UNESCO Recommendation on Open Science

PREAMBLE

The General Conference of the United Nations Educational, Scientific and Cultural Organization (UNESCO), meeting in Paris, from 9 to 24 November 2021, at its 41st session,

Recognizing the urgency of addressing complex and interconnected environmental, social and economic challenges for the people and the planet, including poverty, health issues, access to education, rising inequalities and disparities of opportunity, increasing science, technology and innovation gaps, natural resource depletion, loss of biodiversity, land degradation, climate change, natural and human-made disasters, spiralling conflicts and related humanitarian crises,

Acknowledging the vital importance of science, technology and innovation (STI) to respond to these challenges by providing solutions to improve human well-being, advance environmental sustainability and respect for the planet's biological and cultural diversity, foster sustainable social and economic development and promote democracy and peace,

Also acknowledging the opportunities and the potential provided by the expansion of information and communication technologies and global interconnectedness to accelerate human progress and foster knowledge societies and highlighting the importance of narrowing the STI and digital gaps existing between and within countries and regions,

Noting the transformative potential of open science for reducing the existing inequalities in STI and accelerating progress towards the implementation of the 2030 Agenda and the achievement of the Sustainable Development Goals (SDGs) and beyond, particularly in Africa, least developed countries (LDCs), landlocked developing countries (LLDCs), and small island developing States (SIDS),

Mindful of UNESCO's global priorities, namely gender equality and Africa, and the need to mainstream all these aspects in open science policies and practices with a view to addressing the root causes of inequalities and providing effective solutions to that end,

Considering that more open, transparent, collaborative and inclusive scientific practices, coupled with more accessible and verifiable scientific knowledge subject to scrutiny and critique, is a more efficient enterprise that improves the quality, reproducibility and impact of science, and thereby the reliability of the evidence needed for robust decision-making and policy and increased trust in science,

Also noting that the global COVID-19 health crisis has proven worldwide the urgency of and need for fostering equitable access to scientific information, facilitating the sharing of scientific knowledge, data and information, enhancing scientific collaboration and science- and knowledge-based decision making to respond to global emergencies and increase the resilience of societies,

Committed to leaving no one behind with regard to access to science and benefits from scientific progress by ensuring that the scientific knowledge, data, methods and processes needed to respond to present and future global health and other crises are openly available for all countries, in accordance with the rights and obligations, including the exceptions and flexibilities, under applicable international agreements,

Affirming the principles of the Universal Declaration of Human Rights, notably those contained in Articles 19 and 27 and also affirming the 2007 United Nations Declaration on the Rights of Indigenous Peoples,

Recalling that one of the key functions of UNESCO, as stipulated in Article I of its Constitution, is to maintain, increase and diffuse knowledge by encouraging cooperation among the nations in all branches of intellectual activity, including the exchange of publications, objects of artistic and scientific interest and other materials of information, and by initiating methods of international cooperation calculated to give the people of all countries access to the printed and published materials produced by any of them,

Building on the 2017 UNESCO Recommendation on Science and Scientific Researchers adopted by the UNESCO General Conference at its 39th session, which recognizes, among other things, the significant value of science as a common good,

Also recalling the 2019 UNESCO Recommendation on Open Educational Resources (OER) and the 1971 UNESCO Universal Copyright Convention, and taking note of the strategy on UNESCO's contribution to the promotion of open access to scientific information and research and the UNESCO Charter on the Preservation of Digital Heritage adopted by the UNESCO General Conference at its 36th and 32nd sessions, respectively,

Also recognizing the importance of the existing international legal frameworks, in particular on intellectual property rights including the rights of scientists to their scientific productions,

Further acknowledging that the practice of open science, anchored in the values of collaboration and sharing, builds upon existing intellectual property systems and fosters

an open approach that encourages the use of open licensing, adds materials to the public domain and makes use, as appropriate, of flexibilities that exist in the intellectual property systems to amplify access to knowledge by everyone for the benefits of science and society and to promote opportunities for innovation and participation in the co-creation of knowledge,

Further noting that open science practices fostering openness, transparency and inclusiveness already exist worldwide and that a growing number of scientific outputs is already in the public domain or licensed under open license schemes that allow free access, re-use and distribution of work under specific conditions, provided that the creator is appropriately credited,

Further recalling that open science originated several decades ago as a movement to transform scientific practice to adapt to the changes, challenges, opportunities and risks of the digital era and to increase the societal impact of science, and noting, in this regard, the 1999 UNESCO/ICSU Declaration on Science and the Use of Scientific Knowledge and the Science Agenda – Framework for Action, the 2002 Budapest Open Access Initiative, the 2003 Bethesda Statement on Open Access Publishing and the 2003 Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities,

Further recognizing the significant available evidence for the economic benefits and substantial return on investment associated with open science practices and infrastructures, which enable innovation, dynamic research and economic partnerships,

Agreeing that greater access to scientific process and outputs can improve the effectiveness and productivity of scientific systems by reducing duplication costs in collecting, creating, transferring and reusing data and scientific material, allowing more research from the same data, and increasing the social impact of science by multiplying opportunities for local, national, regional and global participation in the research process, and opportunities for wider circulation of scientific findings,

Recognizing the growing importance of collective science processes carried out by research communities using shared knowledge infrastructure to advance shared research agendas dealing with complex problems,

Considering that the collaborative and inclusive characteristics of open science allow new social actors to engage in scientific processes, including through citizen and participatory science, thus contributing to democratization of knowledge, fighting misinformation and disinformation, addressing existing systemic inequalities and enclosures of wealth, knowledge and power and guiding scientific work towards solving problems of social importance,

Acknowledging that open science should not only foster enhanced sharing of scientific knowledge solely among scientific communities but also promote inclusion and exchange of scholarly knowledge from traditionally underrepresented or excluded groups (such as women, minorities, indigenous scholars, scholars from less-advantaged countries and low-resource languages) and contribute to reducing inequalities in access to scientific development, infrastructures and capabilities among different countries and regions,

Also recognizing that open science respects the diversity of cultures and knowledge systems around the world as foundations for sustainable development, fostering open dialogue with indigenous peoples and local communities and respect for diverse knowledge holders for contemporary problem solving and emergent strategies towards transformative change,

Taking into account, in the adoption and application of this Recommendation, the vast diversity of the laws, regulations and customs which, in different countries, determine the pattern and organization of science, technology and innovation:

1. **Adopts the present Recommendation on Open Science on this twenty-third day of November 2021;**
2. **Recommends that Member States apply the provisions of this Recommendation by taking appropriate steps, including whatever legislative or other measures may be required, in conformity with the constitutional practice and governing structures of each State, to give effect within their jurisdictions to the principles of this Recommendation;**
3. **Also recommends that Member States bring this Recommendation to the attention of the authorities and bodies responsible for science, technology and innovation, and consult relevant actors concerned with open science;**
4. **Further recommends that Member States collaborate in bilateral, regional, multilateral and global initiatives for the advancement of open science;**
5. **Recommends that Member States report to it, at such dates and in such manner as shall be determined, on the action taken in pursuance of this Recommendation.**

I. AIM AND OBJECTIVES OF THE RECOMMENDATION

1. The aim of this Recommendation is to provide an international framework for open science policy and practice that recognizes disciplinary and regional differences in open science perspectives, takes into account academic freedom, gender-transformative approaches and the specific challenges of scientists and other open science actors in different countries and in particular in developing countries, and contributes to reducing the digital, technological and knowledge divides existing between and within countries.

