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Toward a UNESCO Recommendation on Open Science: Canadian Perspectives

Prepared for the Canadian Commission for UNESCO
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For further reading, see:

An introduction to UNESCO's Updated Recommendation on Science and Scientific Researchers https://en.ccunesco.ca//media/Files/Unesco/Resources/2018/11/IntroductionToUNESCOUpdatedRecommendationOnScienceAndScientificResearchers.pdf (2018)

Is Science a Human Right? Implementing the Principle of Participatory, Equitable, and Universally Accessible Science https://en.ccunesco.ca//media/Files/Unesco/Resources/2019/10/IsScienceAHumanRight.pdf (2019)

The Status of Science. The UNESCO Recommendation on Science and Scientific Researchers: Issues, Challenges and Opportunities https://en.ccunesco.ca//media/Files/Unesco/OurThemes/EncouragingInnovation/IdeaLab/ReflectionPaperMicheleStanton-Jean.pdf (2019)

This publication is dedicated to the memory of Mohammad Asadi-Lari, founding member of STEM Fellowship, member of the Canadian Commission for UNESCO Youth Advisory Group, and promoter of youth access to Open Data.

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Contents

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Introduction

Open Science is a concept that embraces all forms of science communications including scientific publications, data, and software, as well as access to and use of materials, equipment and software. For many, the Open Science movement is a natural progression to promote collaboration that took root with the first scientific journals in the 17th century, has gained strength in recent years, and is now of acute interest to many world organizations. The growing momentum of the Open Science movement may be attributed in some part to the awareness of the need to renegotiate the social contract between science and society. In the context of 'post-truth' and the reproducibility crisis[1], to remain relevant, the way in which science is funded, generated and assessed must evolve.

The growing interest in, and support for, Open Science is evidenced by new institutional, national, and multi-national programs, policies, and practices including European projects and policies such as the Amsterdam Call for Action on Open Science, the Budapest Open Access Initiative, and Plan S; initiatives targeted at Latin American and Africa; and pronouncements by international organizations. The United Nations Educational, Scientific and Cultural Organization (UNESCO), as the UN agency dedicated to science cooperation and promotion of the human right to science, has long had an interest in the Open Science movement as demonstrated by its Strategy on UNESCO's contribution to the promotion of open access to scientific information and research (2011), its Global Open Access Portal (GOAP), and specific provisions of the revised UNESCO Recommendation on Science and Scientific Researchers (2017).

More recently, UNESCO studied the possibility of a unique UNESCO Recommendation on Open Science to set out globally agreed-upon standards to guide institutional and state-level legal and policy frameworks. In doing so, UNESCO asserted that such an initiative would be consistent with the UNESCO Constitution and its purpose of maintaining, increasing, and diffusing knowledge, supporting collaboration, and recommending international conventions. This study concluded with a Draft Roadmap toward the adoption of such a Recommendation, which was approved at the UNESCO General Conference in November 2019.

The UNESCO Recommendation on Open Science aims to build a global consensus through an inclusive, transparent, and consultative process involving all countries and all stakeholders[2]. As UNESCO embarks upon the international consultation plan embedded in the Roadmap, member states and national commissions will be called upon to advise on the related issues. Canada would be well served by a national consensus on the relevant issues: one that is informed by multi-stakeholder consultations that involve scientists, research institutions, government, civil society, patients, students, philanthropic organizations, business, and youth. In this paper we focus mainly on Open Access, Open Data, and Open to Society aspects of Open Science, while acknowledging the many other components of Open Science (see Figure). This background paper seeks to ensure that the Canadian perspective is not only clarified but constructed to assist UNESCO in advancing Open Science in a manner that benefits all of humanity.

The Components of Open Science, UNESCO 2020[2]

1. What is Open Science?

The concept of Open science can be viewed as an approach to scientific innovation and discovery that sees collaboration and information-sharing as key pillars. The Organization for Economic Cooperation and Development (OECD) defines this concept as "*efforts to make the output of publicly funded research more widely accessible in digital format to the scientific community, the business sector, or society more generally.*"[3] H.E. Mr. António Nóvoa, Permanent Delegate of Portugal to UNESCO commented,

> "*Open science is about Open Access, free open access to knowledge, especially when it comes to research and knowledge produced with public funds […].More important still are the themes that link science to society, that build trust in science, like scientific popularization, science education, citizen participation in public policies about science [… .] Finally, Open science is about reducing inequalities between countries and regions.*"

FOSTER, a European Union Horizon 2020 project, is more general, defining Open Science as "the movement to make scientific research, data and dissemination accessible to all levels of an inquiring society"[4]. Open Science therefore includes open access, open data, access to the physical materials of science, and the free ability to use shared resources. Open Society refers to the active engagement of all

relevant stakeholders, which includes citizen science and open educational resources. It does not limit Open Science to that funded by public funds.

