Input to the UNESCO Global Consultation on Open Science

By the *Open Science Global Working Group*[*]

1) Open Science: characteristics, principles, stakeholders

Openness is an important scientific norm that is crucial for the critical scrutiny, authentication and circulation of scientific practices and results [1]. Already in the 17th century, when experimental approaches were first established, external witnesses were invited to the laboratory to validate experimental methods and outcomes. Around the same time, the first scholarly journals were established to facilitate open communication between researchers. However, we now find that the practice of science got stuck in the past and did not keep up with changes to society nor did it fully embrace opportunities arising from technological development.

Art 27(1) of the Universal Declaration of Human Rights states: "Everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits."

This places science in the context of human culture, and means that science is to ultimately serve our global society so that every individual takes an equitable share of the benefits and is given the opportunity to participate in the process.

We now need to re-develop a framework for "Open Science" to make it match the realities of the 21st century.

Notably, the scientific process crucially depends on communication, and ways of communication have last changed dramatically with the digital revolution, which has broken down physical and geographical barriers and has allowed for wide dissemination of information while lowering cost. The increased integration of virtual and physical realities allows the sharing of infrastructures, even over long distances. Moreover, communication channels have become multi-directional, with everybody being able to engage in debate, which adds perspectives while posing the challenge of openness to a diversity of views.

Open Science is an ideal to improve science and the connection between science and society by making it more accessible, inclusive, efficient and impactful. Open Science is not only

[*] The Global Open Science Working Group is an initiative by a global network of Young Academies, comprising members from the Global Young Academy and 25 National Young Academies from around the globe.

based on technical and financial considerations; it is also informed by values. Reflecting the imperative of Art 27(1) UDHR, core values defining Open Science are:

- **Accessibility**, making scientific data and outcomes freely available to everyone;
- **Inclusivity,** giving everybody the opportunity to take part in the process;
- **Equity**, fair participation and sharing of the benefits;
- **Transparency**, openly documenting all relevant pieces of the process and engaging in constructive criticism.

Accessibility is not only about making science available online but it needs to reach its audience, and be in usable and understandable form. This not only covers data meeting the FAIR criteria (findable, accessible, interoperable, and reusable), but also applies to dissemination, communication, and outreach in general, so that results, data, tools, procedures and infrastructures can be understood and used by other research communities, other disciplines and the broader public. It also requires clarity and necessary qualifications related to uncertainties and limitations of the results, data, tools and procedures and infrastructures. The fact that we do not share a common language and that our language proficiencies widely vary (including the understanding of technical terms) constitutes a key challenge.

Inclusivity requires to re-address who can make a valuable contribution and what structures and tools should be in place for making wide participation possible, overcoming social and economic barriers. Further obstacles to global collaboration include the cultural rooting of hierarchies, the promotion of competition over seeking common benefit, and political reservations. Moreover, inclusivity cannot work without equity in access. There should be major concerns about those with favourable access due to economic status or language dominating the process at the cost of others.

Equity calls for Open Science driving sustainable development towards a global society where benefits are shared equitably rather than stronger economies exploiting weaker economies. This also requires to sort the financing of required infrastructure and their universal non-discriminatory access. Open participation goes along with skill development and empowerment, thereby overcoming dependency. We need to prevent that investments in innovation further increase disparity, and make a global research ecosystem drive local benefit while others lose out.

Transparency is key to safeguarding the quality and robustness of science by enabling the critical scrutiny of methods and results. It provides the basis for building and sustaining trust. This requires that the full process of science is adequately documented, not just results being published. Transparency also means to actively engage in constructive criticism that exposes but does not penalise unintentional errors and mistakes.

The principles and values of open science are intricately connected to the various aspects of scientific practice [2]. Thereby, the scope of Open Science extends to all aspects and processes of science as Open Science aims at maximising the openness of science as a whole. As such, Open Science includes Open Access, Open Data, Open Software, Open Education, Open Innovation, Open Tools, Open Procedures, Open Collaboration, Citizen Science and much more. Open Science also brings the values of openness to stakeholders and is in favour of open governments and open science advice.

