BIBLIOMETRIC ANALYSIS OF GLOBAL RESEARCH DEVELOPMENTS ON THE ROLE OF TECHNOLOGY DURING COVID-19: CURRENT TRENDS AND FUTURE PROSPECT

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ABSTRACT

This is the first study, to the authors' knowledge, to evaluate and quantify the role of technology during COVID-19 as there are no research that maps out the emerging use of technology during crisis. This research aimed to retrieve journal articles related to technology usage during pandemic and suggest new avenues for future research. Within the span of less than two years, this study was able to conduct a bibliometric analysis of 3,490 publications related to the theme. By using Scopus database, the bibliometric procedures examined the research performance and development within the framework of international impact, while VOS Viewer 1.6.11 visualized the overall research trend of technology during COVID-19. The results indicate that the United States is the country with the most publications related to technology and COVID-19. Javaid, M. and Haleem, A. are the two prominent scholars in this field based on the total number of publications. Most of the articles published in this field are found in both natural sciences and social sciences, in which the top two journals are Sustainability Switzerland and International Journal of Environmental Research and Public Health. While Biosensors and Bioelectronics and Scientific Reports are the top two leading CiteScore journals in technology and COVID-19 studies. Among the most recent author keywords are climate change, academic performance, e-Learning, medical devices, digital health, vaccines, e-mental health, and e-commerce, which demonstrated the current keen interest associated with technology and COVID-19. This paper is beneficial for academicians, organizations, and policymakers in understanding the general picture of the field and enable future scholars to understand the emerging technological development trends during world crisis in "real-time" bibliometrics.

Keywords: Bibliometric, Scopus, VOS Viewer, Technology, COVID-19

INTRODUCTION

Technology related studies has continued to capture interest and attention in recent years due to the emerging technologies and the evolution of Internet such as web 4.0 (Internet of Things) and artificial intelligence (Mukhadis et al., 2021). The role of technology has amplified in the current pandemic which force the world to an emergency lockdown restriction. When the crisis first hit the world in 2020, individuals across the globe were forced to an unprecedented phenomenon such as an increase in online-based consumption such as online education, online shopping, and online media consumption (Lemenager et al., 2021). For example, in response to the coronavirus disease outbreak demonstrated how technology transformed the way we learn and work due to the unplanned and rapid move to online and remote learning and working. The global health crisis called for quick action in adapting to new ways of running business operations and we have seen digitalisation in every sector, particularly in online businesses.

Previous research includes a bibliometric analysis studies of science and technology planning (Huang et al., 2014); technology foresight of personalised medicine (Stelzer et al., 2015); technology mining (Madani, 2015); nanogenerator technology in China (Wang et al., 2018) and artificial intelligence (Zhang et al., 2021). However, to the best of the researchers' knowledge, there is no specific bibliometric analysis done on the current

trends and future prospect of technology during global crisis such as COVID-19. Thus, the present study contributes to the existing literature by providing the first bibliometric analysis on the influence of technology during pandemic (i.e., COVID-19). This is because the COVID-19 crisis has highlighted a different set of needs to analyse trends in scholarship as they occur (i.e., real-time bibliometrics). This borderless and digital world encourages future research to have deeper insights on the importance role of technology especially during global crisis such as COVID-19.

This study aims to present a full picture and map the knowledge of previous research on this area. Moreover, this study suggests new avenues for future research using bibliometric analysis techniques depending on Scopus database. This paper brings a worldwide perspective because it analyses and organise large amounts of journal articles on technology during COVID-19 by identifying the global research trend, the top leading journals published in this area, most influential researcher, and regions where most publications and citations are taking place. As a result, this research provides new insight for future scholars in examining upcoming directions of technology and COVID-19 studies.

METHODS

The main objective of a bibliometric analysis is to examine the current literature development of a particular topic. The analysis results could be useful to provide directions and suggestions for future researchers in the area. In addition to that, bibliometric analysis could provide the trend of research, identifying top authors in writing the relevant papers, and identifying leading journals. These inputs differentiate a review paper and a bibliometric paper (Cobo et al., 2011). In this paper, the authors collected the bibliometric data from Scopus database. Data that was collected is such as affiliation of authors, countries, titles, abstracts, and others. Besides these, other indicators of performance in Technology and COVID-19 were also collected, such as total citations, total publications, and amount of single publication of top countries.

Searching Strategy

The necessary information was extracted on 29th April 2021, from Scopus database. This was done by setting a central theme in our searching, which was "Technology and COVID-19". These keywords were focused to mining the data in order to examine the global trend of Technology in COVID-19.

Due to COVID-19 was announced as a "pandemic" since the year of 2020, only journal articles that were published in the year of 2020 and 2021 were analysed in this bibliometric paper. Hence, the oldest paper was in 2020, and the latest paper was in 2021. Based on this information, the query string is as follows: (TITLE-ABS-KEY ("technology") AND TITLE-ABS-KEY (covid-19) OR TITLE-ABS-KEY (coronavirus) OR TITLE-ABS-KEY (covid)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020)) AND (LIMIT-TO (LANGUAGE , "English")). The result of this query string showed that a total of 5, 113 papers were found.

