Article

The Impact of COVID-19 on Educational Research: A Bibliometric Analysis

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Abstract: As a result of the COVID-19 pandemic and the major challenges generated in education, thousands of scientific papers have been published, contributing to the establishment of a distinct research line in the field. This study provides a bibliometric overview of the educational publications linked to COVID-19 indexed by the Web of Science Core Collection for the years 2020 and 2021. The findings show a growing interest of researchers in education in this area. The proportion of articles among the types of documents proved to be dominant. Journals dedicated to chemistry and medical education stood out for the high number of pandemic-related papers. Higher education has been an intensively explored area during the pandemic. The USA and its universities were the most productive in publishing studies on COVID-19 in education. Our study indicated research themes that have been explored by the researchers, such as online learning in different educational settings, curriculum and instructional approaches in the online learning setting, and the psychological consequences of COVID-19 on the educational actors. The implications of the pandemic on potential research avenues for education research were also emphasized.

Keywords: education; pandemic; COVID-19; challenges; teachers; students; higher education

1. Introduction

The pandemic triggered by the new coronavirus in the spring of 2020 has brought disruptions worldwide in various fields of activity, including education [1,2]. Radical measures have been taken by governments and decision-makers in education to ensure the continuity of learning in a safe environment for students at all levels [3]. Closing educational institutions became necessary amid the crisis. As a result, they quickly made the transition from face-to-face to online instruction. This sudden change brought about many challenges, concerns, and barriers, but also opportunities for the introduction and investigation of novel instructional approaches [4]. Substantial efforts have been invested to research COVID-19's impact on education and to find solutions to adapt and deal with the difficulties brought about by the new context. Consequently, the pandemic generated a new topic addressed in education, full of challenges for which research-based solutions were necessary.

Scientific research related to COVID-19 has become a priority in many fields, especially in healthcare, with extraordinary achievements during the pandemic [5]. The increase in research paper production related to COVID-19 in different fields of research has inspired bibliometric studies that analysed them from various perspectives. In the field of education, several bibliometric studies have analysed the emerging scientific output on COVID-19 from various angles. For instance, Karakose and Demirkol [6] examined, in terms of themes and trends, the top 100 publications that were often cited in 2020 that addressed the connection between education and COVID-19, using information from the Web of Science Core Collection (WoSCC).

In their study, Corell-Almuzara et al. [7] advanced the idea of an initial stage for COVID-19-centered research in education, given the analysis of 940 publications selected

from the same database. In other very recent bibliometric studies, the authors have chosen to analyse pandemic publications focusing on certain levels or domains of the field of education. Thus, Su et al. [8] pointed out tendencies in early childhood education research under the pandemic by analyzing 507 articles identified in two databases—Web of Science (WoS) and Scopus. Karakose et al. [9] examined COVID-19-focused publications in medical education in 2020, while Zhang et al. [10] focused on online teaching in higher education. Although these works enrich the understanding of the way in which educational research has reflected the experiences and challenges resulting from the COVID-19 outbreak at different times and in different areas, a global perspective on the educational research associated with the COVID-19 pandemic is still missing. Consequently, the current research continues and completes prior bibliometric reviews, offering an overview of educational research regarding COVID-19, by integrating publications expanding over two years of the pandemic (2020 and 2021) and from all levels or domains of education.

This research seeks to offer a bibliometric perspective on COVID-19 papers connected to education and indexed by WoSCC in the Social Science Citation Index (SSCI) and the Science Citation Index Expanded (SCI-EXPANDED) for 2020 and 2021. Hence, we report on the following research aspects: the features of document types; the publication performance at the level of journals, countries, and institutions; the articles with the most citations; the research focuses on the field. More precisely, in this study we focused on providing answers to the following research questions:

- RQ1: What are the characteristics of COVID-19 publications in education indexed in WoSCC for 2020–2021 in terms of volume, document types, and citations?
- RQ2: What countries, institutions, journals, and publications have contributed to the COVID-19 education research literature?
- RQ3: What are the main research themes addressed in the literature related to COVID-19 in education?

Researchers, practitioners, and decision-makers connected to the educational environment can be guided in the topic of pandemic research in the field by the findings of this research. They can be inspired in terms of decisions and actions with scientific support. Significant learning and research opportunities regarding COVID-19's implications on education can be discovered based on research analysis in the area during the pandemic.

2. Materials and Methods

2.1. Research Design

The present study is based on a bibliometric approach. Bibliometrics refers to a collection of methods employed for examining research by analyzing scientific publications that are stored in extensive bibliographic databases [11]. According to Zupic and Cater [12], bibliometrics employs a quantitative approach to depict, assess, and track published research. There are two primary bibliometric approaches for investigating a research domain: performance analysis and science mapping [13]. Performance analysis focuses on evaluating the activities of scientific entities (countries, universities and researchers), and their influence, while scientific mapping aims to illustrate the intellectual, social or conceptual framework of scientific research [11,13]. Our study integrated elements of the two approaches. Thus, for the evaluation of educational publications related to the COVID-19 pandemic, we conducted performance analysis by utilizing various performance and citation indicators (described in Section 2.3). For science mapping analysis we opted for keyword co-occurrence analysis which identifies associations among concepts that appear together in document titles, abstracts, or keywords [12]. This kind of analysis generates a network of themes explored in diverse publications and their relationships that illustrate the conceptual landscape of a particular domain [12,14]. In the present study, co-occurrence analysis was applied to the keywords of the authors (more details in Section 2.3).

2.2. Data Collection and Search Strategy

Recognized as a selective database of scientific and scholarly publishing [15], WoSCC was used for document identification in this bibliometric study. The coverage of the field of education through specific categories of source publications facilitated the identification of relevant works for the purpose of this study. In the first phase, data were extracted on 15 July 2022, from the SSCI and SCI-EXPANDED databases. Subsequently, a second data extraction was conducted on 23 February 2023. The search strategy focused on three aspects by using specific field tags: Web of Science education-related categories (WC), topic (TS), and publication year (PY). More precisely, the search was carried out on the following framework: WC = ("education & educational research" or "education, scientific disciplines" or "education, special" or "psychology, educational"); TS = ("2019 novel coronavirus" or "2019-nCoV" or "acute coronary syndromes" or "corona virus disease 2019" or "coronavirus disease 2019" or "COVD-19" or "Covid19" or "COVID-19" or "Covid2019" or "Covid-2019" or "novel coronavirus 2019" or "novel coronavirus disease-19" or "novel coronavirus infection" or "pandemic" or "SARS CoV-2" or "severe acute respiratory syndrome coronavirus"); PY = 2020–2021.