2. The UNESCO Recommendation on Open Science

Open science is enshrined in the Universal Declaration of Human Rights (1948). Article 27.1 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."[5] The International Covenant on Economic, Social and Cultural Rights (1966)[6], acknowledges the right to the benefits of scientific progress and also the right to benefit from the protection of the moral and material interests resulting from scientific endeavors (Article 15).

UNESCO, as the United Nations agency dedicated to science cooperation, was the first UN agency to place the Universal Declaration at the heart of all its actions. It regards science as a human right-- "the greatest collective endeavor"[7]--and an enterprise that has significant value as "a common good". UNESCO's strong interest in the Open Science movement is evidenced by its Strategy on UNESCO's contribution to the promotion of open access to scientific information and research (2011)[8], its Global Open Access Portal (GOAP)[9] and its 2017 Recommendation on Science and Scientific Researchers[10]. It considers science to be a collective human enterprise, as are the resulting findings and data.

UNESCO aims to use its normative power to turn the "right" to Open Science in the Universal Declaration on Human Rights into a "duty" to facilitate and promote Open Science, through its inclusion in multiple paragraphs of its 2017 Recommendation. Those implicated in exercising these duties involve researchers, institutions, educators, publishers, employers, libraries, and policymakers, facilitated by Member States. The 2017 Recommendation identifies the participants in science as everyone, as are the beneficiaries, and places special emphasis on international knowledge mobilization and Indigenous and traditional knowledge. As an agency of the United Nations directly implicated in promoting the implementation of the Agenda 2030 Sustainable Development Goals[11], promoting Open Science also strengthens UNESCO's contribution to the achievement of Sustainable Development Goals. It supports efforts to achieve target 9.5 on scientific research and target 12A on science capacities. There are also elements of Open Science implied in many other SDGs. Given that Open Science is already included in the 2017 Recommendation on Science and Scientific Researchers, and implied in many of the UN Agenda 2030 Sustainable Development Goals, why should UNESCO adopt a separate Recommendation on Open Science?

Generally speaking, people's knowledge of science scales with economic development. There is a persistent disparity in science capacity between developed and developing countries, and within some countries. Apart from a mention of "realizing the full potential of scientific communities worldwide", the 2017 Recommendation is limited when it comes to identifying Open Science as a key tool to reinforce the importance of international scientific cooperation to promote education for sustainable development and to build scientific capacity.

In addition, the 2017 Recommendation does not provide guidance on how to overcome potential clashes between Open Science and intellectual property rights. The onus is on Member States to implement Open Science within their own intellectual property regime contexts. Some Member States may require more support than others in dealing with the legal and policy frameworks regarding the potential rights conflict between Open Science principles and intellectual property, justifying a distinct

Recommendation on Open Science[12]. Moreover, during the process of consultation, the question may well arise as to whether Open Science should be adapted to the needs of intellectual property or if the reverse should be true. For example, in the context of science as a human right, the consultation outcomes may well identify a desire among Member States to adapt intellectual property to Open Science in cases where it is needed to promote the "common good".

The 2017 Recommendation applies to:

- scientific researchers,
- technicians, support staff and students supporting and contributing to research and development, and
- institutions and individuals responsible for research and development and other aspects of science (such as science education, science communication, regulation and policy, oversight, funding, recruitment, peer review and scientific publishing).

A Recommendation on Open Science, however, should provide clarity on any distinction to be made between public science (i.e. science supported by public funds and undertaken in public institutions) and private science (i.e. in-house research in private businesses). One advantage of a distinct UNESCO Recommendation on Open Science would therefore be a clearer definition and description of all the stakeholders potentially involved in or impacted by Open Science, organized by likelihood or extent of impact. This could include citizen scientists and the many different beneficiaries of science and scientific research.

In its brochure on the proposed Recommendation on Open Science, UNESCO states "The question is no longer whether Open Science is happening, but rather how everyone can contribute and benefit from this transition." Stakeholder engagement and co-design are critical to making the transformational change required to achieve the SDGs[13]. One of the key challenges with a Recommendation on Open Science will be developing the metrics required to measure the progress of its implementation, the breadth of its success in being of benefit to all, and its contribution to the achievement of the SDGs.