However, since the authors intended to focus on empirical studies, non-empirical papers were needed to be excluded from the list. Hence, the authors unticked all review papers in the Scopus database. After excluding irrelevant studies, 3, 490 documents remained in the final stage of searching and the authors proceeded to bibliometric analysis. The details of query strings were shown in Table S1 (Supplementary Material).
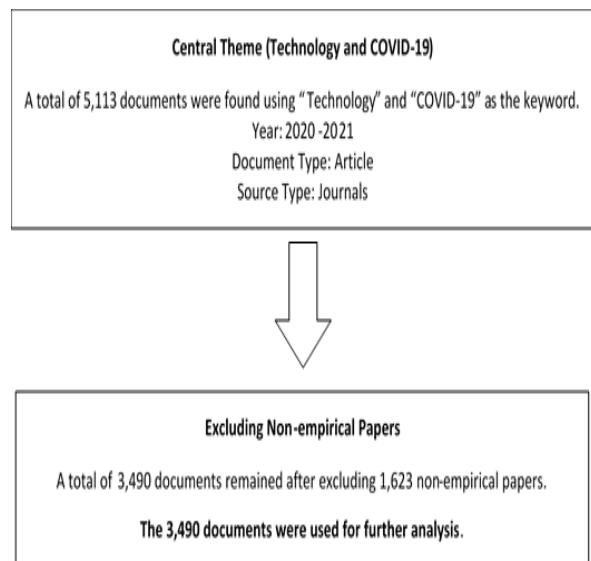
Figure 1: Selection process of Technology and COVID-19 Publications

Bibliometric Map

To illustrate bibliometric map in this analysis, the authors analysed the bibliographical information via VOS Viewer software. This is because VOS Viewer is known as a tool that visualising the bibliometric information by developing a bibliometric map, which to be presented in the coming sections in this paper. The co-authorship and author keywords patters will be presented in the following sections using bibliometric maps which were exported from VOS Viewer.

Co-authorship Analysis

The publications of Technology and COVID-19 involved 129 countries that were affiliated with each other to publish the papers in this topic. The authors ensured that the names of countries were not repeated in different abbreviations, hence thesaurus file was created. In that thesaurus file, similar country names were grouped together, such as "US" and "United States" were grouped as "United States". These affiliated countries were categorised into few regions, which were United States, Europe, United Kingdom, Middle East, Africa, Asia, Eurasia, and Oceania.

Analysis of Co-occurrence

A total of 324 author keywords was analysed in the co-occurrence analysis. Similar to co-authorship analysis, a thesaurus file was created before the authors developed the bibliometric map of author keywords. This is to prevent the similar author keyword to be repeated and affected the co-occurrence analysis. For example, "coronavirus", "covid", and "covid-19" were grouped as one author keyword, which was "COVID-19".

RESULTS AND DISCUSSION

Research Growth

From the information of Scopus database, the research growth of Technology and COVID-19 publications was analysed. From the graph showed in Figure 2, it can be seen that a huge number of publications was published under the theme, which was a total of 2, 061 publications in the year of 2020. The growth of this research scope is still growing rapidly till April 2021, where 1, 429 papers were published in just four months, which was about 70% of the number of publications in 2020. Cumulatively, a total of 3, 490 empirical papers was published in only 16 months.
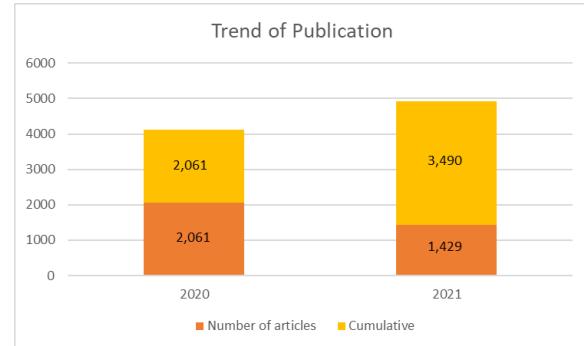
Figure 2: Trend of publications of Technology in COVID-19

The authors conducted further analysis on the subject area. Due to COVID-19 is a disease, Medicine was ranked as the first subject area (1, 405 articles), followed by Social Sciences (1, 014 articles), Computer Science (467 articles), Engineering (440 articles), and Biochemistry, Genetics and Molecular Biology (326 articles). The information here indicated that technology requires the research of computer science and engineering to assist COVID-19 happenings, as well as the technology in medicine and biochemistry. The role of technology during COVID-19 could also be seen when it was connected to Social Sciences, where human might need technology to stay connected with each other when social distancing was practiced.