By utilizing the field tag (TS = Topic), we were able to search for specific terms in a record's title, abstract, author keywords, and keywords plus sections. There were 2619 documents identified between 2000 and 2021, including 2008 articles. As keywords plus provide supplementary search terms from the titles of articles referenced by authors in their bibliographies and footnotes [16], we employed the "front page" filter [17] to exclude any unrelated publications from our search results. This filter allowed us to select only those documents with the search terms in the title, abstract or author keywords. Consequently, documents containing the searched keywords only within the keywords plus field were not included in the analysis (*n* = 7). Eventually, 2612 documents were identified as COVID-19 publications in the SSCI and SCI-EXPANDED education-related categories. Figure 1 illustrates the process of searching for COVID-19 publications in education.
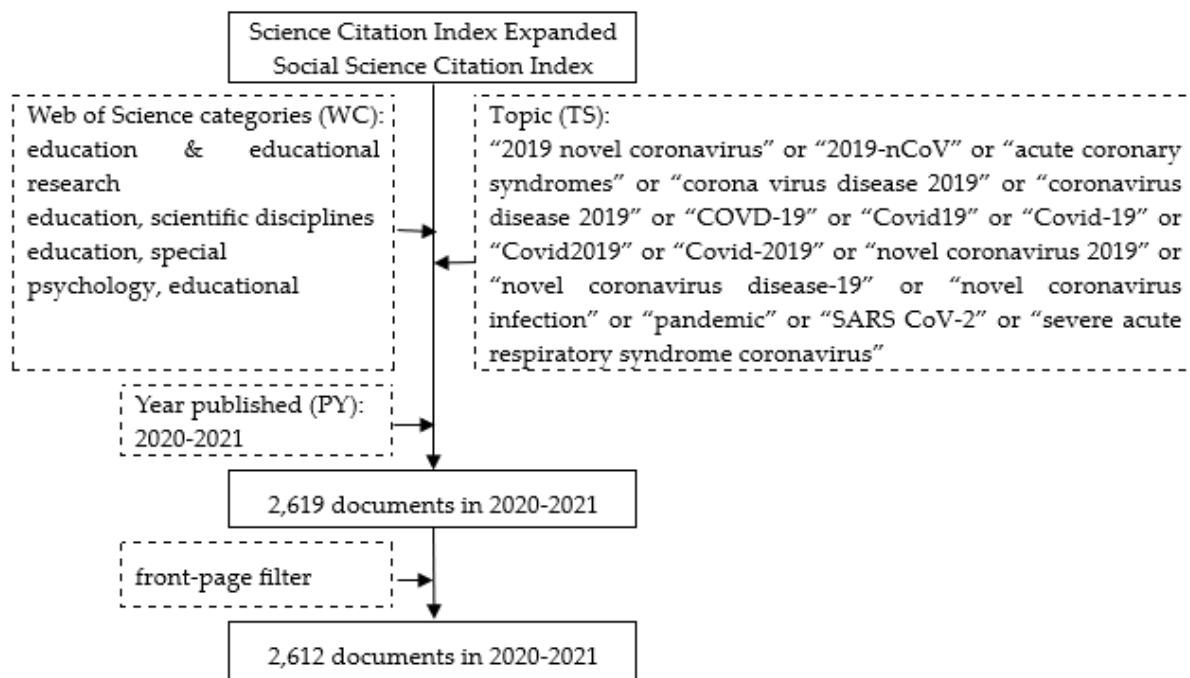

Figure 1. The process of searching for COVID-19 publications in education.

2.3. Data Analysis

Data from SSCI and SCI-EXPANDED were exported to Microsoft 365 Excel, along with the sum of citations for each publication. The Journal Citation Reports (updated 29 June 2022) was used to extract the impact factors for the journals (IF_{2021}). The authors'

affiliations to Wales, Northern Ireland, Scotland, and England were considered as belonging to the United Kingdom (UK). In order to obtain more accurate analysis results, some changes were made, for example Accreditat Council Pharm Educ ACPE was changed into Accreditat Council Pharm Educ; Univ Minnesota Twin Cities, USA was changed into Univ Minnesota, USA; Texas Med Ctr, USA was changed into Univ Texas Hlth Sci Ctr Houston, USA; UNSW Sydney, Australia was changed into Univ New South Wales, Australia; and VA Northeast Ohio Healthcare Syst, USA was changed into Vet Affairs Northeast Ohio Healthcare Syst, USA. Furthermore, publications with corresponding author information in the SSCI and the SCI-EXPANDED that only included addresses without affiliation information were examined, and entries for affiliations were derived from the addresses, for example: 1 Oxford St, B06-40, Cambridge, USA was changed into Harvard Univ, USA; 1 Regina Lane, Glen Head, USA was changed into Columbia Univ, USA; 100 Michigan St, MC 013, Grand Rapids, USA was changed into Michigan State Univ, USA; 1000 S Fremont Ave, Unit 22, Alhambra, USA was changed into Univ Southern Calif, USA; 11715 Autumn Glade Lane, Knoxville, USA was changed into Univ Oregon, USA; Dept Pediat, 4401 Penn Ave, Room 3127 Fac Pavil, Pittsburgh, USA was changed into Univ Pittsburgh, USA; 2150 Pennsylvania Ave, NW, Washington, USA was changed into George Washington Univ, USA; St Andrews Bldg, 11 Eldon St, Glasgow G3 6NH, Lanark, the UK was changed into Univ Glasgow, the UK.

The amount of publications from various countries and organizations was assessed using more indicators such as TP: number of publications overall; IP: one country's output of articles (IP_C) or one-institution articles (IP_I); CP: total number of international co-authored publications (CP_C) or produced through institutional collaboration (CP_I); FP: number of first-author articles overall; RP: corresponding-author articles in total; SP: articles with a single author [18]. To evaluate articles, we used the citation metrics: TC_{year}: the sum of all WoSCC citations from the publication year up until the end of 2021 (TC_{2021}) [19]; CPP_{year}: amount of citations per paper on average ($CPP_{2021} = TC_{2021}/TP$) [20].

Additionally, some citation metrics were used to assess the countries' and organizations' publication results [21]: $TP\text{-}CPP_{2021}$: number of citations of total articles ($TP\text{-}TC_{2021}$) per number of articles overall (TP); $IP\text{-}CPP_{2021}$: number of citations for works from a particular country ($IP_C\text{-}TC_{2021}$) per all articles from a single country (IP_C) or citations to articles from a single institution ($IP\text{-}TC_{2021}$) per all publications from a single institution (IP_I); $CP\text{-}CPP_{2021}$: citations of articles realized by international participation ($CP_C\text{-}TC_{2021}$) per total amount of articles produced through international collaboration (CP_C) or articles produced through institutional collaboration ($CP_I\text{-}TC_{2021}$) per the sum of papers created through institutional participation (CP_I); $FP\text{-}CPP_{2021}$: total number of first-author articles that have been cited ($FP\text{-}TC_{2021}$) per total number of articles by first authors (FP); $RP\text{-}CPP_{2021}$: the citations of corresponding-author articles ($RP\text{-}TC_{2021}$) per number of corresponding-author articles (RP); $SP\text{-}CPP_{2021}$: total number of citations for publications with a single author ($SP\text{-}TC_{2021}$) per total number of publications with a single author (SP).

To examine the conceptual framework of educational research related to COVID-19, we focused on the most frequently used keywords of the documents. Since VOSviewer is a software designed for scientific mapping examination [22], we used it to generate keyword networks using co-occurrence relationships [23]. The minimum co-occurring keyword count was established at ten. The outputs of the co-occurrence analysis of high-frequency author keywords revealed a network of related themes displayed in colorful clusters. Based on this, we identified the prominent themes within COVID-19-related research in education.

3. Results

3.1. Features of Document Types

A total of 2612 COVID-19 papers in the four categories pertaining to education were discovered among the 13 document types listed in Table 1. Of these documents, 740 (28% of the total) were published in 2020, and 1872 (72%) in 2021. In recent years, the average number of citations per publication (CPP_{year}) and the average number of authors per

publication (APP) were used to determine the features of a document type in a field of study [24].

Table 1. Citations and authors according to the document type.

Document Type	TP	%	TP*	AU	APP	TC_{2021}	CPP_{2021}
Article	2002	77	2000	7755	3.9	9719	4.9
Editorial Material	281	11	280	801	2.9	1939	6.9
Letter	139	5.3	139	366	2.6	374	2.7
Meeting Abstract	85	3.3	85	363	4.3	0	0
Review	74	2.8	74	317	4.3	349	4.7
Correction	13	0.50	13	68	5.2	2	0.15
News Item	13	0.50	13	58	4.5	5	0.38
Proceedings Paper	4	0.15	4	26	6.5	2	0.50
Book Review	3	0.11	3	4	1.3	0	0
Book Chapter	2	0.077	2	10	5.0	0	0
Item Withdrawal	1	0.038	1	3	3.0	0	0
Software Review	1	0.038	1	1	1.0	0	0
Withdrawn Publication	1	0.038	1	3	3.0	6	6.0

TP: number of publications; TP*: number of publications with author information; AU: number of authors; APP: average number of authors per publication; TC_{2021}: the total number of citations from Web of Science Core Collection since publication year to the end of 2021; CPP_{2021}: average number of citations per publication (TC_{2021}/TP).

