Trends in Information Management (TRIM)
ISSN: 0973-4163
13(2), pp. 79-94

Open Science Practices: Concepts, Implementation Strategies, and Global Challenges

Mohammad Nazim

Abstract

Open science is transforming the production, evaluation, and dissemination of knowledge. By making research outputs, infrastructures, and processes more accessible and reusable, open science promotes transparency, reproducibility, and social impact. This article synthesizes the conceptual foundations of open science, outlines its main practices (Open Access, Open Data, Open Methods, Open Peer Review, Open Source, and Open Education), explores requirements of relevant infrastructures and policies, and discusses ethical and equity considerations. Drawing on frameworks such as the UNESCO Recommendation on Open Science (2021), Plan S, FAIR, and CARE principles, this paper provides a detailed overview of how open science can be implemented for inclusive, sustainable, and trustworthy research ecosystems. The paper concludes that successful adoption of open science depends on sustained investment in open infrastructures, harmonized policy frameworks, and global equity in digital capacity.

Keywords: *Open Science, Open Access, FAIR Data, Open Education, Citizen Science, Research Infrastructure, Policy Frameworks.*

Introduction

Open science refers to a set of methods, policies, norms, and practical behaviours that make research more accessible, transparent, reproducible, and reusable. It encompasses a set of practices and values that extend beyond open access to publications to include open data, preregistration of hypotheses and analysis plans, sharing data and code, posting preprints, open methodologies, open peer review, and engagement with societal and indigenous knowledge systems. Open science is both a cultural movement and a set of concrete technical practices aimed at enhancing research credibility and accelerating the dissemination of knowledge (Levin et al., 2016). The movement seeks to democratize knowledge creation and ensure that the benefits of research are shared equitably across communities (UNESCO, 2021).

Technological advances, particularly digital repositories, web-based collaboration platforms, and machine-readable metadata, have enabled the open dissemination of scientific research on a global scale. At the same time, public expectations for accountability and reproducibility have intensified, especially for publicly funded research. Open science, therefore, represents both a technical and cultural transformation toward more collaborative and inclusive research practices (UNESCO, 2021).

The significance of open science lies in its capacity to enhance reproducibility, accelerate innovation, and strengthen the relationship between science and society. By fostering equitable access to knowledge and promoting international collaboration, open science supports global sustainable development and aligns with the United Nations Sustainable Development Goals (SDG 9: Industry, Innovation, and Infrastructure; SDG 17: Partnerships for the Goals) (UNESCO, 2021).

Evolution of Open Science

The evolution of open science reflects a profound transformation in how knowledge is created, validated, and shared. Historically, scientific communication was primarily conducted through subscription-based journals and proprietary databases, which restricted access to those affiliated with well-funded institutions. This commercial model, while long dominant, created structural barriers to knowledge equity and became increasingly unsustainable in a digitally connected and data-intensive research environment (Fecher & Friesike, 2014; Suber, 2012; Tennant et al., 2016).

The origins of open science can be traced to the 17th-century Republic of Letters, when scholars exchanged ideas through correspondence and learned societies. However, the rise of commercial publishing in the 20th century gradually centralized scientific communication under closed-access models. The digital revolution of the late 20th century disrupted this system, introducing new methods for disseminating and sharing research. A landmark development was the launch of the arXiv preprint repository in 1991 by Paul Ginsparg for the physics community, which demonstrated that rapid, global, and paywall-free sharing of research was both feasible and transformative (Ginsparg, 2011).

Initially, open access focused mainly on journal articles, but the scope of openness gradually expanded to include open data, open software, open methods, and open peer review (UNESCO, 2021; European Commission, 2016). The digital era amplified these developments by enabling large-scale data sharing, collaborative platforms, and advanced computational research. Technologies such as cloud computing and artificial intelligence further highlighted the need for interoperable and reusable data to enhance reproducibility and innovation (Mons et al., 2017).

In this context, the FAIR Principles (Findable, Accessible, Interoperable, and Reusable) were introduced to ensure that research data are managed and shared in ways that maximize their value to both humans and machines (Wilkinson et al., 2016). FAIR principles have since become global standards for open data stewardship, adopted by initiatives such as the European Open Science Cloud (EOSC) and the U.S. National Institutes of Health (NIH) data-sharing policies.