Top Productive Journals Analysis

Table 1 indicated the top ten journals in terms of their total publication and the amount of citation in Scopus. As indicated in Table 1, top journals were from seven different publishers. The top two journals were from Multidisciplinary Digital Publishing Institute (MDPI). Out of seven publishers, MDPI, Journal of Medical Internet Research, and Frontiers Media S.A. had the greatest number of journals, where each of them had 2 out of 10 journals were from these publishers, followed by Public Library of Science, IEEE, American Chemical Society, and Elsevier. In addition to that, all the top journals were from Quartile 1 and 2 only, none of the leading journals were from Quartile 3 and 4. This proved that the attention towards Technology and COVID-19 was great, where top quality journals were publishing these relevant papers.

Sustainability Switzerland is the most leading journal that published the greatest number of

papers (TP: 87, 2.5%) in Technology and COVID-19, followed by International Journal of Environmental Research and Public Health (TP: 81, 2.3%), Journal of Medical Internet Research (TP: 41, 1.2%), and Plos One (TP: 29, 0.8%). International Journal of Environmental Research and Public Health has the greatest number of citation (TC: 491). The Cite Score analysis showed that, two journals scored more than 5.0 in Cite Score, namely Plos One and Biosensors and Bioelectronics. Cite Score is one of the important information as it can help the future readers to decide which journals to publish their works (Khudzari et al., 2018).

Table 1: Top journals on Technology and COVID-19 Studies

Rank	Journal	Quartile	TP (%)	TC	Cite Score 2019	The most cited article (Reference)	Times cited	Publisher
1	Sustainability Switzerland	Q2	87 (2.5)	157	3.2	The impact of the COVID-19 pandemic on user experience with online education platforms in China (Chen et al., 2020)	19	Multidisciplinary Digital Publishing Institute (MDPI)
2	International Journal of Environmental Research and Public Health	Q2	81 (2.3)	491	3.0	Corona virus (Covid-19) "infodemic" and emerging issues through a data lens: The case of china (Hua & Shaw, 2020)	111	MDPI
3	Journal of Medical Internet Research	Q1	41 (1.2)	145	3.9	Framework for managing the COVID-19 infodemic: Methods and results of an online, crowdsourced who technical consultation (Tangcharoensathien et al., 2020)	47	Journal of medical Internet Research
4	Plos One	Q1	29 (0.8)	54	5.2	Pathogen reduction of SARS-CoV-2 virus in plasma and whole blood using riboflavin and UV light (Ragan et al., 2020)	17	Public Library of Science
5	IEEE Access	Q1	28 (0.8)	195	3.9	A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact (Chamola et al., 2020)	112	IEEE
6	Journal of Chemical Education	Q2	27 (0.8)	46	3.4	Development and Use of Kitchen Chemistry Home Practical Activities during Unanticipated Campus Closures (Schultz, Callahan, & Miltiadous, 2020)	10	American Chemical Society
7	Frontiers in Psychology	Q1	26 (0.7)	25	3.2	Teacher Learning in Difficult Times:	6	Frontiers Media S.A.

Rank	Journal	Quartile	TP (%)	TC	Cite Score 2019	The most cited article (Reference)	Times cited	Publisher
						Examining Foreign Language Teachers' Cognitions About Online Teaching to Tide Over COVID-19 (Gao & Zhang, 2020)		
8	Frontiers in Public Health	Q2	19 (0.5)	48	2.0	Telemedicine as the New Outpatient Clinic Gone Digital: Position Paper From the Pandemic Health System Resilience PROGRAM (REPROGRAM) International Consortium (Part 2) (Bhaskar et al., 2020)	15	Frontiers Media S.A.
9	Biosensors and Bioelectronics	Q1	18 (0.5)	105	17.6	Diagnostic methods and potential portable biosensors for coronavirus disease 2019 (Cui & Zhou, 2020)	51	Elsevier
10	Jmir Mhealth And Uhealth	Q2	18 (0.5)	107	2.1	Peer-to-peer contact tracing: Development of a privacy-preserving smartphone app (Yasaka, Lehrich, & Sahyouni, 2020)	56	Journal of medical Internet Research

Note: TP= Total Publication; TC= Total Citation

Top Nations, Collaboration, and Institutions Analysis

This section discussed the top ten leading countries based on their number of publications in Scopus. In Table 3, the analysis result indicated that United States was ranked as first among the ten leading countries, where it owned 1019 publications, covering 29% of the worldwide publications (3, 490 papers). This brings a meaning that United States is the main contributors in this Technology and COVID-19 research, followed by top second country, China (371 publications), United Kingdom (370 publications), India (251 publications), and Italy (222 publications). As an addition to Table 3, a detailed list of top 30 leading countries and institutions was provided in Table S3, in the section of supplementary material.

As for the single-country publications (SCP) ranking, almost half of the countries scored more than 50% in SCP, where the highest SCP values (72.91%) was from India. Although United Kingdom owned the third highest in number of publications, its SCP value was lower than 50%. The value of SCP should be communicated to readers in this analysis because it shows the frequencies of collaborations between the involved countries (Khudzari et al., 2018). Hence, the higher the SCP value, it means the particular country has higher frequencies to share the knowledge with other countries through collaboration.

