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Digital Education After Covid-19: A Scientometric Analysis

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This study constitutes a comprehensive scientometric analysis to comprehend the developmental dynamics within digital education. The examination focuses on a dataset comprising 2,000 highly cited scholarly articles from each of the 15 most actively publishing countries in the Web of Science database. By meticulously scrutinising factors such as publication trends, influential authors, prominent institutions, prolific nations, and reputable journals, the study furnishes valuable insights into the progressive evolution of the digital education landscape. The findings not only shed light on the current state of affairs but also unveil the trajectory that digital education is taking. Noteworthy is the shift toward embracing metaverses in educational contexts, the discernible influence of robotics on student motivation, and the burgeoning adoption of blockchain technology for validating digital diplomas. To conclude, this research underscores the multifaceted nature of digital education and its intersections with various domains. The discerned patterns and emergent themes establish a robust groundwork for making informed decisions and formulating strategic agendas for educators, researchers, and policymakers alike. As the digital education landscape evolves, the insights gleaned from this study serve as an invaluable guide, navigating the ever-shifting topography and anticipating the potential impacts on forthcoming learning paradigms.

Keywords: digital technologies; digital classroom; digital education; scientometric analysis; VOSviewer.

I. INTRODUCTION

The purpose of education in the twenty-first century is to equip students with the knowledge, skills, and talents they will need to succeed both now and in the future in a world that is technologically advanced and continually changing (Henriksen *et al.*, 2016; Mishra *et al.*, 2011). We may progress towards this aim by enhancing the calibre of instruction, personalising and deepening learning, offering adaptable learning settings, and employing technology tools and digital resources to engage and empower students to successfully and confidently advance their learning paths.

Today, digital education is rapidly replacing traditional education. For example, Emerging technologies affect how teachers teach and students learn (Tarling & Ng'ambi, 2016; Myers *et al.*, 2004). The ability to utilise these technologies in the design of online classes can enhance participation in teaching and learning, and provide opportunities for individuals to connect with their content and classmates.

In the age of digital transformation, the education industry is heavily influenced by technology (Mohamed Hashim *et al.*,

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2022; Albright *et al*., 2022). Digital education refers to using digital tools and technology in teaching and learning. It is frequently abbreviated to "TEL" (Technology-Enhanced Learning) (Daniela *et al*., 2017). Any learning that uses technology is called digital education, which includes a wide range of applications. In digital education, providing lessons to students is done by technology (Veletsianos *et al*., 2021) and removes time and place limitations for them (Holland & Holland, 2014; Xie *et al*., 2020).

Four ways that digital learning improves the quality of education are presented below. Physical presence is no longer required (Conceição, 2006), students can progress at their own pace (Srithar, 2016), information is available and searchable (Oliver, 2006), and endless learning in the classroom (Cassar *et al*., 2021).

Online courses, blended learning, digital content, and resources are just a few examples of the numerous aspects of digital learning that include tools and apps to support and empower teachers and students. In addition, digital learning can be used for special professional training for professors and employees, and to provide students and learners with personal learning experiences. Of course, being "cheaper" (Bradford & Hautzinger, 2010), more coordination with the "physiological rhythm of students" (Bradford & Hautzinger, 2010), "faster learning" (Davis *et al*., 2008), "more participation of all students in course topics" (Hrastinski, 2009), "being accessible" (Bong & Chen, 2021), providing training in the form of "microlearning" (Jomah *et al*., 2016), benefit taking "multimedia electronic content on different platforms" (Ly *et al*., 2021), is one of the factors that attract more students to participate in these courses.

Also, new concepts have been formed in the last decade based on this, the digital literacy that becomes possible with digital education. Preceptors and students are currently challenged to get ready to use digital means to learn and digital benefits based on the entrepreneurial spirit by preparing themselves for the industrial revolution's requirement for digital literacy (Purnomo *et al*., 2020).

According to recent studies, the trend of publishing articles on digital education is on the rise (Haleem *et al*., 2022; Yang *et al*., 2022; Hurajova *et al*., 2022). So, considering the changes in time, especially in the post-corona era, it is necessary to review the articles published in this field. In the meantime, the studies using the scientometric method helped the researchers.

The purpose of scientometrics are: formulation of scientific and research policies and guidelines (Glänzel & Schoepflin, 2005), study of scientific communication and citation analysis (Schloegl & Stock, 2004), quantitative and qualitative evaluation of scientific resources and publications (Ibrahim *et al*., 2015), examination of output (Garg & Kumar, 2014), efficiency/performance and scientific impact (Wagner *et al*., 2021), appropriate efficiency of existing facilities and capabilities For performe a research (Krauskopf, 2005), discovering the existing relationships and patterns between scientists, research fields, countries etc (Leydesdorff, 2005), correct evaluation and ranking of researchers, institutions, countries, specialised journals (Yazdani *et al*., 2015), specialised subjects specially measuring and evaluating scientific innovations (Korzhavykh, 2012), scientific cooperation and participation, networks authorship is an examination of all kinds of scientific frauds and scientific plagiarism (Zhang & Fu, 2022; Zhang *et al*., 2020), and some of the essentials of scientometrics is the rapid measurement and evaluation of scientific products at the macro level: measuring and evaluating scientific products using internationally accepted indicators and providing the possibility of comparison they are the difficulty of qualitative evaluation of the enormous volume of international scientific productions and the necessity of using statistical tools, identifying the scientific fields of interest in leading countries and comparing them with competing countries, in order to draw up correct strategic plans and help the future of scientific thinking in the world.

II. LITERATURE REVIEW

Park *et al.* (2021), with the title "A Scientometric Study of Digital Literacy, ICT Literacy, Information Literacy, and Media Literacy" since the year 2000, concluded that the search keywords related to literacy, ICT, curriculum, pedagogy, learner attitudes, beliefs, and behaviours. Co-authored clusters were mainly established in the Americas and European countries. Digital education may be a multidisciplinary field incorporating proficiency, ICT, web, computing, science, nursing, well-being, and language instruction. The participants and research fields of digital

literacy research are diverse, ranging from elementary school students to experts, and co-author clusters vary by country in the United States and Europe.

In research by Purnomo *et al.* (2020), "Digital Literacy Research: A Scientific Mapping Over the Past 22 Years," from 1997 to 2019, the findings show that every year, more books on digital literacy are published around the world. The United States, Monash University, Marsh, J. Computer Science, and Proceedings of the ACM International Conference are the most active subject areas and publication sources in digital literacy research, as well as the most active countries, affiliations, and authors. They certainly were. In studies on digital literacy, researchers generally followed two trends. This study suggests a convergence-based taxonomy of digital literacy research known as the LITHE themes (learning, information communication, technology, people, and education) to categorise the amount of information from two decades of research.