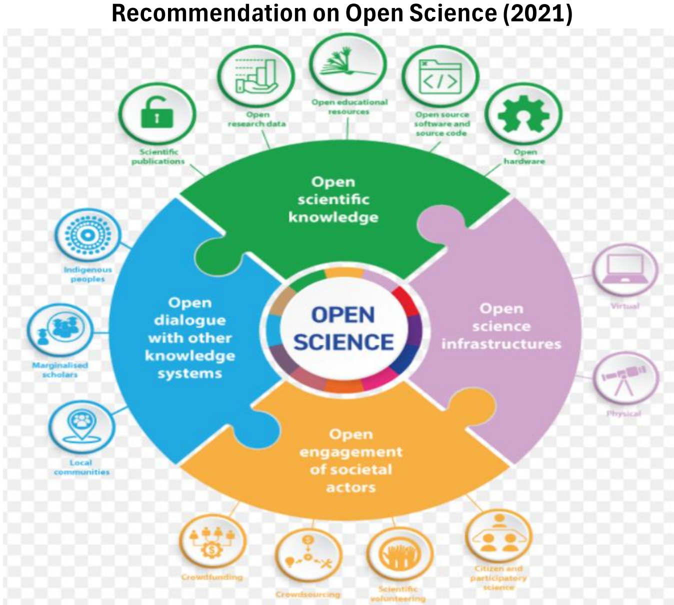
However, openness alone does not guarantee fairness or respect for all knowledge systems. The CARE Principles for Indigenous Data Governance, developed by the Global Indigenous Data Alliance, complement FAIR by centering human and ethical considerations, Collective Benefit, Authority to Control, Responsibility, and Ethics, and ensuring that Indigenous and local communities maintain sovereignty over their data and share equitably in the benefits of its use (Carroll et al., 2020).

Today, open science is recognized as a holistic framework that encompasses the entire research process, including publications, data, software, methods, peer review, and public engagement. It redefines science as a global public good (UNESCO, 2021). This transformation is reinforced by international and national policy initiatives, including Plan S (cOAlition S, 2019), the European Commission's Open Science Cloud, and mandates from governments such as those of India, the United States, and Japan. Together, these developments signify a structural and cultural transition toward a more inclusive, transparent, and collaborative global research ecosystem.

The Four Pillars of Open Science

UNESCO Recommendation on Open Science (2021) includes four pillars of open science: Open Scientific Knowledge, Open Science Infrastructures, Open Engagement of Societal Actors, and Open Dialogue with Other Knowledge Systems (Figure 1). Each pillar contributes to accessibility, transparency, inclusion, and reproducibility.

Fig. 1: Four Pillars of Open Science; Adopted from UNESCO Recommendation on Open Science (2021)



(a) Open Scientific Knowledge

Open scientific knowledge refers to the unrestricted availability of research outputs, such as publications, data, software, and educational resources, licensed for reuse and adaptation. These materials are often stored in open repositories that ensure discoverability and long-term preservation (UNESCO, 2021). Examples include open-access journals, open data repositories (e.g., Zenodo, Figshare), and open-source code platforms (e.g., GitHub).

(b) Open Science Infrastructures

Open science infrastructures comprise the physical and virtual systems, such as repositories, archives, computing platforms, and persistent identifier services, that enable openness and interoperability. Such infrastructures must be community-driven, not-for-profit, and sustainable to ensure equity of access (UNESCO, 2021).

(c) Open Engagement of Societal Actors

This pillar promotes collaboration between scientists and broader society through participatory approaches such as citizen science, crowdsourcing, crowdfunding, and scientific volunteering. These mechanisms enhance collective intelligence and connect science with community needs (UNESCO, 2021).

(d) Open dialogue with other knowledge systems

Open dialogue emphasizes respect for diverse epistemologies, particularly Indigenous and local knowledge systems. It aligns with the *United Nations Declaration on the Rights of Indigenous Peoples* (UNDRIP, 2007) and the CARE principles (Carroll et al., 2020), ensuring that openness does not violate cultural sovereignty or ethical standards.