Based on the World University Rankings 2021, in the list of productive academic institution, more than half (6/10) of the universities were ranked as the top 200 best universities (THE, 2021), which were University of Oxford (5th), Sapienza Università di Roma (171st), Monash University (55th), University of Toronto (25th), Universitat de Barcelona (183rd), and King Abdulaziz University (143rd). This shows that much attention was gained from the universities to study or explore about technology in COVID-19. It is believed that the attention of top global universities could help

to increase the awareness of the importance of technology in COVID-19.

Other than presenting the data in Table 3, the co-authorship was analysed via VOS Viewer in order to visualize the information. As shown in Figure 3, each country was located in different points, where the stronger the link between the countries, both countries will be closer to each other in the map (Khudzari et al., 2018). In addition to that, the lines that were connected each country in the map showed the strength of links as well. The thicker the line, the stronger the link between the countries. The country with the greatest number of publications usually has the biggest font in the map, which was United States as shown in Figure 3.

The analysis of co-authorship indicated that United States had the most affiliations (102 links, 794 co-authorship), followed by United Kingdom (82 links, 639 co-authorship), Spain (79 links, 347 co-authorship), Australia (74 links, 356 co-authorship), Italy (74 links, 447 co-authorship) and other countries. In addition, the analysis result revealed that about half (53%) of the countries had less than 15 co-authorships. This highlighted that, in future, the 53% countries need to collaborate

Table 3: Top Nations and Institutes in Technology and COVID-19 Studies

Rank	Country	TPC	SCP (%)	Productive Academic Institution	TPI
1	United States	1019	69.87	Harvard Medical School	55
2	China	371	59.03	Huazhong University of Science and Technology	30
3	United Kingdom	370	42.70	University of Oxford	30
4	India	251	72.91	Jamia Millia Islamia	12
5	Italy	222	49.55	Sapienza Università di Roma	17
6	Australia	183	41.53	Monash University	23
7	Canada	182	47.25	University of Toronto	38
8	Spain	154	56.49	Universitat de Barcelona	10
9	Germany	133	39.10	Charité – Universitätsmedizin Berlin	9
10	Saudi Arabia	97	44.33	King Abdulaziz University	11

Note: TPC: total publications of the country; SCP: single-country publications; TPI: total publications of the organization
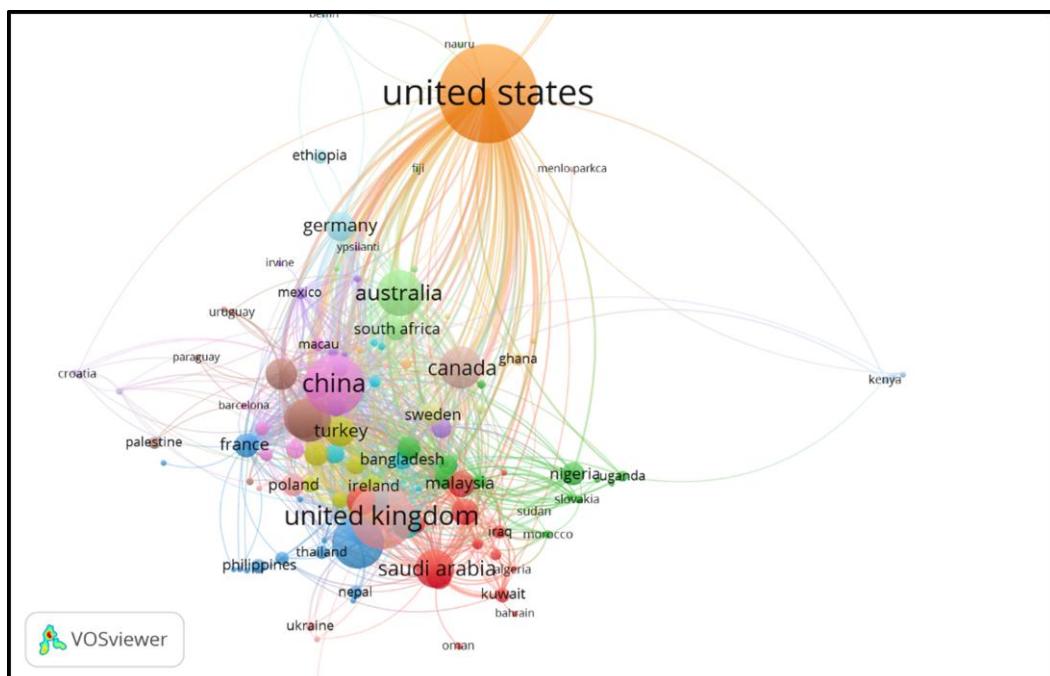
with more international countries in order to speed up the process of knowledge sharing across countries. In order to achieve this, the countries could improve the situation by increasing the research fund, improving the diversity in universities, and encouraging research climate in working places.

