioned in order of their size (i.e., the number of keywords), and in each cluster, keywords are referred in order of their weight (i.e., the number of occurrences). Accordingly, the red cluster includes technology, education, digital, e-health, governance, transformation, case study, and communication. The dark green cluster consists of sustainability, globalization, china, SMEs (small and medium-sized enterprises), sustainable development, entrepreneurship, and knowledge management. The dark blue cluster encompasses big data, digital economy, IoT, blockchain, higher education, cloud computing, and smart city. The yellow cluster comprises ICT (information and communications technology), e-government, information technology, digital divide, and management. The purple cluster contains innovation, digital innovation, strategy, new media, and dynamic capabilities. The light blue cluster includes industry 4.0, digital platforms, manufacturing, disruptive innovation, and technological change. The orange cluster consists of digital technology, artificial intelligence, automation, machine learning, and e-commerce. The brown cluster encompasses business model, servitization, and business model innovation. The pink cluster comprises social media, internet, and journalism. And, the light green cluster contains digitization and simulation. By relying on the most frequent keywords of each cluster of the network, the aforesaid 10 thematic clusters can be respectively labeled as *Technology*, *Sustainability*, *Big Data*, *ICT*, *Innovation*, *Industry 4.0*, *Artificial Intelligence*, *Business Model*, *Social Media*, and *Digitization* which, in turn, can be considered as the most dominant themes in the DT research.

Alongside the clusters identified objectively by the software, the keywords can be categorized subjectively into three major views of the DT topic. These views include *Technological and Industrial View*, *Organizational and Managerial View*, and *Global and Social View*. The keywords of each category have been sorted based on their occurrences in Table 1. This table implies that researchers have mostly focused on which aspects of the DT scholarship, and from each aspect, they have frequently investigated which research issues related to this topic.

Table 2 reports the most central themes in the DT field of research. According to this table, *Industry 4.0*, *Innovation*, *IoT*, *Big Data*, and *Digitization* are respectively the top five influential concepts in the DT research. Also, Table 2 reflects the fact that *Technology*, *Sustainability*, *IoT*, *ICT*, *Innovation*, *Industry 4.0*, *Artificial Intelligence*, *Business Model*, *Internet*, and *Digitization* have occupied central positions in the 10 aforementioned thematic clusters which are related to the DT topic.

Figure 4 illustrates another visualization of the keywords' co-occurrence network. In this network that is structurally as same as the network shown in Figure 3, the color of a node has been characterized by the average occurrence year of the pertinent keyword. Therefore, by relying on this kind of visualization, hottest and coldest themes can approximately be identified. In this regard, Table 3 includes hottest concepts in the DT scholarship which, in turn, can be considered as emerging themes in this field of research. Accordingly, *SMEs*, *Blockchain*, *Machine Learning*, *Knowledge Management*, and *Sustainable Development* are respectively the five trendiest issues in the DT scholarship.

RQ2. The collaborative networks of countries and institutions

Figure 5 visualizes the countries' co-authorship network in which the size of a box correlates to the number of articles published by the respective country, and the link between two countries shows their collaboration on the publication of an article. The more collaboration, the thicker link and the closer locations in the network. In this network, 35 countries have been grouped into five colored clusters based on their co-authorship relationships in the DT field of research. In what follows, clusters are mentioned in order of their size (i.e., the number of nodes), and in each cluster, countries are referred in order of their weight (i.e., the number of articles). Accordingly, the red cluster includes England, Italy, Spain, France, Belgium, Romania, Portugal, Croatia, Serbia, Turkey, and Greece. The green cluster consists of the USA, China, Australia, Japan, India, South Korea, Canada, Taiwan, and South Africa. The blue cluster encompasses Russia, Austria, Poland, Ukraine, Czech Republic, and Slovakia. The yellow cluster comprises Sweden, Finland, Denmark, Norway, and Brazil. And, the purple cluster contains Germany, Netherland, Switzerland, and Hungry. In Figure 5, it can be seen that the majority of clusters and nodes represent European countries. Also, it can be realized that the collaborations of these countries approximately have been formed based on their geographical closeness. In fact, red and purple clusters mainly indicate strong collaborations between central and western European countries. This community can be considered as the most prominent collaborative association of countries in the DT research due to the community's size and members' weight. The blue cluster mostly shows the collaborative relationship between eastern European countries. Besides, the yellow cluster mainly belongs to the scholarly collaboration among northern European countries. It is astoundingly worth noting that non-European developed countries such as the USA, China, Australia, and Canada