Active involvement by all relevant actors is required to make the global research environment adopt a culture that meets the Open Science values.

Open Science requires a constructive, respectful, and open-minded research culture.

Stiff research assessment procedures that mistake bibliometric indicators for research quality have hindered researchers from making most valuable contributions to society, and we urgently need to embrace that such take various forms and appreciate them in their full diversity. Purpose needs to trump assessment, and we need to abstain from introducing new rules and regulations that would again limit freedom. Our future depends on human curiosity and creativity unleashing their potential.

As Open Science tries to take away barriers to research, Open Science aspires to less regulation and bureaucracy.

Everyone can be an actor of Open Science, as Open Science invites all citizens to engage actively with science. Nevertheless, actors take up different roles in the science system.

The principles and values of Open Science are not without conflict with competing values (e.g. privacy or competitiveness), and it requires reasonable decisions for specific cases on whether openness is most desirable. **Open Science is to operate within a wider ethical and social framework**, and there might be an ethical imperative to place limits, in particular once personal clinical data are involved. Overarching principles are that science is to serve global society, while its pursuit respects the Universal Declaration of Human Rights as well as all applicable laws.

We recognise that most of science today is closed in the strong sense, i.e. it is classified or subject to trade secrecy. In 2016, for instance, business and the federal government accounted for 92% of total U.S. Research and Development funding, with most of federal R&D going to classified research for military purposes (see figures in Appendix).[3] Business and state-sponsored research makes important contributions to science. Unfortunately, keeping it closed creates a complicated and expensive bureaucracy of secrecy and causes inefficiencies in the production and circulation of knowledge. We encourage businesses and governments to take up the principles and values of Open Science as much as possible, opening up results, tools, data, methods and processes.

We believe that the social contract between science and society should entail that, unless competing values deserve priority, science that receives public funding should follow the principles and values of Open Science, especially in terms of accessibility, equity, transparency and inclusivity.

UNESCO and the UNDP have an important role to play in facilitating Open Science as this contributes to their mission to eradicate poverty and reduce inequalities through the sustainable development of nations.

2) Benefits of Open Science; challenges and incentives for Open Science implementation

Universal access to scientific research findings and data has the potential to improve productivity, both with regard to efficiency and enablement. Efficiency means producing the same or more at lower cost, whereas enablement refers to delivering new elements, products, collaborations and processes that otherwise would not have emerged [4].

Open Science accelerates the transfer of knowledge and the re-use of results, while actively preventing duplication or redundancy. Moreover, the development of new ideas is fostered by increasing the variety of views and approaches that contribute to the debate. Embracing the core values of Open Science, in particular transparency and inclusivity, also provides a mechanism for overcoming groupthink in established fixed structures and hierarchies. This can substantially boost the path from research to innovation.

Transparency in processes will also enable more robust quality control and provide a solid basis for trust in science.

Open science holds a substantial potential for increasing innovation capacities of countries whose R&D sector and funding mechanisms are underdeveloped, given that it will provide a much-needed access to information without requiring payment. Data mining following Open Science principles makes particularly efficient use of existing valuable resources.

Open Science can lead to **better education and training**, creating well-known benefits to societies, including higher science literacy, better health and wellbeing, higher social trust and participation, lower unemployment and higher productivity and a higher standard of living. In higher education and research, many institutions have made their research seminars open and conferences have gone online in the wake of the COVID-19 crisis and this should set an example for future open education and dissemination of research.

Open Science enables **better decision making in all levels of society**, including businesses and governments, because of the better circulation of knowledge. This knowledge is, furthermore, more easily verifiable in an Open Science context. Also science advice should be made open, to allow for constructive criticism and public dialogue on important decisions. The outcome of Open Science will be increased impact of science and a better opportunity for science to address local and global societal challenges such as the Sustainable Development Goals.

A key challenge is in building a global framework for Open Science that narrows down inequalities rather than further increasing them.

