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Significance of Open Science Approaches Towards the Fight against COVID-19 Pandemic

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Abstract

The Open science approach is based on collaborative knowledge generation, and it makes accessible scientific development to the public domain through networks using advanced technologies and collaborative tools. COVID-19 pandemic put the global scientific community from different disciplines to contribute their disciplinary perspectives and research approach to address the complex issues. This pandemic has witnessed a changing scientific culture among the scientists and scholarly publishers towards a more open science approach through sharing scientific data or statistics, adoption of quick review and more accessibility by lifting paywall by journal publishers to fight the pandemic more collaboratively. The present study aims to provide an overview of the open science approach among scientists and particularly its significance in scientific communication during this current COVID-19 pandemic.

Keywords: Open Science, COVID-19, Preprint, Crowdsourcing

1. Introduction

At the end of December 2019, the World had witnessed a global pandemic caused by severe acute respiratory syndrome coronavirus 2 (SARS- CoV-2). On January 30, 2020, the World Health Organization (WHO) declared this a Public Health Emergency of International Concern (PHEIC), and after that, on February 11, 2020, WHO named it "COVID-19". On March 11, 2020, it was declared a pandemic. The virus had killed over 16,600 people worldwide as of 24th March 2020, with over 380,000 people infected (Hua & Shaw, 2020). As of March 2021, more than 130 million people have been infected with SARS-CoV-2, with approximately three million deaths (Ross, 2021). WHO had reported that this is one of the most significant medical disasters since the Spanish flu pandemic of 1918. It challenges the global scientific community like never before. The whole-genome sequence of COVID-19 was published on the 10th January 2020 by Professor Edward C. Holmes, the University of Sydney, on behalf of the

Consortium led by Professor Yong-Zhen Zhang of Fudan University, Shanghai (Humphreys, 2021), barely after a month, the first patient was admitted into the Wuhan hospital, to the online repositories virological.org and GenBank. While, during the SARS outbreak of 2002-2003, there was a nearly five-month delay due to an information breakout in the first month of the outbreak. The importance of sharing data and publishing to counteract earlier outbreaks has been highlighted by lessons learned from previous outbreaks (Kadakia et al., 2021). In earlier health emergencies caused by the Ebola and Zika viruses, we have also experienced the need for sharing research data as widely and quickly to speed up the investigation. In a similar vein, traditional impediments to data sharing, such as intellectual property constraints, confidentiality issues, and technological and human resource limits, cannot be used to stifle the transmission of research data on COVID-19 (Chretien et al., 2016; van Panhuis et al., 2014; Whitty et al., 2015). In this regard, this COVID-19 pandemic has spurred on and demonstrated the value of Open Science (OS) and exposed gaps in science policy among the scientific community globally.

The present study highlights some of the significant open science initiatives during this COVID-19 pandemic, particularly its significance in scientific communication during the present COVID-19 pandemic. The study excludes literature on coronavirus vaccines, tracking apps and socio-economic impact due to the current pandemic.

2. Related studies

According to Larivière et al. (2020), the current scholarly communication infrastructure does not satisfy the needs of science and society, as revealed by the coronavirus (COVID-19) outbreak. Specifically, the crisis highlights two inefficiencies in the research system; one is the default to closed science and an overemphasis on elite, and the other is publishing only in English, regardless of the circumstances and repercussions of the research. According to Naujokaityt (2021), in the 11 months, approximately 75,000 scientific articles on COVID-19 were published up to the November end of 2020. During this period, scientists and researchers from the United States and China were the top collaborated and contributors to COVID-19 articles. The study of Lee and Haupt (2021) have used the term 'scientific globalism', sometimes referred to as 'techno globalism' (Cantwell & Grimm, 2018), as a primary mission for the advancement of knowledge and open science (Sá & Sabzalieva, 2018), which can be contrasted to scientific nationalism's focus on economic competitiveness, national security and nation-building. During the pandemic, OS has played a critical role in providing information on SARS-CoV-2 and the clinical characteristics of COVID-19. This exponential growth of real-time information has been used directly to justify public health policies (Capp, 2020). COVID19 offers valuable insights for more practical and long-term approaches to "openness" than mandates and laws. (Minari et al., 2020). According to Capp (2020), the real antidote to the epidemic is not segregation but rather cooperation. Ellemers (2021) stated that the present epidemic had spawned encouraging examples of cross-laboratory and cross-national scientific collaboration, with shared data on virus features, risk factors, and medicinal treatments. Many researchers have banded together to discover a solution to this dilemma due to the sense of urgency.