have shaped a global research community together that have also remarkable connections with East Asian countries. In addition, it is worth considering that as Figure 5 implies, most developed countries except central and western European ones have a tendency to share their knowledge on the DT scholarship with some developing countries like Brazil, India, and South Africa.

According to Table 4, in the international collaborations on the DT topic of research, Germany, the USA, England, Netherland, and Sweden are respectively the top five influential actors that are followed by China. It is surprising that the DT scholarship is led by Germany, a European country, unlike other research disciplines which are usually directed by the USA or China. Also, this table reflects the fact that England, the USA, Austria, Sweden, and Germany have occupied central positions in the five aforementioned collaborative communities of global research on the DT topic. By referring to Table 4, it is fair to assert that European countries have been the most powerful actors in the global collaborations on the DT topic of research within recent years.

Figure 6 shows the institutions' co-authorship network in which the size of a circle represents the number of articles published by the respective institution, and the link between two institutions indicates their collaboration on the publication of an article. The more collaboration, the thicker link and the closer locations in the network. In this network, 43 institutions have been grouped into five colored clusters based on their co-authorship relationships in the DT field of research. In what follows, clusters are mentioned in order of their size (i.e., the number of nodes), and in each cluster, institutions are referred in order of their weight (i.e., the number of articles). Accordingly, the red cluster includes Ludwig Maximilian University of Munich, RWTH Aachen University, Technical University of Munich, KTH Royal Institute of Technology, Polytechnic University of Milan, University of Groningen, VU University Amsterdam, University of Zurich, Swiss Federal Institute of Technology, and Polytechnic University of Turin. The green cluster consists of Aalto University, University of Jyvaskyla, VTT Technical Research Centre of Finland, University of Helsinki, Chalmers University of Technology, University of Oulu, University of Tampere, IT University of Copenhagen, University of Illinois, and University of Warwick. The blue cluster encompasses University of Turku, Copenhagen Business School, University of Gothenburg, University of Agder, Tsinghua University, University of Cambridge, University of Belgrade, and Chinese Academy of Sciences. The yellow cluster comprises University of Granada, Aarhus University, University of the West of England, University of Oxford, University of

Copenhagen, University of Amsterdam, University of Oslo, and University of California Irvine. And, the purple cluster contains Linnaeus University, Lund University, University of St. Gallen, Lulea University of Technology, Linkoping University, Karolinska Institute, and Stockholm University. By relying on Figure 6, it can be realized that the majority of nodes represent the institutions of northern European countries including Sweden (9 institutions), Finland (7 institutions), Denmark (4 institutions), and Norway (2 institutions). In other words, 51% of the top institutions in the global collaborations on the DT scholarship consists of Scandinavian institutions, and others belong to other European countries, China, and the USA. Figure 6 reveals that there is not a distinguishable pattern of geographical clustering among institutions. That is, institutions generally prefer to perform some international collaborations instead of national or local collaborating in the DT field of research.

According to Table 5, in the international collaborations on the DT topic of research, Lund University, University of Gothenburg, Lulea University of Technology, and KTH Royal Institute of Technology are respectively the top four influential actors that are all Swedish institutions. It is surprising that the DT scholarship is led by Scandinavian institutions unlike other research disciplines which are usually directed by the American or East Asian institutions. Also, this table reflects the fact that KTH Royal Institute of Technology, VTT Technical Research Centre of Finland, University of Gothenburg, Aarhus University, and Lund University have occupied central positions in the five aforementioned collaborative communities of global research on the DT topic. By referring to Table 5, it is fair to assert that north European institutions have been the most powerful actors in the global collaborations on the DT topic of research within recent years.