The bulk of publications produced between 2009 and 2011 primarily focus on scholastic education, according to Kumar's (2014) results from 1997 to 2011, as seen in the title "A Scientometric Study of Digital Literacy in Online Library Information Science and Technology Abstracts (LISTA)." Universal Data and Library Audit has distributed more articles on higher education.

"Mapping of Global Literature on the Digital Divide in Education: A Scientometric Analysis Based on the Scopus Database" by Mashroofa *et al.* (2023) covers 2001 through 2021. According to the statistics, there are 15.51 citations on average per article for the study period, and the relative quote effect varies from 0.21 in 2003 to 19.81 in 2021. In shared papers, co-writers dedication is more notable than lone authors. With 613 distributions on the advanced partition, the United States was also the leading nation. Choose, J.B., from the School of Commerce, College of Redlands, United States, was the most productive author with 11 distributions on the advanced isolation in instruction.

An article titled "Information literacy trends in higher education (2006–2019): visualising the emerging field of mobile information literacy," between 2006 and 2019 (Pinto *et al.*, 2020) concluded that there is evidence of a growing interdisciplinarity within the logical distributions on versatile data education, which connects the considerations of data and computerised proficiency with e-learning and portable advancements. Six clusters were used to pinpoint the primary thematic themes throughout the study: IL and e-learning, mobile devices and competencies, ethics, library and e-resources, educational technology, and technological environment. There were fifteen main themes. It demonstrates how IL and e-learning are coming together, how e-literacy is developing, how portable devices and data proficiency are developing, and how libraries and e-resources interact.

Wu *et al.* (2022), "Digital Literacy from 2018-2021: A scientometric study of the literature" from 2018 to 2021 showed that during this period, there has been an increasing trend in scientific research in the field of digital literacy. There are five main themes in this area of digital literacy research, each with multiple sub-themes: higher education, digital skills, digital literacy, education, and the digital divide. Most of the studies have been done in Europe and the United States. Additionally, no single definition of digital literacy exists, and the instruments used to assess digital literacy in the classroom have some drawbacks.

Esh and Ghosh (2021), in "Tracing the Global Trend on the Study of Digital Literacy: A Scientometric Analysis" from 2011 to 2020, show that the growth of publications in the field of digital literacy is upward, and the annual citations also increased from 64 to 13,163 during the study period. Also, relative growth rate (RGR) and doubling time (DT) fluctuated during the study. "Internet skills and the digital divide" was the leader among the most essential resource titles used to publish DL studies, with 368 citations. Be that as it may, the Diary of Internet Medical Research got the most noteworthy average citations per record (24.26), and G. Merchant was the most prolific author with an average of 24.38 citations per document.

From 1981 to March 2022, research interest increased steadily, according to Hwang *et al.* (2023) findings in "Exploring Research Trends of Technology Use in Mathematics Education: A Scoping Review Using Topic Modelling" The combination of frequently used words in the article abstracts suggests popular research topics that have been studied during the specified period. Seven study subjects that were not perfectly in line with those found in earlier studies on mathematics education or educational

technology were identified as a consequence of LDA. This indicated innovation integration as a specific area for investigation in scientific education. The seven participants displayed a variety of exploratory patterns across time, including stable, changing, expanding, and shrinking. We looked at potential explanations for these altered designs and made recommendations based on the research's findings.

According to Chen *et al.* (2023), there are several promising areas, including behavioural mining and emotional computing for versatile teaching, recommendation frameworks in personalised learning proposals, eye tracking for conclusions about cognitive grip, recording for review settings, and dialect preparation traits in conversational enquiry and dialect teaching.

The results of Chen *et al.*'s (2022) enquiry uncover the relationship between critical topics through various levelled clustering investigations. Based on the expository, recommendations were made to encourage the definition of an instructive approach to advance the advancement and successful execution of mechanical, logical, and instructive exercises of online learning.

Based on this and by reviewing the background of the research, the necessity and novelty of this article are confirmed.

III. THEORETICAL FOUNDATIONS

Evaluating scientific items using scientific methods has become a crucial topic because of the ever-growing proliferation of knowledge and increasing competition (Bornmann & Leydesdorff, 2014; Xie *et al.*, 2020; Yu, 2015). In scientific research, scientometrics enables the researcher to condense a significant amount of scientific data and portray the current state of knowledge and anticipated future trends of a subject or field of study across time (Gomis *et al.*, 2023).

The rise in systematic surveys carried out with scientific mapping technologies is a rapidly expanding trend (Iftikhar *et al.*, 2023). Scientific mapping tools typically use a set of bibliographic records from a study field to provide an overview of the underlying knowledge domain. Bibliometrix is one example (Aria & Cuccurullo, 2017), SiteSpace (Wang *et al.*, 2022), and VOSviewer (Abdelwahab *et al.*, 2023). A scientometric overview of the field can be helpful information when doing systematic reviews, especially when finding recent and pertinent systematic reviews is difficult.

Therefore, scientometrics has become a fascinating research subject due to the sharp increase in the number of scientific articles and research (Afgan & Bing, 2021; Aviv-Reuven & Rosenfeld, 2021; Guskov *et al.*, 2016; Mukhamediev *et al.*, 2021). Research on scientometric factors can significantly increase people's and organisations' awareness of the course of science and global trends. On the one hand, the growth of scientific articles and, on the other hand, awareness of new fields of digital education require us to turn to scientometrics.

Digital education in today's world has undergone many changes and transformations that only with the tools of scientometrics can one identify the new and hot trends and areas of this field and, as a result, not fall behind the global trend of digital education (Sokolova & Shatrova, 2023). Therefore, this research was carried out to draw a thematic map of the articles published in this field and identify hot, new, and less noticed topics.

IV. MATERIALS AND METHOD

The current article is of a descriptive-applied type (Ehtesham, 2012; Esfanjani *et al.*, 2010; Karimi *et al.*, 2022) and is carried out in the field of scientometrics and was formed based on the illustration of co-occurrence networks and can produce, visualise and analyse bibliometrics based on a network among the documents of many scientific publications (Permana *et al.*, 2022).

VOSviewer software is gaining popularity in bibliographic research (Oladinrin *et al.*, 2022) and has been developed for drawing bibliometric studies (Kholidah *et al.*, 2022). Van Eck and Waltman created this software to make it simple to visualise and create understandable bibliometric maps. The literature is efficiently compiled, similarities in parameters between the chosen publications are established, and an essential subject is established among the papers (van Eck & Waltman, 2009, 2011, 2017). Additionally, data mining, mapping, and clustering of scientific papers are done using VOSviewer.

