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Communication and collaboration competence within the digital competence framework: a bibliometric analysis

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ABSTRACT

This paper evaluates the development of research on communication and collaboration competence within the digital competence framework (CCC-DCF), an increasingly vital area in the digital era. Bibliometric techniques were applied to analyze 449 articles published in the Scopus database from 2000 to 2023. Using VOSviewer and Biblioshiny, publication trends were tracked, leading journals and high-productivity countries identified, as well as collaboration networks, prominent scholars, most-cited documents, and frequently used keywords. Our analysis revealed a steady increase in publications over the past 23 years, with a notable surge in the last 3 years due to the fourth industrial revolution and the COVID-19 pandemic. MDPI AG was the leading publisher, with the United States and Spain as the top-producing countries. Diana Andone and Mark Frydenberg were the most prolific authors, and the British Journal of Educational Technology was the most cited journal. The study also explored collaborations among authors and countries through visualization analysis. Key frequently appearing terms included digital competences, higher education, information and communication technologies, and collaborative learning. This research forms a basis for future studies to enhance communication and collaboration competence in the digital environment for students. It also provides policymakers and researchers with key authors and impactful studies for further exploration.

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1. INTRODUCTION

The core technologies of industry 4.0, including artificial intelligence, the internet of things (IoT), big data, autonomous robotics, cloud computing, and machine learning, have profoundly influenced nearly every aspect of life. Education, in particular, has been one of the sectors most significantly affected by these advancements [1], [2]. Digital technology has become a foundational element of modern education, enriching pedagogical contexts [3]. Its emergence has given rise to numerous learning environments [4] that differ in form, function, features, and patterns from traditional learning spaces [5]. Education is no longer confined to fixed times and locations; it has expanded to allow learning to take place continuously, virtually anywhere [3], [6]. Learning can occur not only in the workplace [7] and at home [8], but also within online communities [9].

As a result, teaching processes, learning strategies, and the dissemination and acquisition of learning resources have undergone significant transformations. Blayone *et al*. [10], [11] have underscored the criticality of digital competence as a cornerstone for effective engagement in digital learning environments. Furthermore, numerous studies emphasize that digital competence should be cultivated early in life [12], [13], as children are already exposed to a multitude of digital information (e.g., watching movies, playing games) and devices (computers, televisions, tablets, and smartphones) while still in school [14]. However, students are often unaware of the risks associated with digital technology use [15]. This highlights both the frequency of exposure and the potential dangers inherent in digital technology, particularly for younger audiences [16], [17]. As experts like van Deursen and van Dijk have argued, the ability to autonomously and strategically navigate digital media is imperative for full societal participation [18]. Thus, fostering digital competence among students has become an essential educational priority.

In 2013, starting with Ferrari's digital competence concept, the European Commission conducted research and analyzed the implications of this concept to build different versions of the European Digital Competence Framework for Citizens (DigComp), laying the foundation for developing digital competence for citizens [19], [20]. After conducting empirical research to evaluate 47 digital competence frameworks from various countries, the United Nations Educational, Scientific and Cultural Organization (UNESCO) found that the competencies described in these frameworks could be mapped to the DigComp framework [21]. Additionally, UNESCO recognized DigComp as the most up-to-date and comprehensive digital competence framework available today [22], [23]. The DigComp has five competence areas: i) information and data literacy; ii) communication and collaboration; iii) digital content creation; iv) safety; and v) problem solving [20], [24]. Among these, communication and collaboration competence holds particular relevance in today's rapidly evolving digital landscape. As technology continues to advance, human communication in digital environments increasingly replaces traditional interpersonal interactions, reshaping how individuals connect, learn, and work [25]. Moreover, effective communication and collaboration competence enable individuals to participate in teamwork, build networks, and co-create knowledge. The digital environment has become a primary domain for modern living, offering unparalleled opportunities for education, cultural exchange, and communication [26]. This study, therefore, focuses on communication and collaboration competence within the digital competence framework (CCC-DCF) as an area of significant importance for students.

Numerous bibliometric studies have highlighted the evolution of research related to digital competences. For instance, Siddiq *et al*. [22] systematically reviewed instruments for assessing information and communication technology or ICT literacy in primary and secondary education. Recent studies [27], [28] emphasize the increasing role of collaborative learning mediated by digital tools. Building on these foundational analyses, this research aims to provide a comprehensive bibliometric overview of CCC-DCF, with a focus on trends, significant contributions, and emerging directions.

