Proceedings of the Indian National Science Academy
https://doi.org/10.1007/s43538-022-00104-2

REVIEW ARTICLE

Open Science: Challenges, Possible Solutions and the Way Forward

Nishant Chakravorty[1,2] · Chandra Shekhar Sharma[1,3] · Kutubuddin A. Molla[1,4] · Jitendra Kumar Pattanaik[1,5]

Received: 28 April 2022 / Accepted: 23 August 2022

Abstract
Everyone agrees that scientific communication should be free for all. Unfortunately, accessing publications from many reputed journals comes at a high cost—a cost that many researchers and institutions cannot afford. Although, open-access publication model is considered by many as a possible route to ensure that science is free for all; however, it is fraught with its own challenges. This review attempts at exploring the possibilities of keeping science accessible. Firstly, we re-visit the meaning of "open science" as a comprehensive concept which includes open source, data, access, resources, peer review etc. and not merely open access publication model. Next, we have discussed the global initiatives towards open access—the Budapest Open Access Initiative, Bethesda Statement on Open Access Publishing, Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, cOAlition S and its Plan S initiative, UNESCO Recommendation on Open Science and the San Francisco Declaration on Research Assessment (DORA). Following this we have included the various open access initiatives from India. In the next part, we have focused on problems with dissemination of scientific outcomes and the challenges associated with existing publication models. Finally, we explore the possible solutions to the existing challenges, which include promotion of pre-print servers and other ideas that we have detailed in the manuscript.

Keywords Open science · Open access publication · Pre-prints · Journal metrics

Introduction

The ongoing COVID-19 pandemic has claimed millions of lives across the globe within a short span of two years and humanity is still grieving. The rapid pace at which the disease emerged and hit us worldwide was completely unexpected to all of us. People across the world started scrambling for answers to questions on the origin of the disease, how to prevent it and to find the remedial strategies. While the clinicians began treating patients with their limited armory, scientists put their machinery to task and began unfolding the mysteries surrounding the new disease. Although there are many questions unanswered to date, yet the concerted efforts of the scientific community have led us to several protocols to prevent the spread of the disease and enabled development of many vaccines. And all this happened at such a pace that no one could have imagined in the 20th century. This journey is a testimony to the fact that exchange and spread of scientific knowledge should be unhindered. While the COVID-19 pandemic has been a wake-up call for a collective and united effort by all countries, scientific predictions suggest that we are faced with greater threats in the near future. The United Nations Secretary General, António Guterres has labeled the recent report by the Intergovernmental Panel on Climate Change (IPCC) as a "code red for humanity". This calls for a faster, greater and quicker action to avert a brooding climate catastrophe on the horizon. It is evident that such progress cannot be achieved in isolation but requires global concerted endeavors. And this in turn requires rapid exchange of scientific ideas, data and results. Unfortunately, accessing scientific publications from many reputed journals comes at a high

✉ Nishant Chakravorty
inyasindia@gmail.com; nishant@smst.iitkgp.ac.in

1 Indian National Young Academy of Sciences (INYAS), New Delhi 110002, India

2 School of Medical Science and Technology, Indian Institute of Technology Kharagpur, Kharagpur 721302, India

3 Indian Institute of Technology, Hyderabad 502284, India

4 ICAR-National Rice Research Institute (NRRI), Cuttack 753006, Odisha, India

5 Department of Geology, Central University of Punjab, Bathinda 151401, India

Published online: 02 September 2022

cost—a cost that many researchers and institutions across the globe cannot afford.

In 2018, an international consortium of funding bodies and research organizations by the name cOAlition S, launched an initiative known as "Plan S" (Plan S 2018). The main principle of cOAlition S is that: "With effect from 2021, all scholarly publications of the results from research funded by public or private grants provided by national, regional and international research councils and funding bodies, must be published in Open Access Journals, on Open Access Platforms, or made immediately available through Open Access Repositories without embargo" (What is cOAlition S?, accessed 2022). At present India is not a part of this consortium. Although, open-access publication is being considered as a possible route to ensure that scientific knowledge is free for all; however, it is fraught with its own challenges, like emergence of predatory journals, exorbitant open access fees/ article processing fees, funding support etc. Considering the fact that many publication houses support self-archiving and pre-print repositories, many scientists are of the opinion that these can be alternatives to keep science free.

The purpose of this white paper is to reflect upon the challenges to open science, possible solutions and the way forward.

Meaning of Open Science

"Open Science" encompasses the broad concept of dissemination of all components of scientific research to all sectors of the society including experts and non-experts. Therefore, open science advocates the principles of transparency and accessibility of scientific knowledge. Such principles can only be nurtured by developing strong and progressive global collaborative networks.

Open Science is not synonymous with "Open Access", although it does form an integral part of the open science initiative. It may rather be considered as a larger movement to make scientific knowledge free for all. Figure 1 highlights the fundamental components of "Open Science" which includes, open access publications, open hardware, open source software, open research methodology, open research data, open resources etc.

The following section discusses these various components briefly:

Open Access: The term "open access" refers to free and unrestricted access to peer reviewed scientific content under appropriate licensing agreement and respecting copyrights. The concept of "open access" in science broadly encompasses (but is not limited to) "open access publications" and "open and free communication channels" and is aimed towards dissipation of scientific knowledge and new findings

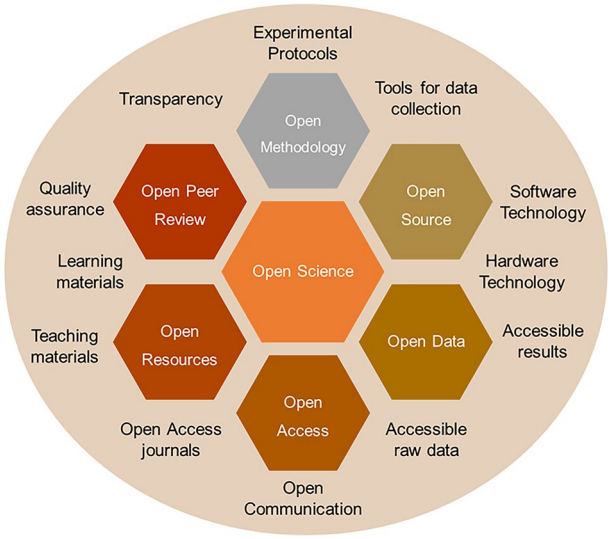

Fig. 1 Principles of Open Science (adapted from (Kraker 2011) and (What is Open Science?, accessed 2022))

to the wider community, without any payment firewalls. However, the scientific publication process requires funds and is mostly managed by professional "for-profit" publication houses, and therefore the costs need to be recovered from other sources, if not the subscribers. This has led to charges like, "article processing fees" and "open access fees", which in most cases need to be paid by authors/institutions or funding agencies. In recent times, several journals have initiated "podcast" communications which encourage authors to directly record the summary of their work for dissipation. Such concepts help in to promotion of open and free communication. Since "Open Access" is considered as one of the most crucial components of "Open Science", this article discusses open access publications and their pros and cons in more detail separately.