3. Objectives

i. To provide an overview of scientific collaboration to fight the pandemic.
ii. To assess the significance of open science in scientific communication during the present COVID-19 pandemic.
iii. To survey the major initiatives taken up towards this end around the world.
iv. To understand the focussed issues on the subject matter.

For the study, most of the literature is downloaded from the web of science database and other website links related to the COVID-19 pandemic. The present study excludes literature on coronavirus vaccine, tracking apps and other socio-economic issues related to the pandemic.

4. Open science approach

Open science (OS) is a novel practice to openness in every step of research to achieve a more accountable, robust, transparent, reproducible and inclusive scientific culture. Open science encompasses several aspects. At the core, this includes open access, open data, open-source/ tools, and open standards that offer unfettered dissemination of scientific discourse. These things enable reproducible science by giving full access to the major components of scientific research. COVID-19 pandemic accelerates the practice of open science among scientists across the globe by sharing research data, methods, tools, and findings to understand the virus. However, unprecedented equipment shortages and qualified personnel have been reported in hospitals and diagnostic laboratories since the global crisis. Supply chains are strained worldwide, and external help may not be readily available. Opening up mobilises knowledge from many different places and unleashes a volunteer army of researchers working in their facilities across different time zones and countries. Here, one of the success stories of collaboration during the pandemic, Karl Gude, former Director of Infographics at Newsweek Magazine, collaborated with a nurse and an epidemiologist, using Centers for Disease Control and Prevention (CDC) resources as a base to create the infographic "Break the Chain of Infection", which was widely circulated on social media in March 2020 (Gude & Navarro, 2020). Translations were crowdsourced in response to demand into Arabic, Chinese, French, Italian, German, Japanese, Korean, Malayalam, Portuguese, and Spanish (Spohn, 2020). To aid stop the spread of COVID-19, the United Nations subsequently called upon the global power of creatives (United Nations, 2020). In response to the challenges posed by COVID-19, the three UN agencies, Directors of the United Nations Educational, Scientific and Cultural Organisation (UNESCO), World Health Organization (WHO), and the Office of the United Nations High Commissioner for Human Rights (OHCHR), launched a Joint Appeal for Open Science. UNESCO mobilised over 122 countries to promote Open Science and reinforced international cooperation. They also coincide with a five-day meeting of UNESCO Member States (6-12 May) to develop a global standard-setting framework for Open Science.

Similarly, on 31 January 2020, Welcome published a statement, signed a statement titled *"Sharing research data and findings relevant to the novel coronavirus outbreak"*, signed by more than 150, including journal publishers like Elsevier, Springer Nature, and Taylor & Francis, funding bodies, and disease prevention centres, pledging to provide immediate open access for peer-reviewed publications for the duration of the outbreak, to make research

findings available via preprint servers, and to share results with the Centers for Disease Control and Prevention (CDC) as soon as possible (WHO). However, it was claimed that the papers and book chapters that have been made available as a result of this approach only make up a small portion of the coronavirus literature. Since the late 1960s, 13,818 articles about coronaviruses have been published, according to Web of Science (WoS). More than half of these articles (51.5%) are still closed to public access (Larivière et al., 2020).

In another collaboration, on 27 April 2020, a group of publishers and scholarly communications organisations, fully supported by, Open Access Scholarly Publishing Association (OASPA), comprises of eLife, F1000 Research, Hindawi, PeerJ, PLOS, The Royal Society, FAIRsharing.org, Outbreak Science Rapid PREreview, GigaScience, Life Science Alliance, Ubiquity Press, UCL, MIT Press, Cambridge University Press, BMC, RoRi and AfricArXiv, announced a joint initiative to maximise the efficiency of peer review, ensuring that crucial work related to COVID-19 is reviewed and published as quickly and openly as possible (OASPA, 2020). The Gates Foundation, in collaboration with the Chan Zuckerberg Initiative (CZI) Foundation and the White House Office of Science and Technology Policy (OSTP), has teamed together to publish in machine-readable form all of the known medical literature on the coronavirus. This was done to examine existing studies to find new ways to fight COVID-19 (Chesbrough, 2020).

