

Original Article

Digital transformation in education: a bibliometric analysis using Scopus

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Abstract

Background: Digital transformation refers to applying digital technology in various fields of society. In the last 5 years, digital transformation has spread to most areas of social life, including education. However, research on digital transformation in education is still fragmented.

Objectives: The aim of the study was to present a comprehensive review of studies on digital transformation in education using bibliometric analysis.

Methods: We searched the Scopus database from inception to 1 January 2023 using the search terms 'digital transformation' AND 'education' within abstracts, keywords, or titles of journal articles or conference papers written in English. The retrieved articles were analysed using VOSviewer and Biblioshiny tools.

Results: A total of 1329 relevant studies were retrieved. Although the first paper in this field was published in 1999, the number of publications has increased rapidly only in the past 4 years. The most influential countries in this field are the developed countries (Russian Federation, Germany, and the United States), but scholars from the developing countries (Indonesia and Thailand) are among the most productive. Papers on digital transformation are frequently published in journals with lower rankings within the Scopus database. Using VOSviewer for keyword co-occurrence analysis, we classified the research topics related to digital transformation in education into four main groups: digital transformation in higher education under the impact of the coronavirus disease pandemic 2019 pandemic, applying the technologies of the Fourth Industrial Revolution to education, digitization and digital competence in education in the context of digital transformation, and learning forms using technology (for example, e-learning, m-learning, and blended learning) in higher-education institutions.

Conclusions: Four research trends related to digital transformation in education were identified. These trends may also change as digital transformation continues to develop.

Keywords:

Bibliometric analysis, digital education, digital learning, digital transformation, Scopus database

Introduction

Digital transformation covers many concepts, such as virtual reality, self-driving cars, three-dimensional printing, and cloud computing. Digital transformation in education creates opportunities to change educational methods and models to help learners access new knowledge more effectively. Research on digital transformation in education is being done in many ways, including technology integration to facilitate learning using interactive applications, virtual reality, and augmented reality.¹ Digital transformation also provides opportunities for online learning and blended learning (in which students learn using electronic and online media as well as traditional face-to-face teaching), enables data-driven decision-making (to analyse learning outcomes and student performance, for example),² and can help streamline administrative processes and management, including automated grading systems, digital student information platforms,³ online tutoring, and virtual counselling.⁴ Digital transformation takes advantage of opportunities offered by technological developments and can connect teachers and learners globally through new education models.^{5,6} Digital learning can also drive skill development to promote digital transformation in other fields.⁷ Digital transformation plays a crucial role in education; it affects the way teachers teach and students learn and benefits other stakeholders, such as parents and educational administrators. Digital transformation has been studied in various fields of education as schools have applied information and communication technologies to teaching.⁸⁻¹⁰

Understanding trends in the applications of digital transformation in education around the world helps in sharing useful experiences and experiments in educational innovation. The digital transformation process can be investigated using bibliometric analysis to

comprehensively evaluate research trends. Qualitative analysis and evaluation of scientific publications can be employed to assess the development of scientific research as well as to determine its current status in a country.^{11,12} This method has been used in the field of educational science, for example in lifelong learning¹³ and social sciences.^{11,14} Such research can be used to analyse gaps in the application of digital transformation in education. It also helps to build networks and promote cooperation among scientists around the world for research on the application of digital transformation.

In the present paper, we review the literature on digital transformation in education (a) to summarize the common characteristics and research trends in scientific publications, the most influential journals, and the most prolific scholars; (b) to analyse international collaborations in this area; and (c) to identify the most popular research topics.

Methods

The primary research question was this: What are the characteristics of Scopus-indexed scientific publications on digital transformation in education from 1999 to 2020?

We chose the Scopus database (<http://www.scopus.com>) for this bibliometric analysis because Scopus contains more indexed documents than Web of Science and Dimensions. Scholars and researchers produce a variety of outputs, including journal articles, books, and conference papers. Conference proceedings have value comparable to that of journal articles in some fields such as computer science and are important in some areas of engineering and technology.¹⁵ We searched Scopus on 29 January 2023 using the search query 'digital transformation' AND 'education' in abstracts, keywords, and titles of journal articles or conference papers written

in English. Only those documents published before 1 January 2023 were considered so as to eliminate the delay between the time of publication of a paper and its inclusion in Scopus. We excluded review studies, bibliometric studies, and books but included book series. Full-text analysis of papers retrieved from the above search enabled us to exclude studies not related to the research topic. This screening was carried out independently by two authors (TTTP and NND), who reached an agreement through consensus. A total of 20 documents were thus removed.