Open Data: "Open Data" can be defined as freely accessible data that can be used, reused and distributed freely, provided that the original data source is appropriately acknowledged. The concept of "open data" encompasses the principle of "scientific data for all" and is focused on finding mechanisms to make scientific data, observations and results available for anyone and everyone who may be interested in accessing, analyzing and interpreting them. The global scientific community has been pushing for open data for a long time now since the 1950s and 60s, when the International Council of Scientific Unions (International Council for Science) created the World Data Centers and established CODATA (Committee on Data) (World Data Center System, accessed 2022; Committee on Data International Science Council, accessed 2022). The Council also recommended machine-readable data formats. In fact, the genesis of the internet and world wide web is believed to be founded on

the idea of open science data. Proponents of the open science movement have well realized the importance of open scientific data in addition to open publications. The Berlin Declaration, in 2003, which was one of the first open science initiatives, also supported the promotion of widespread dissipation of scientific information in various formats. International organizations like the OECD (Organization for Economic Co-operation and Development) have played a critical role in developing open data policies that can be considered truly "international" and not restricted to any borders. The principles for access to research data coming out of publicly funded projects was codified by OECD in 2007 (OECD, accessed 2007). The FAIR (findability, accessibility, interoperability, and reusability) Guiding Principles were published in 2016 in the journal Science Data by a consortium of scientists and organizations and these principles are considered as the cornerstone for open scientific data (Wilkinson et al. 2016). These principles underscore machine-actionability for open science and science data, and machine-actionability requires appropriate formatting of data. The "Findability" principle of FAIR emphasizes the need for proper "metadata" that can be easily findable for humans and computers. "Accessibility" stresses on the mechanisms of accessibility. Since data needs to be correlated and worked-on with other available data, the "Interoperability" principle highlights the need for following appropriate formats following FAIR principles. Lastly, the principle of "Reusability" stresses on the need for well-described metadata and data so that they can be used in any setting.

Open data requires open data sharing platforms. And such platforms are fraught with their own challenges which include addressing privacy concerns, copyright protection, ownership and legal issues. One of the early initiatives for data accessibility was publication of data by journals in the form of associated files, datasets etc. Publication houses have also come up with journals specific for data sharing (e.g. Elsevier's Data-in-brief). Besides these initiatives, several organizations have developed open data repositories. To be successful in the mission for open data sharing, such repositories should be specific to their scientific disciplines and follow the FAIR principles.

Open Source: The term "Open Source" is usually used to describe software codes that are made freely available for users. The code is made available to all users under the terms of a software license and the development model relies on the concept of peer production. Open source software programs have been a boon to the scientific community and many formal institutions supporting the development of open source tools have arisen in the recent past. As per the Battery Open Source Software Index (BOSS), open source software tools like Linux (Red Hat), Git (GitHub), MySQL (Oracle), Node.js (NodeSource), Docker (Docker), Elasticsearch (Elastic), Spark (Databricks, MongoDB (MongoDB amd Selenium (Sauce Labs) are among the most economically important open source projects (McCann 2022; Thakker et al. 2022). Like the concept of open source software, there is also a concept of open source hardware. The basic concept here is to release the initial specifications of the hardware to the general community and allow them to use it without charging any fees.

Open Methodology: "Open Methodology" often is considered synonymous with open source; however, it actually encompasses a wider meaning and refers to opening up of research methods that are used in order to conduct experiments and reach reproducible scientific conclusions. Thus, "Open Methodology" envisions a wider concept and is not necessarily restricted to software and computer codes. Concepts like "Open Notebooks" (making daily research work publicly available), "Open Workflows" (transparency in workflows) and "Open Annotations" (use of appropriate and accepted classification and nomenclature) are often considered parts of open methodology. The primary and most concerning argument against "Open Notebook" ("Methodology") is that it may constitute as a prior publication (disclosure) and thus may make patenting an innovation virtually impossible. Thus, the "Open Notebook" concept is not advisable for such projects which are expecting outcomes that can be patented. Secondly, researchers are also concerned that it may lead to theft of scientific data. However, internet-based platforms with proper time-stamps may help us avoid such conflicts. Several researchers have started practicing open methodology and open notebook principles through different platforms. Prof. Peter Murray-Rust from University of Cambridge who is well-known for this support for open access and open data is also a strong proponent of open science notebook (ContentMine 2015).

Open Peer Review: "Open Peer Review" is considered another step towards increasing transparency in research. There are different mechanisms to enable open peer review, e.g.: publishing peer review content, discussion forums between authors, reviewers and editors, open review in public domain, peer comments during presentations and journal clubs, post-publication review through platforms like Pubpeer. Indeed, all these mechanisms have their own merits and demerits. Publishing peer review content may make reviewers more skeptical in asking questions discussion forums between authors, reviewers and editors may lead to unpleasant altercations in public domain etc. Revealing the names of reviewers has its own concerns—on one hand, it promotes transparency, while on the other hand, it may lead to personal grievances that are detrimental to progress in science.

Open Resources: Open resources includes materials for teaching, learning and research in any form (physical materials or on digital platforms) that are available on open public

domain or are made available under licensed agreements, thus allowing free access, usage, adaptation and redistribution by all. These may be made available with no or limited restrictions as per the 2019 UNESCO Recommendation on Open Educational Resources (OER).

Open Access for Open Science

As highlighted above, "Open Access" constitutes a set of principles that allows free distribution of research outcomes to the society without any barriers and also envisions the mechanisms that allow implementation of such principles. It is considered by many as the structural backbone of "Open Science". While all forms of published research outcomes come under the purview of "Open Access", the primary focus has been on peer-reviewed content—the content, we mostly find in journal publications. Peer-reviewed research publications are highly valued in the scientific community owing to the credibility of the available information, as it is verified through the rigor of scientific scrutiny during the process of peer-review. Open access publications have been classified under various categories depending on the models used:

- Gold Open Access: All scholarly contents under this model are made freely available immediately upon publication under a specific end user license agreement—usually through a Creative Commons license or any other similar license. Under this model, the copyright usually resides with the authors. This model generally relies on the "author-pays" modality in most cases. However, this "author-pays" model has been criticized by many in the scientific community and is believed to widen the gaps between the Global North and Global South.
- Green Open Access: Several journals and publication houses allow self-archiving of scholarly publications by authors under the "Green Open Access" model. Such archival is usually permitted on websites managed by the authors or the funding agencies or by some independent repository. The version of the article under this model may or may not be final accepted version. Several journals, however, do not permit immediate open access and may ask for an embargo period. This is an attractive model for researchers as it does not charge any fees from authors. However, the embargo periods imposed by most journals/publishers makes it challenging to disseminate research outcomes immediately and hence is not considered to be in the true spirit of "open access".
- Diamond/Platinum Open Access: Some publication houses have introduced another model termed as "Diamond/Platinum Open Access" that allows for making publications open access without charging any fees from authors or from users. As understandable, the funding for these publications come from external sources like advertisements, institutions, academies, scholarly societies, funding agencies or philanthropists etc. Although this is an attractive model, unfortunately it is vulnerable to conflict of interest violations because of sponsorship mechanisms implemented.

A brief look at the global initiatives towards "Open Access"

Budapest Open Access initiative (Budapest Open Access Initiative, accessed 2022)

The Budapest Open Access Initiative (BOAI) is among the early initiatives by scientists to make science free for all. The initiative emerged from a conference in Budapest convened by the Open Society Institute in December 2001. There were 16 original signatories to the BOAI who issued a public statement of principles for open access. BOAI recommended that authors should exercise self-archiving and scholars should launch new online open access initiatives. At present there are thousands of signatories for the initiative. On the 10th anniversary of BOAI, it reaffirmed the principles and released recommendations towards the goal that open access will be the default mode of knowledge dissipation for research in the next 10 years.

Bethesda statement on Open Access publishing (Bethesda Statement on Open Access Publishing, accessed 2022)

In 2003, Howard Hughes Medical Institute convened a small gathering of eminent people to discuss the rising concerns with academic publications. The group defined the term "Open Access". The definition of OA publications as per the statement indicated towards meeting two conditions to be considered as an Open Access publication. Firstly, such publications should be made freely available to its users for "copying, using, distribution, transmission and display". And secondly, the publication should be deposited in an appropriate online repository.