5. Major Initiatives on Open Science Approaches

Some of the leading major initiatives taken up around the world on Open science approaches include the following, as shown in the table:

5.1. Major initiatives on Open Science Approaches

Initiatives	Supported by	Descriptions
Open Covid Pledge Launched in April 2020	By a global alliance of scientists, lawyers, and technology firms.	The notable signatories are Intel, Amazon, IBM, Sandia National Laboratories, Facebook, Hewlett Packard, Uber, Open Knowledge Foundation, Microsoft, the Massachusetts Institute of Technology, and AT & T.
Coronavirus Knowledge Hub	Frontiers	Nearly 10,000 COVID-19 related articles were thoroughly reviewed, and waivers worth USD 5 million were granted to aid in the pandemic response. COVID-19 articles have been published in over 2,000 Frontiers journals, with over 10 million views and downloads from research and innovation institutions and pharmaceutical businesses worldwide.
The Johns Hopkins Coronavirus	The Johns Hopkins University & Medicines	COVID-19 data and expert recommendations are collected and analysed on cases, deaths, tests,

Resource Center (CRC)		hospitalisations, and immunisations to assist the public, policymakers, and healthcare professionals worldwide in responding to the pandemic. The CRC was named to TIME's Top 100 Investigators list as the "go-to data source" for COVID-19.
ClinicalTrials.gov COVID-19 related studies	U.S National Library of Medicine	View a list of clinical trials using the coronavirus (COVID-19). Directly from the sponsors and investigators performing the trials, studies are submitted in an organised style. ClinicalTrials.gov posts submitted trial material within two days of the first submission, and the site's content is updated daily. The API also provides access to the entire website's content.
Human Coronaviruses Data Initiative	Lens.org	Building an interactive platform to let people comprehend the landscape of patent and research activities in any field, including human coronaviruses and COVID-19.
Wikiproject COVID-19	Wikipedia	WikiProject dedicated to Wikipedia's coverage of the SARS-CoV-2 virus, COVID-19, and the COVID-19 pandemic.
COVID-19 SARS-CoV-2 preprints	bioRxiv and medRxiv	Nearly 3000 COVID-19 studies were posted by May 7, 2020.
The **Outbreak Science Rapid PREreview**, an open-source platform.	Nature	Which allows scientists and researchers with ORCID IDs to submit their reviews as they read the preprints.
A new journal from **MIT Press, Rapid Reviews: COVID-19**	MIT Press	Prior to human review, employ artificial intelligence (AI) to categorise preprints by discipline, novelty, and importance.
Virus Outbreak Data Network (VODAN)	Joint activities carried out by CODATA, WDS, RDA, and GO FAIR	During the COVID-19 epidemic, specialists in several afflicted nations pledged to make the SARS CoV-2 viral data FAIR, meaning that information is Findable, Accessible, Interoperable, and

		hence Reusable by both humans and machines.
CORD-19-on-FHIR	Allen Institute for AI.	Freely available dataset of 45,000 research publications on COVID-19, SARS-CoV-2, and similar coronaviruses, including over 33,000 with full text. This machine-readable resource is given to allow natural language processing and other AI techniques to be used.
KG-COVID-19 Knowledge graph	https://github.com/Knowledge-Graph-Hub/kg-COVID-19.	A framework for creating knowledge graphs that may be adjusted for downstream applications such as machine learning tasks, hypothesis-based querying, and a browsable user interface allows researchers to explore COVID-19 data and find links.
Google Cloud Platform (GCP) Datasets for COVID-19 Research	Google	GCP is hosting a repository of public datasets and offering free hosting and queries of COVID datasets.
OSCOVIDA: Open Science COVID Analysis	European Union's Horizon 2020 research and innovation programme	Provides an open scientific platform to see and analyse COVID19 infections and deaths over time for US states, German districts, and most other countries worldwide.
The Lean European Open Survey on SARS-CoV-2 Infected Patients (LEOSS)	German Centre for Infectious Research, Willy Robert Pitzer Stiftung Foundations, Robert Koch Institute, etc.	A European registry for the research of COVID-19's epidemiology and clinical course. LEOSS uses an Open Science method to enable evidence generation at the quick pace required in a pandemic, making data available to the public in real-time. Quantitative anonymisation approaches are utilised for safeguarding the continually published data stream containing 16 variables on the course and treatment of COVID-19 from singling out, inference, and linking assaults to protecting patient privacy.
The COVID-19 High-Performance Computing (HPC)	NASA, IBM, Microsoft, Google Cloud, Dell, MIT, Rensselaer Polytechnic	Bringing together the Federal government, industry, and academic leaders to access the World's most powerful high-performance computing

	Institute, University of Illinois, etc.	resources supporting COVID-19 research.