Any inconsistent information in the collected data was revised; for example, authors from China and Vietnam often do not use the same names in all their publications or their names are rendered differently by the journals that publish them. We used information from the author's Google Scholar site or information available from the ORCID entry to reconcile any such differences in rendering names. The affiliations were standardized using information from the official website of the relevant institution.

We sought to identify the most influential authors (that is, those with the highest number of publications), authors' productivity over time, and networks of collaboration between authors. Research trends were examined by analysing keywords. We extracted from Scopus general information about the data set, information about authors (institution, country, total citations), journals (total citations, CiteScore), and citation counts. The citations were classified by Semantic Scholar (www.semanticscholar.org) into three categories based on a specific part of the publication that earned a citation, namely background, methods, or results. We used VOSviewer (version 1.6.20) and Biblioshiny (version 4.0) to identify and plot the networks of collaboration between authors and between countries and to identify trends using keywords.

A given publication was recorded as coming from the country shown in the affiliation of the first author or at least of one co-author. In the keyword trend analysis, keywords that were either irrelevant to research trends, such as 'article', 'student', 'teacher', 'research', or directly linked to the topic in question, such as 'digital transformation', 'digital transformation of education', 'digital transformation in education', and 'education', were excluded. We reviewed all the keywords used by the authors in various forms, ranging from plural nouns to abbreviated words. We selected four keywords for each year to represent the research trends in that year, and each of the keywords was required to appear at least five times to be eligible for this selection.¹⁶

Results

A total of 1329 documents were retrieved from Scopus (586 journal articles and 743 conference papers), published in 637 sources, from 1999 to 2022 (Table 1). These documents had been cited 6856 times in total (a mean of 5.1 citations per document). The h-index of the collected data was 35, that is, 35 items had been cited at least 35 times. The documents were written by a total of 4132 authors (a mean of 3.4 authors per document). One hundred sixty-nine authors had published papers without any co-author, and 177 papers were with one author only, accounting for 13.2% of all the documents that formed the data set.

The first article on digital transformation in education, published in 1999 in the *Educational Media International*, was 'Digital transformation of words in learning processes: a critical view' by H. Saga.¹⁷ However, from then on until 2012, digital transformation in education was rarely mentioned in publications. It is only over the past 10 years that the number of publications on digital transformation in education has steadily

Table 1. Attributes of papers on digital transformation in education published in Scopus: 1999–2022

Attribute	Number or magnitude
Sources (journals, books, etc.)	637
Documents	1329
Articles	586
Conference papers	743
Annual growth rate	30.63%
Average age of documents	2.46 years
Mean citations per document	5.1
References	45,426
Keywords Plus (ID)	4806
Author’s keywords (DE)	3458
Authors	4132
Single authors (with no co-author)	169
Single-authored documents	177
Co-authors per document	3.4
International co-authors	15.58%

increased, the most marked rise being in the past 4 years: 123 publications in 2019, 232 in 2020, 380 in 2021, and 467 in 2022 (Figure 1). Overall, the annual growth rate of these digital transformations in education publications between 2013 and 2022 was 30.63%. The

total number of citations of these publications increased correspondingly (Figure 1), although 603 of them (45.4%) were not cited at all by any of the papers in our data set.

The total of 1329 documents that formed the data set were written by authors from 134 different countries or territories, of which the top 10 in terms of the number of publications are listed in Table 2. The Russian Federation topped the list with 267 publications (20.1% of all publications), nearly twice as many as those from Germany, which ranked second (141 publications).

However, the USA ranked first in terms of the number of citations (1315, or 19.2%, with a mean of 15.3 citations per document) followed by the UK (1047, or 15.3%, with a mean of 18.7 per document).

Figure 2 shows the network of international collaboration for research in digital transformation in education. The network consists of 44 countries, each of which features in at least 10 publications and each with authors from two or more countries.