3. Open Science in Canada

Canada's federal government has made Open Science a high priority, developing key policies and investing in Open Science initiatives. Internationally, Canada has committed to:

- OECD's Declaration on Access to Research Data from Public Funding (2004)
- Commitment to the Open Government Declaration (2011)
- Support the work of the G7 Working Group on Open Science

At the domestic level, Canada and Québec have enacted several policies and programs in support of Open Science with regards to government and research funding. Acknowledging the lengthy process required to implement Open Science in Canada, the Canadian government and the Professional Institute of the Public Service of Canada have been working together to develop new policies and guidelines to facilitate Open Science in Canada.[14] In May of 2016, Canada's Directive on the Management of Communications was updated to address new ideals around transparency and accountability in the communication of research in Canada. The Model Policy on Scientific Integrity was also developed in 2016 to help ensure integrity within the presentation and conduct of scientific explorations within Canada.

Environment and Climate Change Canada is leading the Open Science commitment in Canada's 2018-2020 National Action Plan on Open Government[15]. It outlines Canada's goals and strategies to achieve both Open Government and Open Science, as they work to "*promote openness, transparency, and accountability in the Government of Canada.*" The commitments made to address the issue of Open Government overlap with the commitments to address Open Science. Of the ten sections outlined in the plan, the sections Open Science, Access to information, and Reconciliation and Open Government specifically address issues related to Open Science in Canada.

Most recently, Canada's Chief Science Advisor's Roadmap for Open Science[16] outlines the next steps to be taken to make federal science open to all. The Roadmap's ten recommendations are intended for science and research funded by federal government departments and agencies and sets out a phased approach to Open Science from 2020 to 2025.

The extent of commitment to Open Science in Canada is also exemplified by research council funding policies. Canada's Tri-Agency Open Access Policy on Publications[17], and the Fonds de recherche du Québec's Open Access Policy for the Dissemination of Research[18] both require publicly-funded peer-reviewed journal publications be made freely available within twelve months of publication. The Fonds de recherche du Québec is leading a new program called Engage, which makes the citizen a partner in the development and conduct of research. In addition, their program Dialogue aims to encourage the scientific community to interact with the general public about its work, results, and scientific approach in order to generate interest and a better understanding of science. The Fonds de recherche du Québec is in discussions regarding Plan S, which requires that, from 2021, scientific publications that result from research funded by public grants must be published in compliant Open Access journals or platforms. Québec is also considering signing the San Francisco Declaration on Research Assessment (DORA). DORA has already been signed by five Canadian research funding agencies. The Declaration strives to improve how scientific research is evaluated by encouraging activities relating to open science, such as making datasets available and "impact measures including qualitative indicators of research impact, such as influence on policy and practice."

4. Open Access

Open access broadly refers to measures that make scholarly content, such as published journal articles, free to read, use, modify, and share.[19] The Tri-Agency Open Access Policy states that Open Access "…enables researchers to make their publications freely available to the domestic and international research community and to the public at large, thereby enhancing the use, application and impact of research results." Open Access differs from the traditional model of scholarly publishing, which has been predominately subscription-based. Subscription-based journals publish content that can be exclusively accessed by those who pay a fee, usually paid by university libraries, research institutions, scholarly societies, or individuals.

Open Access removes barriers to access, meaning that anyone can access scholarly content at no cost. In contrast, subscription costs can be prohibitively high which in turn limits public access to scientific information, disproportionately affecting poorly funded research institutions and developing countries. Authors of Open Access content generally have control over their work and have the right to ensure that their work is properly attributed to them if used by others, under a license such as Creative Commons platforms CC-BY.[20] For many subscription-based journals, the publisher retains the copyright of published research.

Under the national action plan on Open Access, the Government of Canada has also committed to providing a platform for Canadians to find and access Open Access reports and other scientific publications from federal scientists. As part of this plan, a web portal will be piloted and a roadmap for the future of the Canadian Federal Science Repository prototype will be published, including next steps after the pilot.

Case study: Tri-Agency Open Access Policy

Like many research funders throughout the world, the Government of Canada has instituted a policy that requires federally funded peer-reviewed journal publications be made freely available within twelve months of publication. Federally funded research includes any research that is funded by Canada's Tri-Agencies: Canadian Institutes of Health Research (CIHR), the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Social Sciences and Humanities Research Council of Canada (SSHRC). This requirement can be met by researchers who either publish their work in a journal that offers full Open Access, or by archiving the accepted version of their manuscript in a freely accessible repository, either immediately or within 12 months. The accepted version of the manuscript refers to the version that has been peer-reviewed and accepted for publication but has not yet undergone a final copyedit and formatting/layout by the publisher.