“Globalisation” needs to be turned into a positive effect on equitable sustainable development. The existing **digital divide** poses a substantial issue, given that we could see the more developed economies reaping the benefits of Open Science and the less-developed economies potentially falling further behind. Who will benefit if those with more powerful infrastructures and science systems use the results and data that is made freely available by those with fewer opportunities to exploit these? With industries from all over the world profiting from faster innovation through Open Science, what will be left to develop and strengthen local science systems, communities, and economies? New rules for the international taxation of commercial profits depending on the

origin of underlying research data and intellectual property might be worth considering in order to avoid placing restrictions or other conditions on reuse.

Open Science should also smoothen social inequalities within countries rather than widening them. It will not meet its goals if there are financial obstacles to participation.

Open Science requires a globally sustainable model of scholarly communication.

It has rightfully been recognised that a subscription model to scientific publications constitutes an obstacle to sharing research results, but shifting the paywall from the reader to the author is not the solution, Open Science needs dually-open access. Researchers should have an unlimited right of free-of-charge write and read access to platforms of scholarly communication that support critical debate in a transparent fashion and enable engagement in a global conversation.

Open science relies on research networks built on global equity, diversity, and inclusion.

Researchers across the world are not equally connected, which affects their visibility and ability to participate in the scholarly process. As the COVID-19 pandemic made in-person meetings impossible, on-line communication became the sole platform, which meant that physical distance itself no longer constituted a barrier. However, this alone does *not* equate to universal globally equitable access in practice, because people continue to live in different time zones and available bandwidth substantially varies and there are often still participation fees for virtual meetings. Moreover, accessibility is not sufficient, but opportunities of active participation need to be provided.

We need intellectual property strategies and underlying legislation that resonate well with Open Science and its values.

IP protection is widely regarded as a mechanism to incentivise commercial investment in R&D, but the “linear model” of innovation progressing from basic research to applied research and further on to product development has also been found to not match reality, where sheer chance as well as unforeseen applications are the norm rather than the exception. As a consequence, policy should facilitate the exchange of ideas as much as possible.

Protecting IP can take various forms, including keeping trade secrets and filing patents. While the latter asserts exclusive rights for a certain period, it ultimately disseminates knowledge to the public. If public funds are involved, a business model should be encouraged that ensures that IP rights are used such as to provide most benefit to society.

Current copyright legislation poorly reflects the interests of academic scholars and conflicts with the principles of Open Science. While it is sensible to protect intellectual works against false attribution (e.g. plagiarism) and misrepresentation, legal barriers to access and reproduction can be counterproductive.

Building trust in science requires awareness of its processes and underlying principles.

As science is knowledge-in-the-making, proposed conclusions are not yet established facts but require independent confirmation by several sources. Also not all aspects of science are necessarily fully robust because they are part of an ongoing conversation. Given that Open Science makes the processes transparent rather than just presenting the end result, due care needs to be taken to avoid misunderstandings.

Messenger and recipient need to find a common language, which calls for researchers to state their case clearly and present the evidence rather than trying to claim authority or exaggerate results. On the other hand, some fundamental scientific literacy is needed from the reader, in particular with regard to probability and statistics, in order to make proper sense of scientific findings and not to misinterpret or inadvertently misrepresent them.

With huge amounts of information becoming available, filtering the relevant bits constitutes a major challenge.

We are already witnessing an increase in scientific outputs. The challenge has shifted from being able to access published material to controlling quality and finding the specific information that is relevant and can be trusted amongst the flood of data. If we reject a-priori gate-keeping, everything can be freely shared as we are seeing in social media.

This raises the question of how we become intelligent consumers, taking into account that not everybody will be able to read everything let alone be able to assess and evaluate quality. Robust and transparent post-publication peer review systems might be key to addressing this issue. In fact, robust scrutiny is strengthened and becomes more efficient with the principles of Open Science.

Two major ingredients are needed, however: suitable platforms and the appreciation for robust scrutiny and constructive criticism by the scholarly community. Erroneous or biased results, methods or data can be more easily exposed and addressed in an open context. It will be important to accept that making unintended errors is part of being human, and thereby part of the self-correcting process of thorough review. This does not mean that fraud should be tolerated.