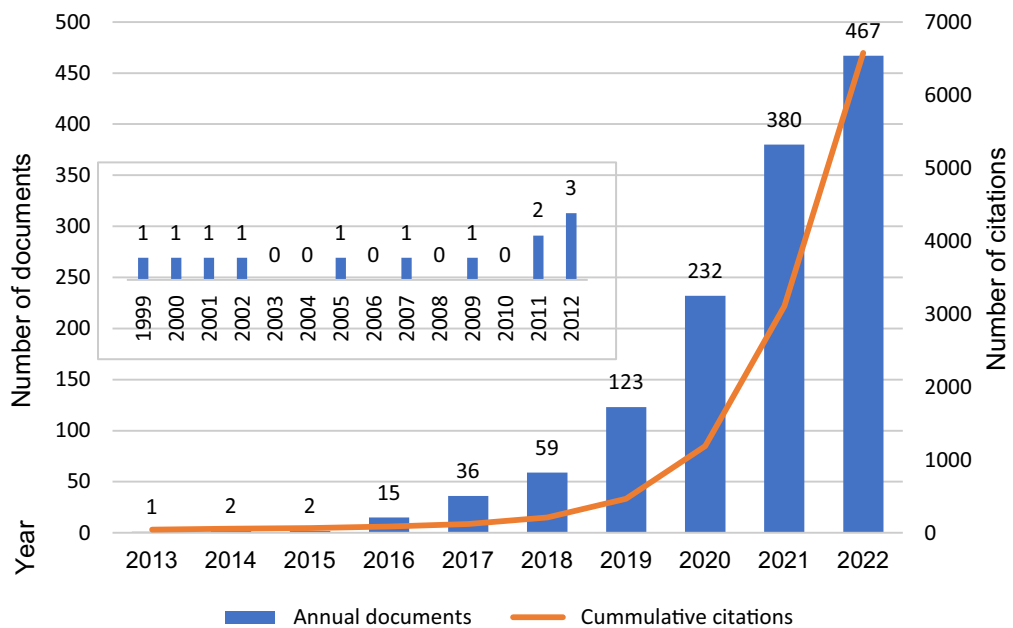


Figure 1. Increase in the number of publications on digital transformation in education and cumulative citations to those publications: 2013–2022.

Table 2. Top 10 countries ranked by the number of contributions on digital transformation in education published by them and by citations of those contributions

Rank	Country or territory	Total publications	Share in total (%)	Total citations	Citation rank	Share in total citations (%)	Total citations/total publications
1	Russian Federation	267	20.1	657	5	9.6	2.5
2	Germany	141	10.6	722	3	10.5	5.1
3	United States	86	6.5	1315	1	19.2	15.3
4	Spain	80	6.0	707	4	10.3	8.8
5	United Kingdom	56	4.2	1047	2	15.3	18.7
6	Portugal	51	3.8	351	8	5.1	6.9
7	Italy	49	3.7	296	9	4.3	6.0
8	India	48	3.6	502	6	7.3	10.5
9	China	40	3.0	98	10	1.4	2.5
10	Australia	39	2.9	400	7	5.8	10.3

The network can be divided into four main groups, or clusters: (1) the Russian Federation, Romania, Austria, Poland, Kazakhstan, Bulgaria, Slovakia, Latvia, Ukraine, and South Korea; (2) Germany, Spain, Portugal, Italy, Brazil, Sweden, France, Finland, Hungary,

Netherland, Mexico, Peru, and Colombia; (3) the United States, the United Kingdom, India, China, Australia, and Saudi Arabia; and (4) Japan and the ASEAN countries such as Indonesia, Malaysia, Singapore, Vietnam, and Thailand.