This software uses the VOS mapping technique (abbreviation for "Visualisation of Similarities"), which produces structured co-occurrence network maps of

multidimensional scaling techniques for scientometrics (Xu *et al.*, 2022). Visual collaboration graphs between various elements can be exhibited in three dimensions using VOSviewer (including network visualisation, overlap visualisation, and density visualisation), depending on factors like countries, institutions, and authors. The above features of VOSviewer are fully compatible with the needs of scientometric research to create cooperative networks (Ying *et al.*, 2023). In addition, VOSviewer has three types of maps: network visualisation, coverage, and density visualisation. Researchers mainly use network visualisation because it can be used to cluster data, whether it is word co-occurrence, co-authorship, or country of origin. This software receives its primary data from the keywords of scientific research, which indicates the related keywords, and finally shows the published topics based on that. In addition, depending on the popularity and similarity of the studies, each cluster has a specific colour. Also, the lines used in the mutual connection of words indicate the connection of variables (Tamala *et al.*, 2022).

The Web of Science Citation data was based on a comprehensive and multidisciplinary citation profile, which was collected with Excel software and a network drawing tool using VOSviewer software.

The search strategy included two keywords: (Education)*(Digital), and a lot of papers (110506) were uploaded, so researchers limited to time from 2021 to 2023 (30032), document type: Research articles and review articles (25858), and countries: 15 countries have the most papers (21011) (Figure 1). Also, between them, 12,207 were open access. Finally, according to co-authorship, papers were normalised to 19903 items. Finally, with the expert option, hole data were extracted in 48 Plain text files and entered into VOSviewer software.

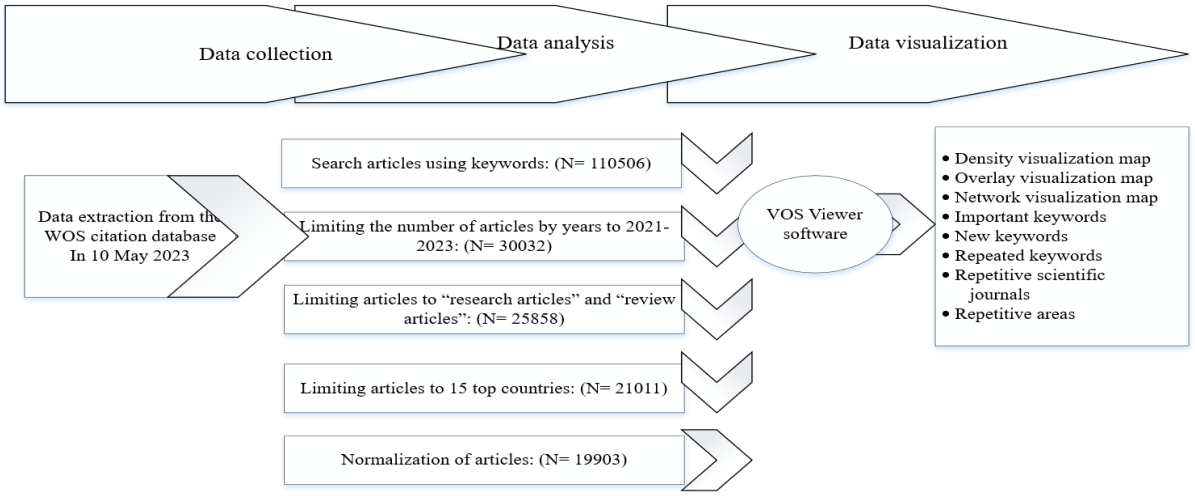

Figure 1. The number of articles published in the period under review

Table 1 shows the top 15 countries regarding the number of articles published in this database. It should also be noted that a limit has been set for the maximum number of articles (2000 articles) per country.

Table 1. Separation of the number of studied articles according to countries

Country	Qty
China	2000
USA	2000
Germany	2000
Spain	1,972
UK	1,957
Russia	1,886
Japan	1522
Australia	1,358
Italy	1,126
South Korea	1,082
Brazil	1,061
India	944
Canada	814
France	671
Taiwan	618

V. RESULT AND DISCUSSION

This article presents a bibliographic analysis of a sample comprising the cumulative total of no more than 2000 most cited journal articles from each of the 15 countries actively engaged in publishing activities in digital education for the years 2021-2023. This imposes certain limitations and enables the examination of a vast array of articles through a partial selection. Our analysis aims to identify critical trends and dependencies that shape educational development's global prospects in the digital transformation era.

It is essential to underscore the steady growth in publication activity within this domain. This indicates a continuous interest from the research community and practising professionals in exploring issues related to digital education. The trends of recent years suggest that, by maintaining this momentum, an increase in the number of publications can be anticipated. Projections for the coming years suggest that by 2023, the number of articles will rise to approximately 9800; by 2024, it will surpass the mark of 10500.

Another significant aspect is the consistent rise in citations of the selected articles, which attests to the substantial significance and relevance of conducted research in digital education. On average, each article in the selection receives 7.4 citations, though this number is achieved through the presence of several highly cited articles. The median value of citations for the articles in the sample is 2, the 75th percentile is 6, and only the 95th percentile reaches 24 citations.

It should be noted that intensive citation accumulation occurs gradually, and new publications do not immediately amass many references. For articles from 2021 alone, the median citation count is 4, the 75th percentile is nine, and the 95th percentile is 35. This indicates at least a moderate level of interest in most publications in the selection.

Although the volume of publications for the year 2022 exceeds the figure for 2021 by only 6% (taking into account some indexing delay), the number of citations during this period amounts to only 39% of the corresponding data for 2021. Furthermore, citations for the year 2023 constitute a mere 2% of the total citations for 2021. This observation suggests that most citations for articles in the digital education field accumulate over three years or more. This phenomenon implies that the substantive portion of citations for such articles is accrued over an extended timeframe. This pattern can be attributed to the enduring significance of research in this domain and the sustained relevance of its contributions.

The well-established prevalence of English-language scholarly publications and articles is evident in the current results (Mongeon & Paul-Hus, 2016; Vera-Baceta *et al.*, 2019). 95% of the articles in the sample are published in English, 2% in Spanish and Portuguese each, 1% in Russian, and less than 0.3% are present in German, French, Italian, Chinese, Korean, Japanese, and Catalan. English is undeniably an international language, and its dominance is understandable. However, considering the significance of national and regional perspectives, a striving for greater linguistic diversity in publications can further enrich knowledge in digital education.

Expanding the range of language groups can contribute to a deeper understanding of issues specific to different contexts and enhance the impact of research on the field. Pursuing greater linguistic diversity can contribute to comprehending questions tailored to various settings and elevate the influence of research on the domain.