Artificial Intelligence for Natural Language Processing might provide powerful tools in the future that can assist the review of scholarly work.

Open Science operates within a wider cultural context.

Implementing Open Science means to review every aspect of the way science is pursued, and thereby provides an opportunity to address existing problems and shortcomings. Its various components, joined by the common values and principles, are intertwined and affect each other.

Putting Open Science into practice is not only a question of technical realisation, but to a large extent one of establishing and fostering a culture that embraces its underlying values.

Particular care needs to be taken not to frame Open Science too narrowly, or we put ourselves at risk of moving around in circles without making progress or even creating more serious problems than we tried to solve. In particular, policies that aim at promoting Open Access carefully need to consider which incentives are given to the various stakeholders and that science is a global endeavour rather than a simple relationship between funder, grant holder, and host institution.

A key principle of Open Science is that it is not centrally-driven, but a complex system of highly-interdependent actors.

Any incentives have to take this into account and therefore cannot prescribe fixed structures, but instead have to respect the dynamics.

Open Science assumes a shared responsibility and its principles support the empowerment of individuals as well as equitable ownership of the processes and its benefits.

Consequently, actors must enjoy their freedom, and no entity can be permitted to dominate the direction of development or claim undue benefit at the cost of others.

Science is naturally a global public good because anyone can use science (it is non-excludable) and the use of science by one individual does not reduce its availability to others (it is non-rivalrous), indeed, the more individuals participate in science the more it grows.

However, a public good is often vulnerable to privatisation and private interests. It can be turned into an *artificially* scarce good by erecting barriers that exclude potential participants to the public detriment. Constructively interacting with private interests while serving the public good is a major challenge for science. [5] Commercial entities can be well set to deliver services for a reasonable amount of payment, but they must not be given control of key functions (such as scholarly publishing or data management).

The most important incentive towards Open Science is the removal of obstacles.

Every single actor holds the potential to drive change, and it will be important for visible and recognised actors to set a new example.

Open Science requires a framework that enables and appreciates continuing change and innovation. This is essential for keeping Open Science able to adapt to changing circumstances associated with societal and technological development.

This also means that any detailed incentive measure needs to be closely aligned with the goals rather than with any perceived proxy. Any short-term incentive needs monitoring for adverse side-effects, prompt review, and adjustment if indicated.

Various bodies will need to set incentives within their scope of influence respecting the wider Open Access framework as well as their specific goals.

The principles of Open Science are well suited to foster diversity and healthy competition. While Open Science is based on respecting shared values, it does not call for uniformity, but leaves everybody with the choice to set priorities according to specific needs. In the future, research-performing institutions are expected to increasingly compete on the best-matching environment for researchers (taking into account that researchers might have different preferences).

University rankings in particular reinforce traditional but misguided perceptions and are drivers towards uniformity rather than enabling competition through diversity and innovation. The opportunities of less-developed economies are in adopting solutions best-matching their needs and in daring to be different (and better). The key evolutionary advantage is in the ability to adapt fast to changing circumstances.

Open Science will move ahead once researchers are convinced that it serves them well and are able to put its principles into practice.

The principles of Open Science should always be in the interest of researchers. They can ease global collaboration, increase visibility, strengthen robustness, and make research a more vibrant

endeavour. However, researchers are currently slow on putting the principles of Open Science into practice due to misincentives standing in their way, in particular the widespread use of unsuitable indicators of research "excellence". A concerted effort of research-performing institutions, funders, and governments should remove such misincentives. In contrast, a positive case should be made on the principles and values of Open Science, as well as research integrity, and good practice actively encouraged.

Putting more pressure on researchers or imposing new sets of rules and regulations on them is not a good policy approach.

Good "citizenship" in Open Science needs to be incentivised by giving due credit.

Contributions to Open Science take a wide range of forms rather than being restricted to countable "publications". Researchers must be able to claim due credit for their work, and their contributions need to be identifiable and verifiable. While a Digital Object Identifier (DOI) can already be attached to research data and software, and authors are electronically identifiable by ORCID, the concept of authorship should be widened in order to trace intellectual contributions not only to concrete outputs, but also outcomes and engagement in scholarly discourse as well as with other stakeholders in the Open Science system.