Berlin declaration on Open Access to knowledge in the sciences and humanities (Berlin Declaration on Open Access, accessed 2022)

The Berlin Declaration was another milestone for open access initiatives globally. The declaration was essentially an international statement on open access that arose during a conference convened by the Max Planck Society in Berlin in 2003. The Berlin Declaration was drafted along the lines of the Budapest Open Access Initiative, Bethesda Statement

on Open Access Publishing and the ECHO charter and was an attempt to advance scientific knowledge across the globe and determine measures for consideration by different stakeholders of scientific research. The definition of Open Access reflected similar ideas as per the Bethesda Statement.

cOAlition S and its plan S initiative (Plan S 2018; What is cOAlition S?, accessed 2022)

In 2018, a group of national research funding bodies of different countries with the support of the European Commission and the European Research Council (ERC) launched the cOAlition S initiative. It was developed around the "Plan S" and an aspiration to make scientific data free, available fully and immediately as published. As per the Plan S, *"With effect from 2021, all scholarly publications on the results from research funded by public or private grants provided by national, regional and international research councils and funding bodies, must be published in Open Access Journals, on Open Access Platforms, or made immediately available through Open Access Repositories without embargo."*

In addition to the basic principle to publish on OA platforms, as per Plan S, funding agencies also aim towards:

1. Ensuring that copyrights shall be retained by authors or their institutions.
2. Devising firm criteria to ensure quality is not compromised by open access journals, repositories and other open platforms.
3. Supporting the establishment of new open access journals and platforms in areas which do not have such services yet.
4. Funding agencies or institutions shall cover open access publication fees and all authors should be able to publish in open access platforms.
5. Supporting different business models for open access publications and platforms.
6. Promoting all organizations to coordinate towards ensuring transparency.
7. Extending all principles to all scholarly publications. However, they recognize that open access for monographs and book chapters may require a longer timeline.
8. Not supporting a hybrid publication model. However, the initiative will allow a progressive transformation towards open access.
9. Monitoring compliance/ non-compliance and levying sanctions in case of non-compliance.
10. Not considering journal metrics when evaluating research outcomes and deciding on granting funds.

UNESCO recommendation on Open Science

The United Nations Educational, Scientific and Cultural Organization (UNESCO) adopted the Recommendation on Open Science in November 2021 at its general conference in Paris. It "provides an international framework for open science policy and practice that recognizes disciplinary and regional differences in open science perspectives" (UNESCO, accessed 2022). The recommendation broadly calls for a common and uniform definition of open science, underlines the core values and guiding principles for open science and specific recommendations for priority areas of action.

The UNESCO recommendation defines open science as: *"…as an inclusive construct that combines various movements and practices aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community. It comprises all scientific disciplines and aspects of scholarly practices, including basic and applied sciences, natural and social sciences and the humanities, and it builds on the following key pillars: open scientific knowledge, open science infrastructures, science communication, open engagement of societal actors and open dialogue with other knowledge systems."* This definition truly encompasses the lengths and breadths of open science and calls for a holistic, all-inclusive version of open science that covers all individuals, ethnicities, languages, countries and scientific disciplines and every aspect of scientific practice. The recommendation further defines and discusses the meanings of open access, open research data, open educational resources, open source software, open hardware, open science infrastructure, open engagement of societal actors and open dialogue with other knowledge systems.

One of the key distinctions of the UNESCO recommendation is the recommendation on engagement of societal actors and open dialogue with other knowledge systems, which seemed to have been missing the earlier initiatives. Open engagement of societal actors recognizes the role of all individuals/community and that science should not be restricted to scientists alone. It calls for collaborations in various forms including crowdfunding, crowdsourcing and scientific volunteering. This recommendation encourages greater degree of interaction and immersion of scientists, policy-makers, entrepreneurs and the community. Such interactions are believed to make research more amenable towards solving real-life problems. It also promotes "Citizen Scientists" and calls for wider participation of the "non-professional scientist". The recommendation on "open dialogue with other knowledge systems" attempts

to recognize the importance of different knowledge systems and calls for collaborative efforts towards working together. It also aims towards increasing inclusivity of traditionally marginalized scholars by building bridges. UNESCO's recommendation also recognizes the need for research funding by private players. The key guiding principles for open science according to UNESCO include transparency, scrutiny, critique and reproducibility; equality of opportunities; responsibility, respect and accountability; collaboration, participation and inclusion; flexibility and sustainability. These guiding principles are expected to uphold the values for which these recommendations stand for: quality and integrity; collective benefit; equity, fairness, diversity and inclusiveness.UNESCO has recommended its Member States to take concurrent action on seven areas that include:

1. Promoting a common understanding of open science, associated benefits and challenges, as well as diverse paths to open science.
2. Developing an enabling policy environment for open science.
3. Investing in open science infrastructures and services.
4. Investing in human resources, training, education, digital literacy and capacity building for open science.
5. Fostering a culture of open science and aligning incentives for open science.
6. Promoting innovative approaches for open science at different stages of the scientific process.
7. Promoting international and multi-stakeholder cooperation in the context of open science and with a view to reducing digital, technological and knowledge gaps.

Open Access initiatives in India

India is uniquely positioned in the geo-political arena. While the World Bank classifies India under the lower-middle-income group, none of the major publishers like Elsevier, Frontiers, Springer, Wiley, Taylor & Francis, PLOS ONE etc. provide automatic OA or APC waivers for authors from India. Although, it must be acknowledged that majority of the leading publishing houses allocate some waivers for researchers without funding support and evaluate each request individually. Some publishers like Elsevier have priority waiver policies for countries eligible for the "Research4Life" program. The Research-4life program has been developed with the aim to provide low-and middle-income countries access to peer-reviewed publications online. Unfortunately, India does not qualify for this program as well.

Thus, the need for open science is more glaring for India and other similarly positioned countries than developed countries. Hence, India has been striding with its own efforts towards with open science, albeit with little success.

Here, we present some of the important initiatives from India to make science accessible for all:

National Digital Library of India (NDLI)

The National Digital Library of India (NDLI) has been developed as a project by the Ministry of Education, Government of India with an aim to provide full text index from several sources. It is essentially a virtual repository of learning tools. The NDLI is developed, operated, and maintained by the Indian Institute of Technology Kharagpur. NDLI is available at https://ndl.iitkgp.ac.in/ and presently hosts > 85,000,000 resources. Besides serving as a repository of scholarly resources, it also provides access to several learning resources.

Vigyan Prasar Digital Library

The Vigyan Prasar Digital Library was launched way back in 1989 by Vigyan Prasar and serves as a repository of digitized version of important scientific works published by Vigyan Prasar. It is available through the website: https://vigyanprasar.gov.in/digital-library/. Users can access the contents by creating a free login.*The Indian Medlars Centre (IMC)* (Indian MEDLARS Centre, accessed 2022): The Indian Medlars Centre is one of the oldest initiatives from India. It was set up by the National Informatics Centre and the Indian Council of Medical Research in an attempt to create a single access point for Indian journals. It's first bibliographic database, IndMed was established in 1998.

Indian Academy of Sciences (IAS)

The Indian Academy of Sciences publishes several journals that are freely accessible over the internet.

Indian National Science Academy (INSA)

The Indian National Science Academy (INSA) also publishes several journals, proceedings, and monographs and provides online access to them. In support with National Information System for Science and Technology (NISSAT), INSA had initiated the e-journal@insa project in 2002 with the purpose to facilitate the conversion of INSA journals to digital forms and create an online repository.

Vidyanidhi

The "Vidyanidhi" initiative of the Department of Library Science, University of Mysore and was supported by National Information System for Science and Technology (NISSAT). It was started in 2000 and aimed towards digitalizing and creating a repository of scholarly theses and dissertations. This has been discontinued since 2014.

IISc e-print archives

The Indian Institute of Science has created an online repository of research publications (including pre and post-prints and unpublished outcomes) of faculty members. Access is available through a secured login to http://eprints.iisc.ac.in/.

NISCAIR research journals

CSIR-National Institute of Science Communication and Information Resources has developed an Online Periodicals Repository (NOPR) (http://www.niscair.res.in/resources/nopr). It provides access to full text articles for nineteen research journals published by CSIR-NISCAIR. NOPR also hosts three Popular Science Magazines, Science Reporter (SR), Vigyan Pragati (VP) & Science Ki Duniya (SKD) and a Natural Products Repository (NPARR).