The limited linguistic diversity within this research domain can also be attributed to the composition of the pool of authors actively publishing in digital education. Within the scope of the examined subject matter, there is a multitude of researchers and author collectives, reflecting the demand and significance of this thematic area. The indicators of publication activity among the most prolific authors exhibit minor variations. However, when considering the combined results of publication activity and citation impact, the following authors stand out: Hwang G.J. (94 articles, 590 citations; National Taiwan University of Science and Technology, Taiwan); Boud D. (62 articles, 438 citations; Deakin University, Australia); Tai J. (46 articles, 337 citations; Deakin University, Australia); Bearman M. (34 articles, 156 citations; Deakin University, Australia); Cabero-Almenara J. (25 articles, 116 citations; University of Sevilla, Spain); Ajjawi R. (34 articles, 146 citations; Deakin University, Australia); Tu Y.F. (24 articles, 98 citations; National Taiwan University of Science and Technology, Taiwan); Palacios-Rodriguez A. (21 articles, 113 citations; University of Sevilla, Spain); These researchers exhibit a

notable combination of prolific publication output and citation impact, showcasing their substantial contributions to the field of digital education.

In most cases, author collectives are formed within individual organisations and universities. However, longer-lasting impacts on the knowledge domain are often achieved through continuous collaboration between universities facilitated by the extensive nature of the theme of new educational technologies. Education is a subject that extends beyond the confines of individual organisations and countries, thus engaging the interest of numerous scholars and necessitating the exchange of experiences and cooperation.

The studied article sample encompasses a multitude of organisations (Figure 2). Nonetheless, among the most active contributors, several universities and organisations stand out for their noteworthy balance between citation count and publication volume: Nanjing University of Information Science & Technology, China (102 articles, 1602 citations); The University of Tokyo, Japan (256 articles, 1587 citations); National University of Singapore, Singapore (97 articles, 1488 citations); Chinese Academy of Sciences, China (148 articles, 1828 citations); Humboldt University of Berlin, Germany (106 articles, 1123 citations); Shanghai Jiao Tong University, China (120 articles, 1084 citations); University of Oxford, England (114 articles, 843 citations); Nanyang Technological University, Singapore (95 articles, 783 citations). Regarding activity and interconnectedness with other universities, those most open to collaboration (besides those mentioned above) include the Russian Academy of Sciences, Russia; The University of Edinburgh, Scotland; Monash University, Australia; Stanford University, USA; and the University of Melbourne, Australia.

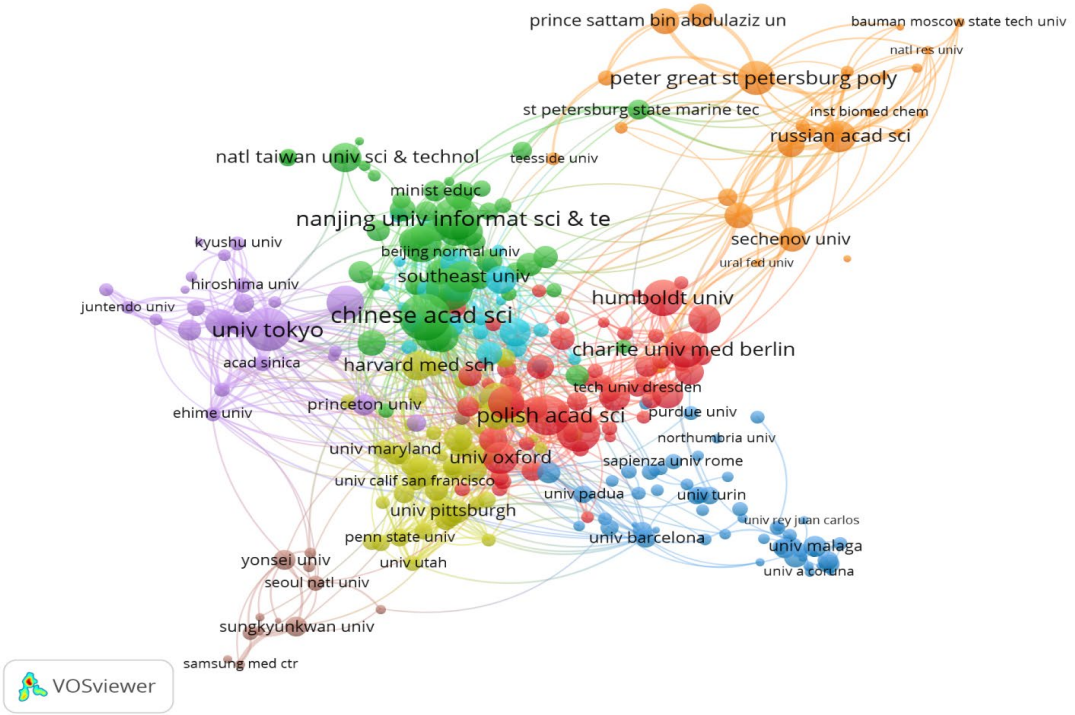

Figure 2. Co-authorship network between organisations according to the data of the study sample

A similar trend is observed at the country level, where numerous nations engage in research in digital education. Due to the specifics of the gathered data, most countries are depicted only as co-authors within the 15 analysed countries. However, the most active countries in terms of collaboration can be grouped into four conditional clusters: (1) Germany (2047 articles, 12392 citations), England (1934 articles, 11714 citations), Italy (1105 articles, 7641 citations), France (652 articles, 5429 citations), Poland (227 articles, 3930 citations), Netherlands (363 articles, 3584 citations), Switzerland (286 articles, 3329 citations), Austria (193 articles, 2523 citations), Belgium (184 articles, 1820 citations), Portugal (201 articles,

1777 citations), Norway (199 articles, 1595 citations), Sweden (196 articles, 1539 citations), Bulgaria (33 articles, 1218 citations), Denmark (166 articles, 1212 citations), Finland (173 articles, 1177 citations), Hungary (67 articles, 1083 citations), Ireland (103 articles, 838 citations), Greece (111 articles, 817 citations), Czech Republic (112 articles, 617 citations); (2) USA (2499 articles, 17120 citations), Spain (1952 articles, 8027 citations), Australia (1340 articles, 6800 citations), Canada (796 articles, 4622 citations), Brazil (1042 articles, 3553 citations), South Africa (143 articles, 1316 citations), Chile (190 articles, 1256 citations), Mexico (122 articles, 772 citations); (3) People's Republic of China (2626 articles, 23622 citations), Russia (1863 articles, 5971 citations), India (926 articles, 4861 citations), Singapore (240 articles, 2461 citations) (Figure 3).

This categorisation showcases the collaborative dynamics across countries, reflecting digital education research's widespread influence and interconnectedness.