6. Focussed Issues

Some focused issues are being discussed in the following sections.

6.1. Preprint during COVID-19

A preprint is a preliminary report of scientific work shared publicly for feedback and discussion to improve before being peer-reviewed (Añazco et al., 2021). For the first time, preprints have been widely accepted and used for speedy scientific communication during this COVID-19 pandemic. Releasing over 125,000 COVID-19 related scientific articles within ten months of the first confirmed case, of which more than 30,000 were hosted by preprint servers (Fraser, 2021). Data from Dimensions shows that 13% (46,006/349,828) of COVID-19 related publications in 2020 were preprinted (Humphreys, 2021). In a study, between 01 January to 31 October 2020, it was found that preprint servers hosted almost 25% of COVID-19 related science, that these COVID-19 preprints were being accessed and downloaded in considerably larger numbers than other preprints on the same sites, and that these were widely shared across multiple online platforms. Among the preprint servers, bioRxiv, medRxiv, PeerJ Preprints, SSRN, Peer review (PubMed), Research Square, RePEc, arXiv, Preprints.org, ChemRxiv, Qeios, IndiaRxiv, etc have been actively engaging in providing COVID-19 related scientific articles.

As of 29th May 2021, The *iSearch* COVID-19 Portfolio, a National Institutes of Health (NIH) comprehensive, an expert-curated source for publications and preprints related to either COVID-19 or the novel coronavirus SARS-CoV-2, and Peer review (PubMed) has hosted a maximum number of publications up to 1,18,329. Whereas among the preprint servers, medRxiv, which was founded recently in 2019 by Cold Spring Harbor Laboratory (CSHL) in collaboration with Yale and BMJ, hosted the most significant number of preprints, i.e., 12,557; followed by the Research Square with 6445, arXiv with 3929, bioRxiv with 3888, SSRN with 3142, and Preprints.org with 1244; all other preprint servers were found to host <1000 preprints. Figure 1 depicts the record counts in preprint servers of COVID-19 publications from the *iSearch* COVID-19 portfolio.
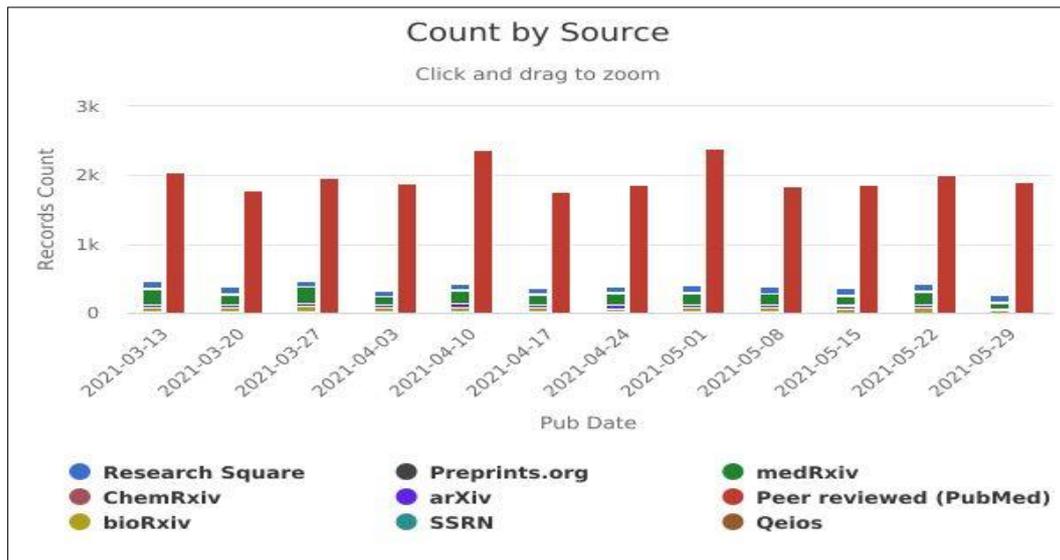
Figure 1: Record counts in preprint servers
Source: https://icite.od.nih.gov/covid19/search/

Although preprint publishing has enhanced quick dissemination and broader sharing of COVID-19 related research, Preprints and other non-peer-reviewed reports should be treated as work in progress rather than conclusive evidence. Furthermore, preprints are not checked for biosecurity issues, increasing the potential for illicit or criminal use of biological data. Most journals are not usually thorough in their checks.

