Open Science and the Academy

A Theoretical Discussion

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***Abstract*— The Open Science movement is gaining traction since the G8 Science Ministers made a joint statement in 2013 on open scientific research data and increasing access to the peer-reviewed published results of scientific research. Major policy developments can be seen in funding agencies mandating open access to scientific results. However, the idea of Open Science represents an alternate approach to the scientific process enabled by digital technologies encompassing the entire research cycle, including how researchers are being evaluated and rewarded. Still, even though the idea of Open Science is envisioned as a systematic change in the way science is performed, the scientific communities remain largely ignorant on this issue.**

This paper presents a theoretical discussion on how academics might adopt the idea of Open Science by scrutinizing the background and evolution of this policy agenda and the issues arising from it, and by analyzing academia's perception of and behavior toward Open Science. The misalignment of Open Science purposes and the researchers' value is pointed out as the major impediment to realization of Open Science concept.

Keywords—Open Science; open access; data sharing; research data management; digital technology; research evaluation; researcher; incentive

I. Introduction—From Open Access of Publications and Research Data Sharing to Open Science

Open Science is used as an umbrella term for opening up aspects of the scientific research process. Open access of research publication, research data sharing, collaboration on information and communications technology (ICT) platforms, open source and open notebooks, and citizen science are all considered part of Open Science [1]. However, major developments in Open Science can be seen in the policy measures of funding agencies requiring research outputs, both publications and research data, be made more readily available to the public [2].

The movement to make research publications openly available first started among academics. Subscription costs have more than quadrupled in the last thirty years, and academics ran into trouble sharing research publications even among themselves [3]. Protests by academics led to two innovative ways of providing research publications in an open format: (1) self-archiving, where scholars deposit their refereed journal articles in open electronic archives (green OA), and (2) submission of their work to open-access journals (gold OA).

Governments and research funding agencies also started to demand open access to research publications that were publicly funded. A medical patient in the United States who wanted to study his illness in research articles claimed that it was unfair to also be charged for the research outputs, as the research itself was already funded by tax-payers [4]. Governments and funding agencies charged with accountability and transparency issues followed the claim. In 2000, the National Institutes of Health (NIH) in the US created a repository called PubMed Central where research publications can be deposited and shared online. In 2007, the deposit of research articles funded by NIH into the repository was mandated, and similar open access policies started to be adopted by other funding agencies. In 2012, Research Information Network in the United Kingdom issued a report, commonly called the Finch Report, clearly recommending gold OA publishing, whereby publishers receive their revenue from authors rather than readers [5]. And in 2013, the Global Research Council, comprised of the heads of funding agencies from around the world, announced the "Action Plan towards Open Access to Publications," following which funding agencies around the world started to pursue open access policy measures [6].

After the mandates on research publications, funding agencies also started to ask for research data to be made publicly available. In 2003, the NIH adopted the Data Sharing Policy, which required investigators submitting an application to include a plan for data sharing or state why data sharing was not possible [7]. In 2004, the Declaration on Access to Research Data from Public Funding was adopted by the Organisation for Economic Co-operation and Development (OECD) and in three other countries [8][9]. In the UK, the Biotechnology and Biological Sciences Research Council (BBSRC) was the first to announce the Data Sharing Policy, which became a common rule among all UK Research Councils in 2011 [10]. In the US, the White House issued the Executive Directive on Increasing Access to the Results of Federally Funded Scientific Research in 2013, which required U.S. funding agencies with annual expenditures in research and development over $100 million to develop a plan to support increased public access to the results of their funded research. This included both research publications and data [11]. The European Commission started the Open Research Data Pilot for selected projects of Horizon2020, the European Union Research and Innovation program for the years 2014 to 2020 [12]. In 2013, the G8 Science Ministers made a joint statement on open scientific research data and increasing the access to

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peer-reviewed published results [13]. In 2014, the Australian Research Council (ARC) started to require researchers to outline how research data will be managed for ARC-funded research. Commercial publishers also started working on research data sharing by establishing data journals where research data can be published. In 2014, the Nature Publishing Group launched "Scientific Data," and Elsevier launched "Data in Brief."