2. This Recommendation outlines a common definition, shared values, principles and standards for open science at the international level and proposes a set of actions conducive to a fair and equitable operationalization of open science for all at the individual, institutional, national, regional and international levels.

3. To achieve its aim, the key objectives and areas of action of this Recommendation are as follows:

    i. promoting a common understanding of open science, associated benefits and challenges, as well as diverse paths to open science;

    ii. developing an enabling policy environment for open science;

    iii. investing in open science infrastructures and services;

    iv. investing in human resources, training, education, digital literacy and capacity building for open science;

    v. fostering a culture of open science and aligning incentives for open science;

    vi. promoting innovative approaches for open science at different stages of the scientific process;

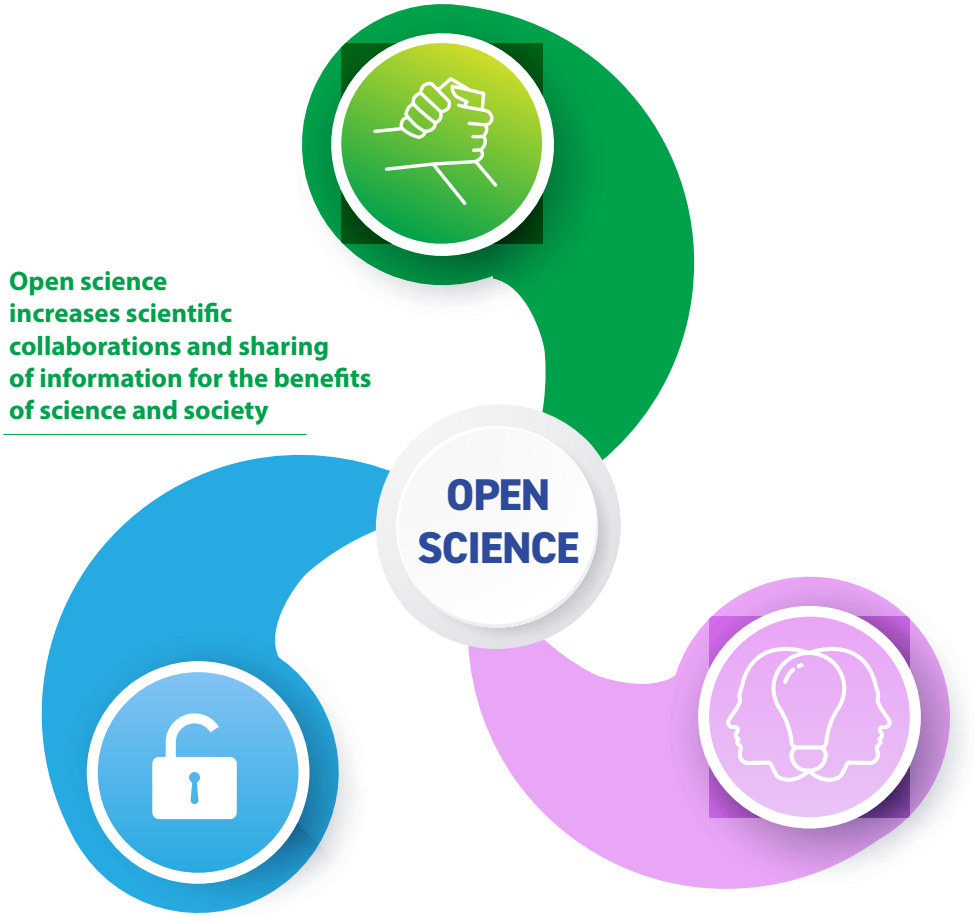
    vii. promoting international and multi-stakeholder cooperation in the context of open science and with view to reducing digital, technological and knowledge gaps.

II. DEFINITION OF OPEN SCIENCE

4. As per the 2017 UNESCO Recommendation on Science and Scientific Researchers, the term 'science' signifies the enterprise whereby humankind, acting individually or in small or large groups, makes an organized attempt, in cooperation and in competition, by means of the objective study of observed phenomena and its validation through sharing of findings and data and through peer review, to discover and master the chain of causalities, relations or interactions; brings together in a coordinated form subsystems of knowledge by means of systematic reflection and conceptualization; and thereby furnishes itself with the opportunity of using, to its own advantage, understanding of the processes and phenomena occurring in nature and society.

5. Building on the essential principles of academic freedom, research integrity and scientific excellence, open science sets a new paradigm that integrates into the scientific enterprise practices for reproducibility, transparency, sharing and collaboration resulting from the increased opening of scientific contents, tools and processes.

6. For the purpose of this Recommendation, **open science** is defined 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.



Open science increases scientific collaborations and sharing of information for the benefits of science and society

makes multilingual scientific knowledge openly available, accessible and reusable for everyone

opens the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community.

7. **Open scientific knowledge** refers to open access to scientific publications, research data, metadata, open educational resources, software, and source code and hardware that are available in the public domain or under copyright and licensed under an open licence that allows access, re-use, repurpose, adaptation and distribution under specific conditions, provided to all actors immediately or as quickly as possible regardless of location, nationality, race, age, gender, income, socio-economic circumstances, career stage, discipline, language, religion, disability, ethnicity or migratory status or any other grounds, and free of charge. It also refers to the possibility of opening research methodologies and evaluation processes. Users therefore gain free access to the following:

    a. ***Scientific publications*** that include, among others, peer-reviewed journal articles and books, research reports and conference papers. Scientific publications may be disseminated by publishers on open access online publishing platforms and/or deposited and made immediately accessible in open online repositories upon publication, that are supported and maintained by an academic institution, scholarly society, government agency or other well-established not-for-profit organization devoted to common good that enables open access, unrestricted distribution, interoperability and long-term digital preservation and archiving. Scientific outputs related to publications (e.g. original scientific research results, research data, software, source code, source materials, workflows and protocols, digital representations of pictorial and graphical materials and scholarly multimedia material) that are openly licensed or dedicated to the public domain should be deposited in a suitable open repository, following appropriate technical standards that allow them to be properly linked to publications. A paywalled method of publication, where immediate access to scientific publications is only granted in exchange for payment, is not aligned with the present Recommendation. Any transfer or licensing of copyrights to third parties should not restrict the public's right to immediate open access to a scientific publication.