Core Open Science Practices

The six main practices are Open Access, Open Data, Open Methods, Open Peer Review, Open Source, and Open Education. They collectively enhance research transparency, accessibility, and reuse. Open Access ensures the free publication of information; Open Data promotes FAIR data; Open Peer Review and Open Methods enhance reproducibility; Open Source and Open Education foster collaboration and innovation.

Open Access Publishing

Open Access refers to making scholarly publications freely accessible online, without financial or legal barriers. OA operates under several models: Gold, Green, Diamond (or Platinum), Hybrid, and Bronze (cOAlition S, 2019). Gold OA provides immediate access via publishers, often with an article processing charge (APC). Green OA involves self-archiving in repositories. Diamond OA offers free publishing and reading, typically subsidized by institutions.

OA enhances visibility, citation impact, and knowledge equity (UNESCO, 2021). However, APCs can create financial barriers for underfunded researchers, leading to inequities. Plan S (cOAlition S, 2019) mandates that publicly funded research be made openly available under Creative Commons (CC BY) licenses, thus promoting a sustainable OA ecosystem. Predatory journals exploit the APC model by failing to provide legitimate peer review or adhere to established editorial standards. To maintain integrity, authors should utilize tools such as the Directory of Open Access Journals (DOAJ) and Think. Check. Submit checklist (COPE, 2018).

Open Research Data and Fair Principles

Open research data refers to publishing the data underlying scientific research results, which are made openly available for others to access, evaluate, and reuse, allowing unrestricted access. Open research data includes digital and analogue data (raw and processed), metadata, code, and workflows that can be used, reused, and redistributed with proper attribution (Wilkinson et al., 2016).

The FAIR Principles (Findable, Accessible, Interoperable, and Reusable) provide an international framework for managing and sharing data responsibly:

- **Findable:** Data should have persistent identifiers (such as DOIs) and be accompanied by rich, searchable metadata, ensuring that datasets can be discovered easily through catalogues or repositories.
- **Accessible:** Once found, data should be retrievable using standardized and open communication protocols (e.g., HTTPS or APIs), even if some access restrictions (like login or request approval) exist.
- **Interoperable:** Data should use widely accepted, machine-readable formats (e.g., CSV, XML, JSON) and standardized vocabularies or ontologies so they can be integrated with other datasets and systems.
- **Reusable:** Data should include explicit licenses (such as Creative Commons) and detailed provenance information describing how the data were collected, processed, and validated, enabling others to reuse them responsibly.

Repositories like Zenodo and Figshare implement FAIR practices by enabling metadata-rich deposits and automated linking between datasets and publications. FAIR compliance improves data longevity and scientific reproducibility (Wilkinson et al., 2016).

Open Methods and Reproducible Workflows

Open methods involve sharing research protocols, analytical code, and computational environments. Pre-registration of study designs through platforms like the *Open Science Framework (OSF)* helps prevent selective reporting and increases methodological transparency (Center for Open Science, n.d.).

Software version control tools (e.g., GitHub, GitLab) ensure that others can reproduce and extend analyses, while container technologies like Docker preserve computational environments. Such practices form the backbone of reproducible research.

Open Peer Review

Open peer review enhances transparency and accountability by disclosing reviewer identities or making review reports public. Journals such as *F1000Research* and platforms like *Publons* promote open peer evaluation (COPE, 2018). While open review can reduce bias and improve review quality, it may also raise concerns about confidentiality and the safety of reviewers. Therefore, clear ethical standards are essential (COPE, 2018).

Open Source and Open Hardware

Open-source code under permissive licenses (e.g., MIT, GPL) enables reuse and community improvement. Repositories such as GitHub and Zenodo allow code archiving with digital object identifiers (DOIs), promoting attribution and traceability (Zenodo, n.d.).

Open hardware involves making design files, blueprints, and specifications publicly available for replication and modification. It fosters innovation, especially in resource-limited settings, by reducing cost barriers and encouraging collaborative improvement (UNESCO, 2021).