In this study, our primary objective is to provide a comprehensive overview of the global development of research related to CCC-DCF, while identifying its key contributions and emerging research directions through bibliometric analysis. This type of analysis offers valuable quantitative insights for scholars intending to pursue future research in this field. Bibliometric analysis, first introduced by Pritchard, is an effective method for measuring scientific activities based on quantitative statistical data derived from scientific literature [29], [30]. This method has wide applications and has been used across various research domains [31], [32], including studies on industry 4.0 [33], [34] and education [35]–[37]. Notable examples include analyses of the adoption of digital technologies in higher education by Wang *et al*. [35] and the global evolution of digital literacy research by Purnomo *et al*. [38]. This study focuses on analyzing research data spanning from 2000 to 2023, utilizing VOSviewer and Biblioshiny tools through R programming to thoroughly examine CCC-DCF studies from the Scopus index database. The objectives of the study include: i) analyzing the growth of the number of publications in the CCC-DCF field over time, while identifying the countries and scholars with the highest publication productivity and impact based on the number of publications and citations; ii) assessing the most influential journals in publishing research in this field, as well as identifying the most highly cited papers to clarify significant contributions; and iii) explore prominent research areas and key trends, offering actionable insights for future research.

By integrating insights from recent bibliometric studies and leveraging advanced analytical tools, this research provides a robust and up-to-date perspective on the global development of CCC-DCF. Thus, it also addresses a critical gap in the literature. Furthermore, it underscores the significance of this field in informing educational policy and practice, particularly in the context of the fourth industrial revolution and post-pandemic digital transformations.

2. METHOD

Bibliometric analysis was initially introduced in the 1960s [29] and has since been extensively employed to examine the scientific development of various research domains on both local and global level.

Among various bibliographic databases, Scopus and Web of Science are two important sources of information in the social sciences. Compared to Web of Science, Scopus surpasses it in terms of research fields covered, the number of journals indexed, and the publication of documents in multiple languages [39]. Furthermore, a priority reporting system for systematic review and meta-analysis has been implemented to ensure the quality of the literature search process [40]. Therefore, for this study, the Scopus database was chosen as the search engine for our research.

The data filtering process adhered to the four-step preferred reporting items for systematic reviews and meta-analyses or PRISMA process: identification, screening, eligibility, and inclusion [40]. Initially, we conducted a search in the Scopus database prior to 2024 using advanced search functionalities, employing search terms and operators compatible with the search tool's syntax. When referring to the ability to communicate and collaborate through digital technology, various terms are used, such as “communication and collaboration skills” [41], “communication and collaboration competences” [42], “collaborative competence” [43], “communicative competence” [44], “digital capabilities” [45], “digital competences” [46], “digital competencies” [47], “digital literacies” [48], and “digital literacy” [49]. To encompass all research publications on this topic from researchers across various countries, we utilized the "*" symbol in the search query to match any group of characters within the Scopus database search syntax. Following this, we identified 906 documents. Secondly, we restricted document types to include articles, conference papers, book chapters, and review papers in the social sciences, written in English. The search string used in the Scopus database was as: TITLE-ABS-KEY ((communica* AND collabora* AND (competenc* OR skill*)) AND (digital AND (literac* OR competenc* OR capabilit*))) AND PUBYEAR < 2024 AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ch") OR LIMIT-TO (DOCTYPE , "re")) AND (LIMIT-TO (LANGUAGE , "English")). It is important to note that the search query was initiated on January 1, 2024.

Subsequently, the titles and abstracts of the remaining 489 documents were screened to eliminate those unrelated to this study. Ultimately, a final set of 449 documents was compiled for data processing and visualization using two widely used bibliographic tools: Biblioshiny [50] and VOSviewer (version 1.6.20) [51]. Biblioshiny is an application developed in RStudio that enables researchers to evaluate the quality and impact of research in diverse fields. This application offers visual representations of research patterns, including content analysis, word clouds, and citation analysis, to assist researchers in gaining valuable insights into the advancement of specific research topics. It can be used to identify prolific authors, popular keywords, and influential publications in a specific field of study. VOSviewer facilitates the grouping of interconnected research publications to offer a comprehensive understanding of the scientific landscape. This software is valuable in helping researchers find precise search terms, identify potential collaborators, locate influential papers and knowledge gaps. Figure 1 shows the flowchart of the document selection process.