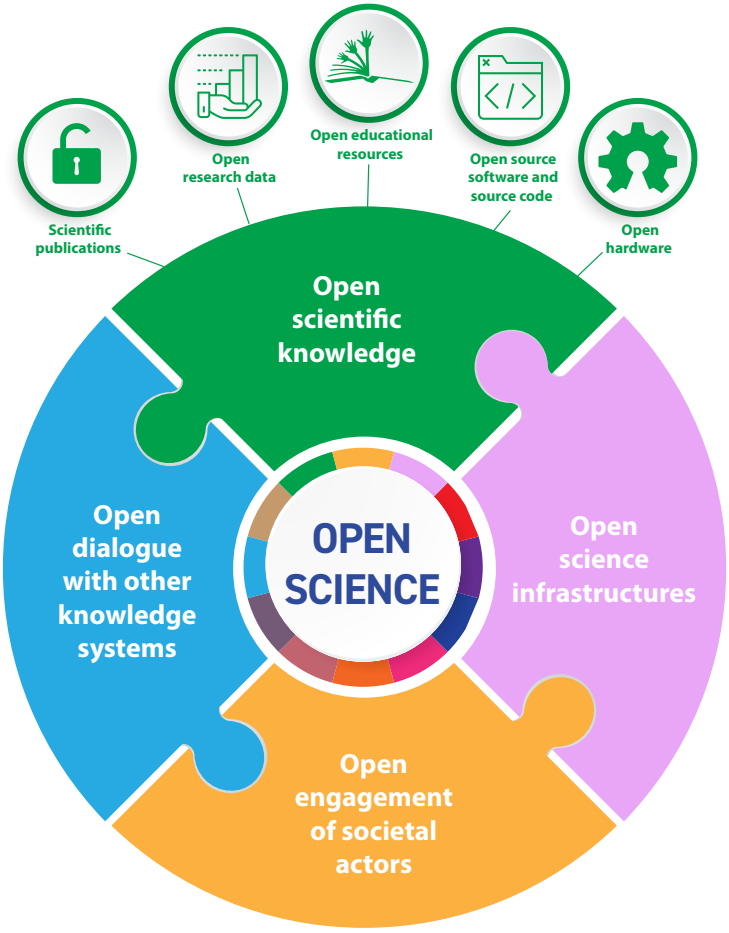
    b. ***Open research data*** that include, among others, digital and analogue data, both raw and processed, and the accompanying metadata, as well as numerical scores, textual records, images and sounds, protocols, analysis code and workflows that can be openly used, reused, retained and redistributed by anyone, subject to acknowledgement. Open research data are available in a timely and user-friendly, human- and machine-readable and actionable

format, in accordance with principles of good data governance and stewardship, notably the FAIR (Findable, Accessible, Interoperable, and Reusable) principles, supported by regular curation and maintenance.

c. ***Open educational resources*** that include teaching, learning and research materials in any medium – digital or otherwise – that reside in the public domain or have been released under an open license that permits no-cost access, use, adaptation and redistribution by others with no or limited restrictions, as defined in the 2019 UNESCO Recommendation on Open Educational Resources (OER), in particular those related to the understanding and use of other openly accessible scientific knowledge.

d. ***Open source software*** and source code that generally include software whose source code is made publicly available, in a timely and user-friendly manner, in human- and machine-readable and modifiable format, under an open license that grants others the right to use, access, modify, expand, study, create derivative works and share the software and its source code, design or blueprint. The source code must be included in the software release and made available on openly accessible repositories and the chosen license must allow modifications, derivative works and sharing under equal or compatible open terms and conditions. In the context of open science, when open source code is a component of a research process, enabling reuse and replication generally requires that it be accompanied with open data and open specifications of the environment required to compile and run it.

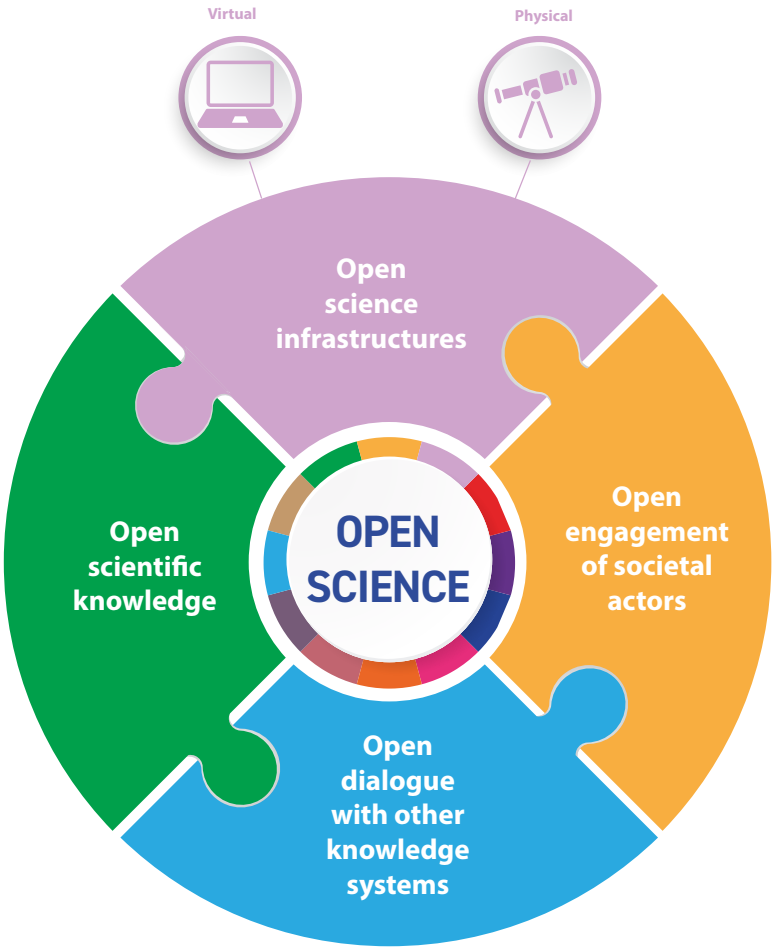
e. ***Open hardware*** that generally includes the design specifications of a physical object which are licensed in such a way that said object can be studied, modified, created and distributed by anyone, providing as many people as possible with the ability to construct, remix and share their knowledge of hardware design and function. In the case of both open source software and open hardware, a community-driven process for contribution, attribution and governance is required to enable reuse, improve sustainability and reduce unnecessary duplication of effort. Software code, description of tools, samples of equipment and equipment itself may be freely circulated and adapted provided that this complies with the national legislation in terms of ensuring safe use.



8. Access to scientific knowledge should be as open as possible. Access restrictions need to be proportionate and justified. They are only justifiable on the basis of the protection of human rights, national security, confidentiality, the right to privacy and respect for human subjects of study, legal process and public order, the protection of intellectual property rights, personal information, sacred and secret indigenous knowledge, and rare, threatened or endangered species. Some data or code that is not openly available, accessible and reusable may nonetheless be shared among specific users according to defined access criteria made by local, national or regional pertinent governing instances. In cases where data cannot be openly accessible, it is important to

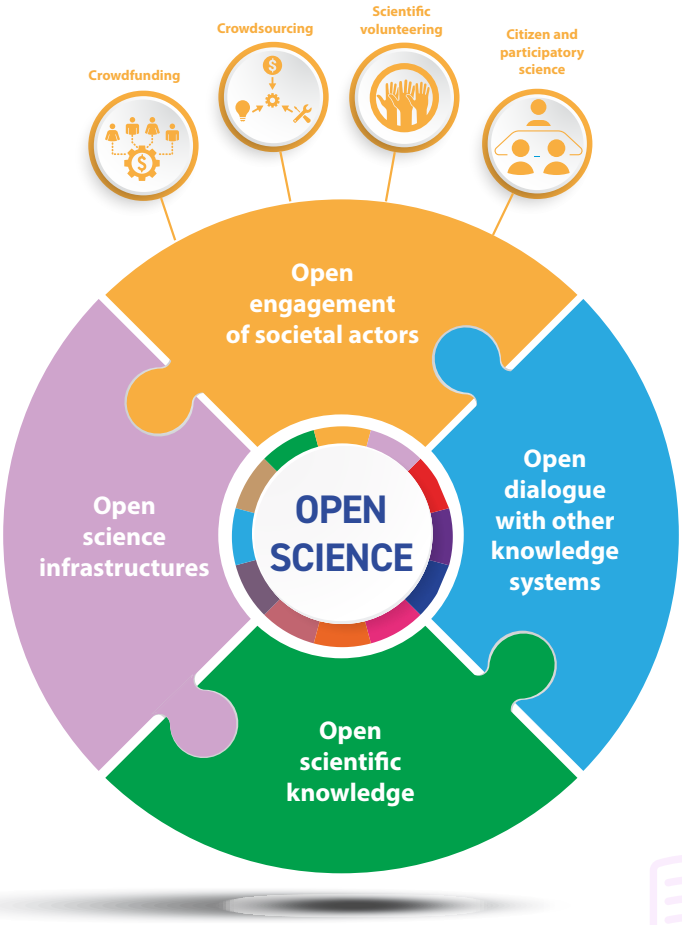
develop tools and protocols for pseudonymizing and anonymizing data, as well as systems for mediated access, so that as much data as possible can be shared as appropriate. The need for justified restrictions may also change over time, allowing the data to be made accessible or restricting access to data at a later point.