The Tri-Agency Open Access policy was implemented in an effort to make research results as widely available and accessible as possible, with the philosophy that access to scientific information "is an essential part of advancing scholarship, promoting intellectual inquiry and critical analysis, and applying knowledge to ensure that practical solutions are found to challenges facing Canadians."[21] The following principles guide the Tri-Agencies in promoting access to research results:

1. **Advance Knowledge:** The advancement of knowledge depends upon peer review to ensure excellence, as well as long-term preservation to ensure that research can be built upon by others.
2. **Minimize Research Duplication:** Broad dissemination increases the effectiveness of public investments in research by reducing the potential for unnecessary duplication.
3. **Maximize Research Benefits:** Publicly funded research should be as accessible as possible in order to maximize the economic, social, cultural and health benefits for Canadians.
4. **Promote Research Accomplishments:** Improving access to research results will better promote the accomplishments of Canadian researchers throughout the world.

Despite efforts to promote Open Access through the Tri-Agency policy, it is important to recognize its limitations. Many authors are either unaware of the policy or deposit their papers in repositories that citizens are unaware of. There is also no enforcement or auditing of compliance, the latter of which would be useful for the implementation of DORA. In these ways, the impacts of the Tri-Agency policies on the implementation of Open Access in Canada are limited and might require further examination. In addition, other funding agencies, such as many provincial and private bodies, do not have set rules regarding Open Access[22]. While these policies can help increase Open Access, so long as publication paywalls exist, particularly in the case of prestigious journals, much of the scholarly publications will likely be locked up behind it. Canada could strive to develop plans like Europe's "Plan S", which was created when the EU Ministers resolved that all European scientific publications should be made immediately accessible by 2020[23].

Maintaining Scientific Excellence

Subscription-based and Open Access journals play an important role in ensuring rigor and expert validation of research results as part of the scholarly publishing process. Scholarly publishing involves the coordination of peer-review and editorial processes, copyediting and formatting, provision of unique identifiers and metadata tagging, safeguarding the preservation of research articles, ensuring professional standards are adhered to with respect to ethics and publishing best practices, and helping to enhance the dissemination of published work.

However, the rapid shift to Open Access has resulted in a proliferation of new Open Access journals from various publishers around the world. This rapid growth of Open Access has been exploited by publishers that attempt to deceive authors into publishing in their disreputable journals. Deceptive publishers exploit the author-pays model for their own profit. In many cases, such journals do not adhere to editorial and peer-review best practices or do not conduct peer-review at all. Deceptive publishers have the potential to jeopardize the scholarly record by publishing content that has not benefited from adequate expert vetting.[24] Fortunately for authors and readers, a number of tools have been made available to authors to help them determine whether or not a journal is legitimate (e.g., Think, Check, Submit[25]) and several organizations have been established to ensure the integrity of scholarly publishing through tools such as *The Directory of Open Access Journals*, which is a "community-curated online directory that indexes and provides access to high quality, open access, peer-reviewed journals."[26]

Funding considerations

Scholarly publishing costs have been traditionally covered through subscription fees, largely funded by research institutions and libraries. With Open Access, there has been a fundamental shift in how publishing costs are covered to a model wherein authors themselves typically pay article processing charges (APCs) to cover publishing costs. Researchers have some capacity to build publication costs into their research budgets, but for most researchers, APCs place additional burden on research budgets that are already tight. Both within Canada and internationally, there has been a movement towards identifying Open Access funding models that move away from the "author pays" APC model but as of yet there is no simple solution to this problem.

Novel approaches, termed "transformative agreements" have been put forward to transition subscription-based journals to Open Access and enable authors to publish their work as Open Access (e.g., read-and-publish[27]; Subscribe to Open[28]). While funders have agreed to cover publishing costs for eligible Open Access journals in certain European countries (e.g., Plan S), few alternatives to the "author pays" APC are available for existing Open Access journals for researchers in Canada and many other parts of the world. Thus, the APC currently remains the standard funding model for Open Access publishing.

The pace of the shift to Open Access has been remarkable, and consequently there is a need to ensure there is a framework in place to support this shift. One essential task is to find a way to unite all the stakeholders in the scholarly community, including researchers (academic, government, industry), research administrators, publishers, funders, and librarians as well as practitioners, policymakers, and the public. Several stakeholders have undertaken independent and often unrelated Open Science initiatives. However, these activities have largely been disparate and diffuse. A cohesive and unified national strategy on Open Science that unites all stakeholders in the Open Science ecosystem could be

developed. Working together, an alternative to the author pays APC can perhaps be identified. It is essential that any funding alternative be robust and sustainable in order to effectively support Open Access both now and in the future.