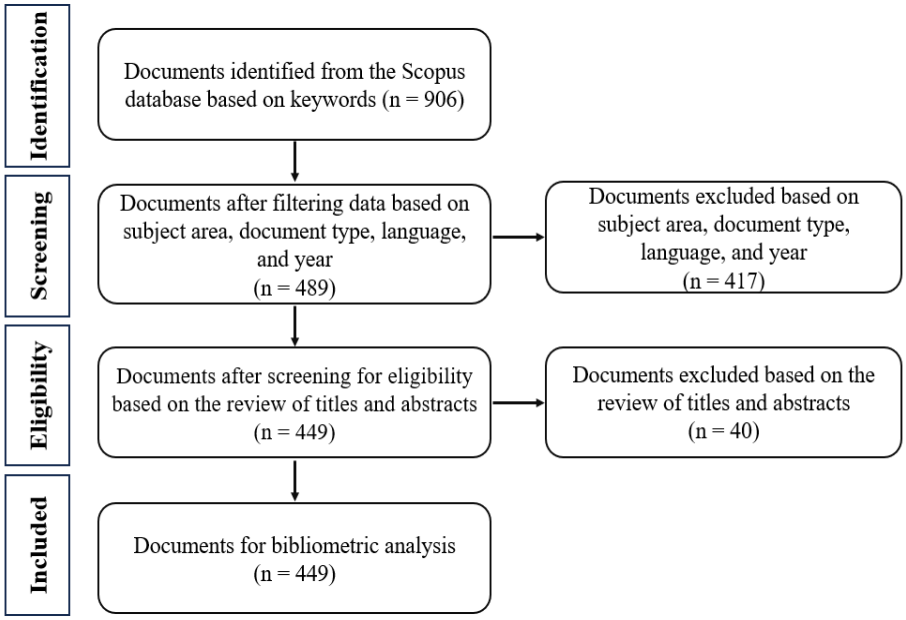

Figure 1. Flowchart of document selection process

3. RESULTS AND DISCUSSION

3.1. Evolution of publications over time

The key information from the set of 449 publications is depicted in Figure 2. Out of the total collection, 294 articles were identified, representing 65.48% of the publications. Additionally, the collection included 49 book chapters, 88 conference papers, and 18 review papers accounting for 10.91%, 19.60% and 4.01% of the collection, respectively. These 449 publications were produced across 312 different sources indexed in the Scopus database between 2000 and 2023. The average number of citations per document was found to be 10.93. The authorship analysis identified 1,243 contributors, with an average of 2.94 co-authors per document, suggesting a trend toward collaborative research. Moreover, 87 single-author papers were authored by 85 scholars, highlighting the role of individual contributions alongside collaborative efforts.

Figure 3 illustrates the annual publication output from 2000 to 2023. Although the first publication in this field was released in 2000, our analysis reveals a substantial increase in academic interest following the COVID-19 pandemic. While only two publications were produced in 2000, the number doubled by 2018, reaching 88 publications by 2023. The profound impact of the fourth industrial revolution and the COVID-19 pandemic has heightened the demand for digital communication, driving increased academic interest in digital communication and collaboration. This outcome aligns with previous studies [52], [53], leading to a significant surge in CCC-DCF research over the past three years. This period also witnessed the emergence of new research focuses and expanded international collaborations, all contributing to the enhanced prominence of this field. This finding highlights the need for educational institutions to place greater emphasis on developing communication and collaboration competence within the digital competency framework in their curricula. This observation is consistent with previous studies [44], [54], [55], which similarly emphasized the growing importance of digital communication and collaboration competence in the modern era and their prioritization in educational programs. This focus ensures students are equipped to meet the demands of a digitally driven world, reinforcing the importance of integrating CCC-DCF within broader educational policies.

Description	Results
MAIN INFORMATION ABOUT DATA	
Timespan	2000:2023
Sources (Journals, Books, etc)	312
Documents	449
Annual Growth Rate %	17.88
Document Average Age	5.29
Average citations per doc	10.93
References	17466
DOCUMENT CONTENTS	
Keywords Plus (ID)	1096
Author's Keywords (DE)	1398
AUTHORS	
Authors	1243
Authors of single-authored docs	85
AUTHORS COLLABORATION	
Single-authored docs	87
Co-Authors per Doc	2.94
International co-authorships %	23.16
DOCUMENT TYPES	
article	294
book chapter	49
conference paper	88
review	18

Figure 2. Main information of the collection

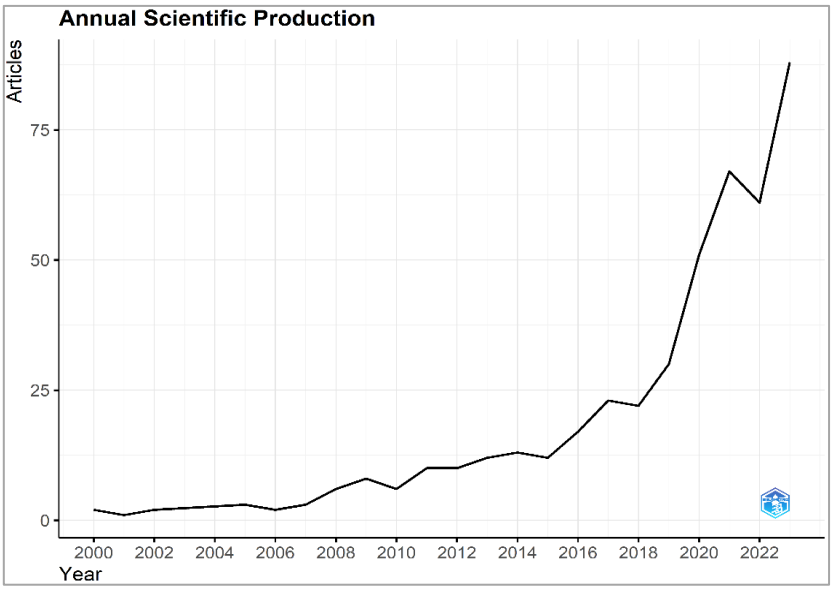

Figure 3. The yearly count of articles on CCC-DCF published in the Scopus database from 2000 to 2023