Shodhganga

The University Grants Commission (UGC) has developed a central repository for Thesis/Dissertation" for public access. It is maintained by INFLIBNET Centre—an autonomous Inter-University Centre of the UGC. Shodhganga is available at https://shodhganga.inflibnet.ac.in/.

Initiatives for manuscripts on cultural heritage

Several initiatives have been taken to preserve our cultural heritage and manuscripts, e.g. Kalasampada: Digital Library Resources for Indian Cultural Heritage (https://ignca.gov.in/divisionss/cultural-informatics/kalasampada/), National Databank on Indian Art and Culture (https://ignca.gov.in/divisionss/cultural-informatics/national-databank-on-indian-art-and-culture/), National Mission for Manuscripts (https://www.namami.gov.in/) and Muktabodha: Digital Library and Archiving Project (https://muktabodha.org/digital-library/) (Trivedi, accessed 2022).

India has also witnessed a national consolidation of efforts towards open access through the *Delhi Declaration on Open Access.* The declaration was released on 14th August, 2018. This declaration aimed at the stakeholders of scientific research to promote open science and advocate openness in research communications (Gutam 2018). An advocacy group, Open Access India (OAI) which promotes the principles of Open Access, Open data and Open education in India, was the flagbearer of this declaration. The Delhi Declaration was signed by > 120 signatories from across the country and included representatives of journals, funding agencies, editors, academicians, scientists, journal editors and other professionals committed towards promotion of open access. The idea for this declaration was initially conceived during the UNESCO-NDL India International Workshop on Knowledge Engineering for Digital Library Design in 2017 held in New Delhi and was drafted at the OpenCon New Delhi in 2018 (Das 2018). The final accepted agenda for the Delhi Declaration included 10 points. Briefly summarizing, the declaration advocates for practices on open science and use of open technology for sharing science; endeavoring to publish interim scientific outcomes as preprints/postprints; practice and promotion of openness in the peer-review and other processes of publications; gathering support for the "Open Access" movement; promote open access principles especially for publicly funded research and support alternative mechanisms to measure scientific research outcomes. The declaration also affirms agreement with other calls for open access—the Joint COAR-UNESCO Statement on Open Access, Jussieu Call and Dakar Declaration and promised to follow the international initiative—"Open Access 2020"; and to work towards formulation of a framework for Open Access in India and South Asia. This declaration also calls for creating more awareness on open access and for development of infrastructure towards the same. Open Access India has also proposed the "National Open Access Policy of India (Draft) Ver. 3"in 2017. Details about Open Access India are available at https://openaccessindia.org/.

The Department of Science and Technology, Government of India has also expressed its intent to establish an Open Science Framework through the fifth Science, Technology and Innovation (STI) policy draft (available at: https://dst.gov.in/sites/default/files/STIP_Doc_1.4_Dec2020.pdf). This draft expects to bring fundamental changes in field of science though short-term, medium-term and long-term mission projects. It also recognizes that such changes can only be brought by developing a proper ecosystem that promotes research and innovation—at the level of individuals and institutions. The policy draft mentions creation of a National STI Observatory as a central repository for data (more details are available under the section "Possible Solutions towards Open Science and Open Access"). It also speaks of improving science education by promoting the principle of inclusivity at all levels and the need for connecting science, economy and

society through interdisciplinary education and research. The policy also focuses on other aspects of the ecosystem like modifying the funding ecosystem, reorienting focus on both fundamental and translational research, promoting entrepreneurship, self-reliance, inclusivity, improving science communication to society etc.

Challenges to Open Science

The advent of the internet towards the end of the 20th century revolutionized every walk of human life and science communication was no exception. Prior to the existence of the internet, sharing of scientific knowledge relied on the pace of print media and journals, and incurred associated expenses. This led to the model of subscription-based access. Typically, journal subscription costs are borne by institutions in exchange for provision of access for students and staff. With the dawn of online access, it was expected that such costs will come down. Unfortunately, on the contrary, subscriptions charges by majority of the publishing houses have increased exponentially over the years. As per an article by Taira Meadowcroft posted on 8th October 2020 in University of Missouri Libraries website, journal subscription charges have been increasing much more than the rate of inflation. The article mentions the projected and actual charges for three renowned journals, Nature, Science and New England Journal of Medicine (NEJM). As per the data the actual charges are 113.78 times higher than projected charges for Nature, 189.18 times for Science and 244.49 times for NEJM (Meadowcroft 2020a). Academic publishing houses are "for-profit" businesses with very little competition. The publishing giants, Elsevier, Wiley-Blackwell, Springer and Taylor & Francis collectively are known to publish more than 50% of global research products (Meadowcroft 2020b). Exorbitant subscriptions charges are often a deterrent to most universities and institutes across the globe. Profit margins of most of the global publication giants have been increasing with each passing year. Elsevier is known to operate at a 37% profit margin and Springer Nature at 23% margin in 2018 (Aspesi 2019). Scientific publications are neither luxury items nor for mass market consumption. It is very difficult for a scientific publishing house to justify having such a margin, particularly when large parts of the world remain ignorant of the scientific knowledge they are withholding that may benefit the lives of countless people. Unsurprisingly, such profit margins have caused a major furor within the academic community in the recent years.

Disruptive innovations like Sci-Hub and Libgen, which although are flagged with ethical and legal concerns, have opened up the public debate on open science. Sci-Hub provides free access to scientific articles. This website acts like a shadow library and provides free access to scholary articles without any regards to copyrights and paywalls (Himmelstein et al. 2018) and has extensive user base across the globe. Libgen is another website which operates as a file-sharing-based shadow library website, providing free access to scholarly content. Although praised by many from the scientific community, these platforms have been embroiled in legal battles in several countries. Even in India, lawsuits have been filed against Sci-Hub and LibGen by Elsevier, Wiley and the American Chemical Society for copyright infringement in Delhi High Court. One of the key arguments put forward by Sci-Hub's legal team has been that the platform provides educational materials to scientists and researchers and thus it should fall under the "fair dealing" exception criterion of India's copyright law—a defense used by academic institutions to justify usage of copyrighted materials for students coming from low-income strata (Else 2021). Such disruptions to the lucrative industry have led to changes in policies by many institutions, universities and the publication houses. There seems to have been a major push towards open access publication, as explained above. Unfortunately, this model has met with a lot of criticism as well. Open access fees for most of the renowned journals are very high and often unaffordable for researchers from the underdeveloped and developing countries. Although, majority of the publication houses offer waivers/ partial waivers for low and medium income countries, and at times to authors with no research funding available, the efforts seem to be restrictive and disproportionate. Many countries, like India, which are classified as a low-middle-income economy by the World Bank (World Bank Country and Lending Groups 2022), are not a part of such lists by publishing houses. Besides this, many scientists who generally support open science and open access, dislike the concept of pay-to-publish.

Open access publication has also been capitalized as an opportunity by many "predatory" journals. Such journals do not respect any bounds of proper peer review process and often publish poor quality articles without any scientific merit in exchange for publication charges.

While the idea of "Open Access" (OA) publications is very attractive to everyone, we need to acknowledge the challenges surrounding the initiative –

1. Associated costs—Who should bear the expenses for OA publication—Funding agencies, Institutions/ Universities, individual researchers, commercial sponsors? Since OA publication charges for journals of repute are usually high, all stakeholders tend to pass the ball to each other and this leaves the researchers to be at the receiving end.
2. Quality issues—concerns with predatory publications—How to ensure strict peer review without using journal metrics? Although peer review is an integral part of the publishing process; unscrupulous publishers do not respect the bounds of stringent and strict peer review

and work on a "pay-to-publish" model, which is devastating for science. It is considered as an exploitative model demanding publication fees from authors and then publishing these articles on their platforms rapidly without any/ minimal scrutiny. Many times, such journals may charge "Article Processing Fees" and not OA fees—which means they charge fees for publishing and yet they are not OA. Unsuspecting researchers fall in the trap of such predatory publishers and end up publishing their outcomes (which may or may not be scientifically appropriate).