Open Education

Open Education includes **Open Educational Resources (OERs)** and **Open Educational Practices (OEPs)** that support inclusive learning. OERs, such as textbooks, videos, and slides, are openly licensed and allow free adaptation and redistribution (UNESCO, 2021). MOOCs (e.g., SWAYAM, edX) further extend open access to learning. Open pedagogy encourages co-creation of knowledge between teachers and students, embodying the participatory spirit of open science. Open education strengthens the social dimension of open science by fostering co-creation of learning resources and community participation in knowledge building (Wiley & Hilton, 2018)

Open science infrastructures

Open science depends on robust and interoperable infrastructures, including:

- Open repositories for publications and data (e.g., Zenodo, Figshare, institutional repositories).
- Persistent identifier systems such as DOIs (for objects) and ORCIDs (for researchers).

- Open metrics and current research information systems (CRIS) that support transparent assessment.
- Community-driven governance to ensure sustainability and inclusivity (UNESCO, 2021).

Repositories should adopt interoperable metadata standards and open APIs to facilitate discoverability by both humans and machines. These infrastructures reduce duplication, enable data federation, and ensure the long-term accessibility of scholarly outputs (UNESCO, 2021).

Engagement and dialogue

Open engagement of societal actors

Citizen science and participatory projects have expanded through digital platforms and low-cost sensors. Examples include biodiversity monitoring networks and community health mapping. These initiatives democratize science by allowing non-specialists to contribute to data collection and interpretation. Crowdfunding and open innovation labs similarly empower communities to shape research agendas (UNESCO, 2021).

Open dialogue with other knowledge systems

Respectful integration of Indigenous and local knowledge requires careful governance and management. The CARE principles (Carroll et al., 2020) provide a framework to ensure that Indigenous communities maintain control over their data and that benefits from data use are shared equitably. These complement FAIR principles by centering human values and ethics in data stewardship.

Global and national policy frameworks

UNESCO recommendation on open science (2021)

UNESCO's Recommendation defines open science as a global public good, urging governments to create enabling environments through policy, infrastructure, capacity building, and funding (UNESCO, 2021). It emphasizes inclusivity, multilingualism, and equitable participation.

Plan S and cOAlition S

Plan S, launched in 2018, mandates that research funded by participating agencies be published in compliant open access venues without embargo (cOAlition S, 2019). It supports open licensing (CC BY), transparent publishing costs, and repository-based dissemination. Plan S has accelerated policy convergence among funders and publishers globally.

National and institutional policies

India's *National Open Access Policy* under the DST-DBT mandates the deposit of publications and data in institutional repositories. The *Shodhganga* repository serves as a national archive for theses and dissertations, promoting access and preservation of these works. Institutional libraries play a key role in policy implementation, training, and compliance.

Implementation of open science practices

Implementing open science practices requires integrating openness into every stage of the research lifecycle, from project design to dissemination and community engagement. Effective implementation not only enhances transparency and reproducibility but also strengthens trust between science and society. The following examples and workflows illustrate how open science can be operationalized at individual, institutional, and national levels.

Open science workflow

An open science workflow involves several interconnected steps designed to maximize the accessibility, reproducibility, and societal impact of research.

- ***Pre-registration of research plans :*** Researchers begin by pre-registering hypotheses, methodologies, and analysis plans on platforms such as the *Open Science Framework (OSF)* or discipline-specific registries (e.g., *ClinicalTrials.gov* or *AsPredicted.org*). Pre-registration helps prevent selective reporting, p-hacking, and other questionable research practices by creating a transparent record of the intended methodology (Nosek et al., 2018). The *Center for Open Science* supports such practices by offering registration templates and project tracking systems (Center for Open Science, n.d.).
- ***Open methods and workflows:*** The next step is to document and share research methods, analytical scripts, and computational environments. Platforms like *GitHub*, *GitLab*, and *Protocols.io* facilitate collaborative code development, version control, and peer contributions (Perkel, 2016). Open methods not only promote reproducibility but also enable others to build upon existing work, thereby accelerating innovation and advancement. For instance, *Protocols.io* enables researchers to publish step-by-step experimental procedures, each with a unique DOI, thereby fostering transparency and ensuring citation credit.
- ***FAIR-compliant data management and sharing:*** During data collection and analysis, researchers should ensure compliance with the FAIR principles, making data Findable, Accessible, Interoperable, and Reusable (Wilkinson et al., 2016). Tools such as *DataCite*, *Zenodo*, *Figshare*, and *Dryad* enable the deposition of datasets along with metadata and persistent identifiers. *Zenodo* (operated by CERN) integrates seamlessly with GitHub, allowing automatic archiving of code and datasets with DOIs (Zenodo, n.d.). For sensitive or human-subject data, controlled-access repositories like the *European Genome-*

Phenome Archive (EGA) strike a balance between openness and protection of privacy.