6.2. Research funding in COVID 19 related research

Coronavirus funding monitor, one of the services of Frontiers, curated a list of open funding calls and other support for researchers from non-profit organisations and commercial organisations, specifically for COVID-19 related research across the globe. Among the funders, Wellcome, Bill & Melinda Gates Foundation and Mastercard, US National Science Foundation (NSF), Central European Research Infrastructure Consortium (CERIC), etc., can be mentioned. For further details, visit https://coronavirus.frontiersin.org/COVID-19-research-funding-monitor.

6.2. Crowdsourcing

As a response to face the pandemic, Crowdsourcing is also being used to improve public health (World Health Organization, 2018). It allows for mobilising a large and diverse community through improved communication and collaboration (Nguyen et al., 2019). As Chesbrough (2020) states, *"good ideas can come from anywhere, making openness is imperative in these times of crisis"*. To name a few Open crowdsourcing projects related to COVID-19 can be mentioned as COVID Near You, FluTracking, Beat the Vid, CovidTesting, NineSigma, Crowdfight COVID-19, NASA@Work, Anti-Coronavirus Hackathon (TopCoder), CODEVID-19 Global Hackathon, EUvsVirus Hackathon, Kaggle's CORD-19, Solve's Health Security & Pandemics, InnoCentive, Call4Ideas COVID-19 Challenge, etc. (Vermicelli et al., 2021).

6.3.   Citizen science and DIY (Do It Yourself) Projects

During this pandemic, we can see more collaborative efforts not only in scientific communities but also among different stakeholders, including companies, NGOs, universities and individual inventors. Besides getting vaccines, there has been a shortage of Personal protective equipment (PPE), masks, gowns, and gloves, ventilators for critical patients. Ventilator manufacturers are forming partnerships with carmakers, aerospace firms and others to boost output as fast as possible. Universities like MIT are trying to alleviate hospital shortages by launching a competition for the best open-source ventilator design.

A German multinational conglomerate, Siemens opened up its Additive Manufacturing Network to anyone who needs help in medical device design. Likewise, Scania, a heavy truck maker and the Karolinska University Hospital have also partnered. Scania is not only renovating trailers into mobile testing stations but has also assigned 20 highly skilled purchasing and logistics experts to find, acquire, and deliver personal protective types of equipment to health care workers. Similarly, Ford is also working together with the United Auto Workers, GE Healthcare, and 3M to build ventilators in Michigan using F-150 seat fans, portable battery packs, and 3D printed parts (Dahlander & Wallin, 2020). Apps such as Zoe in the UK have collected, generated, shared, and analysed vast quantities of health data by citizens during the Covid pandemic and provided the government with far more information about the spread of the pandemic and its effects than would have been possible via the health service alone (Lindley, 2021).

In India, the first COVID-19 case was reported in the State of Kerala, which subsequently initiated an outbreak. Using the concept of citizen-led open- and crowd-sourcing strategies during the devastating 2018 Kerala floods brought experts and the general public together to coordinate rescue missions via social media platforms. Collective for Open Data Distribution Keralam (CODD-K) was designed by technologists, academicians, students, and the public advocating for open data to provide real-time analysis and daily updates of COVID-19 cases in Kerala (Ulahannan et al., 2020).

7. Significant impact on the fight against the COVID-19 pandemic
- Global scientific communities had reaffirmed the urgent need for a transition to open science to fight any pandemic.
- COVID-19 research had received multinational support and rapidly infused in the billions of dollars.
- The sharing of research findings and research data, raising of preprint and review has never been as rapid and efficient.
- Realising the power of collaboration and cooperation through crowdsourcing or citizen science.
- The crisis has also brought disease, health, and healthcare back to the forefront of societal issues and will have a lasting impact on public spending.