Conclusion

The current study employed the methods of co-word analysis, co-author analysis, and network analysis to identify the most important scholarly themes and research collaborations in the DT field of research. Accordingly, three significant findings were revealed. The first key finding stemmed from the keywords co-occurrence analysis is that the most recurring themes in the DT scholarship are *Technology*, *Sustainability*, *Big Data*, *ICT*, *Innovation*, *Industry 4.0*, *Artificial Intelligence*, *Business Model*, *Social Media*, and *Digitization*. Moreover, the most occurred keywords of publications revealed that researchers have mostly focused on three aspects of the DT topic including *Technological and Industrial View*, *Organizational and*

Managerial View, and *Global and Social View*. Figure 7 indicates these aspects and their respective recurring themes or issues sorted based on their prevalence. Also, by relying on the network analysis, *Industry 4.0*, *Innovation*, *IoT*, *Big Data*, and *Digitization* were identified as the top five central or influential themes in the DT field of research. In addition, based on the average occurrence year of the frequent keywords, it was realized that *SMEs*, *Blockchain*, *Machine Learning*, *Knowledge Management*, and *Sustainable Development* are respectively the five hottest or trendiest research issues in the DT scholarship.

The second key finding stemmed from the countries co-authorship analysis is that European countries (especially central and western European countries) have been the most powerful actors in the global collaborations on the DT topic of research within recent years. There are some distinguishable collaborative patterns among these countries implying this fact that European countries have had a tendency to collaborate with their local neighbors on the DT scholarship. Moreover, an important joint community of non-European developed countries and East Asian countries was distinguished in the collaborative network of countries. Furthermore, by relying on the network analysis, it can be asserted that in the international collaborations on the DT topic of research, Germany, the USA, England, Netherland, and Sweden are respectively the top five influential actors that are followed by China. Finally, the third key finding stemmed from the institutions co-authorship analysis is that most of the top institutions in the global collaborations on the DT scholarship consists of north European (Scandinavian) institutions, and others belong to other European countries, China, and the USA. Also, by relying on the network analysis, it was realized that in the international collaborations on the DT topic of research, Lund University, University of Gothenburg, Lulea University of Technology, and KTH Royal Institute of Technology are respectively the top four influential actors that are all Swedish institutions.

The main implications of this study relate to researchers and scholars who are interested in the DT topic. By relying on the findings of the current research, they can be aware of the most recurring themes and their respective sub-themes in the DT field of research. Moreover, researchers can recognize the hottest issues and accordingly, perform their investigations on the trendiest subjects of the DT scholarship such as *SMEs*, *Blockchain*, *Machine Learning*, *Knowledge Management*, and *Sustainable Development*. Besides, by relying on the findings of this study, scholars can be familiar with the prominent research collaborations among countries and universities, recognize the most influential actors of them and subsequently, try to be a member of these communities to enhance their research performance. In summary, the results

of the current study can be served as a general research agenda for researchers who are interested in conducting the DT-related studies. However, this research has some implications for practitioners and artisans. That is, by reviewing the results of the current work, they can be aware about the most dominant digital technologies (e.g., big data, IoT, artificial intelligence, social media, blockchain, machine learning, and cloud computing) and accordingly, try to harness them to actualize the required DT journeys of their organizations. Also, by taking a look at the main findings of this study, managers and businessmen can gain some invaluable insights about the most important issues like digital innovation, digital business model, digital commerce, digital platforms, digital strategy, digital services, digital entrepreneurship, and digital capabilities which should be considered to be successful in digitalizing the enterprises' processes and operations. Finally, it is worth considering that the results of the current scholarly work may help policy and decision makers put their priorities and attentions on the most significant global and social issues of DT such as digital economy, digital sustainability, digital education, digital governance and government, digital health, digital divide, and digital city, and consequently, formulate a more efficient roadmap and plan for the DT of our society.