- ***Open access publication and licensing:*** Research findings should then be published in open access journals or deposited in institutional repositories in compliance with funder mandates, such as Plan S (cOAlition S, 2019). Repositories such as *arXiv*, *bioRxiv*, *SSRN*, and *Shodhganga* (India) provide platforms for preprints and postprints, enhancing the immediacy of knowledge sharing. Open licensing, typically through Creative Commons (CC BY), enables users to reuse and distribute research outputs freely, promoting global accessibility and collaboration (Suber, 2012).
- ***Open peer review and post-publication evaluation:*** The peer review process is also becoming more transparent through open peer review models adopted by platforms like *F1000Research* and *PeerJ*, where review reports are published alongside articles (COPE, 2018). Community commenting systems (e.g., *PubPeer*, *PREreview*) encourage post-publication dialogue and correction, supporting the self-correcting nature of science (Ross-Hellauer, 2017).
- ***Open education, communication, and outreach:*** The final phase of open science involves translating research outputs into educational and public resources. Scholars can create Open Educational Resources (OERs) such as slides, datasets, and MOOCs using platforms like *OER Commons*, *SWAYAM*, and *NPTEL*. These materials make knowledge accessible to learners worldwide, fostering an informed citizenry (UNESCO, 2021). Outreach activities, such as citizen science projects and open workshops, extend the benefits of research to communities and stimulate public participation.

Together, these stages form an integrated workflow that ensures openness at every phase of research, thereby reinforcing the credibility, visibility, and utility of scientific knowledge.

Institutional implementation and good practices

Universities and research institutions play a central role in operationalizing open science by developing policies, infrastructures, and training programs.

- ***Policy frameworks and repositories:*** Many institutions have established *institutional repositories* (IRs) to host publications and data. For instance, Shodhganga and ShodhGangotri in India, managed by the INFLIBNET Centre, serve as national repositories for theses, dissertations, and research proposals, advancing accessibility and preservation.
- ***Capacity building and incentives:*** The European Commission and the U.S. National Institutes of Health (NIH) require data management plans (DMPs) in grant applications, reinforcing open data practices (European

Commission, 2016). Training programs on FAIR principles, data citation, and open licensing, often led by libraries, enhance researcher competence. Some universities, such as the University of Cambridge and Leiden University, link open data sharing to career progression metrics, incentivizing compliance.

- ***Collaborative infrastructures:*** Global initiatives, such as the European Open Science Cloud (EOSC), OpenAIRE, and the Research Data Alliance (RDA), provide frameworks for cross-institutional collaboration and technical interoperability. These networks standardize metadata, facilitate cross-repository searching, and promote the alignment of FAIR data (Mons et al., 2017).

Initiatives at the National and Global Level

- ***European Open Science Cloud (EOSC):*** EOSC provides an interoperable virtual environment for storing, sharing, and processing scientific data across Europe, embodying FAIR data principles (European Commission, 2018).
- ***Open knowledge repository (World Bank):*** This repository provides free access to the World Bank's research and data, exemplifying open policy-making through transparency and reuse (World Bank, 2019).
- ***Shodhganga:*** The National Digital Library of India and Shodhganga enhance access to Indian scholarly content and foster equitable participation in global knowledge systems.
- ***Citizen science projects:*** Platforms like *Zooniverse* and *Foldit* demonstrate large-scale public engagement in data collection and problem-solving, showcasing how open participation enriches research outcomes (Bonney et al., 2016).

Broader impact of implementation

Implementing open science workflows has tangible benefits for research visibility, reproducibility, and collaboration. Studies indicate that open access articles receive higher citation rates and broader societal impact (Tennant et al., 2016). Moreover, open data sharing fosters cross-disciplinary innovation, while open education broadens participation beyond academia. Collectively, these practices embody the transformative vision of open science, making knowledge a shared global resource.