Of the 2612 publications, 2002 are articles (77% of all publications) and have an APP of 3.9 and a CPP_{2021} of 4.9. Reviews were found to have a CPP_{2021} of 4.7. In total, 281 editorial papers were published in 80 journals. Most of these were identified in Academic Medicine with an IF_{2021} of 7.840 (56 editorial materials; 20% of 281 editorial materials; APP of 4.4; CPP_{2021} of 7.3), Medical Education with IF_{2021} of 7647 (29; 10%; APP of 3.2; CPP_{2021} of 12), and Phi Delta Kappan with IF_{2021} of 0.980 (22; 7.8%; APP of 1.1; CPP_{2021} of 0.68). In total, 139 letters were published in 15 journals, mostly in Academic Medicine (84 letters; 60% of 139 letters; APP of 2.6; CPP_{2021} of 1.4), and Anatomical Sciences Education with IF_{2021} of 6.652 (12; 8.6%; APP of 2.0; CPP_{2021} of 15). The editorial materials (281) reached the highest CPP_{2021} score, which was 6.9. Only two highly cited editorials with a TC_{2021} of 100 or more were published by Williamson et al. [25] in Learning, Media and Technology with a TC_{2021} of 142 and Ripp et al. [26] in Academic Medicine with TC_{2021} of 106. Williamson et al. [25] examined the role of politics in shaping the response to the pandemic and the use of technology in education. They highlighted the need for critical reflection on its use in the field. Ripp et al. [26] presented how a crisis assistance task group made up of Mount Sinai Health System staff, faculty, and interns used a rapid needs evaluation approach to identify workforce issues regarding the COVID-19 pandemic. Given that WoSCC allows for the classification of documents into two different document types, cumulative percentages exceed 100% in Table 1. For example, four proceedings papers, two book chapters, and one withdrawn publication were also classified as articles.

Contributions of document types are different. Generally, only articles contain an introduction, methods, results, discussion, and conclusion. Articles were chosen for further analyses. In the four categories connected to education, 2002 COVID-19 articles were identified in six different languages. The most-used language was English with 1953 articles (98% of 2002 articles). Other languages that were less used were Spanish (16 articles), German (15), Russian (9), Portuguese (6), and Italian (3). English-language articles had a CPP_{2021} of 4.9 and an APP of 3.9, whereas those published in languages besides English had fewer citations, with a CPP_{2021} of 2.4 and APP of 2.8.

3.2. Web of Science Categories and Journals

Articles on COVID-19 were published in 212 journals in the four categories related to education. The category of "education and educational research" includes 267 journals with 1142 articles (57% of 2002 articles), followed by "scientific disciplines education"

(45 journals) with 814 articles (41%), educational psychology (61 journals) with 127 articles (6.3%), and "special education" (44 journals) with 82 articles (4.1%). The greatest CPP_{2021} was 6.1 for articles published in the field of special education, whereas the lowest CPP_{2021} was 2.7 for those in the "educational psychology" category. Among articles in the scientific discipline education, the maximum APP of 4.8 was discovered. In the two WoS indexes, journals can be assigned to multiple categories. For example, BMC Medical Education was assigned to the categories of "education and educational research" and "education, scientific disciplines". As a result, the total proportion of categories exceeds 100%. The top twelve most prolific journals with 31 or more papers are presented in Table 2.

Table 2. The top 12 most productive journals with 31 articles or more.

Journal	TP (%)	IF_{2021}	APP	CPP_{2021}
Journal of Chemical Education	234 (12)	3.208	3.5	5.0
BMC Medical Education	114 (5.7)	3.263	7.4	5.9
Education and Information Technologies	70 (3.5)	3.666	2.9	5.6
Biochemistry and Molecular Biology Education	57 (2.8)	1.369	3.0	2.0
Journal of Surgical Education	52 (2.6)	3.524	6.1	14
Academic Medicine	47 (2.3)	7.840	5.8	7.8
ETR&D-Educational Technology Research and Development	42 (2.1)	5.580	1.9	4.6
Medical Education Online	42 (2.1)	6.000	5.3	5.1
Nurse Education Today	32 (1.6)	3.906	5.5	7.8
Aera Open	31 (1.5)	3.427	3.9	1.1
Irish Educational Studies	31 (1.5)	1.576	2.9	0.84
Phi Delta Kappan	31 (1.5)	0.980	2.1	0.84

TP: total number of articles; %: percentage of articles in all COVID-19 articles; IF_{2021}: journal impact factor in 2021; APP: average number of authors per article; CPP_{2021}: average number of citations per publication (TC_{2021}/TP).

The greatest number of papers (234, 12% of all articles) were identified in the Journal of Chemical Education (IF_{2021} = 3.208). COVID-19 publications in the Journal of Surgical Education (IF_{2021} = 3.524) had the highest CPP_{2021} (14), while articles in the Irish Educational Studies (IF_{2021} = 1.576) and Phi Delta Kappan (IF_{2021} = 0.980) had only 0.84, respectively. The APP ranged from 1.9 in ETR&D-Educational Technology Research and Development to 7.4 in the BMC Medical Education. Among the most prolific journals presented in Table 2, the journal with the highest IF_{2021} of 7.840 was Academic Medicine with 47 articles followed by Medical Education Online with IF_{2021} of 6 (42 articles). The journal with the highest IF_{2021} of 11,182 was Computers & Education with four articles.

3.3. The Publication Performance at Level of Countries and Institutions

Eight COVID-19 articles (0.40% of 2002 articles) without affiliations were found in the SSCI and the SCI-EXPANDED. There were 1994 COVID-19 published works by contributors affiliated with 113 countries with a TP-CPP_{2021} of 4.9. Of these, 1659 articles (83%) came from a single country and were written by researchers from 83 countries with an IP_C-CPP_{2021} of 4.7. The other 335 articles (17%) were authored by researchers from 103 different countries in international collaboration with a CP_C-CPP_{2021} of 5.6. This situation demonstrates that internationally collaborative articles raised citations. The top 21 countries with at least 21 publications each and more publication and citation indicators [21] are included in Table 3.

Table 3. Top 21 productive countries with 21 articles or more.