9. **Open science infrastructures** refer to shared research infrastructures (virtual or physical, including major scientific equipment or sets of instruments, knowledge-based resources such as collections, journals and open access publication platforms, repositories, archives and scientific data, current research information systems, open bibliometrics and scientometrics systems for assessing and analysing scientific domains, open computational and data manipulation service infrastructures that enable collaborative and multidisciplinary data analysis and digital infrastructures) that are needed to support open science and serve the needs of different communities. Open labs, open science platforms and repositories for publications, research data and source codes, software forges and virtual research environments, and digital research services, in particular those that allow to identify unambiguously scientific objects by persistent unique identifiers, are among the critical components of open science infrastructures, which provide essential open and standardized services to manage and provide access, portability, analysis and federation of data, scientific literature, thematic science priorities or community engagement. Different repositories are adapted to the specificity of the objects they contain (publications, data or code), to local circumstances, user needs and the requirements of research communities, yet should adopt interoperable standards and best practices to ensure the content in repositories is appropriately vetted, discoverable and reusable by humans and machines. Open innovation testbeds including incubators, accessible research facilities, open license stewards, as well as science shops, science museums, science parks and exploratories, are additional examples of open science infrastructures providing common access to physical facilities, capabilities and services. Open science infrastructures are often the result of community-building efforts, which are crucial for their long-term sustainability and therefore should be not-for-profit and guarantee permanent and unrestricted access to all public to the largest extent possible.

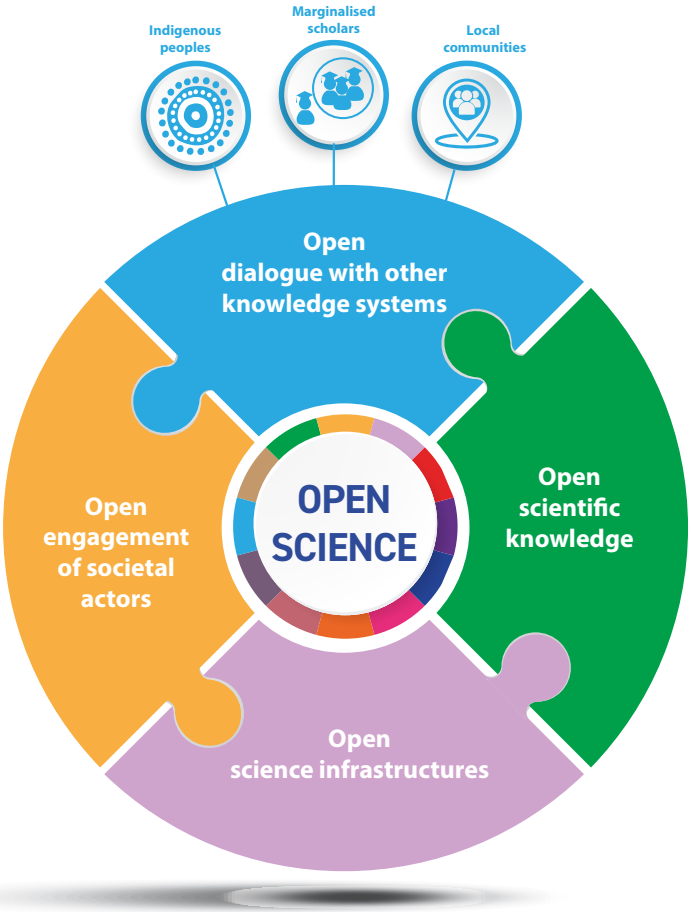


10. **Open engagement of societal actors** refers to extended collaboration between scientists and societal actors beyond the scientific community, by opening up practices and tools that are part of the research cycle and by making the scientific process more inclusive and accessible to the broader inquiring society based on new forms of collaboration and work such as crowdfunding, crowdsourcing and scientific volunteering. In the perspective of developing a collective intelligence for problem solving, including through the use of transdisciplinary research methods, open science provides the basis for citizen and community involvement in the generation of knowledge and for an enhanced dialogue between scientists, policymakers and practitioners,

entrepreneurs and community members, giving all stakeholders a voice in developing research that is compatible with their concerns, needs and aspirations. Furthermore, citizen science and citizens' participation have developed as models of scientific research conducted by non-professional scientists, following scientifically valid methodologies and frequently carried out in association with formal, scientific programmes or with professional scientists with web-based platforms and social media, as well as open source hardware and software (especially low-cost sensors and mobile apps) as important agents of interaction. For the effective reuse of the outputs of citizen and participatory science by other actors, including scientists, these products should be subject to the curation, standardization and preservation methods necessary to ensure the maximum benefit to all.



11. **Open dialogue with other knowledge systems** refers to the dialogue between different knowledge holders, that recognizes the richness of diverse knowledge systems and epistemologies and diversity of knowledge producers in line with the 2001 UNESCO Universal Declaration on Cultural Diversity. It aims to promote the inclusion of knowledge from traditionally marginalized scholars and enhance inter-relationships and complementarities between diverse epistemologies, adherence to international human rights norms and standards, respect for knowledge sovereignty and governance, and the recognition of rights of knowledge holders to receive a fair and equitable share of benefits that may arise from the utilization of their knowledge. In particular, building the links with indigenous knowledge systems needs to be done in line with the 2007 United Nations Declaration on the Rights of Indigenous Peoples and principles for Indigenous Data Governance, such as, for example, the CARE (Collective Benefit, Authority to Control, Responsibility and Ethics) data principles. Such efforts acknowledge the rights of indigenous peoples and local communities to govern and make decisions on the custodianship, ownership and administration of data on traditional knowledge and on their lands and resources.



12. The public sector has a leading role to play in the implementation of open science. Nevertheless, open science principles should also guide the research funded by the private sector. In addition, there are multiple actors and stakeholders in research and innovation systems and each of them has a role to play in the operationalization of open science. Regardless of their nationality, ethnicity, gender, language, age, discipline, socio-economic background, funding basis and career stage or any other grounds, open science actors include, among others: researchers, scientists and scholars, leaders at research institutions, educators, academia, members of professional societies, students and young researcher organizations, information specialists, librarians, users and the public at large, including communities, indigenous knowledge holders and civil society organizations, computer scientists, software developers, coders, creatives, innovators, engineers, citizen scientists, legal scholars, legislators, magistrates and civil servants, publishers, editors and members of professional societies, technical staff, research funders and philanthropists, policymakers, learned societies, practitioners from professional fields, representatives of the science, technology and innovation-related private sector.