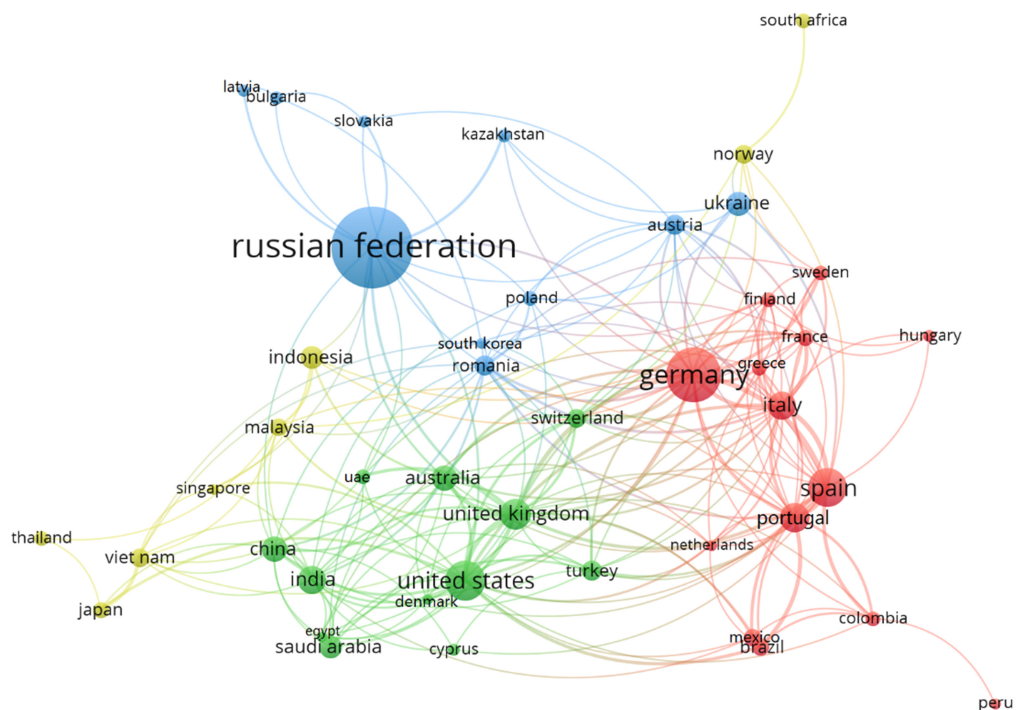


Figure 2. Network of countries participating in collaborative research on digital transformation in education. Note: The size of the circle is proportional to the number of research publications from that country (Table 2).

Table 3. Top 10 sources ranked by the output published by them on digital transformation in education

Rank	Source	Type	Total publications	Total citations	CiteScore 2021
1	<i>ACM International Conference Proceeding Series</i>	Conference proceedings	50	60	1.0
2	<i>Ceur Workshop Proceedings</i>	Conference proceedings	45	159	1.1
3	<i>Lecture Notes in Networks and Systems</i>	Book series	40	15	0.7
4	<i>E3s Web of Conferences</i>	Conference proceedings	36	45	0.8
5	<i>Sustainability Switzerland</i>	Journal	33	591	5.0
6	<i>IEEE Educon (Global Engineering Education Conference)</i>	Conference proceedings	31	95	— ^a
7	<i>Communications in Computer and Information Science</i>	Book series	31	58	0.9
8	<i>Advances in Intelligent Systems and Computing</i>	Book series	26	73	0.9
9	<i>Education Sciences</i>	Journal	20	202	2.9
10	<i>Journal of Physics: Conference Series</i>	Conference proceedings	20	73	0.8

^aCiteScore yet to be assigned.

The top 10 sources – five conference proceedings, three book series, and two journals – that published the output on digital transformation in education, ranked by the number of publications, are shown in Table 3. The *ACM International Conference Proceeding Series* topped the list with 50 papers, followed by the *Ceur Workshop Proceedings* with 45 papers. In 2021, the CiteScore (assigned by Scopus) of the sources in this list was either below 1.0 or was yet to be given, although *Sustainability Switzerland* had a CiteScore of 5.0.

The total of 1329 documents in our data set were written by 4132 authors, of which the top 10 in terms of the number of contributions they published are listed in Table 4, along with their institution and the country, and Figure 3 shows the annual output of these authors from 2017 to 2022 and the number of times their publications were cited.

Whereas Figure 2 shows the network of countries, Figure 4 shows the network of the most productive authors.

The collaboration between authors for research on digital transformation in education mainly involved small research groups comprising co-authors of papers on this topic without significant diversity: a three-author group from Indonesia comprising Aditya, Ferdiana, and Kusumawardani; a two-author group from the King Mongkuts University of Technology, Thailand, comprising Nilsook and Wannapiroon; and another four-author group from Slovakia comprising Sveda, Kires, Hubenakova, and Misianikova. The sole multinational group consisted of Castro and Martin from Spain, Assante from Italy, and Leisenberg and Hamburg from Germany.