Country	TP	TP		IP$_C$		CP$_C$		FP		RP		SP	
		R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP
USA	855	1 (43)	4.6	1 (44)	4.5	1 (37)	4.9	1 (40)	4.6	1 (40)	4.5	1 (44)	3.9
UK	204	2 (10)	6.9	2 (7.2)	6.8	2 (25)	7.0	2 (7.8)	7.4	2 (7.7)	7.7	2 (8.9)	5.1
China	133	3 (6.7)	4.5	3 (4.8)	4.8	4 (16)	4.0	3 (5.6)	4.7	3 (5.7)	4.5	4 (4.6)	10
Australia	124	4 (6.2)	5.5	4 (3.9)	4.6	3 (18)	6.5	4 (4.5)	5.9	4 (4.4)	5.6	3 (6.5)	4.2
Canada	102	5 (5.1)	5.4	5 (3.6)	4.8	5 (13)	6.1	5 (3.5)	5.6	5 (3.5)	5.8	5 (2.4)	2.2
Spain	80	6 (4.0)	5.5	6 (3.3)	5.0	6 (7.8)	6.5	5 (3.5)	4.3	6 (3.4)	4.4	8 (1.9)	4.0
Germany	58	7 (2.9)	5.7	7 (2.4)	6.9	8 (5.7)	3.3	7 (2.3)	6.5	7 (2.4)	6.4	13 (1.1)	2.0
Italy	55	8 (2.8)	3.9	8 (2.0)	4.4	7 (6.3)	2.9	8 (2.1)	3.7	9 (2.1)	3.7	11 (1.6)	3.8
India	50	9 (2.5)	3.4	11 (2.0)	2.3	10 (5.1)	5.5	9 (2.0)	3.1	10 (2.0)	3.3	19 (0.81)	0.33
Ireland	49	10 (2.5)	4.4	8 (2.0)	1.6	12 (4.5)	11	9 (2.0)	1.9	8 (2.1)	1.9	8 (1.9)	0.71
Brazil	43	11 (2.2)	2.4	8 (2.0)	2.6	22 (2.7)	1.7	11 (2.0)	2.4	11 (2.0)	2.5	13 (1.1)	4.5
Turkey	35	12 (1.8)	2.9	12 (1.7)	2.5	29 (2.1)	4.3	12 (1.5)	2.4	12 (1.5)	2.5	6 (2.2)	4.8
Netherlands	31	13 (1.6)	6.0	18 (0.72)	8.1	8 (5.7)	4.7	14 (1.2)	7.3	14 (1.2)	7.6	19 (0.81)	4.0
Saudi Arabia	30	14 (1.5)	11	13 (1.0)	10	13 (4.2)	12	13 (1.3)	12	14 (1.2)	13	6 (2.2)	8.8
Republic of Korea	29	15 (1.5)	3.0	17 (0.78)	2.8	11 (4.8)	3.3	15 (1.0)	2.3	13 (1.3)	2.0	13 (1.1)	6.3
South Africa	27	16 (1.4)	1.5	13 (1.0)	1.4	16 (3.3)	1.7	16 (0.90)	1.2	16 (1.1)	1.5	8 (1.9)	1.9
Sweden	23	17 (1.2)	3.7	26 (0.54)	1.0	13 (4.2)	5.4	27 (0.55)	4.5	22 (0.70)	3.9	19 (0.81)	0.33
New Zealand	22	18 (1.1)	10	21 (0.60)	3.4	15 (3.6)	15	23 (0.60)	3.8	23 (0.65)	3.7	13 (1.1)	3.5
Austria	21	19 (1.1)	7.9	21 (0.60)	1.8	16 (3.3)	13	17 (0.85)	2.4	17 (0.85)	3.5	19 (0.81)	0
Singapore	21	19 (1.1)	12	15 (0.90)	13	30 (1.8)	7.8	17 (0.85)	13	17 (0.85)	13	23 (0.54)	4.5

TP: number of total articles; TP R (%): total number of articles and the percentage of total articles; IP$_C$ R (%): rank and percentage of single-country articles in all single-country articles; CP$_C$ R (%): rank and percentage of internationally collaborative articles in all internationally collaborative articles; FP R (%): rank and the percentage of first-author articles in all first-author articles; RP R (%): rank and the percentage of corresponding-author articles in all corresponding-author articles; SP R (%): rank and the percentage of first-author articles in all first-author articles; CPP: average number of citations per publication (TC$_{2021}$/TP).

With 855 articles, the USA led the six-publication metrics (43% of 1994 articles), an IP$_C$ of 731 articles (44% of 1659 articles of a single country), a CP$_C$ of 124 articles (37% of 335 works produced by international cooperation), an FP of 789 articles (40% of 1994 first-author articles), an RP of 790 articles (40% of 1994 corresponding-author articles), and an SP of 165 articles (44% of 372 single-author articles). Singapore published 21 articles that had the highest TP-CPP$_{2021}$, IP$_C$-CPP$_{2021}$, FP-CPP$_{2021}$, and RP-CPP$_{2021}$ with 12, 13, -13, and 13 respectively. New Zealand published a total of 22 articles (TP), including 12 internationally collaborative articles (CP$_C$) with a total number of citations (CP$_C$-TC$_{2021}$) of 176 and an average number of citations per article (CP$_C$-CPP$_{2021}$) of 15 (CP$_C$-CPP$_{2021}$ = CP$_C$-TC$_{2021}$/CP$_C$) (15 = 176/12). China with 133 articles, including an SP of 17, an SP-TC$_{2021}$ of 166, and an SP-CPP$_{2021}$ of 10 (10 = 166/17), ranked 1st.

Concerning institutions, of the 1994 COVID-19 papers, 1044 (52%) were from a single institution and had an IP$_I$-CPP$_{2021}$ of 4.8, while 950 (48%) were the result of institutional collaborations and had a CP$_I$-CPP$_{2021}$ of 5.0. The top 11 institutions with at least 17 papers each are displayed in Table 4 as being the most productive, along with information about their publication and citation patterns.

Table 4. Top 11 productive institutions with 17 articles or more.

Institution	TP	TP		IP$_I$		CP$_I$		FP		RP		SP	
		R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP
Harvard MedSch, USA	21	1 (1.1)	9.4	41 (0.29)	30	1 (1.9)	5.9	27 (0.30)	16	14 (0.40)	12	54 (0.27)	0
Columbia Univ, USA	20	2 (1.0)	4.0	1 (1.1)	3.4	22 (0.84)	4.8	3 (0.65)	3.2	2 (0.65)	3.2	2 (1.1)	1.8
Monash Univ, Australia	20	2 (1.0)	12	8 (0.57)	14	5 (1.5)	11	1 (0.70)	7.0	1 (0.70)	7.0	N/A	N/A
Stanford Univ, USA	20	2 (1.0)	3.6	78 (0.19)	12	1 (1.9)	2.6	14 (0.40)	5.5	14 (0.40)	3.6	N/A	N/A
Univ Toronto, Canada	20	2 (1.0)	3.6	6 (0.67)	2.0	6 (1.4)	4.5	9 (0.50)	3.1	11 (0.45)	1.7	N/A	N/A
Univ Colorado, USA	19	6 (1.0)	1.6	24 (0.38)	0.50	4 (1.6)	1.9	20 (0.35)	1.7	11 (0.45)	1.7	15 (0.54)	0
Univ N Carolina, USA	19	6 (1.0)	5.6	184 (0.10)	1.0	1 (1.9)	5.8	14 (0.40)	7.3	20 (0.35)	5.6	N/A	N/A

Table 4. *Cont.*

Institution	TP	TP		IP$_I$		CP$_I$		FP		RP		SP	
		R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP	R (%)	CPP
Univ Melbourne, Australia	18	8 (0.90)	8.3	14 (0.48)	2.0	6 (1.4)	11	14 (0.40)	2.9	14 (0.40)	2.9	1 (1.3)	2.6
Michigan State Univ, USA	17	9 (0.85)	4.3	3 (0.77)	6.0	15 (0.95)	2.8	1 (0.70)	5.1	2 (0.65)	5.3	54 (0.27)	0
Univ Calif Irvine, USA	17	9 (0.85)	5.2	14 (0.48)	10	9 (1.3)	3.3	9 (0.50)	5.8	6 (0.55)	5.3	15 (0.54)	1.5
Univ Michigan, USA	17	9 (0.85)	2.1	2 (1.1)	2.3	49 (0.63)	1.8	3 (0.65)	2.2	4 (0.60)	2.3	15 (0.54)	0

TP: total number of articles; TP R (%): total number of articles and percentage of total articles; IP$_I$ R (%): rank and percentage of single-institution articles in all single-institution articles; CP$_I$ R (%): rank and percentage of inter-institutionally collaborative articles in all inter-institutionally collaborative articles; FP R (%): rank and percentage of first-author articles in all first-author articles; RP R (%): rank and percentage of corresponding-author articles in all corresponding-author articles; SP R (%): rank and percentage of single-author articles in all single-author articles; CPP: average number of citations per publication (TC$_{2021}$/TP).