3.2. Countries with the highest productivity and the global network of collaborations

The publication collection of 449 documents was published by scholars from 77 different countries, illustrating the global scope of research on CCC-DCF. Figure 4 illustrates the collaboration network among 48 countries with at least three CCC-DCF publications, reflecting both historical and recent international collaboration trends. Each node represents a country, with its size indicating publication volume and the connecting line thickness showing collaboration strength. The analysis identifies the United States and Spain as central hubs in the network, with significant partnerships expanded, particularly with emerging research regions in Asia and Latin America. Notably, the United States has enhanced collaborations with China, India, and Australia in recent years, aligning with findings from previous studies [56]. Spain, as a leader in the brown cluster, has consistently collaborated with Mexico, Peru, and Colombia, highlighting regional and linguistic ties. Countries are grouped into eight color-coded clusters based on geographical and cultural connections. For example, the red cluster represents strong intra-European collaborations, supported by EU-funded digital competencies projects, while the brown and yellow clusters highlight regional and cross-regional partnerships, respectively. These trends underscore the dynamic evolution of CCC-DCF research, with increasing emphasis on cross-regional collaboration to address global educational challenges.

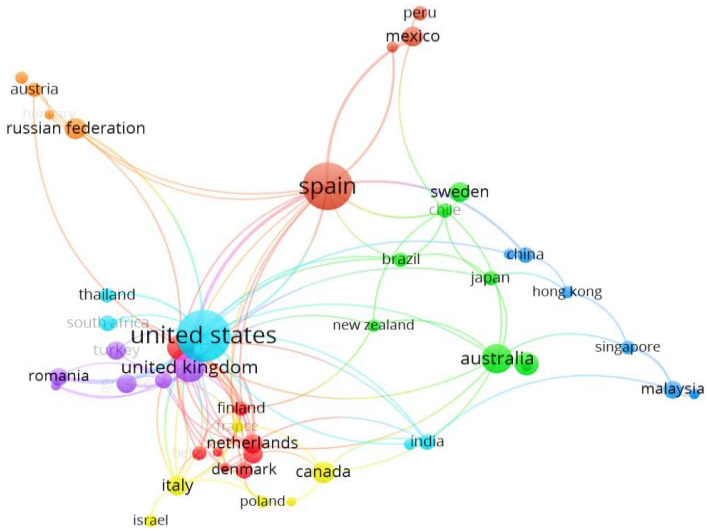

Figure 4. Collaboration network among 48 partner countries, each contributing at least three documents on CCC-DCF

Table 1 displays the top 10 most productive countries, ranked by both publication count and citations. These 10 countries account for 67.93% of the total publications (305 in total) and 75.99% of the total citations (3,729 in total) in the collection. The United States leads with 84 publications (18.71% of the total) and 1,014 citations (20.66%). Spain follows with 72 publications (16.04%) and 952 citations (19.40%). The United Kingdom ranks third with 25 publications (8.59%) and 751 citations (15.30%). Germany ranks fifth in terms of publications with 22 documents (4.90%) but tenth in citations with 83 citations (1.69%). Sweden, ranked tenth in terms of publications with 13 documents (2.90%), holds the fifth position in citations with 197 citations (4.01%). Only two countries in this study received fewer than 100 citations: Russia and Germany, with 97 and 83 citations, respectively. Except for Indonesia and Russia, the remaining eight countries listed in Table 1 are classified as developed countries according to the International Monetary Fund. An important finding is that developed countries, such as the United States and Spain, dominate in publication output. This pattern aligns with previous studies [38], [57], highlighting the role of advanced research infrastructures and robust funding mechanisms in facilitating high productivity and impact in scientific research. Conversely, Vietnam is notably absent from the list of the top ten countries. This underscores the need for Vietnam to invest more in CCC-DCF research and increase its contribution to this globally significant field.

Table 1. Top 10 most productive countries based on the number of publications and citations

Order	Country	Total papers	(%)	Total citations	(%)
1	United States	84	18.71	1014 (#1)	20.66
2	Spain	72	16.04	952 (#2)	19.40
3	United Kingdom	28	6.24	751 (#3)	15.30
4	Australia	27	6.01	145 (#7)	2.95
5	Germany	22	4.90	83 (#10)	1.69
6	Indonesia	17	3.79	100 (#8)	2.04
7	Canada	15	3.34	171 (#6)	3.48
8	Russia Federation	14	3.12	97 (#9)	1.98
9	Italy	13	2.90	219 (#4)	4.46
10	Sweden	13	2.90	197 (#5)	4.01