3. Exorbitant profit margins at the expense of hard-work of authors and reviewers—What is the best model to eliminate oligopolies? Present day scientific publishing is managed by a handful of publishers and hence can be considered oligopolies. This lack of competition leads to the huge profit margins for OA publications.
4. Publication inequality—How to provide equal opportunities to all countries? The World Bank classifies the countries into low-income economies, lower-middle-income economies, upper-middle-income economies and high-income economies. Unfortunately, the waiver policies of the publishing houses do not necessarily match this classification. And this leaves many developing countries deprived of these waivers in spite of being classified under low-income or lower-middle-income economies. This leaves us questioning the merits of the classification system followed by publishers.
5. Publication biases—How to encourage researchers to share all outcomes—positive or negative? Very few journals are keen on publishing negative results, as they believe their impact will be reduced if they publish negative results. And this leads to publication biases amongst researchers. They tend to submit only positive outcomes for publication and dumping their negative results. This is detrimental to science.

Burden of journal metrics and their influence on Open Access publications

Academic careers and journal publications are known to be inter-twinned. "Publish or perish" is an aphorism appropriately describing the pressure on academicians to publish in reputed scientific journals. And the mention of "reputed" scientific journals brings the burden of journal metrics into the picture. While there are several journal metrics in vogue, the most common and arguably the most valued metric is the "impact factor" or "journal impact factor"(IF/ JIF). It is a scientometric index that was devised by Eugene Garfield (Garfield 2006), the Founder of Institute for Scientific Information—ISI (now known as Clarivate Analytics). This metric is essentially a measure of the frequency of an article published in the journal being cited during a particular year or period. Although "impact factor" was initially devised as a parameter to help libraries and institutes prioritize their subscriptions; unfortunately, IF has become synonymous with a journal's reputation. Such a correlation has been described to be fallacious by many experts. Many subject areas are more widely researched and consequently gain more citations compared to others, and this usually gets converted to the higher IF for such journals. And this in turn has been found to be used as a parameter to evaluate an academician's performance, which usually affects their career progression, either directly or indirectly.

As mentioned above, IF is not the only metric used to judge a journal's performance. Several other metrics like CiteScore, Eigenfactor, Google Scholar Metrics, SCImago Journal & Country Rank (SJR), and Source Normalized Impact per Paper (SNIP) have been developed. However, none of the metrics can be considered the "best" or "most optimum" and each have their own merits and drawbacks. Some of the common journal metrics in vogue and their major criticisms have been highlighted in Table 1. Global movements towards "Open Science" and "Open Access" have further complicated the usage of such metrics. It is evident that open access publications have wider readership, since end-users are not restricted behind paywalls and thus receive more citations compared to subscription-based journal articles. This conviction has been corroborated by researchers who investigated this proposition (Harnad and Brody 2004; Hajjem et al. 2005; Kousha and Abdoli 2010). Unfortunately, many journals are seen to openly influence researchers to publish in open access journals by stating that it increases chances of getting cited and hence improving their academic performance. Such forms of promotion should be considered unethical and discouraged. This is not only detrimental to research in general, but also to researchers and journals themselves (both subscriptions based and open access journals). While several traditional and good quality subscription-based journals (in terms of their stringent peer review process and workflow) are losing out on good quality research publications owing to such influences; open access publications are often seen to be tempted to publish attractive and ground-breaking results at record speed without a rigorous peer review process. This has also led to sprawling of predatory journals at times.

"Open Metrics and Impact" are also being considered as the new components of the "Open Science" movement. For example, Altmetrics, enables us to measure and watch the outreach and impact of scholarly articles through online interactions like Wikipedia citations, citations in publicly available policy documents, ongoing discussions in blogs, media coverage, bookmarks on reference managers etc. (Altmetric, accessed 2022). Bibliometrics is another such metric that uses statistical methods to analyze scholarly scientific

Table 1 Common Journal Metrics and their major drawbacks

Journal Metric	Description	Criticism
Journal Impact Factor (JIF)	The average of the sum of the citations received in a given year to a journal's previous two years of publications divided by the sum of "citable" publications in the previous two years	Lack of transparency and reproducibility in the way citations are counted in the numerator and the "subjectivity" involved in considering a "citable item"
h-index	This index shows the journal's number of articles (h) that have received at least h citations	It ignores several critical factors like quality of citing articles, journals, author self-citations etc.
CiteScore	CiteScore is calculated on the basis of number of citations to documents (and not only research/review articles) by a journal over four years, divided by the number of the same document types indexed in Scopus and published in those same four years. It is calculated on a monthly basis for the ongoing year and is fixed as a permanent score in the month of May of the following year	Several high impact journals score low on CiteScore owing to the inclusion of non-research material (news, editorials, letters, etc.) in its denominator while calculating the score
SCImago Journal Rank (SJR)	The SJR metric attempts to take into account the concept of "transfer of prestige" between journals through their citation links. SJR thus assigns more weightage to a citation coming from high-SJR source and vice-versa	SJR has been criticized for the fact that it excludes a lot of information and thus questions are raised regarding its transparency, reliability and suitability
Source Normalized Impact per Paper (SNIP)	The SNIP metric inherently accounts for field-specific differences in citation practices. SNIP compares each journal's citations per publication with the citation potential of its field. Citation potential is defined as the set of publications citing that journal	Complicated calculation of the metric and like other metrics it does not address the bias of review articles. Further, if a journal gets cited by a highly prestigious multi-disciplinary journal like Nature, it's SNIP value will be lowered (although its citation potential becomes higher)
Eigenfactor	This score is expected to measure the significance of the journal to the research community and it takes the origin of the incoming citations into consideration as well. Like SJR, Eigenfactor also account for citations based on "prestige of journals" from which citations are coming. Thus citations from more important journals result in higher Eigenfactor scores. It excludes all journal self-citations (as opposed to SJR which includes them up to a certain limit)	It is difficult to compare across disciplines as it allocates all journals into one category
Immediacy Index	This index measures how frequently an average article from a journal is cited within the same year as publication	Many journals with articles having more impact in the future will have lower immediacy index
Altmetrics	It helps scientists to measure and watch the outreach and impact of scholarly articles through online interactions like Wikipedia citations, citations in publically available policy documents, ongoing discussions in blogs, media coverage, bookmarks on reference managers etc.	Lack of enough data related to Altmetrics and it is difficult to translate the outcomes to actual impact of the articles
Bibliometrics	Uses statistical methods to analyze scholarly scientific publications	Only looks at citations and not at the quality of research or outcomes. It is susceptible to be exploited to artificially boost the scores
Webometrics	Computes the extent of the World Wide Web, to know about the number and kinds of hyperlinks, structure and usage patterns	Lack of stringency over the web samples that are being used to arrive at the score. This is especially important as the world wide web is unregulated to a large extent, which raises questions on the sampling. Moreover, web citations are often seen to be for very small unimpactful reasons
Semantometrics	Uses manuscript fulltexts to evaluate the quality and worth of the publication	Considered as an extension of tools like such as bibliometrics, webometrics, and altmetrics. Lack of clear understanding of its significance when evaluating journals/ articles

publications. Webometrics on the other hand tries to compute the extent of the World Wide Web, to know about the number and kinds of hyperlinks, structure and usage patterns. As opposed to the rest, Semantometrics tries to use the manuscript full-texts to evaluate the quality and worth of the publication. Although none of these new metrics are perfect; however, they clearly acknowledge the burden of traditional metrics and are a step forward towards finding newer alternatives. This points towards the need to move towards more inclusive forms of assessment for researchers and journals.