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Table 1. Major thematic views and issues related to DT

Category	Keywords
Technological and industrial view	industry 4.0, big data, digital technology, IoT, artificial intelligence, digitization, social media, technology, automation, internet, blockchain, ICT, digital, machine learning, cloud computing, information technology, simulation, manufacturing, technological change
Organizational and managerial view	innovation, business model, e-commerce, digital innovation, digital platforms, strategy, servitization, business model innovation, SMEs, disruptive innovation, new media, knowledge management, entrepreneurship, management, case study, dynamic capabilities
Global and social view	digital economy, sustainability, education, e-government, higher education, globalization, China, e-health, governance, transformation, digital divide, sustainable development, smart city, journalism, communication

Table 2. The standardized degree centrality of most central keywords in the co-word network

Keyword	Score	Keyword	Score	Keyword	Score
industry 4.0	1.43	technology	0.57	manufacturing	0.35
innovation	1.00	digital technology	0.49	sustainability	0.33
IoT	0.86	internet	0.45	education	0.33
big data	0.82	blockchain	0.43	ICT	0.33
digitization	0.73	social media	0.39	business model	0.33
artificial intelligence	0.69	automation	0.39	digital	0.31
digital economy	0.63	digital platforms	0.39	machine learning	0.31

Table 3. The average occurrence year of hottest keywords in the co-word network

Keyword	AOY*	Keyword	AOY	Keyword	AOY
SMEs	2018.92	industry 4.0	2018.54	innovation	2018.33
blockchain	2018.88	manufacturing	2018.54	management	2018.27
machine learning	2018.76	business model innovation	2018.39	digital innovation	2018.27
knowledge management	2018.64	entrepreneurship	2018.36	digital economy	2018.20
sustainable development	2018.58	digital platforms	2018.36	big data	2018.13

* average occurrence year

Table 4. The standardized degree centrality of most influential countries in the co-authorship network

Country	Score	Country	Score	Country	Score
Germany	5.06	China	2.44	France	1.79
USA	4.47	Italy	2.38	Australia	1.76
England	4.15	Finland	2.00	Spain	1.73
Netherland	2.79	Denmark	1.85	Norway	1.71
Sweden	2.53	Switzerland	1.82	Austria	1.56

Table 5. The standardized degree centrality of most influential institutions in the co-authorship network

Institution	Score	Institution	Score	Institution	Score
Lund University	0.36	Aalto University	0.19	University of Groningen	0.14
University of Gothenburg	0.29	Swiss Federal Institute of Technology	0.19	University of Tampere	0.14
Lulea University of Technology	0.26	University of Zurich	0.19	University of Oulu	0.14
KTH Royal Institute of Technology	0.21	VU University Amsterdam	0.19	Aarhus University	0.12
University of Agder	0.21	Copenhagen Business School	0.17	University of the West of England	0.12
VTT Technical Research Centre of Finland	0.21	Ludwig Maximilian University of Munich	0.14	University of St. Gallen	0.12
Linkoping University	0.21	RWTH Aachen University	0.14	University of Cambridge	0.12