Most Productive and Highly Cited Authors

The data of most leading scholars was exported from Scopus database. Table 4 showed the top ten active scholars in the scope of Technology and COVID-19. The top ten scholars were from five nations, namely India, Italy, Australia, Canada, and France. Among the ten scholars, three of them were first author, two of them were second author, and half (5/10) of them were third author and above.

Javaid, M., Haleem, A., and Vaishya, R. were the major contributors in Scopus database with 11, 9, and 9 total publication, respectively. Among the three major contributors, as expected, Javaid, M owned the highest citation among the scholars, where TC = 373. In addition to this, although Bragazzi, N.L. was ranked as 4th leading author, Bragazzi, N.L. owned the highest citation among all the ten scholars, where TC = 523. From Table 4, it could be seen that most of the authors were from India, and this result is tally with the ranking of leading country, where India was one of the most active countries in this research area. The top two authors from India were from the same affiliation, namely Jamia Millia Islamia, which was the most productive institution in India in this research area, as indicated in Table 3. This

Table 4: The top 10 productive scholars in Technology and COVID-19 research

Rank	Author	ID of Author in Scopus	First publication year*	TP	h-index	TC	Current Affiliation	Country
1	Javaid, M.	57201798958	2020b	11	19	373	Jamia Millia Islamia, New Delhi	India
2	Haleem, A.	25627604500	2020c	9	30	364	Jamia Millia Islamia, New Delhi	India
3	Vaishya, R.	6602902951	2020a	9	20	310	Indraprastha Apollo Hospitals, New Delhi	India
4	Bragazzi, N.L.	57212030091	2020b	5	33	523	York University, Toronto	Canada
5	Leocani, L.	26643042800	2020c	5	33	62	Università Vita-Salute San Raffaele, Milan	Italy
6	Suman, R.	57191022246	2020c	5	6	216	Govind Ballabh Pant University of Agriculture and Technology, Pantnagar	India
7	Ammar, A.	24491660300	2020a	4	13	267	Université Paris Nanterre, Nanterre	France
8	Bastoni, S.	57217001267	2020c	4	5	267	Università Cattolica del Sacro Cuore, Milan	Italy
9	Bhaskar, S.	57192268582	2020a	4	12	35	NSW Health	Australia
10	Bottiroli, S.	24471204500	2020c	4	15	18	Giustino Fortunato University, Benevento	Italy

Note*= a: First Author, b: Second Author, c: Third Author and above; TP=Total Publication; TC=Total Citation

indicated that this university was active in publishing Technology and COVID-19 research.

Author Keywords

The authors documented 374 author keywords, where 17% (65 author keywords) were used for five times, 18% (69 author keywords) were used for six times, 10% (38 author keywords) were used for seven times, 5% (18 author keywords) were used for eight times, 2% (9 author keywords) were used for nine times, while 33% (125 author keywords) were used for more than ten times.

To avoid identical keywords, the researcher created a thesaurus file in which similar author keywords were re-labelled. As a result, there was a total of 324 author keywords (minimum of five occurrences) generated from the new analysis.

Concept and Terminology

The analysis of the author keywords co-occurrences suggested that 'COVID-19' was the most frequently used keywords in previous studies. There were 1947 occurrences and 314 links to other related keywords as shown in Figure 4.

There were several author keywords often used in relation to COVID-19 studies such as 'technology', in which it had 190 occurrences and 150 links (i.e., third highest occurrences after 'COVID-19'). Several author keywords were also found in conceptualising 'COVID-19' and 'technology'. For instances, 'digital technology' comes in 10th place for the highest number of occurrences with 190 occurrences and 150 links.

Besides that, there were few terms associated with 'COVID-19' and 'technology' found in author keywords analysis, namely 'artificial intelligence' (63 occurrences and 65 links), 'social media' (51 occurrences and 58 links), 'mobile apps' (39 occurrences and 66 links), 'Internet of Things' (34 occurrences and 50 links), 'big data' (31 occurrences and 41 links), 'virtual reality' (20 occurrences and 29 links), 'digital transformation' (20 occurrences and 34 links), and 'digitalisation' (20 occurrences and 23 links). As suggested by past researcher, the use of technology is more prominent during the pandemic and there is now wide range and advancement of digital technology consume by the public (Ting et al., 2020).