3.3. Most popular journals

The collection of 449 documents was published in 312 distinct sources. Table 2 lists the top 10 sources based on the number of published documents, including details such as citations, h-indices, quartiles, and publishers. The journal Sustainability claimed the first position with 14 (3.12%) documents and ranked third in terms of citations with 270 (5.50%). The Education Sciences secured the second position with 11 (2.45%) documents and held the fifth spot with 65 (1.32%) citations. Both journals with the largest number of publications belong to MDPI AG publishing house. MDPI AG is a publisher favored by scholars conducting research on CCC-DCF. The journal British Journal of Educational Technology ranked fifth position with 7 (1.56%) but first position with 405 (8.25%) citations. The journal Proceedings - Frontiers in Education Conference, ranked last with 4 (0.89%) documents and received 3 (0.06%) citations. The top 10 sources collectively published a total of 79 documents, accounting for 15.59% of the collection, and received a total of 1,359 citations, accounting for 27.70% of the overall number of citations. According to the SCImago Journal and Country Rank, among the top 10 journals, four are categorized in the first quartile (Q1), three as second quartile (Q2) in Scopus, while three have not been classified in the Scopus database. This suggests that articles published in reputable and widely recognized journals tend to stand out, attract more citations, and have a greater impact, which aligns closely with the findings from previous research [58], [59]. Figure 5 provides an in-depth analysis of the annual publication of the top ten most popular sources between 2007 and 2023. The first article on CCC-DCF was published in British Journal of Educational Technology in 2007. Since then, publication of proceedings on this subject has increased every year.

3.4. Scholars with the highest number of publications and citations

Table 3 displays the top 10 scholars with the highest number of publications and citations in the CCC-DCF research field. The Russian Federation has the highest number of scholars among the top 10 most productive scholars based on publication count. Among them, two scholars are affiliated with the Russian Languages Russian State Agrarian University. These three scholars have collectively authored three articles. Additionally, due to their collaboration in the Talktech project, two scholars, Diana Andone and Mark Frydenberg, from universities in Romania and the United States, respectively, have published the highest number of articles, totaling 7, since 2011 [60]. Hatlevik Ove Edvard comes from the Norwegian Centre for ICT in Education, Norway ranked tenth based on 2 articles, but first on 247 citations. McLoughlin Catherine is the first researcher to conduct research on CCC-DCF since 2009, and some researchers began very recently

in 2020 and 2021. The top 10 scholars collectively published 37 articles, accounting for 8.24% of the total, and received 537 citations, representing 19.94% of all citations. Notably, Table 3 reveals that eight out of the ten most-cited articles were published between 2014 and 2020. This highlights the significance of articles published during this period as important references and influential contributions to numerous other research studies within this field.

Table 2. Top 10 most active journals based on the number of articles

Order	Sources	Publishing house/country	No. of documents	(%)	No. of citations	(%)	h-index	Quartile*
1	Sustainability	MDPI AG/Switzerland	14	3.12	270 (#3)	5.50	136	Q2
2	Education Sciences	MDPI AG/Switzerland	11	2.45	65 (#5)	1.32	40	Q2
3	Education and Information Technologies	Kluwer Academic Publishers/ United States	10	2.23	58 (#6)	1.18	61	Q1
4	Proceedings of the European Conference on Games-Based Learning	Germany	10	2.23	16 (#7)	0.33	16	
5	British Journal of Educational Technology	Wiley-Blackwell/United Kingdom	7	1.56	405 (#1)	8.25	110	Q1
6	Frontiers in Education	Frontiers Media S.A/Switzerlanc	7	1.56	3 (#9)	0.06	29	Q2
7	Computers and Education	Elsevier Ltd/United Kingdom	6	1.34	396 (#2)	8.07	215	Q1
8	Proceedings of the European Conference on E-Learning, ECEL	United Kingdom	6	1.34	9 (#8)	0.18	10	
9	Comunicar	Grupo Communicar Ediciones/Spain	4	0.89	134 (#4)	2.73	51	Q1
10	Proceedings - Frontiers in Education Conference, Fie	Institute of Electrical and Electronics Engineers Inc/ United States	4	0.89	3 (#10)	0.06	45	

Notes: *According to the SCImago Journal and Country Rank (https://www.scimagojr.com/)