III. OPEN SCIENCE CORE VALUES AND GUIDING PRINCIPLES

13. The core values of open science stem from the rights-based, ethical, epistemological, economic, legal, political, social, multi-stakeholder and technological implications of opening science to society and broadening the principles of openness to the whole cycle of scientific research. They include the following:

a. ***Quality and integrity:*** open science should respect academic freedom and human rights and support high-quality research by bringing together multiple sources of knowledge and making research methods and outputs widely available for rigorous review and scrutiny, and transparent evaluation processes.

b. ***Collective benefit:*** as a global public good, open science should belong to humanity in common and benefit humanity as a whole. To this end, scientific knowledge should be openly available and its benefits universally shared. The practice of science should be inclusive, sustainable and equitable, also in opportunities for scientific education and capacity development.

c. ***Equity and fairness:*** open science should play a significant role in ensuring equity among researchers from developed and developing countries, enabling fair and reciprocal sharing of scientific inputs and outputs and equal access to scientific knowledge to both producers and consumers of knowledge regardless of location, nationality, race, age, gender, income, socio-economic circumstances, career stage, discipline, language, religion, disability, ethnicity or migratory status, or any other grounds.

d. ***Diversity and inclusiveness:*** open science should embrace a diversity of knowledge, practices, workflows, languages, research outputs and research topics that support the needs and epistemic pluralism of the scientific community as a whole, diverse research communities and scholars, as well as the wider public and knowledge holders beyond the traditional scientific community, including indigenous peoples and local communities, and social actors from different countries and regions, as appropriate.

14. The following guiding principles for open science provide a framework for enabling conditions and practices within which the above values are upheld, and the ideals of open science are made a reality:

    a. ***Transparency, scrutiny, critique and reproducibility:*** increased openness should be promoted in all stages of the scientific endeavour, with the view to reinforcing the strength and rigour of scientific results, enhancing the societal impact of science and increasing the capacity of society as a whole to solve complex interconnected problems. Increased openness leads to increased transparency and trust in scientific information and reinforces the fundamental feature of science as a distinct form of knowledge based on evidence and tested against reality, logic and the scrutiny of scientific peers.

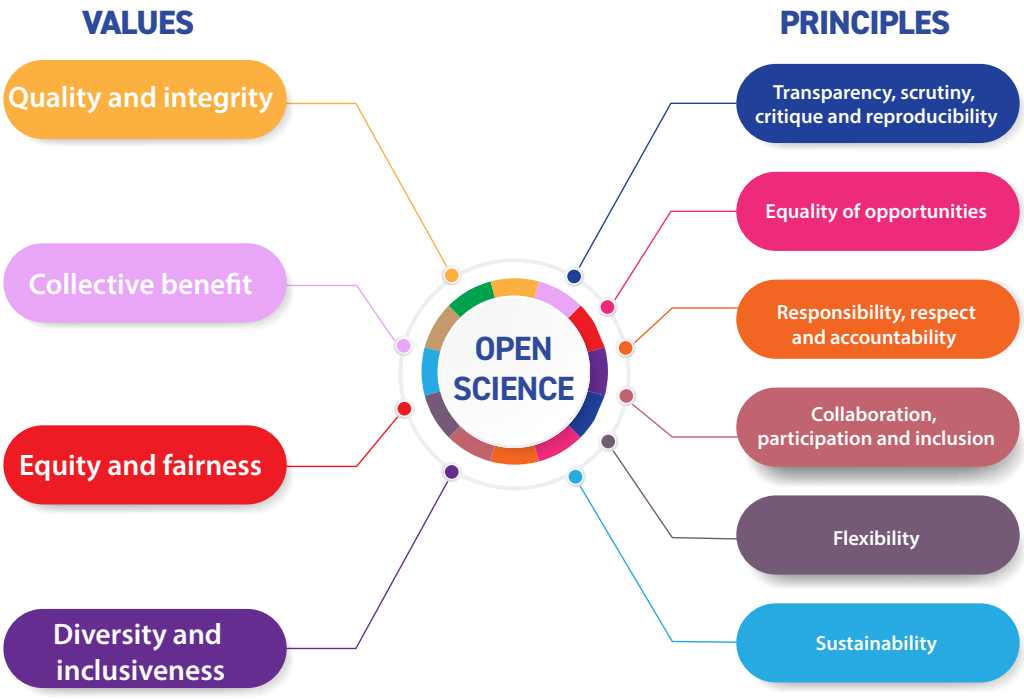
    b. ***Equality of opportunities:*** all scientists and other open science actors and stakeholders, regardless of location, nationality, race, age, gender, income, socio-economic circumstances, career stage, discipline, language, religion, disability, ethnicity or migratory status, or any other grounds, have an equal opportunity to access, and contribute to and benefit from open science.

    c. ***Responsibility, respect and accountability:*** with greater openness comes greater responsibility for all open science actors, which, together with public accountability, sensitivity to conflicts of interest, vigilance as to possible social and ecological consequences of research activities, intellectual integrity and respect for ethical principles and implications pertaining to research, should form the basis for good governance of open science.

    d. ***Collaboration, participation and inclusion:*** collaborations at all levels of the scientific process, beyond the boundaries of geography, language, generations and resources, should become the norm, and collaboration between disciplines should be promoted, together with the full and effective participation of societal actors and inclusion of knowledge from marginalized communities in solving problems of social importance.

e. ***Flexibility:*** due to the diversity of science systems, actors and capacities across the world, as well as the evolving nature of supporting information and communication technologies, there is no one-size-fits-all way of practicing open science. Different pathways of transition to and practice of open science need to be encouraged while upholding the above-mentioned core values and maximizing adherence to the other principles hereby presented.

f. ***Sustainability:*** to be as efficient and impactful as possible, open science should build on long-term practices, services, infrastructures and funding models that ensure the equal participation of scientific producers from less privileged institutions and countries. Open science infrastructures should be organized and financed upon an essentially not-for-profit and long-term vision, which enhance open science practices and guarantee permanent and unrestricted access to all, to the largest extent possible.



IV. AREAS OF ACTION

15. To achieve the objectives of this Recommendation, Member States are recommended to take concurrent action in the following seven areas, in accordance with international law and taking into account their individual political, administrative and legal frameworks.

(i) Promoting a common understanding of open science, associated benefits and challenges, as well as diverse paths to open science

16. Member States are recommended to promote and support the common understanding of open science as defined in this Recommendation, within the scientific community and among the different open science actors, and strategically plan and support open science awareness raising at the institutional, national and regional levels while respecting diversity of open science approaches and practices. Member States are encouraged to consider the following:

    a. Ensuring that open science incorporates the values and principles as outlined in this Recommendation to ensure that the benefits of open science are shared and reciprocal, and do not involve unfair and/or inequitable extraction of data and knowledge.

    b. Ensuring that publicly funded research is undertaken based on the principles of open science in line with the provisions of this Recommendation, in particular paragraph 8, and that the scientific knowledge from the publicly funded research, including scientific publications, open research data, open software, source code and open hardware, is openly licensed or dedicated to the public domain.

    c. Encouraging bibliodiversity through the diversity of formats and means of publications, including those produced by the humanities and social sciences, and diversity of business models, by supporting not-for-profit, academic and scientific community-driven publishing models as a common good.

    d. Encouraging multilingualism in the practice of science, in scientific publications and in academic communications.

    e. Ensuring that the needs and rights of communities, including the rights of indigenous peoples over their traditional knowledge, as expressed

in the 2007 United Nations Declaration on the Rights of Indigenous Peoples should not be infringed on in open science practices.

f. Enhancing open science communication to support the dissemination of scientific knowledge to scholars in other research fields, decision makers and the public at large.

g. Engaging the private sector in the discussion about the ways in which the scope of open science principles and priorities can be enlarged and mutually shared.

h. Enabling open multi-stakeholder discussions on open science benefits and its real and apparent challenges as regards, for example, competition, extraction and exploitation of data by more advanced technologies, links to intellectual property rights, privacy, security and inequalities between publicly and privately funded research, in order to address these challenges constructively and implement open science practices in line with the values and principles outlined in this Recommendation.