8. Conclusion

The COVID-19 pandemic is not yet over. It makes a global death in millions of people and economic losses in the trillions of dollars. COVID-19 pandemic put the human race into a threat. It has infected half of the World's population regardless of nationality, ethnicity, religion, or sex. It severely affects individuals' personal and social lives. It is more than a health crisis; it is also a social and economic crisis. COVID-19 pandemic has to accelerate the open science movement among scientists, economists, policymakers and government authorities across the globe to know the virus on testing and developing therapies and vaccines to treat and prevent it. It has shown the urgent need for more openness in sharing scientific data, rising preprint, rapid review and publishing in open access. Open Science aims to minimise inequities among countries, institutions, and researchers by making science more varied, inclusive, and collaborative across regions. Everyone should embrace Open Science practice in research culture because it is the future of science for a better world.

References

Añazco, D., Nicolalde, B., Espinosa, I., Camacho, J., Mushtaq, M., Gimenez, J., & Teran, E. (2021). Publication rate and citation counts for preprints released during the COVID-19 pandemic: The good, the bad and the ugly. *PeerJ*, *9*. https://doi.org/10.7717/peerj.10927

Azoulay, A. (2020, October 27). *UNESCO, WHO and the UN High Commissioner for Human Rights call for "open science"*. UNESCO. https://en.unesco.org/news/unesco-who-and-high-commissioner-human-rights-call-open-science.

Cantwell, B., & Grimm, A. (2018). The geopolitics of academic science. In B. Cantwell, H. Coates, & R. King (Eds.), *Handbook on the politics of higher education* (pp. 130–148). Cheltenham: Edward Elgar Publishing.

Capps, B. (2020). Where does open science lead us during a pandemic? A public good argument to prioritise rights in the Open Commons. *Cambridge Quarterly of Healthcare Ethics*, *30*(1), 11–24. https://doi.org/10.1017/s0963180120000456

Centers for Disease Control and Prevention. (2012, May 18). *Principles of Epidemiology in Public Health Practice, Third Edition An Introduction to Applied Epidemiology and Biostatistics*. Centers for Disease Control and Prevention. https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html.

Chesbrough, H. (2020). To recover faster from COVID-19, open up: Managerial implications from an open innovation perspective. *Industrial Marketing Management*, *88*, 410–413. https://doi.org/10.1016/j.indmarman.2020.04.010

Chretien, J.-P., Rivers, C. M., & Johansson, M. A. (2016). Make data-sharing routine to prepare for public health emergencies. *PLOS Medicine*, *13*(8). https://doi.org/10.1371/journal.pmed.1002109

Collections. United Nations COVID-19 Response Creative Content Hub. (2020). https://unitednations.talenthouse.com/collections.

Covid-19 Publishers Open Letter of Intent - Rapid Review. OASPA. (2020, April 27). https://oaspa.org/COVID-19-publishers-open-letter-of-intent-rapid-review/.

Dahlander , L., & Wallin, M. (2020, June 5). *Why now is the time for "Open innovation"*. Harvard Business Review. https://hbr.org/2020/06/why-now-is-the-time-for-open-innovation.

Ellemers, N. (2020). Science as collaborative knowledge generation. *British Journal of Social Psychology*, *60*(1), 1–28. https://doi.org/10.1111/bjso.12430

Fraser, N., Brierley, L., Dey, G., Polka, J. K., Pálfy, M., Nanni, F., & Coates, J. A. (2021). The evolving role of preprints in the dissemination of COVID-19 research and their impact on the science communication landscape. *PLOS Biology*, *19*(4). https://doi.org/10.1371/journal.pbio.3000959

Gude, K., & Navarro, C. (2020). *Coronavirus infographic: Breaking the chain of infection.* Gudethinking. https://www.gudethinking.com/coronavirus-infographic.

Hua, J., & Shaw, R. (2020). Coronavirus (COVID-19) "infodemic" and emerging issues through a data lens: The case of China. *International Journal of Environmental Research and Public Health*, *17*(7), 2309. https://doi.org/10.3390/ijerph17072309

Humphreys, G (2021). Has COVID-19 changed researcher behaviour? https://wellcome.org/news/has-COVID-19-changed-researcher-behaviour.