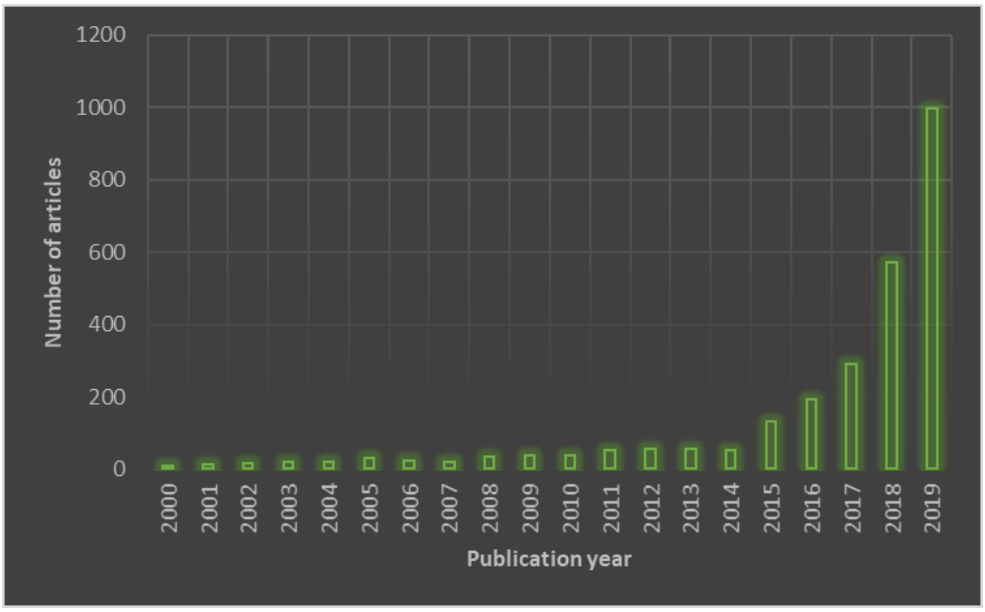

Figure 1. Recent publication trend on DT

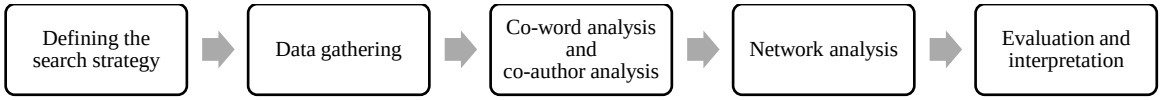

Figure 2. An overview of the research process