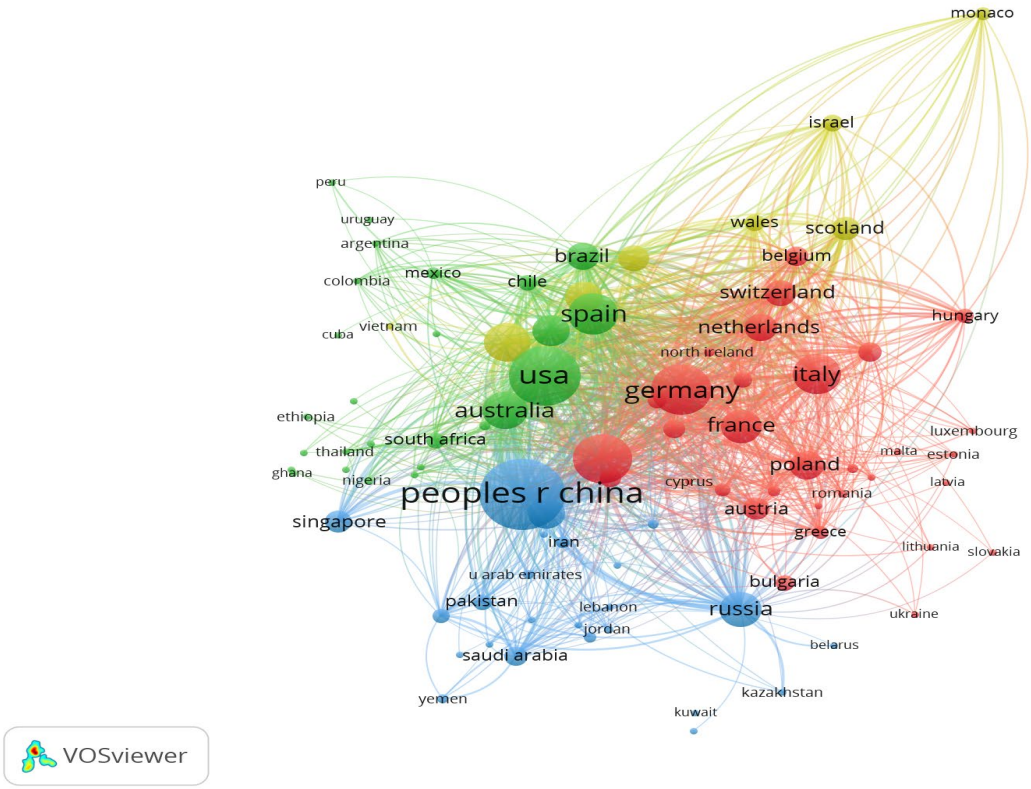

Figure 3. Co-authorship network between countries according to the sample under study

To a more considerable extent, the characteristics of these clusters are determined by the attributes of central countries, which play a pivotal role in forming connections and attracting less active countries for collaboration. Given the nature of the sample, this research identifies China, the USA, England, and Germany as central nodes. These countries exert a significant influence on the advancement of research in the field of digital education, paving paths for collaboration and impacting other countries in this domain. Their activity and status in digital education underscore their significance as central hubs within international research cooperation.

Even within the limited timeframe of this study, new entrants to the global research arena are observed. New collaboration directions stand out among the co-authors of the top 15 leading countries, whose publications constitute the basis of this analysis. These include Tanzania (18 articles, 33 citations), Jordan (29 articles, 309 citations), Cyprus (28 articles, 214 citations), Croatia (28 articles, 200 citations), Iraq (31 articles, 197 citations), Slovakia (23 articles, 28 citations), Lebanon (10 articles, 126 citations), and the Philippines (24 articles, 86 citations). These countries are interested in participating in international research in digital education, signalling the expansion of the geographical scope

of cooperation and engagement in global research networks. This expansion also highlights the increasing importance of digital education as a relevant topic for diverse countries and regions.

In terms of average article citation impact, the most advantageous collaborations involve authors from the following countries (in descending order of average citations per article): Poland, Hungary, Israel, Austria, Switzerland, Scotland, Singapore, Belgium, Netherlands, Northern Ireland, South Africa, and Iran. Collaborating with authors from these countries theoretically could positively impact the level of article citations. This can be attributed to their research's high standards, participation in scholarly conversations, or the demand for their findings in digital education.

Indeed, it cannot be asserted that collaboration with specific countries leads to more citations, just as evaluating research outcomes solely based on citations is not comprehensive. The primary significance of international collaboration lies in knowledge exchange, the formation of solutions applicable in different countries, and addressing global challenges in the education domain. The demand for articles written within multinational research groups should be evaluated based on outcomes and can also vary depending on the publication source, specifically its audience reach.

The total number of publications in the sample encompasses a broad spectrum of scientific journals, and definitively pinpointing one or a few leaders in this field is not feasible. However, a partial list of publications actively featuring articles in digital education and garnering audience attention is presented in Table 2.

Table 2. Partial list of scientific journals in which the articles of the study sample were published

Journal name	Documents	Citations	Category	ISSN (e-ISSN)	JIF Quartile
Sustainability* *Switzerland*	356	2159	Multiple	2071-1050	Q2
Computers & Education *United Kingdom*	99	809	Multiple	0360-1315	Q1
Frontiers in Psychology* *Switzerland*	122	592	Psychology, Multidisciplinary - SSCI	1664-1078	Q1
IEEE Access* *United States*	140	442	Multiple	2169-3536	Q2
Interactive Learning Environments *United Kingdom*	69	368	Education & Educational Research - SSCI	1049-4820	Q1
British Journal of Educational Technology *United Kingdom*	47	356	Education & Educational Research - SSCI	0007-1013	Q1
Education and Information Technologies *United States*	109	330	Education & Educational Research - SSCI	1360-2357	Q1
RIED-Revista Iberoamericana de Educacion a Distancia* *Spain*	40	271	Education & Educational Research - SSCI	1138-2783	Q1
Scientific Reports* *United Kingdom*	81	268	Multidisciplinary Sciences - SCIE	2045-2322	Q2
PLoS ONE* *United States*	78	248	Multidisciplinary Sciences - SCIE	1932-6203	Q2
BMC Medical Education* *United Kingdom*	42	177	Education & Educational Research - SSCI	1472-6920	Q1

* Journals with open-access policies

Digital education is a multidimensional theme encompassing diverse aspects of both technical and social nature. It exists at the intersection of multiple knowledge domains and interacts with various facets of educational organisation and student performance tracking. Given this complexity, the choice of scientific journals to publish research in digital education is limited only by the research topic itself. This choice depends on the primary focuses and directions of the work, as well as the target audience and the scholarly context of the specific study. The diversity of areas touched upon by digital education enables the presentation of research findings in various internationally indexed scientific

journals, depending on which aspects of the research require emphasis and exploration.