Challenges of implementing open science practices

Despite remarkable progress in recent years, the global implementation of open science remains uneven and constrained by a complex set of structural, economic, technical, and cultural barriers. While many governments, universities, and funding agencies endorse open science principles, their translation into sustainable practice is hindered by issues such as funding sustainability, interoperability, capacity building, and policy fragmentation (UNESCO, 2021; Fecher & Friesike, 2014).

Funding Sustainability and Economic Models

One of the most persistent challenges is the **financial sustainability** of open science infrastructures and publishing models. Open access journals and repositories require stable long-term funding for maintenance, curation, and technological updates. The **Article Processing Charge (APC)** model, widely adopted in Gold Open Access, shifts publication costs from readers to authors, often creating inequities between well-funded institutions and researchers in low- and middle-income countries (Tennant et al., 2016; Suber, 2012).

Diamond Open Access models, which do not charge authors or readers, provide a more equitable alternative but depend heavily on institutional or governmental subsidies (Bosman et al., 2021). Without sustainable financial frameworks, many open infrastructures risk obsolescence or commercial capture, contradicting the principle of open science as a public good (European Commission, 2016). UNESCO (2021) emphasizes that open science infrastructures should remain community-driven and not-for-profit, but achieving this balance requires international coordination and long-term investment commitments.

Technical Interoperability and Metadata Standards

A second major challenge lies in achieving **interoperability** across repositories, databases, and digital infrastructures. Scientific data and publications are stored in heterogeneous systems, often using incompatible metadata standards, file formats, and persistent identifiers. This fragmentation limits discoverability and reusability (Mons et al., 2017).
Efforts to harmonize metadata, through initiatives such as Dublin Core, DataCite, and the OpenAIRE Guidelines, aim to improve interoperability; however, adoption remains inconsistent across disciplines and regions. Moreover, semantic interoperability (i.e., ensuring that data carries consistent meaning) requires domain-specific ontologies and machine-actionable metadata, which many repositories lack the resources to develop. To realize the full potential of the **FAIR** (Findable, Accessible, Interoperable, Reusable) principles, technical integration between repositories, persistent identifier systems (e.g., DOIs, ORCIDs), and research information systems (CRIS) is crucial (Wilkinson et al., 2016).

Capacity gaps and inequalities in data literacy

Another significant barrier is the **capacity gap** in data management and open science literacy, especially in the Global South. Many researchers lack training in data stewardship, open licensing, metadata creation, and repository submission. Institutional infrastructures are also unevenly distributed, while universities in Europe and North America benefit from robust repository systems and data management plans, institutions in developing regions often operate with limited digital infrastructure and funding (Bezuidenhout et al., 2017).

UNESCO (2021) underscores that capacity building and digital skills training are prerequisites for equitable participation in open science. Without targeted investments in human capital, open science risks reinforcing existing global asymmetries in knowledge production rather than reducing them. Regional collaborations, such as the **African Open Science Platform (AOSP)** and **Latin American LA Referencia**, demonstrate how local initiatives can bridge these divides by fostering community-led repositories and data networks (Chan et al., 2020).

Policy Fragmentation and Institutional Misalignment

Open science policy frameworks are expanding rapidly, but they often remain **fragmented** across disciplines, institutions, and funding bodies. Different agencies impose varying data-sharing mandates, embargo periods, and licensing requirements, complicating compliance for researchers engaged in international collaborations (Burgelman et al., 2019).

Moreover, institutional incentive systems continue to prioritize traditional metrics, such as journal impact factors and citation counts, over open practices. This misalignment discourages researchers from engaging in time-intensive open activities, such as data curation, pre-registration, or code sharing (DORA, 2012). Integrating openness into research assessment frameworks, as encouraged by the **San Francisco Declaration on Research Assessment (DORA)** and the **Leiden Manifesto**, is essential for systemic change.