Kadakia, K. T., Beckman, A. L., Ross, J. S., & Krumholz, H. M. (2021). Leveraging open science to accelerate research. *New England Journal of Medicine*, *384*(17). https://doi.org/10.1056/nejmp2034518

Larivière, V., Shu, F., & Sugimoto, C. (2020). The Coronavirus (COVID-19) outbreak highlights serious deficiencies in scholarly communication. https://blogs.lse.ac.uk/impactofsocialsciences/2020/03/05/the-coronavirus-COVID-19-outbreak-highlights-serious-deficiencies-in-scholarly-communication/.

Lee, J. J., & Haupt, J. P. (2020). Scientific globalism during a global crisis: Research Collaboration and open access publications on COVID-19. *Higher Education*, *81*(5), 949–966. https://doi.org/10.1007/s10734-020-00589-0

Lindley, A. (2021). *Evidence and opportunities: Incorporating citizen science into policy.* Evidence and opportunities: Incorporating citizen science into policy - Networks of evidence and expertise for public policy. https://www.csap.cam.ac.uk/news/article-policy-incorporating-citizen-science/.

Minari, J., Yoshizawa, G., & Shinomiya, N. (2020). COVID -19 and the boundaries of open science and innovation. *EMBO Reports*, *21*(11). https://doi.org/10.15252/embr.202051773

Naujokaitytė, G. (2021, January 12). COVID-19 triggered unprecedented collaboration in research. *Science Business*. https://sciencebusiness.net/COVID-19/news/COVID-19-triggered-unprecedented-collaboration-research.

Nguyen, V. T., Benchoufi, M., Young, B., Ghosn, L., Ravaud, P., & Boutron, I. (2019). A scoping review provided a framework for new ways of doing research through mobilizing collective intelligence. *Journal of Clinical Epidemiology*, *110*, 1–11. https://doi.org/10.1016/j.jclinepi.2019.02.007

Ross, J. S. (2021). COVID-19, open science, and the Cvd-covid-uk initiative. *BMJ*. https://doi.org/10.1136/bmj.n898

Sá, C., & Sabzalieva, E. (2018). Scientific nationalism in a globalising world. In B. Cantwell, H. Coates, & R. King (Eds.), *Handbook on the politics of higher education* (pp. 130–148). Cheltenham: Edward Elgar Publishing.

Spohn, S. (2020, June 30). *Why infographics and other visual content are saving lives from COVID-19*. Contently. https://contently.com/2020/06/30/visual-content-infographics-COVID-19/.

Ulahannan, J. P., Narayanan, N., Thalhath, N., Prabhakaran, P., Chaliyeduth, S., Suresh, S. P., Mohammed, M., Rajeevan, E., Joseph, S., Balakrishnan, A., Uthaman, J., Karingamadathil, M., Thomas, S. T., Sureshkumar, U., Balan, S., & Vellichirammal, N. N. (2020). A citizen science initiative for Open Data and visualisation of COVID-19 outbreak in Kerala, India. *Journal of the American Medical Informatics Association*, *27*(12), 1913–1920. https://doi.org/10.1093/jamia/ocaa203

United nations global call out to creatives - help stop the spread of COVID-19. Talenthouse. (2020). https://www.talenthouse.com/i/united-nations-global-call-out-to-creatives-help-stop-the-spread-of-COVID-19.

United Nations. (2020). *Coronavirus*. United Nations. https://www.un.org/en/coronavirus.

van Panhuis, W. G., Paul, P., Emerson, C., Grefenstette, J., Wilder, R., Herbst, A. J., Heymann, D., & Burke, D. S. (2014). A systematic review of barriers to data sharing in public health. *BMC Public Health*, *14*(1). https://doi.org/10.1186/1471-2458-14-1144

Whitty, C. J., Mundel, T., Farrar, J., Heymann, D. L., Davies, S. C., & Walport, M. J. (2015). Providing incentives to share data early in health emergencies: The role of journal editors. *The Lancet*, *386*(10006), 1797–1798. https://doi.org/10.1016/s0140-6736(15)00758-8

Why open science is critical to combatting COVID-19. OECD. (2020, May 12). https://www.oecd.org/coronavirus/policy-responses/why-open-science-is-critical-to-combatting-COVID-19-cd6ab2f9/

World Health Organization. (2018). *TDR | crowdsourcing in health and health research: A practical guide*. World Health Organization. https://www.who.int/tdr/publications/year/2018/crowdsourcing-practical-guide/en/.