Based on the analysis of keywords used by authors in their articles, a range of topics of interest to researchers in the field of digital education can be highlighted: (1) online and distance learning; (2) blended learning; (3) game-based learning; (4) flipped classroom; (5) virtual and augmented reality in education; (6) self-regulated learning and self-assessment; (7) gamification and the use of games to enhance engagement in learning; (8) application of game elements and interactive methods in teaching younger students; (9) influence of parental support on the success of online education in elementary school; (10) digital skills and education in information technology; (11) development of mathematical literacy through digital tools; (12) digital resources and tools for arts and music education; (13) evaluation of the effectiveness of digital teaching methods; (14) study of the impact of digital technologies on academic achievement; (15) research on the use of digital technologies in pedagogical practise; (16) technology in inclusive education; (17) ensuring equal opportunities in digital education; (18) training and preparation of teachers for the use of digital methods; (19) enhancing teachers' competence in digital technologies; (20) integration of digital tools into pedagogical practise; (21) development and application of methods to assess the effectiveness of digital teaching methods; (22) collection and analysis of data for evaluating academic achievement and student engagement; (23) processes of digital transformation in educational institutions; (24) accounting for changes in educational practise due to the digital revolution; (25) cloud computing and its role in educational processes; (26) online platforms; (27) virtual and augmented reality in learning; (28) ethical considerations of technology use in education; (29) generation of educational materials and comprehensive use of chatbots in education; (30) interactive applications and mobile technologies in the learning process; (31) development of specialised digital educational programmes for the elderly generation; (32) mental health of students in the era of digital technologies; (33) the role of distance communication in students' psychological well-being; (34) development of apps and platforms for monitoring students' psychological state; (35) educational interventions to improve public health; (36) student engagement through digital technologies; (37) adapting education to crisis situations using digital technologies, such as pandemics; (38) benefits and challenges of digital transformation in higher education; (39) bridging the digital divide and ensuring equal opportunities in education; (40) social justice and participation through digital platforms; (41) preparing students for ethical and safe behaviour in the digital environment; (42) use of social networks and platforms in the educational process; application of augmented reality for studying architectural concepts; etc. (Figure 4).

The analysis results indicate that even within the limited timeframe of the dataset, specific themes related to digital education have only recently started to attract researchers' attention. Some of the newer thematic research directions include (1) comprehensive integration of metaverses into the educational process; (2) cognitive load and practical learning, strategies to reduce cognitive load during learning; (3) creation of digital diplomas and certificates based on blockchain; (4) development of programming and engineering skills through working with robots and the impact of robot interactions on students' motivation and interest in science and technology; (5) the influence of investments in educational digitisation on economic growth; (6) optimisation of the learning process through the combination of traditional and online teaching methods, as well as the advantages and limitations of hybrid learning for different age groups; (7) self-directed learning; (8) problem-based learning; (9) education through mobile devices.

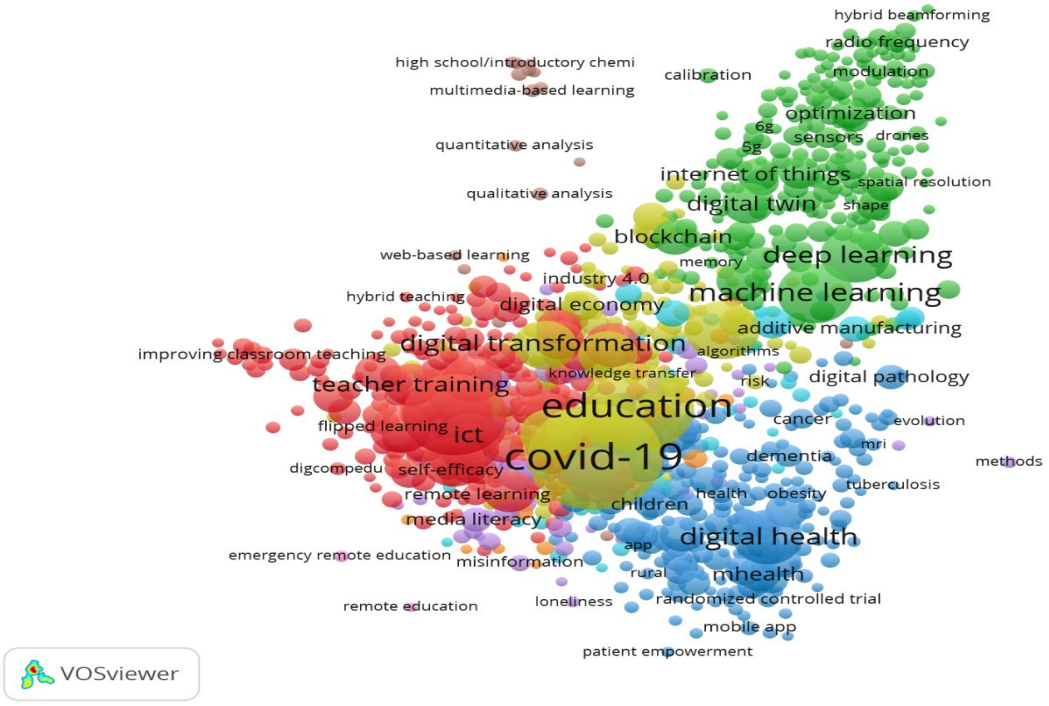

Figure 4. The network of keywords used in the articles of the study sample

The varying demand for different themes in digital education also reflects their uneven popularity. Among these themes, some usually achieve higher average citation rates compared to others: (1) development and application of apps in digital education; (2) comprehensive integration of metaverses into the educational process; (3) hybrid learning; (4) digital competencies and 21st-century skills; (5) assessing the role of digital technology implementation on students' academic performance; (6) distance learning in emergencies; (7) digital inequality.

The above topics attract greater academic and public attention, fostering active discussion and research. Their high average citation rates point to the significance of these themes in the context of current educational challenges and needs.

VI. CONCLUSION

The study results provide a profound understanding of the structure and dynamics of publications in digital education. Significant aspects of studies were illuminated throughout this research, and an analysis of the collected sample, active participants, publications, and thematic directions covering numerous scientific areas related to the use of modern technologies in educational processes was conducted.

Analysing the publication activity and external citations testifies to the dynamic development of the digital education field. The scholarly community and educational institutions are keenly interested in engaging in scientific discourse and researching new methods and tools. Notably, the geographical scope of participation in research in the digital education realm is expanding, encompassing countries that were not previously active participants in the scholarly dialogue. This signifies global interest in this thematic area.

Based on the utilised terminology, various digital education applications were identified and explored by the article authors, including programme development for the elderly, the role of digital technologies in medical education, adaptation of learning during crises, and others. Novel research trends have been detected, such as integrating metaverses in education, the influence of robotics on student motivation, digitising diplomas using blockchain technology, and more.

The conducted analysis revealed positive trends and challenges, such as the uneven distribution of research activity among countries and the necessity for effective integration of digital technologies into the educational

process. However, these challenges also present new opportunities for scholarly research and practical implementation.