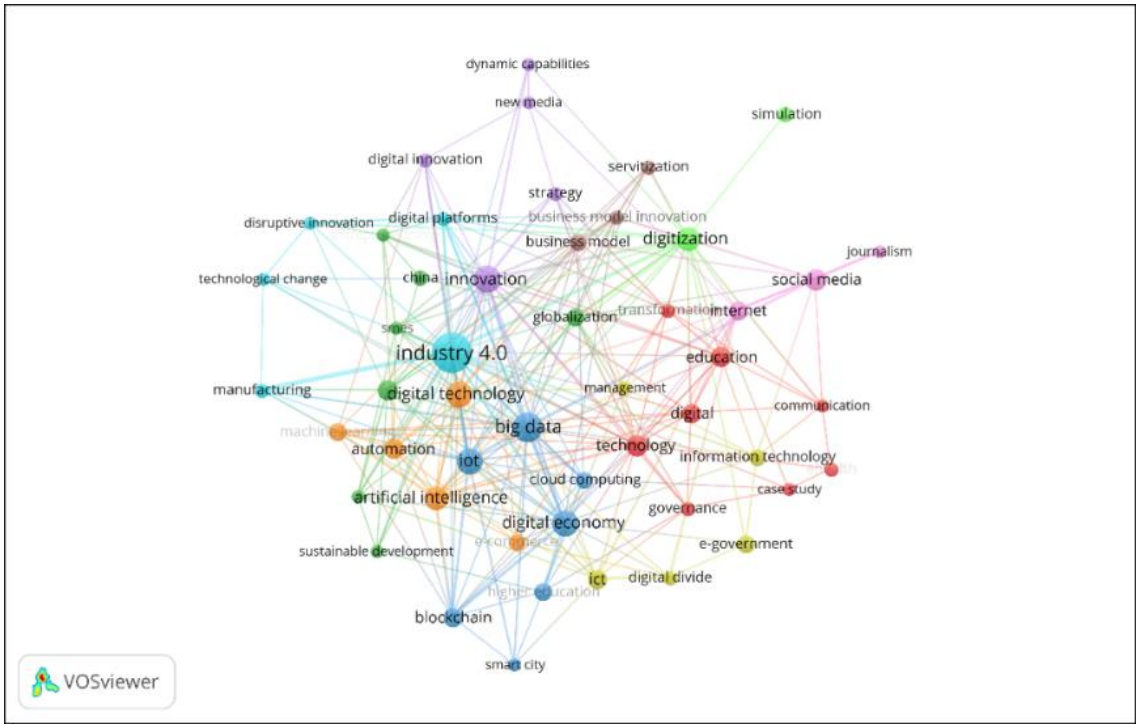

Figure 3. The co-occurrence network of keywords

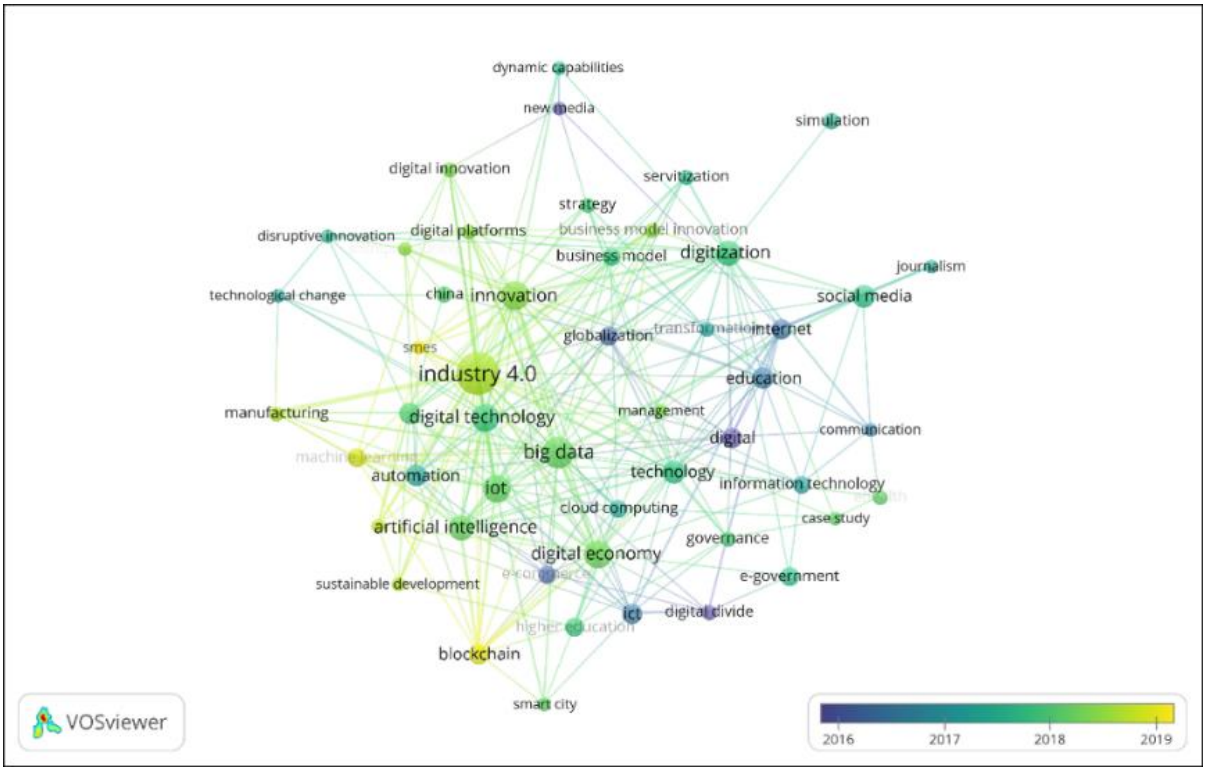