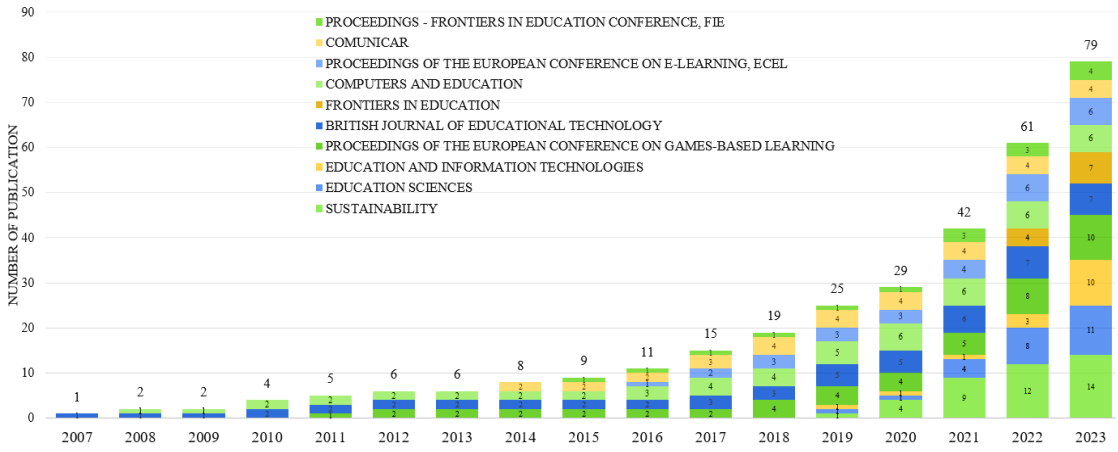

Figure 5. Yearly publications from the top ten most popular journals between 2007 and 2023

Table 3. Top ten most productive scholars based on the number of publications

Order	Authors	Institution/country*	No of articles	No. of citation	Year of first article
1	Andone, Diana	Politehnica University of Timisoara/Romania	7	30 (#4)	2011
2	Frydenberg, Mark	Bentley University/United States	7	30 (#5)	2011
3	Muñoz-Repiso, Ana García-Valcárcel	University of Salamanca/Spain	3	12 (#7)	2021
4	Reisoğlu, İlknur	Recep Tayyip Erdogan University/Turkey	3	98 (#2)	2020
5	Çebi, Ayça	Trabzon University/Turkey	3	89 (#3)	2020
6	McLoughlin, Catherine	Australian Catholic University/ Australia	3	16 (#6)	2009
7	Rubleva, O.S.	Vyatka State University/ Russian Federation	3	5 (#8)	2020
8	Ryabchikova, V.G.	Russian Languages Russian State Agrarian University/ Russian Federation	3	5 (#9)	2020
9	Sergeeva, N.A.	Russian Languages Russian State Agrarian University/ Russian Federation	3	5 (#10)	2020
10	Hatlevik, Ove Edvard	The Norwegian Centre for ICT in Education/ Norway	2	247 (#1)	2016

Note: * Information gathered from the author's most recent publications

Figure 6 illustrates the collaboration network among 51 co-authors who have collectively published at least two articles on CCC-DCF. Each node represents a scholar, sized proportionally to their publication count, and the connections between nodes indicate the intensity of collaboration. Scholars closely aligned in collaboration are grouped within color-coded clusters, with some clusters centered around the scholars listed in Table 3. For instance, the group created by the two scholars with the highest number of publications, Andone Diana and Frydenberg Mark. Another group made up three scholars, including three scholars Rubleva, Ryabchikova, and Sergeeva from the Vyatka State University and Russian Languages Russian State Agrarian University, Russian Federation. In this collaboration network, there are 13 groups with more than two scholars, while 17 isolated scholars remain disconnected from others in the network. This highlights the underutilized potential for collaboration and suggests the need for initiatives such as international conferences and joint research programs to enhance connectivity. The analysis of the author collaboration network reveals that large groups consist of scholars within the top 10 most productive authors, as shown in Table 3. These scholars have a higher number of publications and citations compared to independent researchers. Similar to previous studies [61], [62], our analysis confirms that a robust and extensive collaborative network among scholars, particularly cross-national cooperation, can enhance the scientific outcomes of researchers. Organizing international conferences and fostering international collaboration may further encourage the establishment and development of networks among scholars.

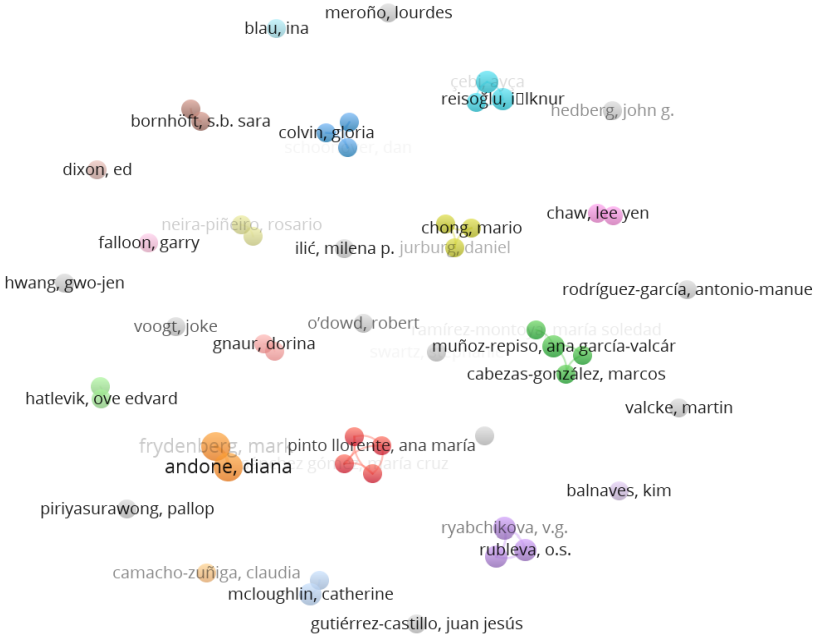

Figure 6. Collaborative network involving 51 co-authors each with over two publications