3) What are the needs to make OS possible?

Infrastructure:

Infrastructures for research need to support equitable active participation in Open Science, involving both generating data and results and sharing these, which includes the provision of access to hardware, equipment as well as to results, data, educational material, notebooks, etc. These virtual and physical infrastructures also need to include appropriate tools, interoperable standards, operational guidelines and open protocols. Such infrastructures should be user-friendly, secure (encryption/user authentication & authorisation), robust, sustainable and itself open where possible. Examples of such infrastructures are: open-source software to generate data or gain access to shared hardware at a distance; open-source hardware; open data and publication platforms (including enough OA journals) with adequate structures of quality control (e.g. peer review or data stewardship); systems that allow access to high performance computing centres so that computational modelling and large data analyses can be performed from places with basic computational infrastructure; etc. Open Science infrastructure should be built exclusively on open standards; proprietary standards for hard- or software constitute substantial obstacles and fail to comply with the principles of Open Science.

Reflecting the fact that science is truly global, with a huge amount of global cooperation and exchange that is set to increase even further in the future, researchers, funding agencies, and governments should be most strongly encouraged to engage in building universally accessible global infrastructures for research, rather than focusing on national or regional platforms, as we are currently seeing for scholarly publishing. However, global infrastructures could in principle be

built by linking up existing platforms. Moreover, decentralised solutions avoid a single point-of-failure as well as national appropriation.

Stakeholders, which include **national governments and intergovernmental organizations, should facilitate or build global "diamond" open infrastructures** (free-of-charge contributing and using of the infrastructures, e.g. for Open Access, Open Data and other forms of sharing research [6].

Researchers should assume key roles in developing most suitable infrastructures, given their expertise as well as their ability of coming up with innovative solutions. Policies should reflect the fact that Open Science was and should remain researcher-driven.

In addition to specific requirements, Open Research needs to be facilitated by more general infrastructure, most notably on transportation and communication. Digital connectivity for an affordable price constitutes a particular challenge for low- and middle-income countries as well as for rural areas. As technology evolves, we are likely to continue to face substantial disparities, which calls for a "fair" sharing of resources based on standards that do not waste bandwidth excessively. In particular, using off-line data processing rather than on-line interaction reduces pressure on bandwidth. UNESCO and national governments should explore ways to support researchers to access the platforms they need. [7]

Capacity building:

Achieving a general science literacy across the population will be a key factor in determining how large the benefits arising from Open Science will be, and this needs to be fostered through formal and informal education. This is not only a condition for active participation but also for drawing the correct conclusions from shared data and results.

Moreover, the values and principles of Open Science are to be at the core of university curricula, with further training being provided on all relevant technical and practical aspects.

It should be acknowledged that much of the progress in Open Science is driven by researchers, and in particular younger scholars are frequently fastest in adopting new ways of making efficient use of emerging technologies. It would be useful to have mechanisms that support scholars in sharing experiences and learning from each other, overcoming the confines of both research areas and national borders. Young researchers should be particularly empowered to take a lead.

Training towards Open Science in a changing global landscape also provides an opportunity to strengthen inclusivity.

Building capacity on Open Science skills should be part of national strategies for implementing the UN Strategic Development Goals.

Financial needs:

In the long term, an equitable Open Science system is expected to provide substantial savings due to much increased efficiency. Moreover, it will yield financial returns that otherwise would not

emerge. However, it requires some upfront injection of infrastructure investment as well as the coverage of maintenance costs.

The World Wide Web already revolutionised global communications and the sharing of information and data. We need to further develop our digital infrastructure while aiming at cost-efficient solutions and tools to use it. In the end, the equity and inclusivity values of Open Science demand that it has to be affordable to everyone. Governments must defend these values for their citizens.

In contrast, we have arrived at a system of scholarly communications that follows a business model that is not financially sustainable. This means that it will be necessary in any case to change the current system and this should be seen as an opportunity to fully commit to Open Science.