Figure 4. The temporal co-occurrence network of keywords

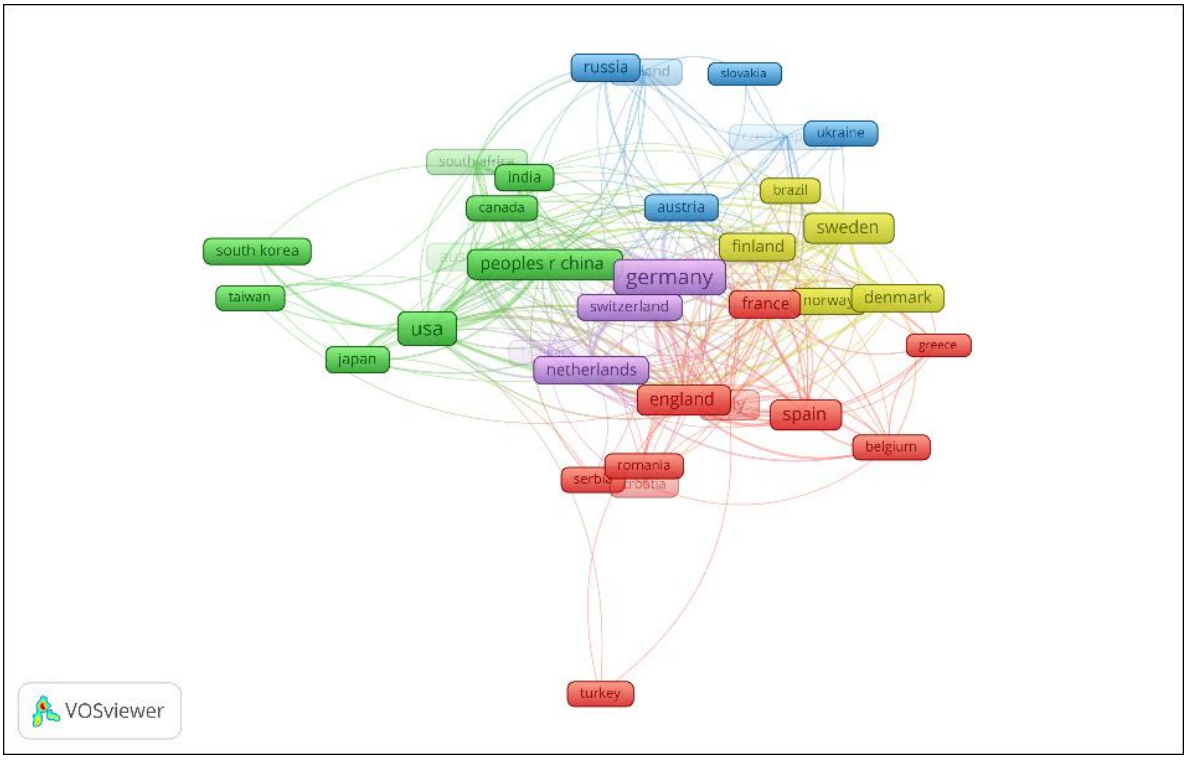

Figure 5. The co-authorship network of countries

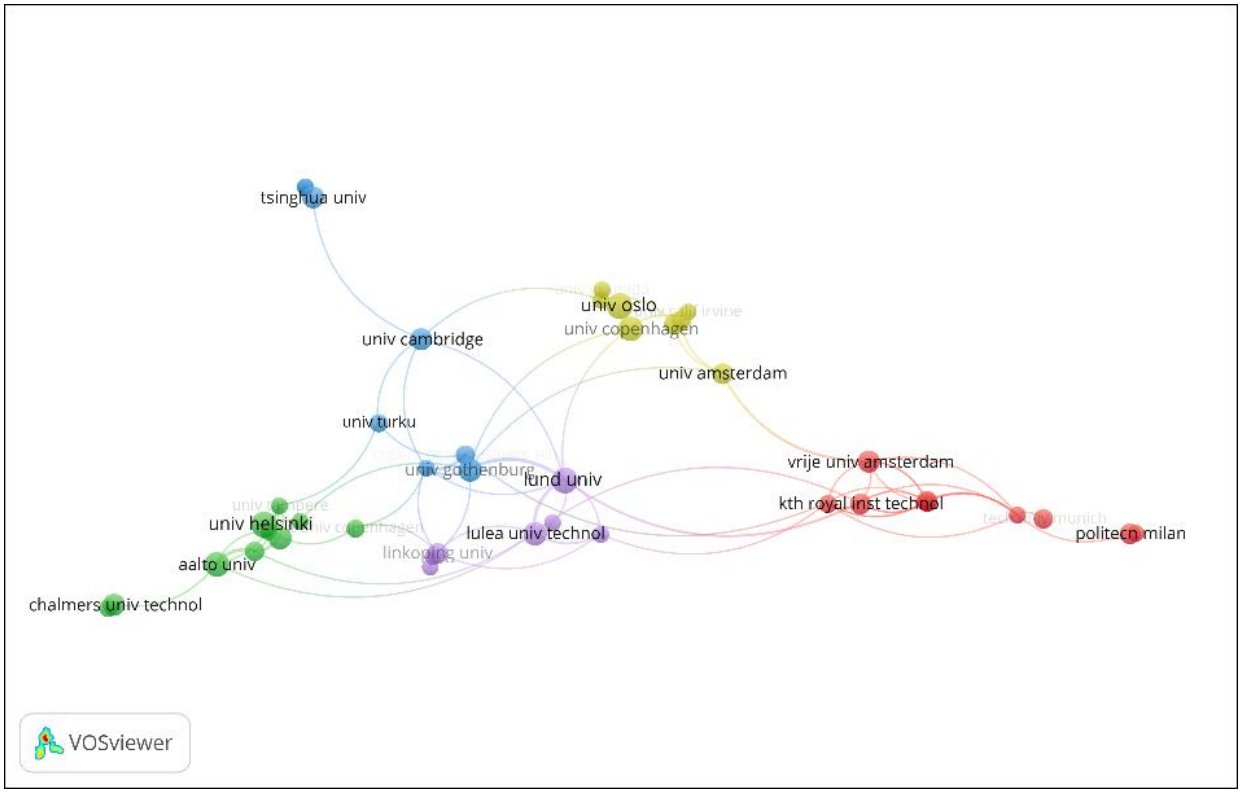