In 2015, a policy concept named Open Science became widely recognized. Open Science includes the idea of making research outputs—both publications and research data—openly available, but is also a broader concept encompassing the entire research cycle.. The European Commission (EC) adopted the term "Science 2.0." However, they renamed it after the term Open Science was suggested through public consultation. Science 2.0 is described as "the on-going evolution in the modus operandi of doing research and organizing science…enabled by digital technologies and driven by the globalization of the scientific community, as well as the need to address the grand challenges of our times" [14][15]. Also in 2015, the OECD published the report "Making Open Science a Reality" [2]. In 2016, the EC announced "Open Innovation, Open Science, Open to the World – a Vision for Europe" in order to realize the priority policy "Digital Single Market" [16]. Under the "Amsterdam Call for Action on Open Science," policy actions are underway such as the establishment of the European Open Science Policy Platform, which gives advice to the EC, and the development of the European Open Science Cloud for hosting and processing research data in a trusted environment [17][18].

The vision of Open Science involves a systematic change in the way science is performed, which cannot be realized without the involvement of academia. However, the scientific communities remain largely ignorant on this issue [14]. Under such circumstances, it would seem that the idea of Open Science cannot be fully realized.

This paper presents a theoretical discussion on how academics would adapt to the idea of Open Science by scrutinizing the background and evolution of this policy agenda and the issues arising from it, and by analyzing academia's perception of and behavior toward Open Science.

II. Overview of Open Science

A. Definition

Open Science is defined in many different ways. However, major policy documents refer to Open Science as a systematic change in the way science is performed.

Rather than framing Open Science with a fixed definition, Open Science is commonly referred to as an umbrella term. In "Open Innovation, Open Science, Open to the World," an EC policy document, the following terms are included in describing Open Science: open data, open tab books/workflow, data-intensive, citizen science, open code, pre-print, open access, alternative reputation systems, collaborative bibliographies, science blog, and open annotation. This openness is meant to occur throughout the entire research lifecycle: from conceptualization and data-gathering, to analysis, publication, and review [16]. This shows that Open Science, though it advocates making research outputs publicly available, is a broader concept encompassing the entire research cycle.

The OECD (2015) names economist Paul David (2003) as the coiner of the term "Open Science" [19]. However, the concept of Open Science became more widely known through Michael Nielsen's 2011 book Reinventing Discovery: The New Era of Networked Science [20]. The Scholarly Publishing and Academic Resources Coalition (SPARC), a major organization advocating open sharing of research outputs and educational materials, honored Michael Nielsen as an innovator for bringing Open Science into the mainstream [21].

It should be noted that different aspects of Open Science are emphasized depending on the advocates. Michael Nielsen's book focused largely on citizen science, where professional scientists pursue research in collaboration with amateur scientists. The EC prefers to emphasize the big picture of systematic change in the way science is performed in a digitally networked society. The OECD puts the idea of sharing with society the research outputs of publicly funded research in the center and pursues policies requiring research funders making research publications and research data openly accessible. The US used to use the term "public access," but has recently started using the term "Open Science" after Europe and the OECD began emphasizing its Open Science policy agenda.

B. Drivers of Open Science

There are several drivers of Open Science, which is calling for a systematic change in the way science is performed.

1) Proliferation of Digital Technology

Most of the Open Science advocates agree that digital technology, especially ICT, is the main driver of Open Science. Furthermore, the impact of digital technology can be observed in several different aspects.

First, the distribution of information was enabled dramatically through the Internet. In the print age, the physical size and the distribution cost of printed matter placed major constraints on how much information could be acquired and distributed. However, once research articles started being digitally created and provided online, these restrictions disappeared. Theoretically, everyone became able to acquire information instantly without any cost. In reality, research articles continue to be constrained by page limits, the number of articles in a journal, and high subscription charges of academic journals, based on the established practices of the print age. However, research publications could be made fully open at a minimum processing charge for research publications, data, and other related materials.