Ethical and Legal Barriers

Open science also faces **ethical and legal Barriers**, particularly regarding data privacy, intellectual property, and Indigenous data governance. Legal frameworks such as the **General Data Protection Regulation (GDPR)** in Europe impose strict controls on personal data, which may conflict with open data mandates. Similarly, concerns about the misuse of sensitive or Indigenous knowledge necessitate culturally appropriate governance models, as articulated in the **CARE Principles for Indigenous Data Governance** (Carroll et al., 2020).

Balancing openness with respect for confidentiality, consent, and community rights remains a delicate and evolving challenge. Ethical data sharing requires contextualized policies that consider both the benefits and risks of openness (Bezuidenhout et al., 2017).

The way forward

Addressing these challenges requires a **global strategy** that combines technical, financial, and cultural reforms. UNESCO (2021) recommends developing harmonized international frameworks, strengthening funding for non-commercial infrastructures, and embedding open science competencies into higher education curricula. Furthermore, fostering south–south and north–south collaborations can ensure that open science contributes to narrowing, rather than widening, the global research divide.

Ultimately, the success of open science depends not only on technology or policy but also on cultural transformation, valuing transparency, collaboration, and inclusivity as integral to the scientific enterprise.

Conclusion

Open science represents a paradigm shift from closed, competitive research toward a collaborative, transparent, and inclusive model. Supported by frameworks such as UNESCO's *Recommendation on Open Science* (2021), Plan S (cOAlition S, 2019), and FAIR and CARE principles, it redefines the relationship between science and society. Universities, libraries, and researchers must collaborate to operationalize open practices, striking a balance between openness and ethical governance and sustainability. When effectively implemented, open science strengthens trust, accelerates discovery, and ensures that knowledge truly serves the public good.

References

Bezuidenhout, L., Leonelli, S., Kelly, A. H., & Rappert, B. (2017). Beyond the digital divide: Towards a situated approach to open data. *Science and Public Policy, 44*(4), 464–475. https://doi.org/10.1093/scipol/scw036

BOAI. (2002). *Budapest Open Access Initiative*. https://www.budapestopenaccessinitiative.org/read/

Bonney, R., Phillips, T. B., Ballard, H. L., & Enck, J. W. (2016). Can citizen science enhance public understanding of science? *Public Understanding of Science, 25*(1), 2–16. https://doi.org/10.1177/0963662515607406

Bosman, J., Frantsvåg, J. E., Kramer, B., Langlais, P. C., & Proudman, V. (2021). The OA diamond journals study. *Science Europe* and *cOAlition S*. https://doi.org/10.5281/zenodo.4558704

Burgelman, J.-C., Pascu, C., Szkuta, K., Von Schomberg, R., Karalopoulos, A., Repanas, K., & Schouppe, M. (2019). Open science, open data, and open scholarship: European policies to make science fit for the digital age. *Frontiers in Big Data, 2*(43). https://doi.org/10.3389/fdata.2019.00043

Carroll, S. R., Garba, I., Figueroa-Rodríguez, O. L., Holbrook, J., Lovett, R., Materechera, S., Parsons, M., Raseroka, K., Rodriguez-Lonebear, D., Rowe, R., Sara, R., Walker, J. D., Anderson, J., & Hudson, M. (2020). The CARE principles for Indigenous data governance. *Data Science Journal, 19*(1), 43. https://doi.org/10.5334/dsj-2020-043

Center for Open Science. (n.d.). *Open Science Framework (OSF)*. https://www.cos.io/products/osf

Chan, L., Okune, A., & Posada, A. (2020). *Reimagining open science from the Global South*. African Minds.

cOAlition S. (2019). *Plan S: Making full and immediate open access a reality*. https://www.coalition-s.org/

Committee on Publication Ethics. (2018). *Best practices for preprints: Guidance on preprints*. https://publicationethics.org/guidance/discussion-document/best-practices-preprints

DORA. (2012). *San Francisco Declaration on Research Assessment (DORA)*. https://sfdora.org/read/

European Commission. (2016). *Open innovation, open science, open to the world: A vision for Europe*. Publications Office of the European Union.

European Commission. (2018). *Implementation roadmap for the European Open Science Cloud*. Publications Office of the European Union.