(ii) Developing an enabling policy environment for open science

17. Member States, according to their specific conditions, governing structures and constitutional provisions, should develop or encourage policy environments, including those at the institutional, national, regional and international levels that support operationalization of open science and effective implementation of open science practices, including policies to incentivize open science practices among researchers. Through a transparent participatory, multi-stakeholder process that includes dialogue with the scientific community, especially early-career researchers, and other open science actors, Member States are encouraged to consider the following:

    a. Developing effective institutional and national open science policies and legal frameworks that are consistent with existing international and regional law and are in line with the definition, values and principles as well as actions outlined in this Recommendation.

    b. Aligning open science policies, strategies and actions from individual institutions to local and international levels, while respecting the diversity of open science approaches.

    c. Mainstreaming gender equality aspects into open sciences policies, strategies and practices.

d. Encouraging research-performing institutions, particularly those in receipt of public funds, to implement policies and strategies for open science.

e. Encouraging research-performing institutions, universities, scientific unions and associations, and learned societies to adopt statements of principle in line with this Recommendation to encourage open science practice in coordination with national science academies, associations of early-career researchers such as young academies and the International Science Council (ISC).

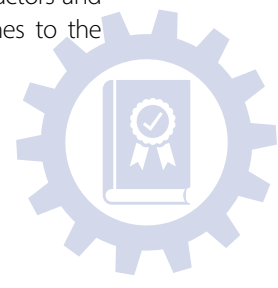
f. Enhancing the inclusion of citizen and participatory science as integral parts of open science policies and practices at the national, institutional and funder levels.

g. Designing models that allow co-production of knowledge with multiple actors and establishing guidelines to ensure the recognition of non-scientific collaborations.

h. Encouraging responsible research and researcher evaluation and assessment practices, which incentivize quality science, recognizing the diversity of research outputs, activities and missions.

i. Fostering equitable public-private partnerships for open science and engaging the private sector in open science, provided that there is appropriate certification and regulation to prevent vendor lock-in, predatory behaviour and unfair and/or inequitable extraction of profit from publicly funded scientific activities. Given the public interest in open science and the role of public funding, Member States should ensure that the market for services, relating to science and open science, functions in the global and public interest and without market dominance on the part of any commercial entity.

j. Designing, implementing and monitoring funding and investment policies and strategies for science based on the core values and principles of open science. The costs associated with operationalization of open science relate to the support of open science research, publishing, data and coding practices, the development and adoption of open science infrastructures and services, capacity building of all actors and innovative, highly collaborative and participatory approaches to the scientific enterprise.



(iii) Investing in open science infrastructures and services

18. Open science both requires and merits systematic and long-term strategic investment in science technology and innovation, with emphasis on investment in technical and digital infrastructures and related services, including their long-term maintenance. These investments should include both financial and human resources. Considering science as a global public good, open science services should be viewed as essential research infrastructures, governed and owned by the community and funded collectively by governments, funders and institutions reflecting the diverse interests and needs of the research community and society. Member States are encouraged to promote non-commercial open science infrastructures and ensure adequate investment in the following:

    a. Science, technology and innovation, and make an effort to contribute at least 1% of national gross domestic product (GDP) dedicated to research and development expenditure, as a guide.

    b. Reliable Internet connectivity and bandwidth for use by scientists and science users across the world.

    c. National research and education networks (NRENs) and their functionality, encouraging regional and international collaboration to ensure maximum interoperability and alignment between NREN services.

    d. Non-commercial infrastructures, including computing facilities and digital public infrastructure and services supporting the open science approach. These should facilitate ensuring the long-term preservation, stewardship and community control of research products, including scientific information, data, source code and hardware specifications, co-operation among researchers and the sharing and reuse of research products. Any research-supporting infrastructure or service should have a strong community-led base and ensure interoperability and inclusivity. Digital infrastructures for open science should be based, as far as possible, on open source software stacks. These open infrastructures could be supported by direct funding and through an earmarked percentage of each funded grant.

    e. Federated information technology infrastructure for open science, including high-performance computing, cloud computing and data storage where needed, and robust, open and community managed

infrastructures, protocols and standards to support bibliodiversity and engagement with society. While avoiding fragmentation by enhancing the federation of existing open science infrastructures and services, at the national, regional and international levels, attention should be given to ensuring that this infrastructure is accessible for all, internationally interconnected and as interoperable as possible, and that it follows certain core specifications, notably the FAIR (Findable, Accessible, Interoperable, and Reusable) and CARE (Collective Benefit, Authority to Control, Responsibility and Ethics) principles for data stewardship. Technical requirements specific to every digital object of significance for science, whether a datum, a dataset, metadata, code or publication, should also be addressed. The capacities of data stewardship infrastructures should serve the needs of all scientific disciplines in an equitable way, regardless of the volume and nature of data they use and the methods they employ to process it. Open science infrastructures and services should be oriented towards the needs of scientists and other audiences using them, develop functionalities tailored to their practices and present user-friendly interfaces. Due care should also be given to persistent identifiers of digital objects. Examples include the definition and attribution of open persistent identifiers as appropriate for each type of digital object, the necessary metadata for their efficient assessment, access, use and re-use, and proper stewardship of data by a trusted regional or global networks of data repositories.

h. Community agreements, concluded in the context of regional or global research communities, and which define community practices for data sharing, data formats, metadata standards, ontologies and terminologies, tools and infrastructure. International scientific unions and associations, regional or national research infrastructures and journal editorial boards each have a role to play in helping develop these agreements. In addition, convergence between the various semantic artefacts (particularly vocabularies, taxonomies, ontologies and metadata schema) is essential for the interoperability and reuse of data for interdisciplinary research.

i. North-South, North-South-South and South-South collaborations to optimize infrastructure use and joint strategies for shared, multinational, regional and national open science platforms, including through the promotion of research collaborations, sharing of open science infrastructures, technical assistance, transfer and coproduction of technology related to open science and exchange of good practices

under mutually agreed terms. Such initiatives are a mechanism to provide coordinated support for open science covering: access to open science services and research infrastructures (including storage, stewardship and data commons), alignment of policies, educational programmes and technical standards. With a number of initiatives under way in different regions, it is important that they should interoperate from the perspective of policy, practices and technical specifications. It will also be important to invest in funding programmes to enable scientists to create and use such platforms, particularly in low- and middle-income countries.

j. A new generation of open information technology tools that automate the process of searching and analysing linked publications and data, making the process of generating and testing hypotheses faster and more efficient. These tools and services will have maximum impact when used within an open science framework that spans institutional, national, and disciplinary boundaries, while addressing potential risks and ethical issues that may arise from the development and use of those tools using artificial intelligence technologies.

k. Innovative approaches at different stages of the scientific process and the international scientific collaboration as outlined, respectively, in paragraphs 21 and 22 of this Recommendation.

l. Funding for the necessary costs associated with transformation towards and maintaining open science practices, as well as the promotion of open licensing schemes.

m. Infrastructure for non-digital materials (e.g. reagents).

n. Platforms for exchanges and co-creation of knowledge between scientists and society, including through predictable and sustainable funding for volunteer organizations conducting citizen science and participatory research at the local level.

o. Community-based monitoring and information systems to complement national, regional and global data and information systems.