Details of the 10 most cited publications on digital transformation in education are given in Table 5. These publications received a total of 1687 citations, accounting for 24.6% of all the citations received by the publications in our data set. The two most cited journal articles, both on the impact of the COVID-19 pandemic, were published in the *International Journal of Information Management*: one assessed the impact on

Table 4. Top 10 authors ranked by the number of publications on digital transformation in education and their affiliations

Rank	Author	Affiliation	Total publications	Total citations	Total publications/total citations
1	Aditya B R	Telkom University, Indonesia	7	22	3.1
2	Nilsook P	King Mongkuts University of Technology, Thailand	7	22	3.1
3	Wannapiroon P	King Mongkut’s University of Technology North Bangkok, Thailand	7	22	3.1
4	Ferdiana R	Universitas Gadjah Mada, Indonesia	7	14	2.0
5	Kusumawardani S S	Universitas Gadjah Mada, Indonesia	6	13	2.2
6	Moreira F	Universidade Portucalense Infante D.Henrique, Portugal	5	53	10.6
7	Shyshkina M P	Institute for Digitalisation of Education of the NAES of Ukraine, Ukraine	5	53	10.6
8	Block B M	Leuphana Universität Lüneburg, Germany	5	15	3.0
9	Pisoni G	Université Côte d’Azur, France	5	9	1.8
10	Wolff C	Fachhochschule Dortmund, Germany	5	8	1.6

information management research and practice (355 citations) and the other focused on basic education for younger generations and information management. The article ranked third was a study on digital transformation in German higher education

(175 citations); the article reported that both teachers and students use a limited number of digital technologies for predominantly assimilative tasks, with learning management systems being considered the most helpful tool. The authors also proposed strategies

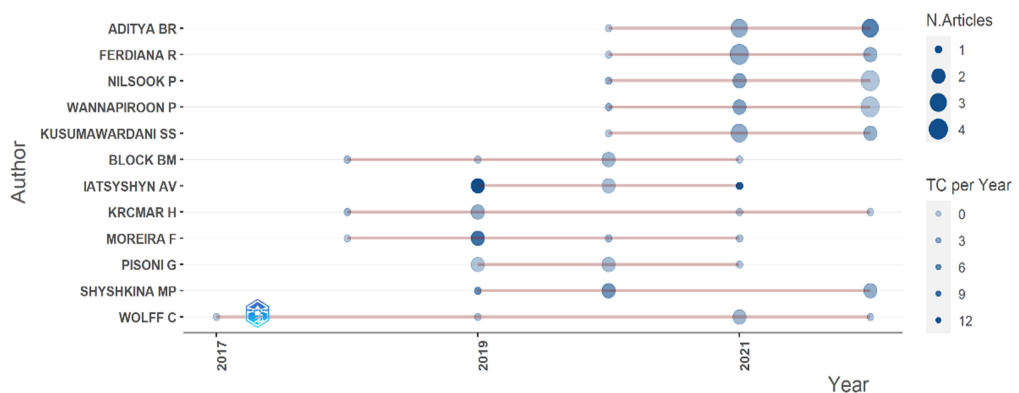


Figure 3. Top 10 most prolific authors’ publication production over time. (Each node (circle) represents one author, and the size of the circle is proportional to the output of that author. The lines between the nodes represent collaboration between the corresponding pair of authors, and the thickness of the line is proportional to the number of collaborative publications jointly authored by them.)

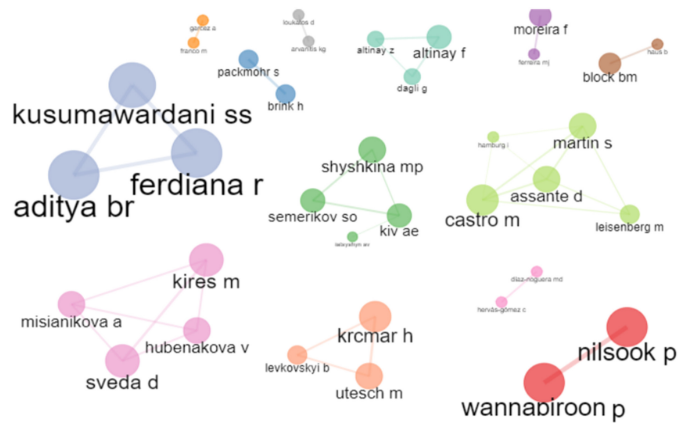


Figure 4. Network of authors participating in collaborative research on digital transformation in education. Note: The size of the circle is proportional to the number of research publications from that author (Table 4).