Harvard Medical School in the USA leads the ranking with the greatest TP of 21 articles (1.1% of 1994 articles) and the CP$_I$ of 18 articles (1.9% of 950 articles produced through institutional collaboration). Both Stanford University and the University of North Carolina in the USA also had a CP$_I$ of 18 articles. Monash University in Australia ranked the top with an FP of 14 articles (0.70% of 1994 first-authored articles), and an RP of 14 articles (0.70% of 1994 corresponding-author articles). Michigan State University in the USA also had an FP of 14 articles. Columbia University in the USA ranked top with an IP$_I$ of 12 articles (1.1% of papers from a single institution). In addition, the University of Melbourne in Australia with 18 articles had an SP of five articles (1.3% of 372 articles with a single author). Monash University in Australia had the greatest TP-CPP$_{2021}$ of 12 and a CP$_I$-CPP$_{2021}$ of 11. Harvard Medical School in the USA had the highest IP$_I$-CPP$_{2021}$, FP-CPP$_{2021}$, and RP-CPP$_{2021}$ with 30, 16, and 12 respectively. For articles the APP was 3.9 whereas the most authors in a single article were 35. Of the 2000 articles with author information, 377 (19% of 2000 articles), 374 (19%), 373 (19%), 271 (14%), and 201 (10%) articles were written by one, two, three, four, and five authors, respectively. There were 7219 authors who contributed to this scientific output.

It is worth mentioning the efforts of some prolific researchers who published several articles over these two years (2020–2021) and pursued specific lines of investigation. For instance, the experiences of workers supporting intellectually disabled people or their families in a pandemic context was a common topic of interest for researchers such as Lunsky, Y. (Canada) and Embregts, P.J.C.M. (Netherlands). Each of the two researchers together with their collaborators addressed the subject in several works [27–30]. Through joint efforts, other researchers focused on the experiences and challenges at the academic level in response to the pandemic [31,32]. School teachers' experience during the COVID-19 outbreak was also a topic of interest among several researchers [33,34]. As the single or first author of four articles, Pressley, T. (USA) also demonstrated an interest in the pandemic's consequences on teachers' burnout, stress, self-efficacy, or anxiety [35–38]. Collaborating with other scientists, Centeio, E. (USA) addressed various aspects of physical education in schools during the COVID-19 outbreak [39–41]. We can appreciate that in the unprecedented context generated by COVID-19, researchers have developed a wide range of research interests.

3.4. The Most Frequently Cited Articles

The articles with the most citations at the end of 2021 (TC2021) are displayed in Table 5. For each of the ten most cited articles, the Category Normalized Citation Impact (CNCI) was calculated, considering TC2021 and the expected number of citations (as indicated by InCites, Clarivate Analytics). For journal articles assigned to different or multiple categories, the expected citation rates for each individual category were used. Based on the CNCI, the influence of a scholarly article in a specific field of study can be evaluated. The ten

articles have CNCI scores between 22.12 and 58.62. Since values that exceed 1 are regarded as above average, the high scores obtained indicate that these documents are highly cited compared to others in the same field and year of publication. Most of these articles were published in 2020 by authors from eight countries. Four of the ten papers with the most citations came from the USA. The ranking also includes works whose authors come from other countries such as the UK (three articles), Saudi Arabia (two articles), and Germany, Jordan, Australia, New Zealand, and Ireland (each with an article). In what follows, we summarize the ten most frequently cited articles indicated by WoSCC.

Table 5. Top 10 most frequently cited articles.

Title	Journal	Rank (TC2021)	CNCI
Using Technology to Maintain the Education of Residents During the COVID-19 Pandemic	Journal of Surgical Education	1 (282)	58.62
Adapting to online teaching during COVID-19 school closure: teacher education and teacher competence effects among early career teachers in Germany	European Journal of Teacher Education	2 (146)	40.00
Exploring the critical challenges and factors influencing the E-learning system usage during COVID-19 pandemic	Education and Information Technologies	3 (133)	36.44
COVID-19 and digital disruption in UK universities: afflictions and affordances of emergency online migration	Higher Education	4 (124)	33.97
Forced Disruption of Anatomy Education in Australia and New Zealand: An Acute Response to the COVID-19 Pandemic	Anatomical Sciences Education	5 (119)	26.33
Projecting the Potential Impact of COVID-19 School Closures on Academic Achievement	Educational Researcher	6 (110)	30.14
Shift to digital perspectives on Hilton (2016) from the perspective of practice	ETR&D Educational Technology Research and Development	7 (107)	29.31
The impact of the COVID-19 pandemic on final year medical students in the United Kingdom: a national survey	BMC Medical Education	8 (101)	25.00
Strength, Weakness, Opportunity, Threat (SWOT) Analysis of the Adaptations to Anatomical Education in the United Kingdom and Republic of Ireland in Response to the COVID-19 Pandemic	Anatomical Sciences Education	9 (100)	22.12
The sudden transition to synchronized online learning during the COVID-19 pandemic in Saudi Arabia: a qualitative study exploring medical students' perspectives	BMC Medical Education	10 (90)	22.28

TC$_{2021}$: the total number of citations from Web of Science Core Collection since publication year to the end of 2021; CNCI: Category Normalized Citation Impact.

Ranking first, we found an article published by seven American authors who suggested several innovative solutions based on technology that surgical educators can use to maintain rigorous training for surgical residents throughout the pandemic [42]. Among the solutions proposed by the authors, we can identify the flipped classroom, online practice exercises, teleconferencing, telemedicine clinics, procedural simulations, and facilitated access to surgical videos. The next most cited article is the result of the collaboration among three authors from the University of Cologne (Germany). Based on research undertaken in the first months after the total or partial closure of schools in a German state, the paper reports on the way early career teachers faced the challenges of teaching in the new context [43]. The authors emphasize the need for initial and continuous teacher education to provide opportunities for the improvement of teachers' digital abilities. In their article ranking third, Almaiah et al. [44] state that problems with change management, technical assistance, and financial support affected the adoption of online education at six academic institutions in Jordan and Saudi Arabia during the pandemic. The viewpoints of academics working in UK institutions on the shift to online instruction are revealed in the article written by Watermeyer, Crick, et al. [31]. The authors revealed profound professional and personal disruption in the education workforce during the pandemic. Online migration was seen negatively by most participants, with only a minority showing a more positive tone.

In the fifth-place work, more authors discuss the changes and disturbances in teaching anatomy in Australian and New Zealand universities at the beginning of the pandemic, as well as the opportunities brought about by the new context [45]. In another article of interest in the field, six authors express concern about the possible harm that school closures could have on students' performance, such as lower reading and mathematics learning gains, relative to pre-pandemic years [46]. The authors consider long-term recovery efforts in education are needed.

Ranking seventh, we found the work of Hodges [47], an American author who emphasizes the practical implications of Hilton's work in the pandemic era when open educational resources can inspire the efforts of instructors to redesign courses. However, based on the visualization in a full-text format of many works indicated by the WoSCC as citing the previously mentioned Hodges' paper, we have reasons to believe that the cited work is another one, with the same Hodges as the first author [48]. This paper was published in March 2020 by a group of five authors and is not indexed in the Web of Science. In this seminal paper, the authors bring to the attention of researchers and professionals a clear conceptual distinction between online learning experiences planned with time and care to be delivered in distance mode and those courses migrated online due to pressing circumstances (such as the pandemic). For the latter, the authors recommended using the term "emergency remote teaching", which is seen as a temporary response to a crisis, and which is different from high-quality online education [48]. It is worth mentioning that this work reached a record level of citations in a very short time (more than 6000 citations on Google Scholar, February 2023). We anticipate the citation indicators for Hodges' paper [47] to be changed in WoSCC, as soon as this indexing issue is resolved.

The study carried out by Choi et al. [49] offers helpful insights regarding the consequences of the pandemic on medical students' education in the UK. Within the difficult context generated by the pandemic, the authors recommended different approaches to medical education and assessment. Then, Longhurst et al. [50] examine the strategies used by higher education institutions in the UK and the Republic of Ireland to provide anatomical instruction online. Finally, in another collaborative work from Saudi Arabia, Khalil et al. [2] present the undergraduate medical students' views on synchronized online learning in one university. The authors found that, despite the fact that the medical students had a positive experience with synchronized online learning, they also encountered challenges generated by technical issues, poor internet access, or teachers' inability to communicate verbally. However, online synchronized learning was viewed as a good promise in medical education.