Figure 6. The co-authorship network of institutions

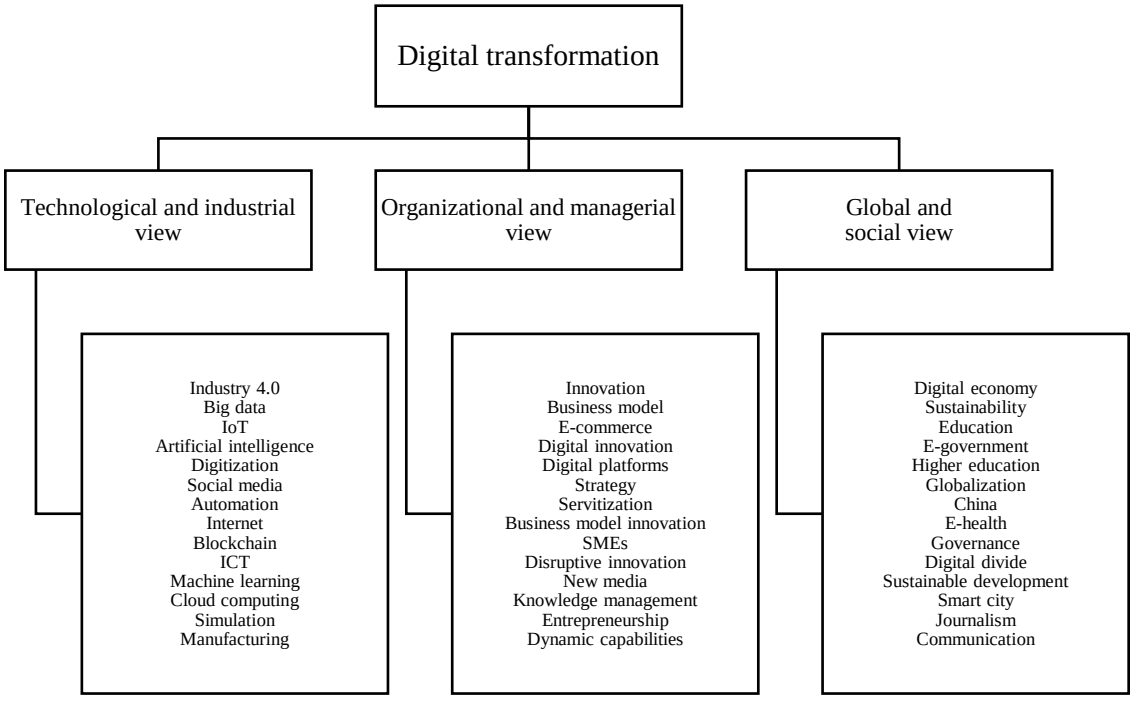

Figure 7. Major thematic views and issues related to DT