(iv) Investing in human resources, training, education, digital literacy and capacity building for open science

19. Open science requires investment in capacity building and human capital. Transforming scientific practice to adapt to the changes, challenges, opportunities and risks of the twenty-first century digital era, requires targeted research, education and training in the skills required for new technologies and in the ethos and practices of open science. Member States are encouraged to consider the following:

    a. Providing systematic and continuous capacity building on open science concepts and practices, including broad comprehension of the open science guiding principles and core values as well as technical skills and capacities in digital literacy, digital collaboration practices, data science and stewardship, curation, long-term preservation and archiving, information and data literacy, web safety, content ownership and sharing, as well as software engineering and computer science.

    b. Agreeing on a framework of open science competencies aligned with specific disciplines for researchers at different career stages, as well as for actors active in the private and public sectors or in civil society, who need specific competences to include the use of open science products in their professional careers; and developing recognized skills and training programmes in support of the attainment of these competencies. A core set of data science and data stewardship skills, skills related to intellectual property law, as well as skills needed to ensure open access and engagement with society, as appropriate, should be regarded as part of the foundational expertise of all researchers and incorporated into higher education research skills curricula.

    c. Investing in and promoting advanced education and the professionalization of roles in data science and data stewardship. Enabling open science also requires data governors capable, in cooperation with the scientific community, of setting strategic directions for data management and openness at the national or local levels and advanced and professional data stewards who manage and curate data according to agreed principles, notably FAIR and CARE principles, within trusted institutions or services. In order to take advantage of the opportunities offered by open science, research projects, research institutions and civil society initiatives need to call on advanced data science skills including

analysis, statistics, machine learning, artificial intelligence, visualization and the ability to write code and use algorithms with scientific and ethical responsibility.

d. Promoting the use of open educational resources (OER) as defined in the 2019 UNESCO Recommendation on Open Educational Resources (OER), as an instrument for open science capacity building. OER should therefore be used to increase access to open science educational and research resources, improve learning outcomes, maximize the impact of public funding and empower educators and learners to become co-creators of knowledge.

e. Supporting science communication accompanying open science practices with a view to the dissemination of scientific knowledge to scholars in other research fields, decision-makers and the public at large. Dissemination of scientific information through scientific journalism and media, popularization of science, open lectures and various social media communications builds public trust in science while increasing the engagement of societal actors beyond the scientific community. To avoid misinterpretation and dissemination of misinformation, the quality and appropriate citation of original sources of information are of paramount importance to science communication as regards open science.

(v) Fostering a culture of open science and aligning incentives for open science

20. Member States, according to their specific conditions, governing structures and constitutional provisions, in a manner consistent with international and national legal frameworks, are recommended to engage actively in removing the barriers for open science, particularly those relating to research and career evaluation and awards systems. Assessment of scientific contribution and career progression rewarding good open science practices is needed for operationalization of open science. Attention should also be given to preventing and mitigating the unintended negative consequences of open science practices, such as predatory behaviours, data migration, exploitation and privatization of research data, increased costs for scientists and high article processing charges associated with certain business models in scientific publishing that may be causes of inequality for the scientific communities around the world and, in some cases, the loss of intellectual property and knowledge. Member States are recommended to consider the following:

a. Combining efforts of many different stakeholders, including research funders, universities, research institutions, publishers and editors, and scientific societies across disciplines and countries, to change the current research culture and to recognize researchers for sharing, collaborating and engaging with other researchers and society, and to support, in particular, early-career researchers in particular to drive this cultural change.

b. Reviewing research assessment and career evaluation systems in order to align them with the principles of open science. Considering that a commitment to open science requires time, resources and efforts that cannot be automatically converted into traditional academic output, such as publications, but which can have a significant impact on science and society, evaluation systems should take into account the wide breadth of missions within the knowledge creation environment. These missions come with different forms of knowledge creation and communication, not limited to publishing in peer reviewed international journals.

c. Promoting the development and implementation of evaluation and assessment systems that:

- build on the existing efforts to improve the ways in which the scientific outputs are evaluated, such as the 2012 San Francisco Declaration on Research Assessment, with an increased focus on the quality of research outputs rather than quantity, and by fit-for-purpose use of diversified indicators and processes that forego the use of journal-based metrics such as the journal impact factor;

- give value to all relevant research activities and scientific outputs including high-quality FAIR data and metadata, well-documented and reusable software, protocols and workflows, machine-readable summaries of findings, and teaching, outreach and engagement of societal actors;

- take into account evidence of research impact and knowledge exchange, such as widening participation in the research process, influence on policy and practice and engaging in open innovation with partners beyond academia;

- take into account the fact that diversity of disciplines requires different approaches in open science;
- take into account the fact that assessment of researchers against open science criteria should be fit for different stages of careers, with particular attention to researchers at the beginning of their careers.

h. Ensuring that the practice of open science is well known, and is taken into account as a scientific and academic recruitment and promotion criterion.

i. Encouraging funders, research institutions, journal editorial boards, learned societies and publishers to adopt policies that require and reward open access to scientific knowledge, including scientific publications, open research data, open software, source code and open hardware, in line with the provisions of this Recommendation.

j. Ensuring diversity in scholarly communications with adherence to the principles of open, transparent and equitable access and supporting non-commercial publishing models and collaborative publishing models with no article processing charges or book processing charges.

k. Enforcing effective governance measures and proper legislation in order to address inequality and prevent related predatory behaviours as well as to protect the intellectual creation of open science methods, products and data.

l. Promoting materials that are in the public domain and existing open licensing schemes, copyright and other intellectual property exceptions for research and educational uses that allow distribution and re-use of a copyright work, or work subject to other intellectual property protection, including partial or derivative use, on the condition that the creator is appropriately credited, in accordance with international law.

m. Promoting high-quality and responsible research in line with the 2017 UNESCO Recommendation on Science and Scientific Researchers and exploring the potential of open science practices to reduce scientific misconduct, including the fabrication and falsification of results, violation of scientific ethical norms, and plagiarism.