Several institutions across the globe are deciding to do away with the use of such metrics while evaluating academic performance. Instead, evaluation committees should put more weightage on the actual merits of the research outcomes—which may be measured by citations/ usage in online interactions (much like Altmetrics)/ relevance to the work being considered at the institute/ performance during direct interactions/ feedback responses etc. Such a move should be considered as a welcome change in the right direction. The San Francisco Declaration on Research Assessment (DORA) emerged in December 2012 during a meeting of the American Society for Cell Biology. The declaration aims towards derecognizing journal impact factors as a marker for scientific contribution. Although the DORA declaration may not be considered as a direct promotion for open science; however, the implications of the declaration have far reaching consequences towards open science. The primary vision of DORA has been *"to advance practical and robust approaches to research assessment globally and across all scholarly disciplines"*. DORA intends to raise awareness about new tools for research assessment and judicious usage of metrics. It intends to facilitate implementation of the declaration through formulation of new framework for hiring/ promotions and research funding decisions and plans to catalyze changes by working across all disciplines. Another objective of DORA is to improve equity by calling researchers' representation while designing policies for research assessment, especially for the ones that directly address structural inequalities in the academic sector. The signatories intend to achieve these objectives through better community engagements, development of resources for good practices, creating partnerships, advising academic institutions and funding agencies to revisit their policies and organizing academic meetings of various stakeholders.

Possible solutions towards Open Science and Open Access

Prof. Peter Murray-Rust from University of Cambridge is a world-renowned advocate of Open Science. According to Prof. Murray-Rust, *"We must reset our values to put the world first and fast—if we do not, then global problems will overwhelm us. Open Science is a key part of our toolset. But "Open" is a broad and often misused label ("openwashing"). True Openness—such as in Open Notebook Science—brings major benefits…"*. Their team has been illustrating these principles through their projects on open notebook data science, mining open access for open science, CEVopen: for plant literature mining. Their approach is a clear example of incorporating majority of the principles of Open Science not merely focusing on Open Access.

The need for Open Science cannot be overstressed. Science activists across the globe have been advocating the need to find alternative and newer mechanisms to ensure the principles of open science are upheld. This is of interest to developing economies like ours. However, there is no clear path towards developing mechanisms to enable science to be open for all. In a recent article by Chakraborty et al., the need for a national framework for publications and access to scientific literature in India has been discussed in detail (Chakraborty et al. 2020). Chakraborty et al. have also listed out the possible paths for open access to global scientific literature in India which includes promotion of pre-prints and archival of preprints and published articles; creation of a "recommended" list of journals which can be considered for payment of article processing and/or OA charges (although, this path has it's own concerns, like lack of consensus regarding journal qualities, unfair weightage on the journal instead of the quality of the work) and devising a "One Nation-One Subscription" model. They have further recommended promotion of green open access publications, development of institutional mechanisms for national level preprint archive for national science, allocation of 'Publication Charges' as a part of the extra-mural research funds, promotion of national journals published by reputed academies and re-visiting the assessment process of scientific output by focusing on quality of research and not on publication metrics. In another recent article, Koley et al. have highlighted the significance of non-commercial approaches for scientific publications and have cited the examples of Latin American Council of Social Sciences (CLACSO), SciELO (Scientific Electronic Library Online), Redalyc, Latindex and La Referencia, which provide decentralised platforms for e-publication of open access journals from Ibero-American countries (Koley et al. 2020). Such approaches have enabled exchange of open-source software, interoperability and better visibility of scientific publications from Latin America. Koley et al. also appreciate the Open Journal System (OJS)—which is an open-source alternative to manage a journal's editorial process. Other important models include the Latin American initiatives like the collections of OA Diamond Journals which are run jointly by universities, institutions and non-profit organizations. Furthermore, Koley et al. have also highlighted initiatives like Open Research Europe which ensures fast publication and

open peer review for outcomes of Horizon 2020 funded projects; Scholastica as a software for publication process and blockchain-based technologies. They have also proposed a possible alternative publication model that involves minimal editorial involvement, incorporates AI based reviewer selection and allows direct posting of the manuscript during the review process. As per this model, the final call on whether the article merits publication is taken by the Editorial team, based on the reviewer comments; however, it avoids over-dependence on editorial team in the initial phase of scrutiny—a process that overburdens the editorial team and often leads to "desk rejections".

Here, we have attempted to summarize some of the plausible solutions and efforts towards "Open Science" and "Open Access":

- *Consolidated global efforts towards Open Science:* There have been several attempts towards Open Science and Open Access in different parts of the world, as discussed earlier. Historically, the world has been witness to the fact that sporadic movements encompassing global issues have not provided us with long-standing solutions—and science is no exception. Fortunately, we are gradually witnessing the move towards more consolidated global approaches. As mentioned earlier, UNESCO laid down its Recommendation on Open Science and adopted a new open science framework in November 2021. This has been signed by all the 193 Member States of UNESCO. The pressing need for all countries to come together on a single platform to address the problems related to open science seems to be converging finally; however, the member states need to keep the momentum going. Critical resolutions in alignment with the UNESCO recommendations on open science need to be passed and should be made binding for the member states. The initial path on such resolutions will not be simple; however, they will require all stakeholders to adapt to such unpleasant changes and thus make way towards a better future of open science with greater transparency.
- *Promotion of pre-print servers:* The world has been a witness to the rise of pre-print servers for faster and wider dissemination of scientific knowledge. The challenges posed by websites like Sci-Hub and Libgen, along with the push from various scientific organizations have been gradually forcing the publication houses to accept the usage of pre-print servers. Pre-print servers have been a big boon to research and development in COVID-19 as well. They have allowed scientists to post their findings to peer groups as soon as they became available. This in turn has led to many vital outcomes during the pandemic. Pre-prints have been welcomed by the Indian scientific community as well. Chakraborty et al. have stressed the need to promote pre-prints and they have further suggested that the archival of pre-prints and published articles are the key paths to "Open Access" to scientific materials and they recommend the development of institutional mechanisms for national level preprint archive for national science (Chakraborty et al. 2020). Some of the most common pre-print servers that have really helped promote Open Science include arXiv, bioRxiv, ChemRxiv etc. Presently there are possibly more than 60 pre-print repositories. Open Access India & Center for Open Science also have developed a pre-print repository of India which is known as IndiaRxiv. While pre-prints have been very helpful in fast dissemination of scientific outcomes, they should be used with caution, owing to lack of initial peer review before posting. Albeit, the open feedback system does help researchers enrich their work.
- *Reduction of Open Access and Article Processing Fees for the reputed journals:* Open Access Publication requires payment of hefty fees in the form or OA charges of Article Processing Charges (APC). While it is acknowledged that publishing requires expenditure; however, it has been evident that publication houses are charging exorbitantly in the name of these fees and this enables them to make significant profits at the expense of the hard work of scientists and researchers. If websites like Sci-Hub and Libgen are considered "unethical", such practices by publication houses also should be termed "unethical". Many present-day scientists have used harsher words such as "modern day-slavery" for such practices. The need of the hour demands that scientific academies across the globe should come together on a common platform to oppose such unscrupulous cultures and device mechanisms to break these oligopolies.
- *Changing publication models:* Presently-day publication models can broadly be categorized as: (i) Subscription based and (ii) Open Access. The recent addition of pre-print archives has been a welcome move towards developing another layer of access which is immediate and openly accessible to everyone. However, critics do express their concern that pre-print manuscripts are not peer-reviewed and should be dealt with caution.

In the recent years, there has been a major push towards Open Access publication models. And this has led many journals to adopt a "Transformative" approach, wherein they are gradually moving towards becoming fully Open Access (the so-called "gold open access"). However, it is important to note that the Open Access model is also fraught with many of its own challenges as discussed earlier. And thus, many experts express the greater need to promote "green open access" models than fully open access, especially for developing economies (Chakraborty et al. 2020).