3.5. Most cited documents

Table 4 presents the ten most frequently cited publications. As of the time of this study, these ten articles, published between 2007 and 2020, have collectively accumulated 1,279 citations, accounting for 26.06% of the total citations. The British Journal of Educational Technology leads with two of these highly cited articles. The most cited article globally, "New directions for early literacy in a digital age: The iPad," authored by Flewitt *et al.* in 2015, was published in the Journal of Early Childhood Literacy and has received 215 citations. The second most cited publication, authored by Pivec Maja in 2007, appeared in the British Journal of Educational Technology. The third, written by Siddiq Fazilat *et al.* in 2016, was published in the Educational Research Review. These findings underscore that the CCC-DCF topic has attracted substantial scholarly attention and is widely relevant across various educational levels, from primary to higher education, as well as in teacher training. Moreover, these publications illustrate the broad relevance of CCC-DCF across educational levels and teacher training programs, echoing the priorities highlighted by Mattar *et al.* [63].

3.6. Main research topics on CCC-DCF

The main research topics on CCC-DCF are identified based on the frequently co-occurring keyword phrases in documents. Figure 7 displays a word cloud consisting of 43 popular author keywords, with larger font sizes representing keywords that appear more frequently. Author keywords are selected by the authors

themselves to summarize the key concepts or subjects addressed in their research articles [64]. The prominent keywords in this word cloud signify the primary research focuses within CCC-DCF. The leading keyword is "digital competences" followed by "digital literacy", "higher education", "information and communication technologies", "collaborative learning", "collaboration" and "communication". The active utilization of these keywords underscores the critical role of digital competencies and digital literacy within higher education. The integration of information and communication technologies in collaborative learning environments significantly enhances learners' communication and collaboration competence.

Table 4. Top 10 most cited documents

Title	Authors	Sources	First's author institution/Country	Year	Citations	Times cited per year
New directions for early literacy in a digital age: The iPad	Flewitt, Rosie, Messer, David; Kucirkova, Natalia	Journal of Early Childhood Literacy	University of London/ United Kingdom	2015	215	21.50 (#1)
Editorial: Play and learn: Potentials of game-based learning	Pivec, Maja	British Journal of Educational Technology	Dept. of Information Design/ Austria	2007	181	10.06 (#8)
Taking a future perspective by learning from the past - A systematic review of assessment instruments that aim to measure primary and secondary school students' ICT literacy	Siddiq, Fazilat; Hatlevik, Ove Edvard; Olsen, Rolf Vegar; Throndsen, Inger; Scherer, Ronny	Educational Research Review	University of Oslo/ Norway	2016	135	15.00 (#4)
Can I say something? The effects of digital game play on willingness to communicate	Reinders, Hayo; Wattana, Sorada	Language Learning and Technology	Anaheim University/ United States	2014	130	11.82 (#7)
Examining the Relationship between Teachers' Self-Efficacy, their Digital Competence, Strategies to Evaluate Information, and use of ICT at School	Hatlevik, Ove Edvard	Scandinavian Journal of Educational Research	The Norwegian Centre for ICT in Education/ Norway	2017	112	14.00 (#5)
Teacher training in lifelong learning-the importance of digital competence in the encouragement of teaching innovation	Artacho, Esther Garzón; Martínez, Tomás Sola; Ortega Martín, José Luís; Marín Marín, José Antonio; García, Gerardo Gómez	Sustainability (Switzerland)	University of Granada/ Spain	2020	103	20.60 (#2)
Learning in Digital Networks – ICT literacy: A novel assessment of students' 21st century skills	Siddiq, Fazilat; Gochyyev, Perman; Wilson, Mark	Computers and Education	University of Oslo/ Norway	2017	103	12.88 (#6)
Using avatars and virtual environments in learning: What do they have to offer?	Falloon, Garry	British Journal of Educational Technology	University of Waikato/ New Zealand	2010	102	6.80 (#9)
Do Web 2.0 tools really open the door to learning? Practices, perceptions and profiles of 11-16-year-old students	Luckin, Rosemary; Clark, Wilma; Graber, Rebecca; Logan, Kit; Mee, Adrian; Oliver, Martin	Learning, Media and Technology	Institute of Education/United Kingdom	2009	101	6.31 (#10)
How does the pedagogical design of a technology-enhanced collaborative academic course promote digital literacies, self-regulation, and perceived learning of students?	Blau, Ina; Shamir-Inbal, Tamar; Avdiel, Orit	Internet and Higher Education	The Open University of Israel/Israel	2020	97	19.40 (#3)