for higher-education institutions to promote the use of education technologies for teaching and learning. In the fourth place, with 160 citations, was the article that provides a fundamental framework to interpret the shift to distance education in emergencies, such as the COVID-19 pandemic, through changes in universities, the business world, and learners. The author presents a three-stage model highlighting the development of online learning in business schools. The next item on the list was an empirical study involving Brazilian manufacturers about organizational learning paths based upon the adoption of Industry 4.0.¹⁸ Table 5 also presents the specific sections – background, methods, or results – from the top 10 most cited publications that had led to the citations. Most of the citations (88.5%, or 665 citations) were to the text from the background section.

All the publications in the data set together yielded had a total of 3458 keywords; of these, 51 keywords that had featured in at least 10 publications were selected and represented as a network based on the co-occurrence of these keywords (Figure 5). Clustering within the network enabled us to identify four research trends. The digital transformation in higher education under the impact of the COVID-19 pandemic is associated with the main keywords

‘higher education, COVID-19, technology, online learning, information and communication technology (ICT), online education, distance learning, distance education, and education 4.0’. Applying the technology inspired by the Fourth Industrial Revolution in education is associated with the main keywords: ‘Industry 4.0, AI, machine learning, IoT, engineering education, big data, block chain, cloud computing, cyber security’. Digitization and digital competence in education is associated with the main keywords: ‘digitalisation, digital technology, digital competence, digital literacy, digital skills, digital education’. Learning forms using technology in higher-education institutions are associated with the main keywords: ‘e-learning, higher education institution, MOOC, mobile learning, blended learning’.

The research trends identified based on the co-occurrence of the keywords and the respective year in which they gained prominence are shown in Figure 6. For example, in 2018, the following keywords gained prominence: data analysis, the internet, and society; in 2019, the keywords were digital society, m-learning, collaborative learning, and learning. Most of the keywords representing the three most recent years continue to reflect the interest they attract from scholars in the field.

Table 5. Top 10 most cited papers on digital transformation in education and the section of the paper that was cited

Rank	Title of the publication	Authors and year	Published in	Total citations	Citations per year	Background	Methods	Results
1	Impact of COVID-19 pandemic on information management research and practice: Transforming education, work and life	Dwivedi, Hughes, Coombs 2020	<i>International Journal of Information Management</i>	355	118.33	156	10	1
2	Digital transformation of everyday life – How COVID-19 pandemic transformed the basic education of the young generation and why information management research should care?	Iivari, Sharma, Ventta-Olkkonen 2020	<i>International Journal of Information Management</i>	315	105.00	122	7	10
3	Digital transformation in German higher education: student and teacher perceptions and usage of digital media	Bond, Marin, Dolch, Bedenlier, Zawacki-Richter 2018	<i>International Journal of Educational Technology in Higher Education</i>	175	35.00	84	6	7
4	The future of business education: A commentary in the shadow of the COVID-19 pandemic	Krishnamurthy 2020	<i>Journal of Business Research</i>	160	53.33	58	1	0
5	Organizational learning paths based upon Industry 4.0 adoption: An empirical study with Brazilian manufacturers	Tortorella, Cawley Vergara, Garza-Reyes, Sawhney 2020	<i>International Journal of Production Economics</i>	157	52.33	28	6	2
6	Digital economy as a factor in the technological development of the mineral sector	Litvinenko 2020	<i>Natural Resources Research</i>	142	47.33	44	3	0
7	Sustainable management of digital transformation in higher education: Global research trends	Abad-Segura, Gonzalez-Zamar, Infante-Moro, Garcia 2020	<i>Sustainability (Switzerland)</i>	125	41.67	46	5	0
8	COVID-19 and the digital transformation of education: What are we learning on 4ir in South Africa?	Mhlanga, Moloi 2020	<i>Education Sciences</i>	114	38.00	72	8	5
9	A digital twin to train deep reinforcement learning agent for smart manufacturing plants: Environment, interfaces and intelligence	Xia, Sacco, Kirkpatrick, Saïdy, Nguyen, Kircaliali, Harik 2021	<i>Journal of Manufacturing Systems</i>	72	36.00	22	13	0
10	Entrepreneurship education: Time for a change in research direction?	Ratten, Usmanij 2021	<i>International Journal of Management Education</i>	72	36.00	33	0	2

COVID-19: coronavirus disease 2019.