In the long-term perspective, the following developments in the digital education field can be anticipated: (1) upcoming research might delve into a deeper analysis of specific technologies, their impact on the psychological aspects of learning, and the creation of new educational standards; (2) the potential of digital education also allows educational institutions and researchers to actively engage with the business sphere and government structures to prepare specialists in demand in the modern economy.

Overall, the culmination of identified positive trends renders the digital education domain promising for further research and practical implementation. The authorial team intends to continue exploring this thematic area with deeper investigation and updating.

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VIII. REFERENCES

Abdelwahab, SI, Taha, MME, Moni, SS & Alsayegh, AA 2023, 'Bibliometric mapping of solid lipid nanoparticles research (2012–2022) using VOSviewer', Medicine in Novel Technology and Devices, vol. 17. doi: 10.1016/j.medntd.2023.100217.

Afgan, S & Bing, C 2021, 'Scientometric review of international research trends on thermal energy storage cement based composites via integration of phase change materials from 1993 to 2020', Construction and Building Materials, vol. 278, p. 122344. doi: 10.1016/J.CONBUILDMAT.2021.122344.

Abdelwahab, SI et al. 2023, 'Bibliometric mapping of solid lipid nanoparticles research (2012–2022) using VOSviewer', Medicine in Novel Technology and Devices, vol. 17.

Albright, J et al. 2022, 'COVID-19 and the Key Digital Transformation Lessons for Higher Education Institutions in South Africa', Education Sciences 2022, vol. 12, p. 464, no. 7, viewed 12 May 2023, <https://www.mdpi.com/2227-7102/12/7/464/htm>.

Bong, WK & Chen, W 2021, 'Increasing faculty's competence in digital accessibility for inclusive education: a systematic literature review', viewed 12 May 2023, <https://www.tandfonline.com/doi/abs/10.1080/13603116.2021.1937344>. doi: 10.1080/13603116.2021.1937344.

Bradford, CS & Hautzinger, M 2010, 'Digital Statutory Supplements for Legal Education: A Cheaper, Better Way', Journal of Legal Education, vol. 59, no. 4, pp. 515–544, <http://www.jstor.org/stable/42894139>.

Cassar, S, Neal, M & Schofield, C 2021, 'Limitless Learning, Active Blended Learning and the Pandemic: Using Technology to Enable Student Learning in In-Class, Online, and Hybrid Ug Classrooms', Inted2021 Proceedings, vol. 1, pp. 6252–6261.

Chen, X et al. 2022, 'Online learning research in the era of COVID-19: Bibliometric analysis and topic modeling', Proceedings of the 2022 IEEE International Conference on Behavioural and Social Computing, BESC 2022.

Chen, X et al. 2023, 'Exploring contributors, collaborations, and research topics in educational technology: A joint analysis of mainstream conferences', Education and Information Technologies, vol. 28, no. 2, pp. 1323–1358.

Conceição, SCO 2006, 'Faculty Lived Experiences in the Online Environment', Adult Education Quarterly, vol. 57, no. 1, pp. 26–45, viewed 12 May 2023, <https://journals.sagepub.com/doi/abs/10.1177/1059601106292247?journalCode=aeqb>.

Daniela, L, Kalniņa, D & Strods, R 2017, 'An Overview on Effectiveness of Technology Enhanced Learning (TEL)', International Journal of Knowledge Society Research (IJKSR), vol. 8, no. 1, pp. 79–91, viewed 12 May 2023, <https://www.igi-global.com/article/an-overview-on-effectiveness-of-technology-enhanced-learning-tel/181263>.

Davis, K, Dykman, CA & Davis, CK 2008, 'Part One-The Shift Toward Online Education', Journal of Information Systems Education, vol. 19, no. 1, viewed 12 May 2023, <https://www.researchgate.net/publication/228649898>.

Esh, M & Ghosh, S 2021, 'Tracing the Global Trend on the Study of Digital Literacy: A Scientometric Analysis', International Journal of Digital Literacy and Digital Competence (IJDLDC), vol. 12, no. 3, pp. 32–46, viewed 12 May 2023, <https://www.igi-global.com/article/tracing-the-global-trend-on-the-study-of-digital-literacy/291971>.

Garg, KC & Kumar, S 2014, 'Scientometric profile of Indian scientific output in life sciences with a focus on the contributions of women scientists', Scientometrics, vol. 98, no. 3, pp. 1771–1783, viewed 12 May 2023, <https://link.springer.com/article/10.1007/s11192-013-1107-4>.

Glänzel, W & Schoepflin, U 2005, 'Little scientometrics, big scientometrics ... and beyond?', Scientometrics, vol. 30, no. 2–3, pp. 375–384, viewed 12 May 2023, <https://akjournals.com/view/journals/11192/30/2-3/article-p375.xml>.

Haleem, A et al. 2022, 'Understanding the role of digital technologies in education: A review', Sustainable Operations and Computers, vol. 3, pp. 275–285.

Henriksen, D, Mishra, P & Fisser, P 2016, 'Infusing Creativity and Technology in 21st Century Education: A Systemic View for Change on JSTOR', Educational Technology & Society, vol. 19, no. 3, pp. 27–37, viewed 12 May 2023, <https://www.jstor.org/stable/jeductechsoci.19.3.27>.

Holland, Janet & Holland, John 2014, 'Implications of Shifting Technology in Education', TechTrends, vol. 58, no. 3, pp. 16–25, viewed 12 May 2023, <https://link.springer.com/article/10.1007/s11528-014-0748-3>.

Hrastinski, S 2009, 'A theory of online learning as online participation', Computers & Education, vol. 52, no. 1, pp. 78–82.

Hurajova, A, Kollarova, D & Huraj, L 2022, 'Trends in education during the pandemic: modern online technologies as a tool for the sustainability of university education in the field of media and communication studies', Heliyon, vol. 8, no. 5, p. e09367.

Hwang, S, Flavin, E & Lee, JE 2023, 'Exploring research trends of technology use in mathematics education: A scoping review using topic modeling', Education and Information Technologies.

Ibrahim, N, Habacha Chaibi, A & Ben Ahmed, M 2015, 'New scientometric indicator for the qualitative evaluation of scientific production', New Library World, vol. 116, no. 11–12, pp. 661–676.

Jomah, O et al. 2016, 'Micro Learning: A Modernized Education System', BRAIN. Broad Research in Artificial Intelligence and Neuroscience, vol. 7, no. 1, pp. 103–110, viewed 12 May 2023, <https://www.brain.edusoft.ro/index.php/brain/article/view/582>.

Korzhavykh, EA 2012, 'Scientometric assessment of the progress of innovative pharmacy in Russia', Russian Journal of General Chemistry, vol. 82, no. 3, pp. 527–534, viewed 12 May 2023, <https://link.springer.com/article/10.1134/S1070363212030310>.