Second, communication among people increased dramatically in terms of the number of people who could communicate with one another and the distance over which they could communicate. Before the Internet, to communicate at a distance people relied on sending letters by post and telephone calls. These means of communication were highly constraining for people wanting to work together on a project over a distance. The Internet removed the physical constraints and enabled instant messaging among multiple people simultaneously. The Internet also has the advantage of enabling people to share documents and to work on them at the same time.

Third, digital technology is said to have led to an immense volume of data being handled by researchers. Internet activity led to what are called life logs—vast records of people's transactions, information exchanges, and site visits,. Even physical experiments such as in material or life sciences generate a massive amount of data through automated measuring instruments. Nowadays, chemists and biologists are asked to analyze massive amounts of data as data scientists. The science involving such massive amounts of data is termed "data-driven science," or "data-intensive science," and is said to be the fourth scientific paradigm following theoretical science, experimental science, and simulation science [22]. Such massive amounts of data are often stored in cloud drives and analyzed with tools provided as an Internet service.

2) Demand for Accountability and Efficiency

Societal demands for accountability and efficiency are also pushing for openness in research output as large investments in academic research are made using taxpayers' money.

Severe cases of research fraud in recent years have also led to calls for greater accountability. False research publications involving data fabrication and plagiarism have been exposed to the public, which led to severe distrust of academia. Also, some studies have shown the low reproducibility of research findings published in research articles. Nature conducted a web survey in 2016 where more than 70% of researchers reported having failed in reproducing other scientists' experiments and more than half reported to have failed in reproducing their own research experiments [23]. Such vulnerability in research is leading to demands for increased accountability among researchers by making the evidential data used in research articles open [24].

At the same time, marketization around the world is resulting in calls for economic efficiency even in the academic world. In general, the research outputs of heavily funded research are transmitted to the public through research publications and applications using the research findings. However, the actual research data obtained are usually kept by the researchers; the information is likely stored on a hard drive where it may be forgotten. There is an expectation that these research data could lead to new research findings when reused by other researchers with different research interests. Also, combining the data with data from different disciplines could lead to interdisciplinary work that might solve grand challenges and lead to further innovations.

3) Global Challenges and Social Aspects

The complexity of global grand challenges in recent decades has led to demands for stakeholders and experts in different disciplines to work together to tackle the challenges. These challenges ask for societal problem solving rather than purely academic research, so the scientists are required to work with society more than ever. Such projects involving different stakeholders working together can be enabled through an Internet platform where communication and documents can be stored, shared, and made available with transparency.

So-called citizen science is also attracting attention. Also known as crowdsourcing, citizen science involves the cooperation of citizens in academic research where a lot of human effort is needed. For instance, citizens might be asked to report on some particularly rare species when observed. Galaxy Zoo is a well-known project that asks citizens to classify the shapes of galaxies. Rather than working on societal problems, citizen science usually follows from the lead of an academic researcher who defines the research agenda and the collaboration needed.

C. Developments of Open Science and its Actors

There are several developments with different actors working under the term Open Science.

1) Mandates for Research Data Management for Publicly Funded Research—by Funding Agencies and Universities

This is the clearest development regarding Open Science. As mentioned in section 1, the funding agencies in the US, the UK, and the EU are asking for data management plans (DMPs) to be submitted when applying for research grants. Even though the implementation of the submitted DMPs is not being monitored yet, it is said that the DMPs have led to awareness among researchers of the need to properly manage data. Submission of DMPs, or the research data management (RDM) itself, is considered to be the responsibility of the researchers. However, in 2011 the Engineering and Physical Sciences Research Council (EPSRC) took it one step further with its policy framework on research data by asking institutions to be responsible for the RDM of their constituent researchers.

2) Provision of Data Repositories and Data Analysis Tools—ICT Centers at the University and National Level

ICT centers both at universities and at the national level are starting to provide data repositories and data analysis tools for research data. These are not necessarily provided to meet the requirements of funding agencies. Rather, they are provided as research infrastructure to facilitate research using digital technology. For instance, in the EU, GÉANT provides the Global Research Data Infrastructures, an e-infrastructure which links researchers and their data across borders and disciplines. Additionally, these infrastructures can serve as the base to store and make data publicly available as required by funding agencies, and can be stated as official data repositories in researchers' DMPs. Now, there is also a registry of research data repositories, called the "re3data.org," where researchers can search for an appropriate repository.