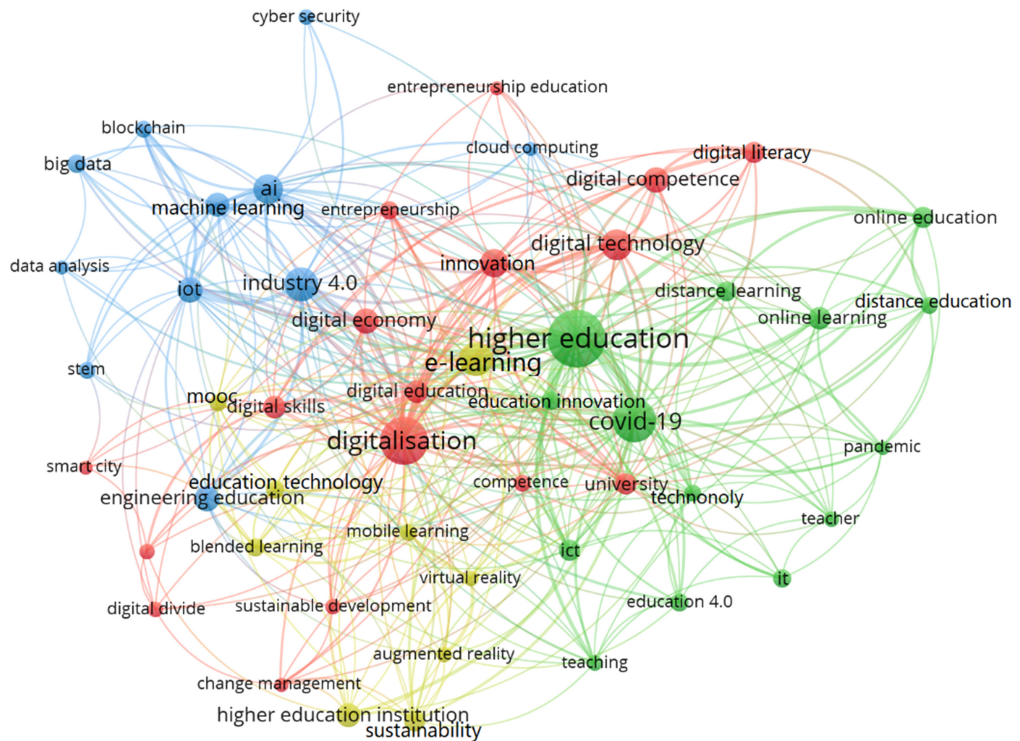


Figure 5. Network of keywords – based on their co-occurrence – most frequently used in publications on digital transformation in education. Note: Relevant keywords were grouped together and given the same colour. The links between keywords represent their co-occurrences, and the size of the keyword is proportion to its frequency of occurrence.

Discussion

In this study, we used bibliographic data from Scopus to analyse publications on digital transformation in education from 1999 to 2022. Although the first contribution on

digital transformation in education was published in 1999, the topic attracted little interest until 2020; from then on, it attracted a great deal of interest. This pattern is consistent with a similar analysis based on a different database, namely the Web of Science.¹⁹ The period