In particular, the role of 'Internet of Things' and 'artificial intelligence' is evidence in Table 1, in which these two terms are among the most cited papers when assessing 'COVID-19' such as article by Chamola et al., (2020) on 'a Comprehensive Review of the COVID-19
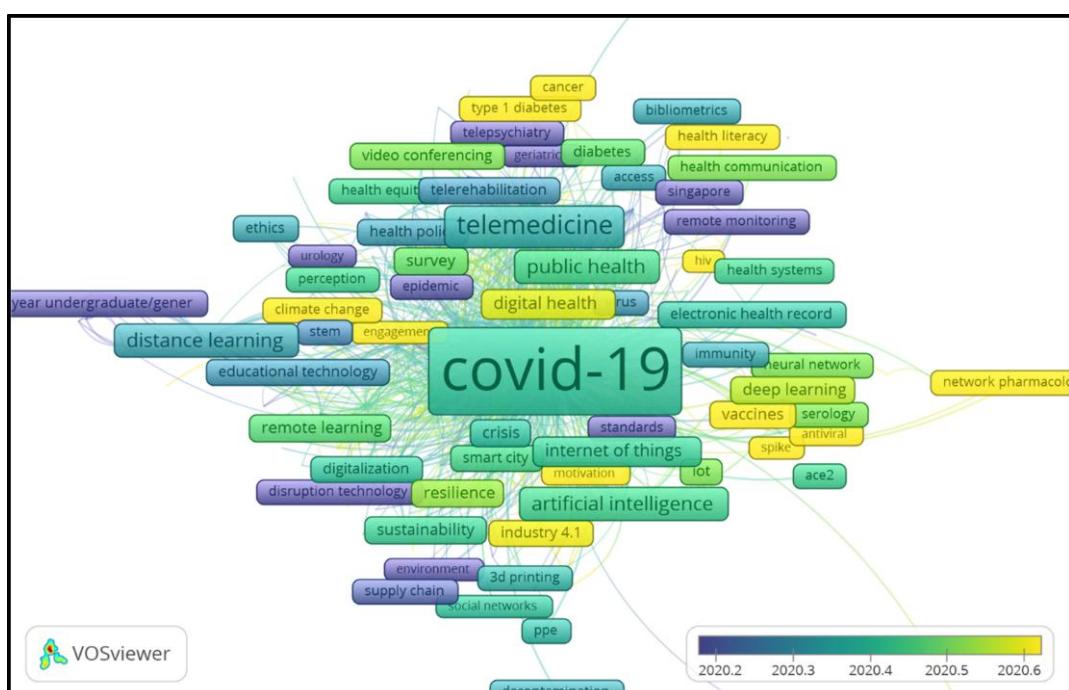
Figure 4: The Bibliometric Map of Author Keywords (Minimum Occurrences: 5)

Source: This Study

Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact'.

Based on the analysis, the author keyword such as 'contact tracing' (42 occurrences and 46 links) and 'mobile apps' (39 occurrences and 66 links) had a lot of occurrences in relation to COVID-19 studies. This finding is consistent with the analysis in Table 1, where one of the top cited papers mentioned about 'contact tracing' and 'mobile apps', namely 'Peer-to-peer contact tracing: Development of a privacy-preserving smartphone app' by Yasaka, Lehrich, and Sahyouni (2020). For instances, the adoption of COVID-19 contact-tracing technology is widely used globally as a tool to control and break the transmission of the infectious disease outbreaks (Walrave et al., 2020)

Topic of Interest
The bibliometric analysis revealed that the author keywords were related to technology and medical sciences such as 'telemedicine' (198 occurrences and 126 links), 'telehealth' (122 occurrences and 89 links), 'telerehabilitation' (17 occurrences and 20 links), and 'digital health' (42 occurrences and 75 links). For instances, 'telemedicine' is the second highest occurrences after 'COVID-19', with 198 occurrences and 126 links, and 'telehealth' is the fourth highest occurrences after 'technology', in which it had 122 occurrences and 89 links. This finding is evidence by one of the most cited articles in Table 1, in which it is linked to 'telemedicine', namely, 'Telemedicine as the New Outpatient Clinic Gone Digital: Position Paper from the Pandemic Health System Resilience Program (Reprogram) International Consortium (Part 2)' by Bhaskar et al., (2020), and 'Diagnostic methods and potential portable biosensors for coronavirus disease 2019' by Cui and Zhou (2020). This is because the current health system is using telemedicine and virtual care for remote treatment in response to COVID-19 pandemic (Jnr, 2020).

Besides the link between COVID-19, technology and medical sciences, the analysis of author keywords suggested the essential roles of technology and education during COVID-19 such as 'online learning' (117 occurrences and 75 links), 'higher education' (68 occurrences and 61 links), 'distance learning' (64 occurrences and 51 links),

'remote learning' (26 occurrences and 30 links), 'educational technology' (20 occurrences and 23 links), and 'blended learning' (16 occurrences and 14 links). As evidence in Table 1, 'online education' is among the most cited papers when assessing COVID-19 such as article by Chen et al., (2020) on 'The Impact of the COVID-19 pandemic on User Experience with Online Education Platforms in China', and article by Gao and Zhang (2020) on 'Teacher Learning in Difficult Times: Examining Foreign Language Teachers' Cognitions About Online Teaching to Tide Over COVID-19'. Moreover, this finding is consistent with the analysis in Table 1, where one of the top cited papers mentioned about remote and distance learning due to unanticipated campus closured during the pandemic, namely 'Development and Use of Kitchen Chemistry Home Practical Activities during Unanticipated Campus Closures' by Schultz, Callahan, and Miltiadous (2020).