3) Open Accessing of Research Publications and RDM—University Libraries and Publishers

There are also efforts to make research publications openly available as part of Open Science endeavors. University libraries are providing institutional repositories where research articles can be deposited (green OA). Publishers are publishing open access journals and also providing options to make particular research articles open access upon payment if the academic journal is not fully open (gold OA).

A similar evolution can also be seen for research data. Publishers are providing an infrastructure where evidential data can be deposited as a supplement to an article. Several university libraries have started to establish and provide data repositories in cooperation with their ICT centers. They are also providing support to add metadata to the research data to make them more findable and reusable. Many libraries support the drafting of DMPs, using "DMP online" in the UK, and "DMP tool" in the US.

4) Research Evaluation Reform—Publisher, Scholarly Communication Community

Several new methods for evaluating academic research are also developing. They make evaluation open in various aspects.

First, there is the open peer review, which is aimed at making the review process of research articles transparent. There are also attempts to evaluate research based on new perspectives rather than using traditional academic metrics such as paper and citation counts. Altmetrics is one example; it measures the social impact of research articles from social media. There are also efforts to incentivize researchers to pursue Open Science. Data journals are established to provide a base where research data can be published and cited, which in turn leads to an evaluation of the researcher who generated the research data. Post-publication peer review allows the articles to be published immediately after submission and to be valued based on the impact of research, which typically emerges over time.

5) Enhancing Transparency and Reproducibility—Governments, Universities, Academic Communities

As described in Section 2-B-2, governments, universities, and academic communities are taking measures to prevent research fraud. Data repositories where research data can be submitted and made public, as well as rules to preserve research data for ten years, have been established. Various guidelines are also being introduced. Research reproducibility is being tested by academia for various disciplines. There are also attempts to use open notebooks to enhance research transparency.

6) Citizen Science

Citizen science, as explained in Section 2-B-3, is a way to conduct academic research in cooperation with citizens. However, the research topics that can be crowdsourced are limited.

III. Challenges of Open Science

Open Science has become the trend of national science and technology policies since the G8 Science Ministers made a joint statement in 2013 on open scientific research data. It even became one of the top three research and innovation priorities of the EC. The US was using the term "public access," especially during the Obama administration, but has recently started to use the term Open Science. Various Open Science policies have also been announced by different countries.

However, perhaps because Open Science is an umbrella term rather than a term with a clear definition, there are concerns that Open Science is not progressing as desired, or that it is not on firm ground [14]. Even for the RDM agenda, where policy measures are most concrete, challenges such as those described in the following sections make the realization of Open Science hard to achieve.

A. Lack of Incentives for Sharing Research Data

This is the most pressing issue and the most difficult to solve. In the Open Science context, there is no reasonable incentive for researchers to share data.

As discussed in section 2-B, Open Science is pursued for the purposes of accountability, data-reuse efficiency, and/or to solve global challenges. Since the interests of researchers lie in pursuing their own research, researchers do not show interest in accountability or data-reuse efficiency. Even in solving global challenges, it is difficult to convince researchers to share data since this will benefit researchers outside the academic community to which the data-holding researcher belongs. Data sharing within an academic community has occurred, even facing at times the resistance of researchers to share data because of self-interest, for the sake of that community. In Open Science, the researchers who are working to share data and researchers who are analyzing the data and realizing the fruit of the research are different sets of people, making it difficult to establish a data reuse ecosystem.

Attempts are being made to incentivize the sharing of research data. As discussed in Section 2-C-4, data journals are established to allow data generation to be counted in research evaluation. There are studies that show that making research data available to the public leads to citation increases. However, there is a long-standing tradition in which researchers are evaluated and shown respect for the articles they produce. Such criteria are deeply rooted in the academic system, especially when it comes to hiring and promotion, funding allocation, and university rankings, making it difficult to change the status quo.