Krauskopf, M 2005, 'Scientometric indicators as a means to assess the performance of state supported universities in developing countries: The Chilean case', Scientometrics, vol. 23, no. 1, pp. 105–121, viewed 12 May 2023, <https://akjournals.com/view/journals/11192/23/1/article-p105.xml>.

Kumar, K 2014, 'A Scientometric Study of Digital Literacy in Online Library Information Science and Technology Abstracts (LISTA)', Library Philosophy and Practice (e-journal), viewed 12 May 2023, <https://digitalcommons.unl.edu/libphilprac>.

Leydesdorff, L 2005, 'The relations between qualitative theory and scientometric methods in science and technology studies: Introduction to the topical issue', Scientometrics, vol. 15, no. 5–6, pp. 333–347, viewed 12 May 2023, <https://akjournals.com/view/journals/11192/15/5-6/article-p333.xml>.

Ly, TNL, Nguyen, TL & Nguyen, HN 2021, 'Using E-Learning Platforms in Online Classes: A Survey on Tertiary English Teachers' Perceptions', AsiaCALL Online Journal, vol. 12, no. 5 SE-, pp. 34–53, <https://www.asiacall.info/acoj/index.php/journal/article/view/75>.

Mashroofa, MM et al. 2023, 'Mapping of Global literature on Digital Divide in Education: A Scientometrics Analysis Based on Scopus Database', Journal of the University Librarians Association of Sri Lanka, vol. 26, pp. 42–71, viewed 12 May 2023, <http://ir.lib.seu.ac.lk/handle/123456789/6565>.

Mishra, P, Mishra, P & Kereluik, K 2011, 'What 21st Century Learning? A review and a synthesis', Society for Information Technology & Teacher Education International Conference, vol. 2011, no. 1, pp. 3301–3312.

Mohamed Hashim, MA, Tlemsani, I & Matthews, R 2022, 'Higher education strategy in digital transformation', Education and Information Technologies, vol. 27, no. 3, pp. 3171–3195, viewed 12 May 2023, <https://link.springer.com/article/10.1007/s10639-021-10739-1>.

Myers, CB et al. 2004, 'Emerging Online Learning Environments and Student Learning: An Analysis of Faculty Perceptions', Journal of Educational Technology & Society, vol. 7, no. 1, pp. 78–86, <http://www.jstor.org/stable/jeductechsoci.7.1.78>.

Oliver, R 2006, 'Exploring strategies for online teaching and learning', Distance Education, vol. 20, no. 2, pp. 240–254, viewed 12 May 2023, <https://www.tandfonline.com/doi/abs/10.1080/0158791990200205>.

Park, H, Kim, HS & Park, HW 2021, 'A Scientometric Study of Digital Literacy, ICT Literacy, Information Literacy, and Media Literacy', Journal of Data and Information Science, vol. 6, no. 2, pp. 116–138.

Pinto, M et al. 2020, 'Information literacy trends in higher education (2006–2019): visualizing the emerging field of mobile information literacy', Scientometrics, vol. 124, no. 2, pp. 1479–1510, viewed 12 May 2023, <https://link.springer.com/article/10.1007/s11192-020-03523-4>.

Purnomo, A et al. 2020, 'Digital literacy research: A scientometric mapping over the past 22 years', Proceedings of 2020 International Conference on Information Management and Technology, ICIMTech 2020, pp. 108–113.

Schloegl, C & Stock, WG 2004, 'Impact and relevance of LIS journals: A scientometric analysis of international and German-language LIS journals—Citation analysis versus reader survey', Journal of the American Society for Information Science and Technology, vol. 55, no. 13, pp. 1155–1168, viewed 12 May 2023, <https://onlinelibrary.wiley.com/doi/full/10.1002/asi.20070>.

Srithar, U 2016, 'Learning at Your Own Pace: M-Learning Solution for School Students', International Journal of Information and Electronics Engineering, vol. 5, no. 3, pp. 216–224, viewed 12 May 2023, <https://www.researchgate.net/publication/280758553>.

Tarling, I & Ng'ambi, D 2016, 'Teachers pedagogical change framework: a diagnostic tool for changing teachers' uses of emerging technologies', British Journal of Educational Technology, vol. 47, no. 3, pp. 554–572, viewed 12 May 2023, <https://onlinelibrary.wiley.com/doi/full/10.1111/bjet.12454>.

Veletsianos, G et al. 2021, 'Temporal flexibility, gender, and online learning completion', Distance Education, vol. 42, no. 1, pp. 22–36, viewed 12 May 2023, <https://www.tandfonline.com/doi/abs/10.1080/01587919.2020.1869523>.

Wagner, G et al. 2021, 'Which factors affect the scientific impact of review papers in IS research? A scientometric study', Information & Management, vol. 58, no. 3, p. 103427.

Wang, H et al. 2022, 'A bibliometric review on stability and reinforcement of special soil subgrade based on CiteSpace', Journal of Traffic and Transportation Engineering (English Edition), vol. 9, no. 2, pp. 223–243.

Wu, M et al. 2022, 'Digital Literacy from 2018-2021: A scientometric study of the literature', viewed 12 May 2023, <https://www.researchsquare.com/article/rs-1848300/latest.pdf>.

Xie, X, Siau, K & Nah, FFH 2020, 'COVID-19 pandemic – online education in the new normal and the next normal', Journal of Information Technology Case and Application Research, vol. 22, no. 3, pp. 175–187, viewed 12 May 2023, <https://www.tandfonline.com/doi/abs/10.1080/15228053.2020.1824884>.

Yang, D et al. 2022, 'Research Status, Hotspots, and Evolutionary Trends of Global Digital Education via Knowledge Graph Analysis', Sustainability, vol. 14, no. 22, pp. 15157–15157, viewed 12 May 2023, <https://doi.org/10.3390/su142215157>.

Yazdani, K et al. 2015, 'Scientometrics: Review of Concepts, Applications, and Indicators', Iranian Journal of Epidemiology, vol. 10, no. 4, pp. 78–88, viewed 12 May 2023, <http://irje.tums.ac.ir/article-1-5292-en.html>.

Zhang, Q, Abraham, J & Fu, HZ 2020, 'Collaboration and its influence on retraction based on retracted publications during 1978–2017', Scientometrics, vol. 125, no. 1, pp. 213–232, viewed 12 May 2023, <https://link.springer.com/article/10.1007/s11192-020-03636-w>.

Zhang, Q & Fu, HZ 2022, 'Productivity patterns, collaboration and scientific careers of authors with retracted publications in clinical medicine', Scientometrics, vol. 127, no. 4, pp. 1883–1901, viewed 12 May 2023,

<https://link.springer.com/article/10.1007/s11192-021-04252-y>.