Case Study: The Canadian Science Fair Journal

The Canadian Science Fair Journal is an online, peer-reviewed journal that showcases science projects conducted and written by students from across the country. The journal was founded by researchers at the Children's Hospital of Eastern Ontario who had been studying rates of scientific publication in younger generations and recognized a lack in accessible platforms for STEM (Science, Technology, Engineering and Mathematics)-driven students to share and discuss their work. It is operated by volunteers and has so far published over 50 articles by students aged 6-18 years old, over four print editions.

The studies published in the Canadian Science Fair Journal are a wealth of localized, solution-based knowledge. Moreover, the students publishing their research draw on published research and data to provide context to their studies, and hence depend on Open Access and Open Data for the success of their projects. Organizations such as Canadian Science Fair Journal recognize youth as key change agents in the movement toward global sustainability, and actively foster qualities of citizenship, responsibility, and scientific awareness. They are therefore key stakeholders in the Open Science debate.

5. Open Data

The concept of Open Data is both an integrated element of the broader Open Science movement and a notion that can stand apart with its own merits and considerations. The Government of Canada defines it as structured data that is machine-readable, freely shared, and can be built upon without restrictions. This definition further states that Open Data should be available, preferably through downloading over the internet in a modifiable form and under terms that permit reuse and intermixing with other datasets.[29]

Within a scientific context, the Open Data concept applies specifically to data that support the results and conclusions of the published article and that could enable the results to be replicated or reproduced. Such scientific data can refer to “representations of observations, objects, or other entities used as evidence of phenomena for the purposes of research or scholarship.”[30] This definition extends to “raw data, processed data, code, media files (e.g., images, maps, video, and audio).”

As science is conceived as the systematic organization of knowledge that can be rationally explained and reliably applied, there should be a rational, logical link between the data concerned and related scientific claims such that the claims can be tested through experimentation. To make data open and useful to this end, many experts thus contend that it must be more than simply accessible, it must take the form of what is called “intelligently open” to allow thorough scrutiny and re-use.[31]
While Open Data systems generally find that it is not possible to make large data sets currently available within the infrastructure of a standard scientific publication, it can meet the accessibility standard by referencing data with a digital identifier linked to holdings in a trusted repository. Some repositories not only make datasets available, but also share the code used to analyze data (e.g. GitHub, BitBucket, or

GitLab)[32] often in a plug-and-play format – allowing reviewers to run an author's analyses to verify results.

Case Study: Big Data

The Open Science movement has gained a lot of momentum, especially with the implementation of Open Access publication policies and new Open Science ecosystems like Mendeley or Figshare to name a few. Thinking of science as a continuum it is also important to mention Quora and Science Reddit as an extension of scholarly knowledge into the public domain.

Open Science provides access to research data as well as ideas with which everyone can approach the wealth of Open and Big Data generated by the digital world. It is a game-changer in research that particularly affects the young generation. Having gained natural analytics skills by growing up around technology and Big Data, the new generation of students brings with them their lifetime experience and a natural talent for data analysis.

Young people play a critical role in the Open Science sites and social networks where they find knowledge and skills through collaboration and various contributions of community members. Here, they also get an opportunity to share their own understanding and receive a true learning assessment. It is a safe and impartial place to get feedback on their ideas, receive an appreciation of their knowledge, and find role models to follow.

To demonstrate how it works, let's consider a randomly picked example of a "hot" Science Reddit post: "Researchers show that socioeconomic attributes such as income, race and voting patterns can be inferred from cars detected in Google Street View. For example, if the number of pickup trucks is greater than the number of sedans, the neighborhood is overwhelmingly likely to vote Republican." [33] It is interdisciplinary, intellectually surprising, and very specific information. There is a feedback loop where young people respond with reflections and comments ranging from jokes to intelligent thoughts converting this rich information piece into a digital learner's knowledge building block.

This way Big Data undermines socioeconomic barriers and enables wider groups to build upon Open Science knowledge by using and reusing data in novel ways. It makes Big Data analysis an essential part of the scientific method and calls upon the young generation to take a lead role in critical thinking, reasoning, and decision-making with Big Data.