B. Bearing the Cost of Open Science

The time and work needed to share data is also of concern. Researchers devote their time and work for their own academic purposes and for the academic community they belong to. There is no rationale for using time and work for people outside their community. Moreover, when sharing research data with the general public, researchers must add thorough explanations and metadata and standardize the format to make the data understandable.

Some funding agencies have stated that the cost incurred from sharing data can be included in research funding applications. However, this is not a general rule. The UK indicated in the Concordat on Open Research Data (2016) that researchers and institutions who share the data should bear the cost of doing so [25]. The researchers providing the data are considered the beneficiaries of data sharing in this case. There is an expectation that university librarians will take up the role of data curators. Still, it is impossible for university librarians to handle all research data generated within their institution, especially at large research universities. Additionally, as data curation involves special skills such as knowledge in scientific disciplines and data curating skills, it is not easy to find people with the right skill sets.

C. Specialization and Career Assurance

As research teams expand in number, specialization among the research members occurs. Some generate data through experiments, some clean the data, some analyze data, and some curate data. Such division of labor seems to be ideal, as each task involves highly professionalized skills.

However, the division of labor raises other concerns. How should specialized professionals in niche fields be cultivated, and how should the career of the person in charge be assured? Researchers have a fixed system in place where they are evaluated by their research achievements, which assures their salary and promotion. However, there is nothing like this for professionals who are not general researchers, such as those in data generation and data curation.

D. Range of Open Data

Contrary to sections A to C, which discussed who would bear the burden of sharing research data, there are also issues concerning how much and what type of data should be made open and what should be kept secure.

There is general agreement that data with privacy concerns or data that involves industrial confidentiality should be allowed to be kept secure and should be made available only under certain conditions. However, the details of the procedure such as the criteria to determine which data should be kept secure or open, what procedure should be involved to decide this matter, and the range of openness in cases where the data will be disclosed under certain conditions, still needs consideration and further discussion.

At the same time, even for publicly funded research data that are in principle expected to become publicly available, consideration should be made as to whether it is worth the time and effort of data curation even for small and local datasets. As discussed in section 2-B, in Open Science, there is an expectation of innovation and solving global challenges through the reuse of research data. If the research data are too local or too small to be combined with other data or reused for other purposes, the priority to make such long-tail data available to the public might be lower.

IV. Discussion: The Possibility of Universities Adopting the Idea of Open Science

A. Tension between Open Science Advocates and Academia

The issues raised in section 3 indicate a serious conflict between researchers values and the aim of Open Science.

Researchers put the greatest value on pursuing excellent research in their own academic field. Data sharing and international research collaborations happen only if they lead to this. In contrast, Open Science advocates promote accountability, data reuse and economic efficiency, societal problem solving, and innovation as benefits of and reasons to pursue Open Science. Improved accountability and efficiencies are passive reasons and are not drivers for excellent research. Even for the societal problem solving and innovation that are given as the fruits of Open Science, industry and society are the recipients of the fruits in the first place, and academia benefits from the fruits only indirectly. On top of this, there is no clear evidence indicating that Open Science and data sharing lead to any innovations. Provision of research tools such as the data repositories and data analysis tools as described in Section 2-C-2 contribute to excellent research but also rather in a passive way.

There are attempts to align researchers' values and the purposes of Open Science. The research evaluation reform described in Section 2-C-4 is a leading example of this. However, these attempts to change the academic value system in a rather forceful way are not acceptable to the academic communities. Showing evidence that sharing data leads to enhanced citations is also not sufficiently compelling, since academics know that they are respected based on the quality of research articles and not by research data that are the material for theoretical thoughts. Academics are by definition scholars working to create new scholarship.

Additionally, many do not see that universities do not act as a single entity. There are different actors within a university, and they have different views on Open Science. The university administration and research office try to follow the mandates of the funding agencies as a matter of institutional compliance. The university administration might also pursue Open Science as part of their open access policy or research strategy. University libraries and IT centers are pursuing Open Science to provide research support through data curation and the provision of advice and e-infrastructure, such as data repositories and research tools. These libraries and IT centers show the most excitement, as the idea of Open Science could give them a greater role within the university. However, in general, their voice is not strong enough to change the way research is performed. Lastly, the academics follow the mandates of the funding agencies but usually do not understand the points of the mandates.