Since pre-prints and "Open Access" models are not the only solutions, there is a need to explore other possible

alternatives in publication models. Some of the proposed models may include:

- *Non-Commercial Models:* In the article by Koley et al., the authors have highlighted the significance of non-commercial approaches for scientific publications. The Latin American Council of Social Sciences (CLACSO), SciELO (Scientific Electronic Library Online), Redalyc, Latindex and La Referencia, which provide decentralised platforms for e-publication of open access journals from Ibero-American countries have been cited as classic examples of successful non-commercial publication models (Koley et al. 2020). Such approaches have enabled exchange of open-source software, interoperability and better visibility of scientific publications from Latin America. Other important models include the Latin American initiatives like the collections of OA Diamond Journals which are run jointly by universities, institutions and non-profit organizations (Koley et al. 2020).
- *Federal Publisher Model*—The Federal government or agencies which are responsible for the funding of research can adopt a publisher route and keep them open and free to publish, read and download. Recipients of grant funds may also serve as peer-reviewers for other projects funded by the agencies (with strict policies to avoid any conflict of interest). This will ensure proper peer review mechanism.
- *One Nation One Subscription model*—Federal subscription model conceptualizes that the government negotiates a subscription fee on behalf of the country. The Government of India has been planning to negotiate with publication houses of journals to come up with a "One Nation, One Subscription" policy for India that will ensure access to scientific publications to all citizens in return for a single centrally-negotiated payment and thus help ending the exorbitant individual/ institutional journal subscription models (Draft STIP Doc 2020). This process might lead to fluctuating prices from publishers from year-to-year.
- *An OTT-type subscription model*—There is a need to adopt small subscription charge based models like OTT (over-the-top) entertainment platforms. Such a platform can host different journals, books, monographs etc. like OTT content and can act as a "cloud library" for anyone to access. Since this will be a customer satisfaction-oriented model, this can enable removal of predatory publications from the system as well. The small fee charged as part of this model can increase the subscriber base and effectively lead to similar revenues for publication houses while increasing accessibility.
- *Developing funding mechanisms for Open Access Publications:* The need for developing funding mechanisms for open access publications has been point-out by several researchers. In the article by Chakraborty et al., they have suggested creation of a "recommended" list of journals which can be considered for payment of article processing and/or OA charges. However, they have also raised their concerns with this mechanism, like lack of consensus regarding journal qualities, unfair weightage on the journal instead of the quality of the work etc. (Chakraborty et al. 2020). They have also proposed allocation of 'Publication Charges' as a part of the extra-mural research funds, promotion of national journals published by reputed academies and re-visiting the assessment process of scientific output by focusing on quality of research and not on publication metrics. Herein, we propose an alternative mechanism: governments and funding agencies across the globe may develop funding mechanisms along similar lines as research funding proposals. Such calls should be open throughout the year and should have fast turn-around times. A peer review committee shall evaluate the merits of the manuscripts and accept/ reject the funding request for bearing Open Access Charges. The funding body may specify the journals for which the Open Access charges may be payable.
- *National and international data sharing portals:* Considering the vast amounts of data being generated by the different institutions, countries should consider development of national and international data sharing portals. This will enable fast and easy access of data amongst the scientists and will enable fast and fruitful collaborations. The 5th Science, Technology and Innovation (STI) policy draft by Department of Science and Technology, Government of India intends to establish an Open Science Framework (Draft STIP Doc 2020). This framework will give access to scientific data and resources to all individuals engaged in the Indian STI ecosystem without any bias. The STI Policy draft also talks about creation of a dedicated portal for storing and giving access to data generated by publicly funded projects. This will be created through Indian Science and Technology Archive of Research (INDSTA). The policy draft further calls for mandating self-archiving of accepted versions of manuscripts in institutional or central repositories.
- *Developing a unified social scientific media:* Considering the dearth of "quality" publication houses, they are known to enjoy the oligopoly and absence of true competition. This in turn converts to a lack of accountability when it comes to the entire publication process. Scientists around the globe are aware of the different standards of journals even from the same publication houses. Unfortunately, there is no unified social scientific media, where researchers can rate and review journals, based on their experiences during the publication process. Some online platforms, like Pubpeer (https://

pubpeer.com), ResearchGate (https://www.researchgate.net/) and Academia (https://www.academia.edu/) have attempted to bring researchers on their platform and have enabled sharing of articles, exchange of feedbacks and engagement in discussions on various research topics. However, this new proposed social scientific media platform forsees development of such a platform that will help researchers in the field to be aware of different journals' manuscript handling practices and performances, based on first hand peer-group information, without relying on third-party performance metrics. This platform will initially create a searchable database for journals of "repute" in each field and will have different questions related to the journals (e.g. quality of papers published, time to first decision, review time, quality of reviewers engaged, publication process), which users can answer using a numerical scale. Another section of the platform may engage in a similar exercise for individual articles, where users can like, share and comment (similar to other social media platforms). Since this will be an independent platform, it is expected to be free from biases of individual publication houses and perhaps make them more accountable. The purpose of this platform is not to eliminate third party metrics; however, to strengthen such metrics, by adding a layer of review of the journal performances. This is expected to make journals improve their responsiveness to authors' concerns and eliminate Editor's biases, optimize peer reviews etc.

- *Dissipation of scientific information through genuine social media handles*—Social media platforms like Facebook, Twitter, Instagram and WhatsApp etc. have become part and parcel of our lives. We may choose to love them or hate them, but we surely cannot ignore them. We are all aware of the impact of such platforms when it comes to dissemination of information. Several critics of social media argue that they are mostly means of spreading misinformation. This contention makes an even stronger case for developing mechanisms to spread scientific information through such handles. Despite the initial hesitancy, majority of the members of scientific community have adopted the use of such channels for appropriate dissemination of information. Government ministries and funding agencies also are seen to efficiently use such services. However, there is a need for consolidated efforts towards effective utilization of such resources.
- *Simplifying scientific communication*—The demand for scientific innovations arises from challenges faced by the society at large. However, it is often seen that dissipation of the outcomes of such research rarely reaches the community, unless it is a ground breaking innovation impacting human lives in some way or the other. This disconnect between the scientific community and the general population is detrimental. People are not able to understand the relevance and impact of basic, incremental and pre-translational research. Unless, the general populace is connected to the scientific community as the natural stakeholders, they will not be able to empathize with the challenges and hurdles faced by the scientific community. And the world is aware of the fact that sporadic movements are easily crushed; however, mass movements can move mountains. Initiatives like short essay writing competitions for research scholars, flash presentations in a non-technical language which are being conducted by many scientific organizations are good examples of such opportunities. The success of commercial television programs like SharkTank and Dragon's Den which provide platforms for elevator pitches for entrepreneurs, has shown us a way to make research attractive to the community. Programs modeled on similar lines may be created and showcased on televised media. The Awsar program by Department of Science and Technology, Government of India is a wonderful opportunity for young researchers pursuing PhD/post-doctoral fellowships to connect with the general population of the country through their research stories written in non-technical language that can be understood by anyone. Indian National Young Academy of Sciences' (INYAS) three-minute thesis initiative, "Saransh" is also a unique opportunity for PhD scholars to present their work to the general population within three minutes. The usage of open video sharing platforms like YouTube ensures that such stories can reach everyone. Similar events are organized by different countries across the globe and they are wonderful attempts to engage with the society at large. Such events and initiatives are in alignment with the UNESCO's Recommendation on Open Science Framework which calls for communication to societal actors who are beyond the conventional scientific community. It is expected that such interactions will enable better collaborations between scientists and society and make the scientific process more inclusive by enabling crowdfunding, crowdsourcing and scientific volunteering. Greater engagement of citizens and society at different levels will further help developing scientific practices that focus more on real world outcomes and promote growth of "Citizen Scientists".

Concluding remarks

The world is moving through a major transitional phase—especially in the context of human behavior and lifestyle. The ongoing pandemic, global climate change, and the rapid adoption of new technologies have already created a "new

normal" and we are all witnesses to these changes. Such a transition needs devising new measures and their implementation to open science for all. Implementation of such new measures often requires disruptive changes—changes that encounter resistance from different stakeholders—the common man, academicians, scientists, academic institutions, industries, publishers etc. It is evident that a "one size fits all" approach will fail inevitably.