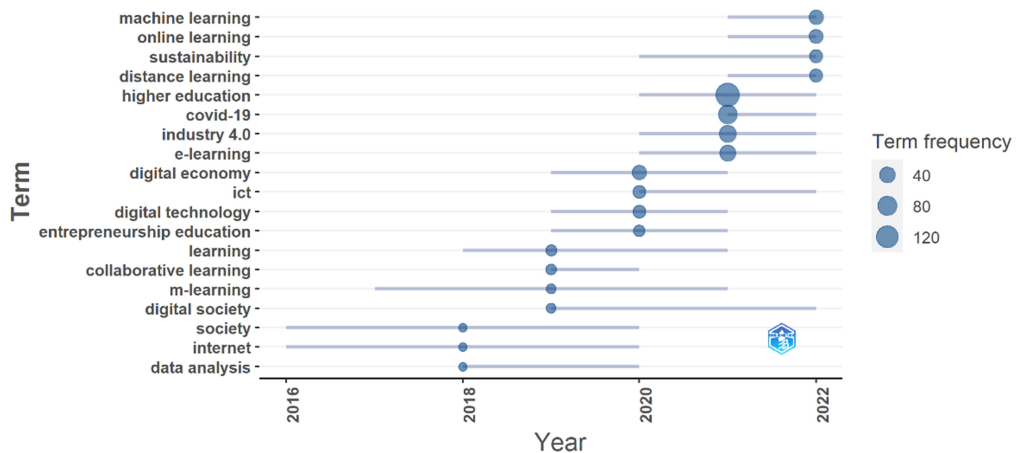


Figure 6. Research trends in digital transformation of education as ascertained through co-occurrence of keywords in publications on that topic.

2020–2022 was marked by the COVID-19 pandemic, when the requirements of social distancing were put in place to prevent the spread of disease. As a result, most universities and schools switched to virtual teaching.

The Russian Federation contributed the largest number of publications in our data set, probably because Russia has been encouraging digital transformation in education to strengthen its human resources to meet the requirements of Industry 4.0 to catch up with the European Union in the use of big data technology, artificial intelligence, internet of things, radio-frequency identification, and cloud technology.²⁰

Nearly half of the 1329 publications (603 documents) on digital transformation and education remained uncited, probably because most of these publications were published in the past 3 years and have not been widely accessible to many interested researchers.

The finding that four of the 10 most cited documents were on the impact of the COVID-19 pandemic on the process of digital transformation in education in particular and different aspects of life in general^{21–24} can be explained easily enough: the pandemic had a widespread impact on all sectors, and higher education was no exception.

Each of the four trending topics or directions for research emerged because of different circumstances and interests. ‘Applying the technology of the Fourth Industrial Revolution in education’ called for the involvement of technologies such as machine learning and artificial intelligence being applied to education to create decision support systems, automate assessment processes, and provide individual feedback to students. Artificial intelligence can also support the creation of instructional content and help personalize the learning process. Virtual reality and augmented reality technologies are being applied in education to create more immersive learning experiences

and increase student engagement with instructional content.²⁵

The research direction ‘Digitalization and digital competence in education’ shows that digital transformation is not just about digitizing lectures or using software to prepare lessons but also about the transformation of all teaching methods and techniques, classroom management techniques, and interaction with learners into the digital space, harnessing information technology to organize successful teaching. This gives learners the opportunity to benefit from modern teaching methods and develop the ability to self-study and undertake research in an open educational environment.

The third direction, namely ‘Learning forms using technology in higher-education institutions’, shows some commonly used teaching methods in universities, such as blended learning (or hybrid learning), in which teaching needs to be harmonized with learning using digital technologies and digital learning materials. The direction also encompasses project-based learning, flipped learning, adaptive learning, and using learner data analysis and artificial intelligence to support teaching and learning, to personalize learning, and to make instant adjustments to learning materials and assessment forms.^{26,27}

Some limitations of the research also need to be kept in mind. First, our research was limited to publications covered by Scopus and only in English; books were excluded, which may affect the results of our analysis.¹⁶ Secondly, although we tried to eliminate irrelevant articles, the weeding out might not have been fully optimal, and a few irrelevant publications might have been overlooked. Thirdly, some elements in the data, such as author names and affiliations, are not standardized in Scopus, which can skew our findings. Finally, information such as the years of research experience of individual authors and

the variety of research topics they worked on cannot be obtained from Scopus.

Authors from the developed nations were most highly cited, although authors from Indonesia and Thailand were remarkably productive. Publications on digital transformation in education appear primarily in lower-ranking journals within Scopus. The research landscape of digital transformation in education can be subdivided into four primary domains: the impact of the COVID-19 pandemic on digital transformation in higher education, the integration of Fourth Industrial Revolution technologies in educational settings, digitization and digital competency in the context of educational transformation, and innovative pedagogical approaches employing technology within higher-education institutions.

Our findings offer a global and comprehensive view of digital transformation in education. In particular, the major topics and researchers identified in the present study can help researchers in identifying more promising research directions and can provide funding organizations with an objective basis to allocate funds for research.

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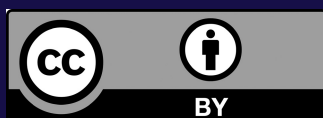
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