(vi) Promoting innovative approaches for open science at different stages of the scientific process

21. Open science requires relevant changes in scientific culture, methodologies, institutions and infrastructures, and its principles and practices extend to the entire research cycle, from formulation of hypothesis, development and testing of methodologies, data collection, analysis, management and storage, peer-review and other evaluation and verification methods, to analysis, reflection and interpretation, sharing and confrontation of ideas and results, communication, distribution and uptake, and use and re-use. Open science is continually evolving and new practices will emerge in the future. To promote innovative approaches for openness at different stages of the scientific process, Member States are encouraged to consider the following:

    a. Promoting open science from the outset of the research process and extending the principles of openness in all stages of the scientific process to improve quality and reproducibility, including the encouragement of community-driven collaboration and other innovative models, for example preprints, clearly distinguished from final peer-reviewed publications, and respecting the diversity of scientific practices, in order to accelerate dissemination and encourage rapid growth in scientific knowledge.

    b. Promoting, as appropriate, open peer review evaluation practices including possible disclosure of the identity of the reviewers, publicly available reviews and the possibility for a broader community to provide comments and participate in the assessment process.

    c. Encouraging and valuing publication and sharing of negative scientific results and those that do not conform to the results expected by the researchers who carried them out, and data associated with them, as these results also contribute to the advancement of scientific knowledge.

    d. Developing new participatory methods and validation techniques to incorporate and value inputs from social actors beyond the traditional scientific community, including through citizen science, crowdsource-based scientific projects, citizen involvement in community-owned archival institutions, and other forms of participatory science.

e. Developing participatory strategies for identifying the needs of marginalized communities and highlighting socially relevant issues to be incorporated into the science, technology and innovation (STI) research agendas.

f. Developing strategies that facilitate the deposit of data in archives in order to promote their curation and preservation and make them usable and reusable for the appropriate time period.

g. Promoting the development of shared infrastructures for the collection, preservation and user-friendly access to open source software and source code.

h. Supporting scientists and other societal actors in accumulating and using open data resources in a transdisciplinary mode to maximize scientific, social, economic and cultural benefits, and stimulate the creation of hybrid disciplinary collaborative spaces where scientists from different disciplines interact with software developers, coders, creatives, innovators, engineers and artists, among others.

i. Encouraging sharing, promoting interoperability, and enhancing open access of large-scale research infrastructures, such as international infrastructures in physics, astronomy and space science, as well as collaborative infrastructures in other fields, such as health and environmental and social sciences, among others.

j. Promoting open innovation practices that connect the practices of open science to more rapid translation and development of its discoveries. Like open science, open innovation and other open science partnerships assume broad and effective engagement and participation in the innovation process as well as the discovery and development of a business model for effective commercialization of new knowledge.

(vii) Promoting international and multi-stakeholder cooperation in the context of open science and with a view to reducing digital, technological and knowledge gaps

22. To foster open science globally, Member States should promote and reinforce international cooperation among all open science actors mentioned in paragraph 12 of this Recommendation, whether on a bilateral or multilateral basis. While recognizing the merits of ongoing efforts and activities in the context of open science for the benefit of science and society, Member States are encouraged to consider the following:

    a. Encouraging international scientific collaborations, as one of the integral practices of open science and the most important driving factor for an intensive exchange of scientific knowledge and experience, as well as the paramount for the openness of science.

    b. Promoting and stimulating cross-border multi-stakeholder collaboration on open science, including by leveraging existing transnational, regional and global collaboration mechanisms and organizations. This should include joining efforts towards universal access to the outputs of science, regardless of discipline, geography, gender, ethnicity, language or socio-economic circumstances or any other grounds, development and use of shared open science infrastructures, as well as technical assistance and transfer of technology, capacity building, repositories, communities of practice and solidarity between all countries regardless of their state of open science development.

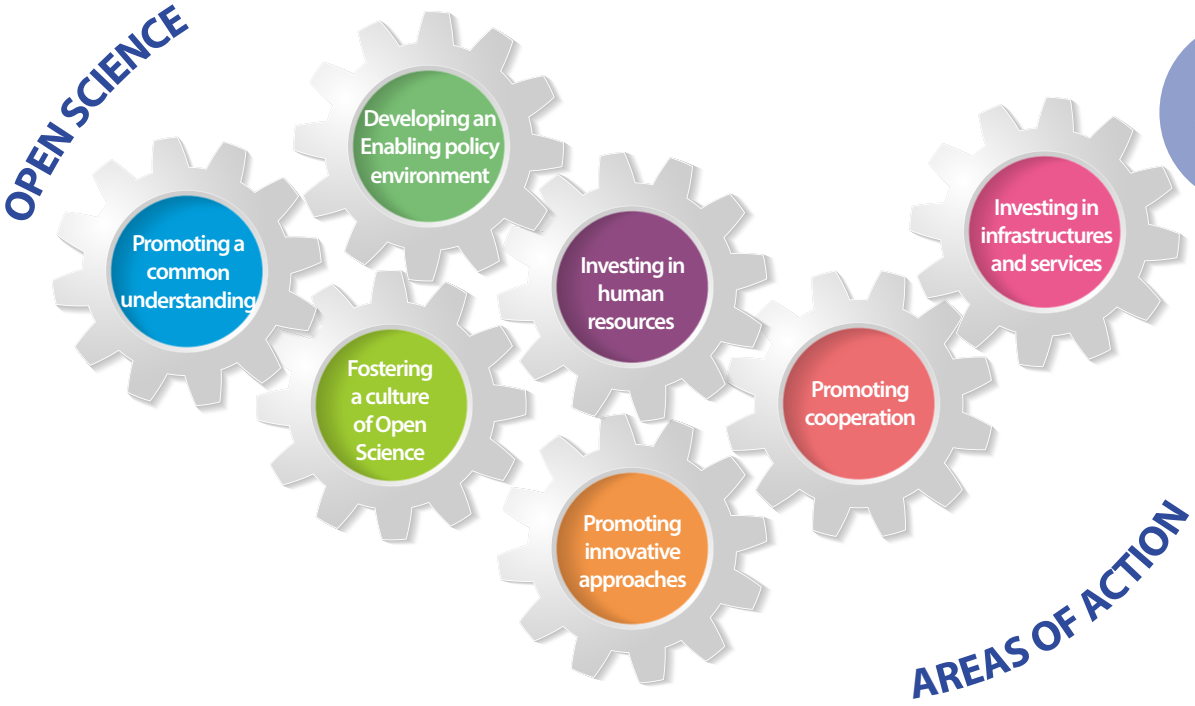
    c. Establishing regional and international funding mechanisms for promoting and strengthening open science and identifying those mechanisms, including partnerships, which can support international, regional and national efforts.

    d. Supporting the creation and maintenance of effective collaborative networks to exchange best open science practices and lessons learned from the design, development and implementation of open science policies, initiatives and practices.

e. Promoting cooperation among countries in capacity building for open science, including infrastructure development, software sustainability and data management and stewardship and to prevent the exploitation and misuse of open data across borders.

f. Promoting international collaboration on metrics for open science.

g. Entrusting UNESCO with the mission to coordinate, in consultation with Member States and relevant stakeholders, the development and adoption of a set of open science goals, which will guide and stimulate international cooperation to advance open science for the benefit of humankind and planetary sustainability.



V. MONITORING

23. Member States should, according to their specific conditions, governing structures and constitutional provisions, monitor policies and mechanisms related to open science using a combination of quantitative and qualitative approaches, as appropriate. Member States are encouraged to consider the following:

    a. Deploying appropriate monitoring and evaluation mechanisms to measure the effectiveness and efficiency of open science policies and incentives against defined objectives, including the identification of unintended consequences and potential negative effects, especially on early-career researchers.

    b. Collecting and disseminating progress, good practice, innovation and research reports on open science and its implications, with the support of UNESCO and with a multi-stakeholder approach.

    c. Considering the development of a monitoring framework with qualitative and quantitative indicators, within national strategic plans and shared at the international level, with objectives and actions in the short, medium and long term for the implementation of the present Recommendation. The monitoring of open science should be explicitly kept under public oversight, including the scientific community, and whenever possible supported by open non-proprietary and transparent infrastructures. This monitoring aspect could include but should not be delegated to the private sector.

    d. Developing strategies to monitor the effectiveness and long-term efficiency of open science, which include a multi-stakeholder participatory approach. Such strategies could focus on strengthening the nexus between science, policy and society, increased transparency and accountability for inclusive and equitable quality research, which effectively responds to global challenges.

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