Remarkably, seven of the ten articles with the most citations present investigations from higher education and half of them addressed aspects of medical or anatomical education, the latter being published in journals like Anatomical Sciences Educations (two articles), or BMC Medical Education (two articles), or Journal of Surgical Education (one article).

3.5. Research Focuses

Examining the keywords within research publications can be beneficial in recognizing the themes being studied within a field or linked to a specific line of research [12,51,52]. To reveal the major themes addressed in COVID-19 publications, a co-occurrence analysis was conducted on authors' keywords for publications within the dataset. A keyword co-occurrence analysis determines how often two keywords appear together in the title, abstract, or list of keywords of publications included in the database. A thesaurus file was employed to unify related keywords, such as "COVID-19", "COVID-19 pandemic", and "pandemic", "school" and "schools", "wellbeing" and "well-being". Under the term "chemistry", we merged different types of chemistry disciplines founded as keywords such as "analytical chemistry", "organic chemistry", "inorganic chemistry", "biochemistry chemistry", or "physical chemistry". Of the 4274 author keywords, only those with at least 10 occurrences were included in the analysis, more precisely 72. We used VOSviewer

software tool to visualize the relationships between these keywords extracted from the documents selected. In the map resulted (Figure 2), each keyword or term is represented as a node, and the strength of the relationship between them is represented by the thickness of the connecting lines. The strength of a link indicates the number publications in which two terms occur together. Keywords were grouped into clusters, distinguished by node color, that frequently co-occurred. These clusters indicate the main focuses of research pertaining to COVID-19 in the field of education.
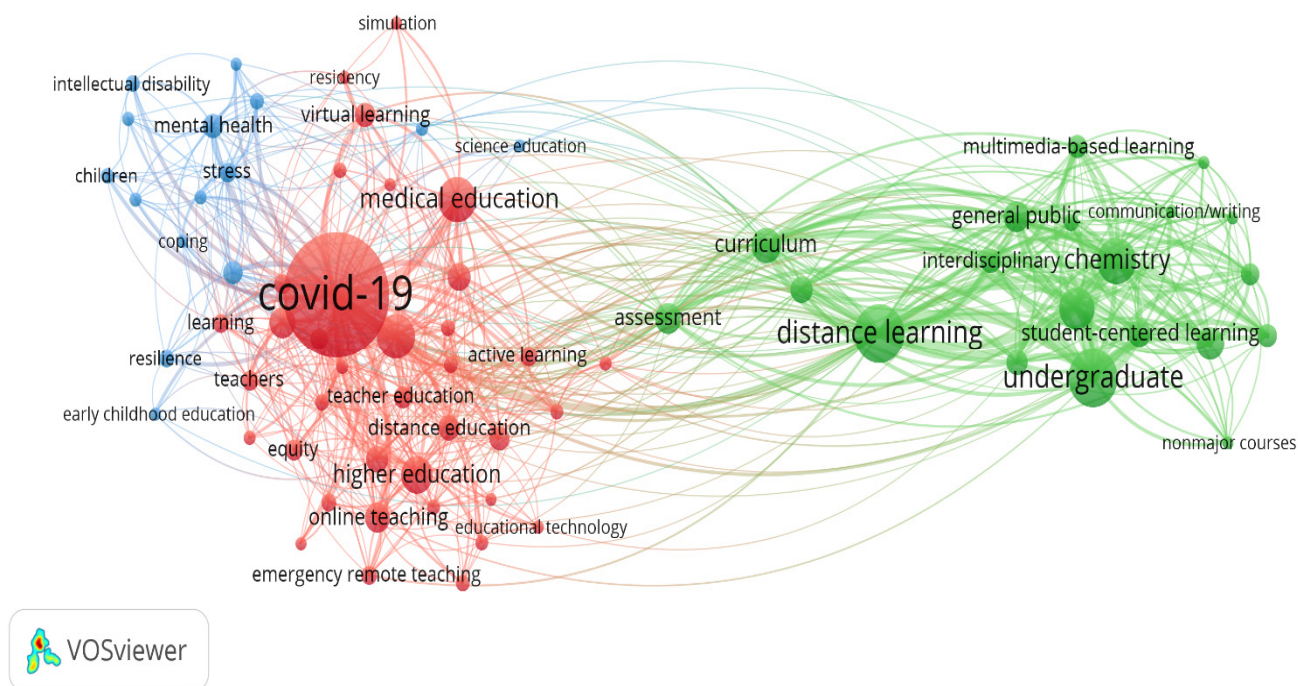
Figure 2. Author keywords co-occurrence of COVID-19-related research in the field of education.

The keyword with the highest frequency was clearly "COVID-19" (900 occurrences/895 total link strength). Apart from this, which was the keyword searched for, other frequent keywords were: "distance learning" (205 occurrences/614 total link strength), "undergraduate" (193/628), "chemistry" (125/433), "medical education" (119/188), "online education" (116/179), "computer-based education" (103/377), "higher education" (83/120), etc. Three major keyword clusters emerged, containing keywords with high co-occurrence (Figure 2).

The largest of the clusters, with 37 high-frequency co-occurrence terms, is the red one. There are 20 and 15 co-occurring keywords in the blue and green cluster, respectively. Based on their analysis, we identified research themes addressed by authors in articles on COVID-19 in education.

The red cluster encompasses research on "online learning" in different educational settings. It is worth noting that "medical education", "higher education", and "teacher education" appear as well-defined areas of investigation. There have been investigations on actors in the field ("teachers" and "students"), and on the processes involved ("teaching" and "learning") with the support of "educational technology". The authors used various terms to indicate technology-enhanced learning approaches during the pandemic such as "online learning", "distance education", "online teaching", "virtual learning", or "emergency remote teaching".

The green cluster reflects research on curriculum and instructional approaches particularly in laboratory settings. "Computer based-learning", "inquiry-based learning", and "student-centered learning" in the context of "distance learning", especially for undergraduates have been intensively explored by researchers. As a subject matter, Chemistry seems to be more investigated. "Professional development" is another keyword within this cluster.

The blue cluster reveals concern about the pandemic's psychological consequences on different educational actors (children, persons with disabilities, teachers, students, families, etc.). This is suggested by the frequency of keywords such as: "mental health", "stress", "depression", and "anxiety". We also noted the interest in investigating COVID-19's implications on "early childhood education" and on individuals with special needs (especially with "autism" and "intellectual disabilities"). Some authors have invested research efforts in investigating ways to cope with the "stress" or to build/practice "resilience" in conditions of the educational disruptions generated by the pandemic.

4. Discussion

This study maps the scientific work on COVID-19 in education accumulated over two years (2020–2021) through bibliometric analysis of documents indexed in the SSCI and SCI-EXPANDED. This has allowed us to gain insights into the characteristics of educational research on this topic that suddenly appeared in the global research landscape.

As regards RQ1, the findings revealed that in the field of education, COVID-19 pandemic was first researched in 2020, and in 2021 this line of inquiry was further developed. The number of publications increased in 2021 by two and a half times compared to 2020. Considering this trend, we conclude that the subject of COVID-19 in education has drawn growing interest from field researchers. In addition to the growing attention to the subject matter and the mobilization of scientists, "faster publication times" during the pandemic supported the rise in the number of articles, as well as their rapid citation in the literature [6]. Within scholarly publishing concerning the COVID-19 pandemic, articles written in English are dominant as document-type and accumulate the highest number of citations. However, it is worth noting that the editorial materials published especially in journals covering the area of medical education enjoy special attention.