STEM Fellowship is a youth-run Canadian non-profit organization that uses mentorship and experiential learning to equip the next generation of change-makers with indispensable skills in data science and scholarly writing. The role of organizations such as STEM Fellowship that run an annual High School Big Data Challenge[34] are essential in building young peoples' interest, skills and understanding in Big Data. They rely on the open availability of Big Data to foster the current and future generation of data literate researchers.

This understanding of Open Data in science has been put forward for several decades in many disciplines, and though technical and administrative processes for requisite data recording, retention, and sharing can vary, some well-established models have been developed and implemented within specific scientific arena. These include those built upon the culture of data sharing in the fields of

bioinformatics, linguistics, crystallography, genomics,[35] and astrophysics as well as those established for internal sharing by individual institutions. Some disciplines are even encouraging researchers to preregister a hypothesis/experiment plan, indicating the code that will be used to analyze the data before an experiment begins (e.g. Center for Open Science).[36]

Reasons for Rise in Open Data

Support for the concept of Open Data continues to grow and the issues have drawn the interest of many institutions and organizations internationally as documented in *the 2015 Science International report Open Data in a Big Data World*.[37] In 2016, an international consortium of scientists from academia, industry, and funding organizations articulated a set of standards as the FAIR Data Principles using an acronym of the categories of Findability, Accessibility, Interoperability, and Reusability.[38] The memorable name and its promotion in scientific literature have together raised the profile of the key issues around Open Data including questions around enhancing the ability of machines to automatically find and use data.

Other influential groups include the Research Data Alliance, an international body of over 8,000 members from some 137 countries that promotes collaboration on the infrastructure for data-sharing and data-driven research.[39] Research Data Canada (RDC) is a stakeholder-driven and supported organization dedicated to improving the management of research data within Canada.[40] These and other supporters[41] of Open Data policies cite a variety of trends and considerations to buttress the call for accessible and freely available data. They include:

Productivity for the Public Good: Calls for openness and accessibility typically focus on data flowing from publicly funded science and the view of it as a resource having been made possible by public interest and resources. This in turn implies not only a right of access but a responsibility on the part of scientists to communicate new knowledge and to make it available as soon as possible after its production. Open Data would also permit its re-use and application to next generation research and the ongoing quest to build and test knowledge in the public interest. Data can, for example, be semantically linked by computers in ways that identify deeper relationships than are immediately apparent. This integration of data from diverse fields will be key to confronting global challenges such as infectious disease, migration, environmental change, and international development. A pioneer in this field in Canada is the Montreal Neurological Institute “The Neuro”, which has an Open Science, Open Data policy to accelerate discovery and discover cures.[42]

Complexity of Big Data: Arguments for urgency in support of the Open Data trend include the advent of “big data,” data characterized not only by volume but also complexity and speed of transfer.[43] This phenomenon has emerged from the interconnectedness of communications systems, data collection by the “Internet of Things,” and the increase in data-driven science. As scientific researchers were among the first users of these digital networks and computer access to data, science today feels the full impact of the “big data” era, which has thus magnified the challenges and benefits of data access.

Reproducibility: Perhaps, however, the most persuasive argument for Open Data and supporting policies rests on the need to ensure the integrity of science and the peer review system that upholds it. Without access to underpinning data and the tools to understand it, reviewers are impaired in their efforts to judge the merit of scientific discoveries and to attest to reproducibility, replicability and repeatability[44]. These challenges grow with the complexity of data systems and the sophistication of methodologies to interpret data. Open Data, as defined above, not only facilitates, but arguably

constitutes an essential tool in the self-correction processes that distinguish scientific knowledge and give it a peculiar value.

Limitations and Considerations

Though there are strong arguments for making the open release of data a default position for scientific research, certain issues suggest some caution should be exercised in the pursuit of such a policy and point to practical limitations to an Open Data regime.

1) Cost: One is the financial and human cost of time-intensive data management both for institutions and researchers. To be useful in the processes of assessment and reuse, data must be coupled with (1) rich metadata and preferably with associated text in a format that anticipates integration with other systems and (2) permanent digital identifiers that permit citation and verification of provenance long into the future. This requires high-level skills and capacities to manage deposition and long-term stewardship as well as a trusted data infrastructure. While investments in these systems and facilities might rightly be regarded as essential to the integrity of the scientific base, they challenge priorities and constitute an issue that all countries, institutions, and research communities will be compelled to consider. For example, the Open Government License for data is an attribution license. As datasets are combined the number of attributions, attribution types, and links to licenses increases, with associated increases in time and costs.