The bibliometric analysis revealed that the author keywords were indeed related to the excessive amount of information concerning the pandemic and the technological capacity to store information such as 'information and communication technologies' (47 occurrences and 56 links) and 'infodemic' (6 occurrences and 9 links). This finding is consistent with the analysis in Table 1, where two of the top cited papers mentioned about 'infodemic', which is the combination of the word information and pandemic, for example, article by Hua and Shaw (2020) on 'Evidence by Corona virus (Covid-19) 'infodemic' and emerging issues through a data lens: The case of china'; and article by Tangcharoensathien et al. (2020) on 'Framework for managing the COVID-19 infodemic: Methods and results of an online, crowdsourced who technical consultation'.

Accordingly, scholars have also explained the relation between individuals' well-being, health, technology, and COVID-19. For instances, the analysis of author keywords suggested the following: 'mental health' (68 occurrences and 84 links), 'public health' (64 occurrences and 71links), 'healthcare' (39 occurrences and 52 links), 'vaccines' (22 occurrences and 25 links). These findings are consistent with the analysis in Table 1, where one of the top cited papers mentioned 'digital mental health' in relation to COVID-19, namely, 'Digital Mental Health and

COVID-19: Using Technology Today to Accelerate the Curve on Access and Quality Tomorrow by Torous et al., 2020. Due to the social distancing and remote living, the public is turning to technology to support wellbeing of their own during this pandemic challenging times (Goldschmidt, 2020).

The analysis of author keywords recommended that future research should concentrate on 'climate change'. This is because 'climate change' (8 occurrences, 11 links) had become one of the latest author keywords in COVID-19 studies (Average Publication Year: 2020). The COVID-19 pandemic not only changed human lives but also had a global implication for energy management systems and climate change, especially since experts warn that pandemics are recurring risks that worsen with climate change (Chen et al., 2021; Meinrenken et al. 2020).

Besides that, the analysis of author keywords suggested that future studies should also concentrate on examining the effect of COVID-19 on academic performance, as well as the effect of e-Learning. This is because 'academic performance' (6 occurrences, 9 links) and e-Learning (5 occurrences, 10 links) had become two of the recent author keywords in COVID-19 studies (Average Publication Year: 2020). The changes in emergency remote learning have caused massive disruption in the way traditional education system deliver the knowledge to students, as well as psychological distress among school children due to the school suspension (Iglesias-Pradas et al., 2021; Chen et al., 2020).

Future research should continue to investigate the positive and negative effects of online and remote learning during the pandemic on the overall academic performance. There are still room for future research to shed light on this matter by examining the advantages, limitations and recommendations of virtual teaching and learning during this global catastrophe.

The analysis of author keywords recommended that future studies should focus on the relationship between medical related studies during COVID-19 such as medical devices, digital health as well as health literacy and vaccines. This is because 'medical devices' (6 occurrences, 13 links), 'digital health' (42 occurrences, 75 links), 'health literacy' (6 occurrences, 5 links), and 'vaccines' (22 occurrences, 25 links) have become among the recent author keywords in COVID-19 studies (Average Publication Year: 2020). For example, future scholars should further explore medical devices advancement and ensuring the safety and effectiveness of those devices in assisting those in need during this pandemic (WHO, 2020). In the race of finding the solution to the contagious disease outbreak, it is vital for future researchers to continue investigate the significant role of digital health, health literacy and vaccines.

The author keyword such as 'acceptance' (5 occurrences, 9 links), 'quality of life' (7 occurrences, 10 links), 'new normal' (5 occurrences, 7 links), 'uncertainty' (7 occurrences, 10 links), 'well-being' (15 occurrences, 22 links) and 'e-mental health' (5 occurrences, 15 links) has also been getting a significant attention in the recent years (Average Publication Year: 2020), especially when this unprecedented deadly disease has affected the way people lives their life and transition towards the 'new normal of living'.

Future research should investigate individuals' acceptance towards the new norms that requires fewer human interactions and social distancing. To ensure a sound and healthy social well-being, future scholar is encouraged to further develop the mental health technology revolution such as technology-based therapy in the COVID-19 pandemic to assist individuals in thriving during this challenging and uncertain times (Figueroa and Anguilera, 2020).

Finally, future studies should emphasize on the role of 'e-commerce' (6 occurrences, 6 links) and 'industry 4.1' (12 occurrences, 19 links) as both are the recent authors keywords in relation to COVID-19 studies (Average Publication Year: 2020). A major concern in COVID-19 studies is related to the adoption of e-commerce (Gao et al., 2020). Future studies should further explore the role of e-commerce and industry 4.1 as there may be opportunities to build on social changes catalysed by COVID-19 and further improve the economic recession, especially that the pandemic has accelerated e-commerce trends post-lockdown (Tran, 2021).