The analyses carried out regarding the WoS categories and journals performance allow us to draw two important ideas: (1) most published articles are in the category of "education and educational research"; and (2) the journals covering the areas of chemical and medical education have provided a generous venue for sharing research work connected to COVID-19 in education. Similar findings were reported in the bibliometric analysis carried out by Corell-Almuzara et al. on a smaller sample of 940 publications [7]. In their study, Zhang et al. [10] also identified the Journal of Chemical Education, BMC Medical Education, and Education and Information Technologies among the journals with significant number of publications on higher education during the COVID-19 period. Notably, the scientific articles published in medical and health education journals such as the Journal of Surgical Education, Academic Medicine, Nurse Education Today, and BMC Medical Education have received substantial attention if we refer to citation (CPP_{2021}). Education and Information Technologies is the first journal in citations not specifically focusing on medical or health education. This reflects the two areas of research interest during the pandemic period: medical education and the implementation of information technologies in condition of emergency remote teaching.

Concerning RQ2, our results show that researchers in over 100 countries addressed problems associated with COVID-19 in education. While there were fewer international collaborations than national ones, the articles resulting from the former tended to receive more citations. Even if COVID-19 is a global problem with implications in education all over the world, most publications come from several advanced countries. The USA leads by far the list of countries that produce the most scholarly articles. The effort of the researchers' communities in the UK, China, Australia, Canada, and Spain in addressing the pandemic crisis in education is also important to note. The most prolific countries have proven to be the most open to international collaborations. China was also found as the top contributor to early childhood education research among Asian countries in the bibliometric analysis carried out by Su et al. [8]. Considering citations per publications (CPP_{2021}), the articles written by authors from Singapore, New Zealand, Austria, the UK, and Australia were the most frequently cited.

US universities are dominant in the top ten most prolific institutions, with 15 articles or more. Two universities, one from Canada and Australia, respectively, are also present. The emphasis placed on the research activity in these institutions, the access to resources, the highly skilled researchers, and their better mobilization in times of crisis are factors that may explain this situation. Different scientists believe that the role of universities in controlling the pandemic by providing research avenues for researchers' collaboration is essential [10,53]. This ranking will certainly be quite dynamic since we can expect that research on COVID-19 will continue in the field in 2022 and perhaps even over the following years.

As regards the most cited articles, all of these were published in open access format, either in open access journals or in some with the option of open access publishing. This has increased their visibility worldwide and has improved the chances of being read and cited in other works. They are also the result of national or international collaboration between researchers. Most of the top ten referenced articles were released in 2020 or were made available in the early access version since 2020. In a very short time, they have accumulated an impressive number of citations, which led them to very high CNCI scores by reference to the field and year of publication. If we examine the WoSCC rankings for highly cited articles in education from 2020 (whether related to COVID-19 or not), we find that six out of the ten articles identified as highly cited in the present study, are among the top ten most cited articles in education, as of the time of our research (February 2023). This is out of over 50,000 articles indexed in 2020. Another essential point to consider is that most of the top ten articles cited presented findings of investigations carried out in higher education. This reflects the great interest and engagement of researchers at this level in investigating the difficulties and opportunities for online education emerging from the pandemic [10]. These highly cited articles continue to accumulate citations in the scientific literature. Furthermore, it is worth noting the high number of citations received by a review-type paper published in 2020 which examines the difficulties, opportunities, and crisis-driven migration tactics adopted by universities, faculty, and students in response to COVID-19 [53]. These demonstrate a major interest in COVID-19-related publications in the education scientific community. Therefore, it is evident that the COVID-19 pandemic has become a highly relevant topic in education starting with 2020 and it continues to retain the attention of researchers three years after its emergence.

As far as RQ3 is concerned, the results indicated that within the context generated by the pandemic, different research interests have been explored. The examination of terms' co-occurrence revealed interrelated thematic networks and provided interesting insights about COVID-19-related research in education in recent years (2020–2021). Three relevant lines of research topic have been addressed: (1) online learning in different educational settings; (2) curriculum and instructional approaches within the distance learning environment; and (3) COVID-19's psychological effects.

The first line of inquiry reflects the switch from in-person instruction to remote learning in various educational environments to limit infections. The sudden transition became possible through the adoption and integration of technology. We noted the use of different concepts such as "online learning", "distance learning", "online teaching", or "virtual learning", to describe a common global reality in a pandemic context that has been labeled as "emergency remote teaching" [48]. Other researchers also discovered the tendency for these terms to be used interchangeably in the scientific literature by different authors [6]. In this line of research, we can find studies that highlight the challenges, experiences, perceptions in different educational contexts under the conditions of emergency remote teaching with the help of technology.

Higher education research appears to have drawn more attention in terms of how students perceive the new learning contexts, challenges, or opportunities generated by the pandemic [44,53,54]. The pandemic was considered an impetus for digital transformation in academic institutions [55]. Consistent research has also been carried out throughout the pandemic in the medical education, contributing to the advancement of the field. Nu-

merous documents have been published by various journals in the field (BMC Medical Education, Journal of Surgical Education, Academic Medicine, Medical Education Online, Nurse Education Today, etc.). The increased interest in articles in this area reinforces the idea that COVID-19 has impacted medical education throughout the world, generating not only challenges and barriers but also opportunities [56,57]. Zhang et al. [10] also reported extensive medical education research during the pandemic. "Teacher education" proved to be another area of interest for researchers. Its knowledge base has expanded and incorporated evidence-based approaches mainly focusing on the emerging practices, challenges, and opportunities in initial or continuing teacher training during the coronavirus outbreak [1,43,58,59].

The second research theme incorporates studies focused on curriculum and instructional strategies in distance learning environment. This cluster seems to be built around chemistry teaching and learning. Zhang et al. [10] discovered a comparable cluster. The incorporation of computer or inquiry-based learning have been more frequently addressed in studies, especially in laboratory instruction. Exploring the learning experiences of undergraduate students from different corners of the world has been of interest for chemistry education researchers. This situation can also be explained by the initiative of the Journal for Chemical Education to call for pandemic papers for publication in a special issue [60]. The chemistry education community responded generously through the contribution of hundreds of authors who wrote manuscripts. The chemistry education community responded generously through the contributions of hundreds of authors who wrote manuscripts. As part of this cluster, the "professional development" keyword brings to our attention the needs and opportunities for teachers' professional growth and cooperation in reaction to the difficulties brought on by the pandemic [61,62].

The third line of inquiry provides insights into psychological problems such as stress, anxiety, depression, etc. faced by the actors in the field during the pandemic. In several studies conducted during the COVID-19 period, teachers were shown to be highly stressed [33,63–65]. In an already stressful profession, teachers had to deal with an unprecedented teaching situation in a very short time and in some cases with limited training in the application of technology to remote education [62]. The suggestion advanced by some authors [64], according to which coping with stress should become a professional competence integrated into all initial and continuing programs for teacher education, deserves careful consideration. University and school students experienced pandemic-related stress, too [66–68].

COVID-19 also unfavourably impacted parental stress, especially in families with children who require special education [69,70]. The researchers have emphasized the need for support programs to address psychological problems. For example, some researchers informed about the positive outcomes of a mental health literacy initiative for medical trainees implemented at the Finnish University of Turku [71]. The pandemic's psychological consequences were noticed not just in schools and higher education, but also in early education. Stress and mental health were relevant concepts for research on early childhood education [8].

The COVID-19 outbreak has given rise to several concerns related to sustainability. Recent research [72–76] draws attention to the consequences of the pandemic crisis on the achievement of the sustainable development goals (SDGs) in the context of the Sustainable Development Agenda launched by the United Nations [77]. Quality education (SDG 4) was identified among the goals most affected by the COVID-19 pandemic in a study carried out in 2020 in Italy [78]. The negative consequences brought by the COVID-19 pandemic on SDG 4 (youth out of school, weight gain in children, increased risk of juvenile delinquency), but also the positive ones such as innovative school food supply, distance education and health education were highlighted in another study [76]. In developing countries, however, it has been difficult to provide a quality education that is inclusive and equitable during the COVID-19 crisis. For example, many barriers to online learning and ICT integration were identified in a study conducted in Ghana [79]. Some authors suggest that to assess

the long-term sustainability impacts of the COVID-19 pandemic on the education system, two key factors should be considered: (1) access to an equitable education for vulnerable children and youth (2) the quality of distance learning, as well as its potential benefits and difficulties in the future [74]. It is undeniable that education is an essential component of the worldwide endeavor towards achieving the United Nations' SDGs [80,81] and plays a crucial role in the sustainable recovery from the impact of COVID-19 [72,82]. For it to succeed, education decision-makers, schools and universities, teachers, students, parents, and society must work together continuously and concertedly.