2) Ethics of Privacy and Confidentiality: While the sharing of datasets containing personal information empowers research in many fields of human concern from health care to economics, doing so in an Open Data format can threaten confidentiality, humanity's right to privacy, and the practice of ethical research. The Big Data paradigm, on the other hand, is characterized by uncontrolled and unconsented access to personal information. This is, in part, due to the increasing challenge of ensuring complete anonymization of personal records. Furthermore, anonymization procedures cannot erase the ethical concerns around all possible uses of personal data. For this reason, there is a strong public benefit to Open Data policies and strategies that, for example, require consent for data release or require deposition of data in secure repositories with limited access.

3) Commercialization: The trend toward Open Data in scientific research would seem to conflict with the inclination to protect and control intellectual property for commercial exploitation in a monopoly business model. For this reason, business firms are not normally expected to share proprietary data of economic value. Yet the route to greatest public benefit from research often lies in the development, production, and dissemination path of commercial enterprise. Questions thus arise when a scientific discovery has been publicly funded as part of a private-public sector collaboration or when data supporting a commercially important discovery, such as a medical treatment, relate to public risks. At the same time, some business activities have benefited from Open Data and shared understandings that provide the platform for further innovation and competition.

4) Safety and security: Some scientific discoveries hold the potential for harm as well as public benefit, and this advocates against publishing data related to national security, public safety, or health when such information could be misused though the research is publicly funded. While such work demands caution and care, Open Data proponents urge a balanced approach with case-by-case decisions and proportionate measures.

Case Study: Open Science Framework

The Open Science Framework (OSF)[45] is a collaboration tool for researchers developed and maintained by the Center for Open Science (COS), whose mission is "to increase the openness, integrity and reproducibility of scientific research". The OSF is a free, open source project management tool that supports all aspects of a research project, from developing ideas and designing a study, to data collection, storage and analysis, to publication of the project findings.

The tool allows researchers to make projects only accessible to certain users or publicly accessible for broad dissemination. Those that are public can be found online through a search tool, facilitating the sharing of all stages of the project such as protocols, data, code, materials and preprints. One advantage of the platform is the ease with which third-party functions can be integrated. For example, among others, Mendeley and Zotero can be integrated to support citation management, while Dropbox, figshare, and GitHub, can be integrated to support storage.

A Mix of International, National, and Disciplinary Approaches

A number of international organizations (notably, the International Science Council's (ISC) Committee on Data for Science and Technology (CODATA) and the World Data System and the Research Data Alliance) have adopted or endorsed statements of principle and proposed governance frameworks to manage these issues while supporting the move to openness. The FAIR Data Principles have also been embraced by influential bodies such as the Association of European Research Libraries.

However, these statements and policies typically refrain from prescribing operational and delivery processes, recognizing that these are best defined at the level of nations. This recognizes that benefits often flow to the national jurisdiction in which a discovery is made, and thus the arguments for corresponding investments in the scientific base and specifically in data storage, transmission, and preservation infrastructures are best put forth in this context.

Furthermore, although science is an international enterprise, it is largely done within disciplinary systems that are organized, funded, and motivated within their own codes and practices. Effective Open Data in a data-intensive age can only be realized if there is systemic action at the disciplinary level as well as within the framework of national and international norms. For example, even though general measures like embargoes on the release of data can have appeal, individual disciplines develop procedures that are sympathetic to their needs and codes of ethics.

Nevertheless, as illustrated in the above examples, international bodies have a role in the promotion and development of systems and procedures that ensure data access, interoperability and sustainability. But any new effort to articulate international norms should respect and acknowledge significant prior statements on the issue and aim for easy integration with established national procedures and disciplinary standards.

6. Open to Society

Citizen Science

Citizen Science is the movement to involve more non-expert citizens in the scientific process. This movement thus strives to involve citizens in many aspects of the scientific process – from data collection to analysis.[46] As mentioned above, federal and Québec funding agencies promote numerous research projects that give citizens an opportunity to collect data, solve problems, and contribute to the development of a scientific project. In addition, civil society plays an important, but sometimes overlooked contribution to citizen science engagement, particularly with young people. It is encouraging that the consolidated roadmap[47] towards a possible UNESCO Recommendation on Open Science names the Global Young Academy as one of the key Open Science stakeholders to consult in the drafting of the Recommendation. However, it is up to Member States to ensure that the voices of citizen scientists, particularly youth, are included in the text. The case studies below highlight some of the work of civil society in engaging young citizen scientists in Canada.