While building the network communications infrastructure itself is mostly a national effort, the provision of storage capacity as well as the development and maintenance of platforms and tools is best coordinated globally. The cost of the latter needs to be shouldered across countries in a fair way, e.g. by taking into account the capacity to pay, similar to the determination of the contribution of Member States to the United Nations.

Policy Needs

National legislation can lead to disparities for the pursuit of science as a global endeavour. Currently, ethical standards and the degree of their enforcement vary strongly across countries. Moreover, data protection policies are far from being globally uniform. Procedures need to be put in place that regulate cross-border sharing in an equitable and purposeful way. In particular, researchers need to be protected against recourse.

National lawmakers, guided by supranational facilitation, should change copyright and rights retention legislation for scientists, allowing them to share their publications, data and other relevant products without embargo.

Publishing on the internet currently technically requires conforming to the laws of about 200 jurisdictions, which is practically unfeasible. A legal framework that accounts for the reality of engagement across borders is long overdue.

4) Recommendations

1. Engagement in ongoing processes of shaping the culture of Open Science

Keep engaging in a global dialogue that informs shaping a culture in the global science system supporting the principles of Open Science

- Acknowledge that Open Science builds on a continuously evolving process that needs to adapt flexibly to changes in circumstances
- Consider sharing of benefits and supporting sustainable development, recognising differences in economic power between countries and the need to work together as a global society
- Recognise young scientists as key drivers of innovation

2. Right of participation in global scholarly communication and transparent debate

Researchers should have an unlimited right of free-of-charge write and read access to platforms of scholarly communication that support critical debate in a transparent fashion and enable engagement in a global conversation.

3. Right to due credit

Researchers must be able to claim due credit for their work, and their contributions need to be identifiable and verifiable. Such take a wide range of forms rather than being restricted to countable “publications” or other forms of concrete outputs, and also include outcomes and engagement in scholarly discourse as well as with other stakeholders in the Open Science system

4. Right to accessibility of scholarly research

Results arising from scholarly research and their underpinning data must not only be accessible in the sense that a suitable technical infrastructure is provided, but moreover these must be provided in forms that make them usable for potential users and enable sharing across academia, government, commercial entities, and citizens. This requires support for scholarly communication platforms that meet the needs of various audiences, both with regard to their technical background and the various natural languages spoken. Support should be available for citizens who want to access and engage in their mother tongue.

5. Open Science requires open standards

Open Science infrastructure should be built exclusively on open standards; proprietary standards for hard- or software constitute substantial obstacles and fail to comply with the principles of Open Science.

6. Infrastructure investment

Open Science requires a substantial investment in suitable infrastructure, which supports both the generation and the sharing of data and results. It needs to include appropriate tools, interoperable standards, operational guidelines and open protocols. Researchers, funding agencies, and governments should be most strongly encouraged to engage in building universally accessible “diamond” global infrastructures. Digital connectivity for an affordable price constitutes a particular challenge for low- and middle-income countries as well as for rural areas.

7. Efficient sharing that avoids wasting resources

As technology evolves, we are likely to continue to face substantial disparities in digital infrastructure provision, which calls for a “fair” sharing of resources based on standards that do not waste bandwidth excessively. In particular, using off-line data processing rather than on-line interaction reduces pressure on bandwidth.

8. Support for training and education

The principles of Open Science need to be incorporated in training programmes, covering all education sectors as well as providing support for businesses, government or not-for-profit organisations and individuals. As societal benefits depend on the width of participation, a wide general scientific literacy should be fostered.

9. Equitable sharing of benefits

Open Science needs to operate within a framework that smoothens economic and social inequalities in line with the UN Strategic Development Goals rather than widening gaps. This means that the intellectual property of weaker players requires some protection against the exploitation by stronger players. New rules for the international taxation of commercial profits depending on the origin of underlying research data and intellectual property might be worth considering in order to avoid placing restrictions or other conditions on reuse.

10. Capacity building on Open Science and UN SDGs

Building capacity on Open Science skills should be an integral part of national strategies for implementing the UN Strategic Development Goals.