The findings of the present study are in line with those of other bibliometric investigations carried out in the field [6,7,10] where medical education, chemical education, online learning, psychological impacts of the pandemic on students were found among the most investigated topics. Similar trends were identified in the current research. Our study continues the efforts of other researchers concerned with the bibliometric examination of the scientific literature in education connected to COVID-19 and complements their contribution. The inclusion in the analysis of works from different areas and levels of education that have been published over two years during the pandemic leads us to believe that the present study distinguishes itself through a more comprehensive and more updated approach in the landscape of bibliometric studies focusing on the analysis of pandemic publications in education.

The study's contribution can be summarized as follows: (i) presenting performance and citation indicators for scientific production related to COVID-19 in education over two years (2020 and 2021), (ii) identifying research themes in pandemic-related publications in education through the use of keyword co-occurrence analysis, and (iii) suggesting research directions for those interested in furthering the analysis of COVID-19 in education.

However, this study has some limitations. First, our data involved research articles extracted from the SSCI and SCI-EXPANDED (WoSCC), but scientific literature on COVID-19 in education can be found in other citation indexes, too. Second, we focused on research articles, while other types of documents (conference proceedings, book chapters, etc.) were not included in the analysis. Third, the study analysed a sample of documents from WoSCC, while other databases like Scopus, Google Scholar, etc. also contain scholarly publications on COVID-19 in education. Fourthly, the research themes were determined by using author keywords rather than by reading the articles. Since in our study we utilized co-occurrence analysis of keywords to cluster research themes, we suggest that other clustering techniques such as co-authorship or co-citation, should be explored in future studies. These additional results can provide a complementary perspective to the findings of our current study. However, for a deeper and more detailed understanding of COVID-19 related research in education, bibliometric analysis can be complemented by qualitative investigations of relevant works.

The present bibliometric study can inspire future research in several directions. First, other bibliometric studies on the same subject may consider various types of documents from more databases to ensure better coverage of the COVID-19 knowledge base. These could extend the analysed interval, up to the limit generated by the long-awaited end of the pandemic and provide a global picture of the entire period marked by COVID-19. Second, the themes detected in research related to COVID-19 in education can be investigated through more detailed bibliometric analyses. For instance, other researchers may focus on analysing teacher education research in the context of COVID-19 or the psychological repercussions of COVID-19 on the actors in the field. Third, opportunities for original research could be identified in the development of bibliometric analyses of pandemic publications across education levels. As early childhood and higher education have been more visible in our study and have already been investigated in the specialized literature [8,10], future bibliometric investigations could be conducted at specific levels such as primary, secondary, or adult education. Moreover, examining pandemic publications from the lens of disciplines or knowledge areas presents another opportunity for researchers. For example, in our study, publications in medical and chemistry education were at the

forefront, but researchers from other fields or disciplines may have valuable insights as well. Future bibliometric analyses could explore these areas to uncover and showcase their contributions. Fourth, bibliometric approaches to pandemic publications could also be developed by focusing on educational actors, such as teachers, students, parents, principals, or government officials and their actions during the pandemic or in post-pandemic times. We see this as a possibility to make research more relevant to specific groups within the education system. Fifth, other research opportunities could be related to comparative studies on how education systems in developed and developing countries managed the pandemic period. This could be in terms of policies, practices, obstacles, opportunities, etc.

There are several challenges in addressing future research on COVID-19 in education. While there has been a significant amount of research on COVID-19 in education, there are still gaps in the data, especially in developing countries. As a result, researchers may face challenges accessing and analyzing relevant data. Bibliometric analysis is dependent on the accessibility of data. There may be certain publications that are not indexed in the databases used for bibliometric analysis, leading to restricted coverage of the research landscape. Then, educational systems vary widely between countries and regions, and researchers may need to consider these differences when conducting cross-country or cross-cultural studies. Many studies on COVID-19 in education have been conducted over a relatively short period, and there is a need for longitudinal studies for a more profound understanding of the long-term impacts of the pandemic on education.

5. Conclusions

The COVID-19 pandemic has disturbed educational systems and its actors' activity at all levels worldwide. Confronted with major challenges, education had to continue its course. Considerable effort has been put into adapting educational institutions to emergency remote teaching. This reality inspired and fueled a distinct COVID-19-related area of inquiry in education. The present study maps the COVID-19 research in education based on documents published in 2020 and 2021 and indexed in the WoSCC database (SSCI and SCI-EXPANDED). The findings show a growing interest of researchers in education for this topic since the COVID-19-related research has experienced an increase of 2.5 times in output in 2021, compared to 2020. The proportion of articles among the types of documents proved to be dominant. Journals dedicated to chemistry and medical education stood out for the high number of papers published during the pandemic. Higher education proved to be an intensively explored area during the pandemic. The USA and its universities had the highest rate of publication for COVID-19 research publications in education. Our study indicates research themes that have been explored such as online learning in different educational settings, curriculum and instructional approaches within the distance learning environment, and COVID-19's psychological effects.

Through the bibliometric analysis performed, this study helps to gain a clearer knowledge of the response offered by educational research in the pandemic years 2020 and 2021. Researchers, practitioners, and decision-makers connected to the educational environment can be guided in the issue of COVID-19 in education by this study. For instance, by mapping the research landscape on COVID-19 in education this study can help researchers to better understand the state of research in this area. They can also identify opportunities for further study, such as those suggested in the previous section. The analysis undertaken here can be useful for researchers interested in finding possible collaborations for future investigations. In addition, this study has practical implications for policymakers and educators. The research analyzed and discussed here could serve as a foundation for further exploring policies and practices that have proven effective in mitigating the impact of COVID-19 on education. Policymakers can thus be inspired to make decisions about how to support education systems, students, and teachers during challenging times. Research on education during the pandemic offers valuable knowledge of crisis management in education. It provides insights into developing contingency plans, enhancing remote learning strategies, prioritizing student well-being, addressing digital disparities, and strengthening

collaboration among stakeholders. Educators can identify effective teaching and learning strategies suitable for online learning environments that can be used in their institutions. Special attention should be paid to the development of interventions to address educational inequities during the pandemic and support measures for vulnerable categories of students affected by the pandemic. Additionally, the research accumulated during the pandemic period can provide ideas for reshaping the curriculum, by emphasizing health education, digital skills, self-regulated learning opportunities for students, and education for sustainable development.

We estimate that COVID-19 pandemic-related topic will persist to be of interest to academic researchers in the years to come, especially through its pedagogical implications on educational practices. One of the possible implications is the growing use of blended learning in education in the future [83,84]. This is also a research line that is worth exploring. Finally, other research directions may choose to approach the measures taken to recover the educational loss accumulated during the pandemic, especially for vulnerable groups. The research agenda can be inspired by the education-related concerns that became more prominent during the pandemic such as the availability of instructional technology and its effective use, alternative learning opportunities, the development of digital literacy, approaches to delivering curricula, the well-being of students and teachers, the potential of global collaboration, etc. It would be worthwhile for researchers in the field to pay attention to how education will evolve once the pandemic is over. According to some scholars, education has two options in this regard: one that involves a "shift back to normal" to pre-pandemic practices, and another one that might propel it into a digital age [85]. It remains to be seen in which direction the future of education will evolve.

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