Case Study: Mission Monarch

Mission Monarch is a joint initiative of the Insectarium – Montréal Space for life and the Institut de recherche en biodiversité végétale[48]. A truly pan-Canadian project, the initiative involves researchers from the University of Ottawa, the Université du Québec à Rimouski, the University of Calgary and Environment and Climate Change Canada. It is aimed at gathering data on monarch and milkweed distribution and abundance; participants find milkweed, look for monarch caterpillars and share their observations via an online database. In addition to submitting data to help researchers identify the monarch's breeding hotspots, participants can also explore the data that has been gathered.

Indigenous Knowledge

In 2019, the World Science Day for Peace and Development, had the theme "Open science, leaving no one behind".[49] The UN Environment Programme suggested in its announcement about the day that "One way that open science could lead to a sustainable future is by helping to capture the experience of indigenous peoples in future assessments of climate change and to reflect indigenous knowledge on a global scale. In doing so, it could help to do away with the old rivalry between Western science and indigenous knowledge systems." It went further to suggest that Open Science could be beneficial "so that a more diverse group of people have access to it, including traditional knowledge holders. This could drive understanding and encourage collaboration between scientific researchers and traditional knowledge holders."

The relationship between Open Science and Indigenous knowledge needs to be carefully navigated with respect to data sovereignty and the ongoing process of reconciliation. Canada's 2018-2020 National Action Plan on Open Government commits to co-creation and co-implementation of approaches to open government with Indigenous Peoples. It draws specifically on the responsibilities placed on governments in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP) to respect and promote cultures, traditions, histories and philosophies.

Recommendation #8 of the 2018 Report to the Clerk of the Privy Council, "A Data Strategy Roadmap for the Federal Public Service"[50] states "Recognizing that Indigenous Peoples have an inherent right to self-determination, co-develop with Indigenous partners distinctions-based strategies to advance Indigenous data governance and institutional capacity. The Government of Canada should also work with Indigenous partners, who are the custodians of their data, to co-develop indicators and data collection strategies." It similarly aims to establish collaborative approaches to data collection, sharing, and stewardship, and to advance Indigenous governance of their own data.

The Canada Research Coordinating Committee's Strategic Plan "Setting new directions to support Indigenous research and research training in Canada" (2019-2022)[51] is a co-developed interdisciplinary Indigenous research and research training model that contributes to reconciliation. It arose out of regional consultations during which Indigenous Peoples emphasized the need for greater ownership and control over Indigenous data. It recommends that the three major federal funding agencies should champion and support Indigenous data management protocols, and highlights issues of consent, ownership and protection of Indigenous intellectual property rights.

Indigenous people need to be incorporated every step of the way in terms of the development of Open Science at all levels from academic and civil-society institutions to government. This would include working in partnership with communities that are already leaders in these fields, such as the First Nations Technology Council[52], and Inuit Tapiriit Kanatami[53]. It also requires considering different definitions of data sovereignty and designing protocols for working with the over 50 First Nations, Métis and Inuit in Canada.

Conclusions

Open Science is a key tool to reinforce the importance of international scientific cooperation, to promote education for sustainable development, and to build scientific capacity. A Recommendation on Open Science will cement UNESCO's leadership in upholding science as a fundamental human right. It will also foster the establishment of national and international networks, research collaborations, and technical linkages that flow from data sharing and access to information. This would enable Least Developed Countries and Small Island Developing States to strengthen their science base and innovation ecosystems.

There is widespread support for Open Science in Canada, with leadership from federal and Québec government initiatives, national research councils, and research organizations such as the Montreal Neurological Institute-Hospital. When considering national or international policies on Open Science, Canada and Canadians should carefully consider the following:

- Funding models for journals should be robust and sustainable in order to effectively support Open Access both now and in the future;
- The potential clashes between Open Science and intellectual property rights should be carefully examined;
- Funding for the development of systems and procedures should ensure data access, interoperability, and sustainability;
- Consultations should include all civil society, and especially youth;
- How to define metrics and measure progress in access to science and its benefits;
- Clearly define how Open Science applies to public vs. private science; and

- There should be broad consultation with Indigenous Peoples in both the development and implementation of Open Science policies.

There is a clear opportunity with the development of this Recommendation to enhance the interfaces between science and society. Open Science is not simply a question of ensuring free and open scientific knowledge but how this is achieved. A UNESCO statement on Open Science could thus serve a practical purpose if it not only drew and built upon other policy initiatives, but also considered the full scope of concerns as a whole and articulated them in a unified instrument that addressed those global concerns and spoke to the interests of all humanity.

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