Fecher, B., & Friesike, S. (2014). Open science: One term, five schools of thought. In S. Bartling & S. Friesike (Eds.), *Opening science* (pp. 17–47). Springer. https://doi.org/10.1007/978-3-319-00026-8_2

Ginsparg, P. (2011). ArXiv at 20. *Nature, 476*(7359), 145–147. https://doi.org/10.1038/476145a

Levin, N., Leonelli, S., Weckowska, D., Castle, D., & Dupré, J. (2016). How do scientists define openness? Exploring the relationship between open science policies and research practice. *Bulletin of Science, Technology & Society, 36*(2), 128–141. https://doi.org/10.1177/0270467616668760.

Mons, B., Neylon, C., Velterop, J., Dumontier, M., da Silva Santos, L. O. B., & Wilkinson, M. D. (2017). Cloudy, increasingly FAIR; revisiting the FAIR data guiding principles for the European Open Science Cloud. *Information Services & Use, 37*(1), 49–56. https://doi.org/10.3233/ISU-170824

Nosek, B. A., Ebersole, C. R., DeHaven, A. C., & Mellor, D. T. (2018). The preregistration revolution. *Proceedings of the National Academy of Sciences, 115*(11), 2600–2606. https://doi.org/10.1073/pnas.1708274114

Perkel, J. M. (2016). Democratic databases: Science on GitHub. *Nature, 538*(7623), 127–128. https://doi.org/10.1038/538127a

Ross-Hellauer, T. (2017). What is open peer review? A systematic review.

F1000Research, 6, 588. https://doi.org/10.12688/f1000research.11369.2

Suber, P. (2012). *Open access.* MIT Press.

Tennant, J. P., Waldner, F., Jacques, D. C., Masuzzo, P., Collister, L. B., & Hartgerink, C. H. (2016). The academic, economic and societal impacts of open access: An evidence-based review. *F1000Research, 5*, 632. https://doi.org/10.12688/f1000research.8460.3

UNESCO. (2021). *UNESCO Recommendation on Open Science.* United Nations Educational, Scientific and Cultural Organization. https://unesdoc.unesco.org/ark:/48223/pf0000379949

United Nations Declaration on the Rights of Indigenous Peoples (2007). https://www.un.org/development/desa/indigenouspeoples/wp-content/uploads/sites/19/2018/11/UNDRIP_E_web.pdf

Wilkinson, M. D., Dumontier, M., Aalbersberg, I. J., Appleton, G., Axton, M., Baak, A., Blomberg, N., Boiten, J. W., da Silva Santos, L. B., Bourne, P. E., Bouwman, J., Brookes, A. J., Clark, T., Crosas, M., Dillo, I., Dumon, O., Edmunds, S., Evelo, C. T., Finkers, R., ... Mons, B. (2016). The FAIR guiding principles for scientific data management and stewardship. *Scientific Data, 3*, 160018. https://doi.org/10.1038/sdata.2016.18

Wiley, D., & Hilton, J. (2018). Defining OER-enabled pedagogy. *The International Review of Research in Open and Distributed Learning, 19*(4), 133–147.

World Bank. (2019). *Open Knowledge Repository.* https://openknowledge.worldbank.org/

Zenodo. (n.d.). *Zenodo repository.* CERN. https://zenodo.org/

Corresponding Author

Dr Mohammad Nazim can be contacted at: nazim76@gmail.com

Author Biography

Dr Mohammad Nazim is an Associate Professor in the Department of Library and Information Science at Aligarh Muslim University (AMU). He has more than 20 years of experience in teaching, research, and librarianship. He holds a Ph.D. in Library and Information Science from Banaras Hindu University (BHU) and a Master's degree in the same field from AMU.

He has authored over 80 publications, including research articles in prestigious journals from Emerald, Taylor & Francis, and Elsevier, as well as a book titled Knowledge Management in Libraries (Chandos Publishing/Elsevier, USA). He has guided 47 Master's dissertations and three Ph.D. theses, and has completed three research projects funded by the

ICSSR.

He serves on the editorial boards of several journals, including Scientific Reports (Nature) and Frontiers in Research Metrics and Analytics. His research interests include knowledge organization and information retrieval, knowledge management, open science, and bibliometrics/scientometrics.