Limitations of Study

In the query string, this bibliometric analysis focused on only empirical studies from journal articles. This searching strategy might overlook other types of journal articles such as review papers, as well as other sources of information, such as book chapters and conference proceedings. In addition to that, the data mining was conducted in Scopus database only, which could limit the searching result. Web of Science (WOS) is recommended for future researchers to combine both database in order to obtain a more thorough result.

CONCLUSION

The current study has successfully analysed and discussed the research growth trend of technology and COVID-19 based on 3,490 related studies in Scopus database. Within the span of less than two years, the growth of COVID-19 and technology studies has been increasing rapidly and will continue to expand as the world start to recover from this deadly disease and the development of technology advancement.

It was also discovered that climate change, academic performance, e-Learning, medical devices, digital health, vaccines, e-mental health, and e-commerce were new area in examining COVID-19 and technology with average publication year of 2020. These topic areas have the potential to become prominent upcoming topic in the future, hence future researcher should investigate these concepts in relation to COVID-19 and technology.

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SUPPLEMENTARY MATERIALS

Supplementary information:
Table S1: Search strategies and query strings
Table S2: The leading Cite Score journals in Technology and COVID-19 studies (Minimum 15 research articles)
Table S3: The top 30 most productive institutions in Technology and COVID-19 studies

Table S1: Search strategies and query strings

Items	Theme	Search for:	Query Strings
i.	Central	Technology and COVID-19	(TITLE-ABS-KEY ("technology") AND TITLE-ABS-KEY (covid-19) OR TITLE-ABS-KEY (coronavirus) OR TITLE-ABS-KEY (covid)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020)) AND (LIMIT-TO (LANGUAGE , "English"))
ii.	Central	Technology and COVID-19 (Journal Articles only)	(TITLE-ABS-KEY ("technology") AND TITLE-ABS-KEY (covid-19) OR TITLE-ABS-KEY (coronavirus) OR TITLE-ABS-KEY (covid)) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020)) AND (LIMIT-TO (LANGUAGE , "English"))

Table S2: The leading CiteScore journals in Technology and COVID-19 studies (with minimum requirement of 15 publications and above) rank based on cite score

Rank	Name of Journal	Cite Score in 2019	Publisher	Amount of Publication
1	Biosensors and Bioelectronics	17.6	Elsevier	18
2	Scientific Reports	7.2	Springer Nature	15
3	Journal of Diabetes Science and Technology	5.4	Diabetes Technology Society	16
4	Plos One	5.2	Public Library of Science	29
5	Journal of Medical Internet Research	3.9	Journal of medical Internet Research	41
6	IEEE Access	3.9	IEEE	28
7	Journal of Chemical Education	3.4	American Chemical Society	27
8	Sustainability Switzerland	3.2	Multidisciplinary Digital Publishing Institute (MDPI)	87
9	Frontiers in Psychology	3.2	Frontiers Media S.A.	26
10	International Journal of Environmental Research and Public Health	3	Multidisciplinary Digital Publishing Institute (MDPI)	81
11	Journal of Intelligent and Fuzzy Systems	2.6	IOS Press	18
12	Diabetes and Metabolic Syndrome Clinical Research and Reviews	2.6	Elsevier	15
13	Jmir Mhealth And Uhealth	2.1	Journal of medical Internet Research	18
14	Frontiers in Public Health	2	Frontiers Media S.A.	19
15	Medicine	0.9	Elsevier	18
16	Education Sciences	0.8	Multidisciplinary Digital Publishing Institute (MDPI)	15
17	Library Philosophy and Practice	0.3	University of Idaho Library	18

Table S3: The top 30 most productive institutions in Technology and COVID-19 Research

Rank	Institution	Country	No. of Publications
1	Harvard Medical School	US	55
2	University of Toronto	Canada	38
3	Huazhong University of Science and Technology	China	30
4	University of Oxford	UK	30
5	Massachusetts General Hospital	US	28
6	Tongji Medical College	China	26
7	Imperial College London	UK	26
8	University of Cambridge	UK	26
9	King's College London	UK	25
10	University of California, San Francisco	US	25
11	University College London	UK	24
12	Monash University	Australia	23

Rank	Institution	Country	No. of Publications
13	University of Washington	US	22
14	The University of British Columbia	UK	21
15	Stanford University	US	21
16	UNSW Sydney	Australia	21
17	Ministry of Education China	China	20
18	University of Pennsylvania	US	20
19	Brigham and Women's Hospital	US	20
20	Chinese Academy of Sciences	US	20
21	University of Melbourne	Australia	20
22	University of Alberta	Canada	20
23	University of Michigan, Ann Arbor	US	19
24	Stanford University School of Medicine	US	19
25	University of Calgary	Canada	18
26	The University of Hong Kong	Hong Kong	18
27	Harvard University	US	18
28	The University of Sydney	Australia	17
29	University of Minnesota Twin Cities	US	17
30	The University of Queensland	Australia	17

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