This article has attempted to summarize several approaches directed towards various aspects of open science. While some approaches may be more user-friendly, others seem to be more acceptable to the scientific community and yet others may be more amenable to publishers. These approaches raise critical debates amongst different stakeholders at times when it comes to identifying the "universal solution". We need to realize the search for the "universal solution" is futile. Instead, the way forward should be a basket of solutions, each having its own advantages and disadvantages, which is subject to the observer's standpoint. This will allow users to have the freedom to pick and choose solutions that are acceptable to them. The major push towards making everything fully "open access" in exchange for fee from scientists, therefore may not be the only way forward. We are already witnessing the impact of the Plan S that is gradually increasing the gap between the Global North and Global South in the academic and scientific community, and this is detrimental to collective growth and scientific prosperity of the world.

Open Science is a movement that impacts everyone in one way or the other and we are possibly standing at the doorstep of this movement. Concerted and collaborative global efforts at every level, starting from individuals to countries at large are needed to make this movement a success. Let us all unite together to make it a better world through Science.

Acknowledgements The authors would like to thank Prof. Peter Murray-Rust, University of Cambridge; Dr. Sridhar Gutam (Convener for Open Access India), ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru and Dr. Oishik Banerji, Science Policy and Evidence team, Royal Society of Chemistry, UK and post-doctoral researcher in Structural Biology and Biochemistry, at Birkbeck, University of London and University College London (the views expressed are entirely in personal capacity and do not represent any organization's viewpoints) for sharing their insights during the 2nd Mid-Meeting of Indian National Young Academy of Sciences (INYAS) held on 13th of August, 2021. A recording of the meeting is available as a permanent link at https://www.youtube.com/watch?v=Vo_RBNBWmQ4.

Declarations

Conflict of interest There is no conflict of interest to declare.

References

Altmetric, How it works. 2015–07–09. Retrieved 2017–02–09. Accessed 28th July 2022.

Aspesi, C. & SPARC (Scholarly Publishing and Academic Resources Coalition). (2019). Research Companies: Elsevier. Landscape analysis. https://infrastructure.sparcopen.org/landscape-analysis/elsevier. Accessed 20th March 2022

Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities https://openaccess.mpg.de/Berlin-Declaration Accessed 06th April, 2022

Bethesda Statement on Open Access Publishing. http://legacy.earlham.edu/~peters/fos/bethesda.htm. Accessed 22nd March 2022

Budapest Open Access Initiative. https://www.budapestopenaccessinitiative.org/read/. Accessed 22nd March 2022

Chakraborty, S., Gowrishankar, J., Joshi, A., Kannan, P., Kohli, R.K., Lakhotia, S.C., Singhvi, A.K.: Suggestions for a national framework for publication of and access to literature in science and technology in India. Curr Sci **118**(7), 1026–1034 (2020). https://doi.org/10.18520/cs/v118/i7/1026-1034

Committee on Data International Science Council. "CODATA Archive". https://codata.org/about-codata/codata-archive/ Accessed 28th July 2022

ContentMine: (2015–11–03) 2014 lecture: Open notebook science by Peter Murray-Rust. https://www.youtube.com/watch?v=-wPYkJJ1PqQ Accessed 28th July 2022.

Das, A.K.: Delhi declaration on Open Access 2018: an overview. Ann. Library Inform. Studies **65**, 83–84 (2018)

Draft STIP Doc 1.4, Science, Technology, and Innovation Policy. December 2020. https://dst.gov.in/sites/default/files/STIP_Doc_1.4_Dec2020.pdf Accessed 28th July 2022

Else, H.: What Sci-hub's latest court battle means for research. Nature **600**, 370 (2021)

Garfield, E.: The history and meaning of the journal impact factor. JAMA **295**(1), 90–93 (2006). https://doi.org/10.1001/jama.295.1.90

Gutam, S.: Delhi declaration on Open Access—signatories. In Advocacy, Conference, Definition, Open Access, Open Access Policy, 14th Feb, 2018

Hajjem, C., Harnad, S., Gingras, Y.: Ten-year cross-disciplinary comparison of the growth of open access and how it increases research citation impact. IEEE Data Eng. Bull. **28**(4), 39–47 (2005)

Harnad, S., Brody, T.: Comparing the impact of open access vs. non OA articles in the Same Journals. D-Lib Magazine, **10**(6) (2004). http://www.dlib.org/dlib/june04/harnad/06harnad.html. Accessed May 23, 2017.

Himmelstein, D.S., Romero, A.R., Levernier, J.G., Munro, T.A., McLaughlin, S.R., Greshake Tzovaras, B., Greene, C.S.: Sci-Hub provides access to nearly all scholarly literature. Elife **7**, e32822 (2018). https://doi.org/10.7554/eLife.32822

Indian MEDLARS Centre: Internet and biomedical information for the Indian Medical Professional. https://www.hon.ch/Mednet2003/abstracts/994528224.html Accessed 06th April, 2022

Koley, M., Namdeo, S.K., Bhattacharjee, S., Afifi, N.A.: Digital platform for open and equitable sharing of scholarly knowledge in India. J. Librariansh. Inf. Sci. (2020). https://doi.org/10.1177/09610006221083678

Kousha, K., Abdoli, M.: The citation impact of Open Access agricultural research: a comparison between OA and non-OA publications. Online Inf. Rev. **34**(5), 772–785 (2010). https://doi.org/10.1108/14684521011084618

Kraker.: Science and the Web (2011). https://science20.wordpress.com/about/. Accessed 21st March, 2022

McCann, J.: The meteoric rise of open source and why investors should care. Forbes. https://www.forbes.com/sites/forbestechcouncil/

2017/09/22/the-meteoric-rise-of-open-source-and-why-investors-should-care/?sh=697c3ae15484 Accessed 28th July 2022.
Meadowcroft, T.: Journal Prices Increase More than True Inflation. Library News (2020a). https://library.missouri.edu/news/lottes-health-sciences-library/scholarly-publishing-and-the-health-sciences-library. Accessed 25th August 2021
Meadowcroft, T.: One journal publishing company is more profitable than Netflix. Library News (2020b). https://library.missouri.edu/news/lottes-health-sciences-library/one-journal-publishing-company-is-more-profitable-than-netflix. Accessed 25th August 2021
OECD: OECD principles and guidelines for access to research data from public funding. OECD Publishing, Paris (2007)
Plan S: Accelerating the transition to full and immediate Open Access to scientific publications. Science Europe. Archived from the original (PDF) on 4 September 2018. https://web.archive.org/web/20180904122211/https://www.scienceeurope.org/wp-content/uploads/2018/09/Plan_S.pdf Accessed 20th March, 2022
Thakker, D., Schireson, M., Nguyen-Huu, D.: Tracking the explosive growth of open-source software. TechCrunch (2017–04–07). https://techcrunch.com/2017/04/07/tracking-the-explosive-growth-of-open-source-software/ Accessed 28th July 2022.
Trivedi, K.: Digital Library Initiatives in India (Part I) Accessed 28th July 2022 http://epgp.inflibnet.ac.in/epgpdata/uploads/epgp_content/S000021LI/P000038/M001887/ET/1483076309P8_M23.pdf
UNESCO: Open Science. https://www.unesco.org/en/natural-sciences/open-science Accessed 28th July 2022.
What is cOAlition S? Plan S making full & immediate Open Access a reality. https://www.coalition-s.org/about/. Accessed 20th March, 2022.
What is Open Science? OpenScienceASAP. http://openscienceasap.org/open-science/. Accessed 21st March, 2022
Wilkinson, M., Dumontier, M., Aalbersberg, I., et al.: The FAIR guiding principles for scientific data management and stewardship. Sci Data **3**, 160018 (2016). https://doi.org/10.1038/sdata.2016.18
World Bank Country and Lending Groups.: Country Classification. https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups. Accessed 21st March, 2022
World Data Center System.: "About the World Data Center System". NOAA, National Geophysical Data Center. http://www.ngdc.noaa.gov/wdc/about.shtml Accessed 28th July 2022.