Figure 7. Word cloud of 43 most popular author keywords

Figure 8 provides a detailed analysis of the co-occurrence network among the 43 most frequently used author keywords, each appearing at least five times. Each node in the visualization represents a distinct keyword, and the thickness of the connecting lines indicates the strength of their relationship, determined by their frequency of co-occurrence in published articles. These author keywords are categorized into seven clusters, distinguished by different colors, each representing a major research focus within CCC-DCF. The first research topic pertains to technology in education, including virtual reality, web 2.0, and gamification [65], [66]. The second research topic focuses on the perception of digital competences [27], [67], [68]. The third research topic explores educational innovation in higher education [11], [69]. The fourth research topic centers around awareness of information literacy skills [70]. The fifth research topic examines collaboration through information and communication technologies for acquiring digital competences [44]. The sixth research topic focuses on the role of digital technology in developing creativity and critical thinking [71]. The last research topic discusses collaborative learning [28].

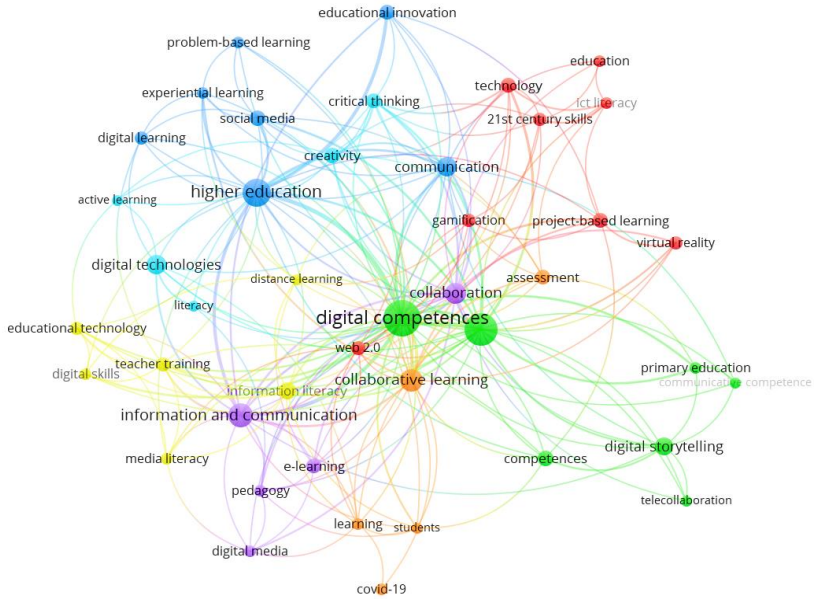

Figure 8. Co-occurrence network of the 43 most frequently used author keywords

4. CONCLUSION

This paper presents a bibliometric analysis of the development of research on CCC-DCF, outlining key research directions and major contributors from the inception of the field in the early 2000s to 2023, utilizing VOSviewer and Biblioshiny through R. The analysis encompasses the volume of publications in the CCC-DCF domain over time, identifies countries and authors with high publication and citation counts, and examines collaboration networks among nations and scholars, as well as prominent journals and frequently

occurring keywords. Over the past 23 years, the United States and Spain have emerged as the leading countries in terms of publication volume, with MDPI AG identified as the top publisher in the CCC-DCF field. Furthermore, the CCC-DCF area has garnered significant interest from the academic community and is widely relevant across various educational levels, from primary education to higher education, including teacher training. The analysis of the author collaboration network reveals that international cooperation can enhance the scientific output of researchers.

This study represents the first bibliometric analysis of research related to CCC-DCF, employing the Scopus database. With rapid technological advancements, communication and collaboration in the digital environment have gained increasing prominence, resulting in a rising number of articles addressing this field. Therefore, the information presented in this paper is expected to evolve rapidly and diversely in the future. Conducting regular analyses of this nature is essential for closely monitoring developments in this research area. Additionally, our analysis is based solely on bibliometric data from the Scopus database. While Scopus is a comprehensive database, it may not encompass all publications related to CCC-DCF. Including additional databases, such as WoS and IEEE Xplore could provide a more comprehensive perspective on the research landscape in the chosen field. Furthermore, the manual process of filtering, screening, and cleaning data may introduce human errors, potentially affecting the accuracy of our analysis. Thus, developing automated tools or algorithms for data filtering and cleaning processes could minimize human errors and enhance the accuracy of subsequent analyses.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Hong Hue Cao	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓
Lai Thai Dao	✓	✓			✓		✓			✓			✓	✓
Trung Tran	✓				✓		✓			✓				
Huyen Thi Thanh Nguyen					✓		✓			✓			✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study were retrieved from the Scopus database using a defined search string. Due to licensing restrictions, the dataset is not publicly available but can be obtained from the corresponding author upon reasonable request.

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