B. The Value of Open Science Academics Might Favor

As discussed, academics do not favor Open Science that benefits people outside their academic community. The claim that digital technology is opening up new ways to perform research is not itself convincing, as there have been plenty of new technologies in the past where the change was more subtle than claimed in its propaganda. The argument that a swift adoption of new technology will lead to a competitive advantage is appealing to institutions and university administrators, but not to researchers.

However, even academics are in greater need of RDM through the rapid expansion of international collaborations and the use of big and diverse data due to the globalization trend and the proliferation of digital technology. The data produced by a research team can easily get out of control, as each team member has a different stake in the project. Additionally, researchers are usually involved in multiple research projects in which they hold different roles, and this can make it difficult for them to keep track of various data. It sometimes even happens that researchers cannot locate their data after the project has finished. However, researchers do want to maintain control of their work, so a system enabling RDM and project management would be beneficial.

The same applies for alternative metrics for research evaluation. There are growing numbers of researchers who are working on societal issues rather than purely academic topics, and who write articles and reports targeted to the general public. These papers are usually non-academic papers that are barely assessed in terms of researcher evaluation. However, since the average person does not read academic research articles, researchers working on societal issues have to find a balance between what is meaningful to their work and what is effective for research evaluation. These researchers would be happy if the work targeted towards society was also valued in academic terms. This way, the quality of societal work would also be enhanced. Likewise, there are growing numbers of researchers working in areas on the periphery of research—public relations, data curation, and project management—that require highly professionalized skills as well as discipline-specific knowledge but are not valued as academic work in the traditional sense. These researchers would also benefit if such academic support work was evaluated properly.

There is also a movement in academia to make research data public to enhance research transparency. The Climategate scandal in 2009 prompted the Royal Society to issue a report called "Science as an Open Enterprise," which became influential in the Open Science movement [26]. The report "Open Data in a Big Data World" was announced by four international academic associations (ICSU, IAP, ISSC, TWAS) [27]. Studies have also been done to check the reproducibility of research articles, following cases of research fraud [28]. There is even a movement among psychologists called the Peer Reviewers' Openness Initiative not to review any papers when evidential data are not provided.

Also, the long-standing movement by the academia towards open access of research publications should be mentioned; although this is happening more as a protest to the rising subscription cost of academic journals rather than the desire to open up the scientific research process. There are Open Access Weeks held internationally, and several universities around the world have adopted open access policies. Similar developments can be seen also for research data.

C. Possible Future of Open Science

The Open Science movement started with academics in protest to the rising subscription cost of academic journals. However, governments and funding agencies started to promote this from the point of accountability and economic efficiency, which transformed the agenda into a research and innovation policy measure without the commitment of academics. On top of this, the policy measure was renamed from "open access" and "research data sharing" to the abstract term Open Science, which made it even more difficult to get the buy-in of academia. The Open Science agenda was influential in the establishment of open access policies by governments and of mandates by funding agencies to make publicly funded research achievements openly available. Still, even though Open Science was envisioned as a systematic change in the way science is done, the scientific communities remain largely ignorant of this issue.

Even though the term or idea of Open Science is not accepted by academia, new technologies, such as digital technology, are being adopted by researchers and transforming the way researchers communicate and do research. Some researchers are proactive in experimenting with new ways of doing research and working on societal issues with citizens, and there are also efforts to enhance research transparency. With more such endeavors, these trends might eventually reach a critical point, and the idea of Open Science realized.

The idea of Open Science where research achievements are shared openly and where research is performed in an open manner will eventuate without any intentional efforts. Still, if policymakers are to accelerate the movement, it would be better to pursue the Open Science agenda from the standpoint of researchers by meeting their needs and supporting the researchers who try new ways of doing research. As for researcher evaluation, it is a system entirely embedded in the academic world and is difficult to change. However, if opting for research evaluation reform in a rather forceful way, it would be better to approach the academic institutions where hiring and promotions occur. Proposals for changes in research strategies, faculty reviews, and research support structures might be adopted by academic institutions that believe these will lead to a competitive advantage over peer institutions.

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