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OPEN SCIENCE

Open Science in Context

"What science becomes in any historical era depends on what we make of it" - Sandra Harding[1]

We are currently witnessing fundamental changes in the *modus operandi* of science spanning the entire spectrum of research practices. Every day researchers are making use of open online tools, data and educational materials, creating and publishing their own content via social media and sharing platforms, independent of traditional forms of knowledge distribution and evaluation.

Open Science is based on the idea that scientific knowledge of all kinds should be openly shared as early as is practical in the discovery process[2]. By demanding maximum transparency and shareability in knowledge production and transfer as well as the participation of (all) relevant stakeholders in the scientific process, the open science movement strives to increase

- reproducibility and accountability
- re-usability and new applications
- collaboration and societal participation

in science.

Realms of Open Science practices include Open Access, Open Research Data, Open Methods, Open Education, Open Evaluation, and Citizen Science, all based on sustainable research infrastructures and supported by Open Policies in all fields of science, including social sciences and humanities.

Regarding openness as accessibility and transparency only in terms of meeting society's expectations, or of making science easier to understand, would be too simplistic. Open Science is part of a broad shift in networked societies: The internet and social media have brought about new modes of socially produced knowledge and the creation of new socio-epistemic spaces, experimenting with modalities of shared production, (re-)use, and (re-)distribution of knowledge and common goods. Openness leads to the creation of new environments for public debate and participation.

[1] Harding, Sandra. *Whose Science? Whose Knowledge? Thinking from Women's Lives*. Contemp. Sociol. 536. 1991.
[2] Nielsen, Michael. *Doing science in the open*. 2011.

In European policy, Open Science is regarded as a central component of Open Innovation, enabling new forms of stakeholder interaction in order to build and maintain sustainable eco-systems for co-creation. In this context, emphasis could be put both on the successful commercialisation of research outcomes as well as on the benefits of common goods, such as information commons[3] for businesses and society at large.

Hot Topics: The Open Science Multiple

Today's Open Science movement grew bottom-up from scientific communities influenced by free (and open-source) software and the free culture movements of the 1980s and 1990s. It has found its way into policy-making in the early years 2000 with the shift to Open Access publishing in science and via the need for restructuring research infrastructures for e-science.

European innovation policy regards Open Science as the solution to better, more transparent and effective research and scholarship, eradicating fraud, enhancing reproducibility, and confronting redundancy. Therefore it is embedded as a cross-cutting theme into the work programmes of Horizon 2020. Elements are also feeding into the shaping of policies for Responsible Research and Innovation, and are contributing to the realisation of the European Research Area and the Innovation Union[4].

Seen as a key driver of economic and societal innovation, Open Science delivers its full potential in many dimensions.

The Human Genome project as Open Science Pioneer: Open Innovation based on creating commons

From 1990 until 2003, an international research consortium sequenced all 3 billion base pairs in the human genome in a concerted public effort. An Ethical, Legal and Social Implications research programme accompanied the project from the start. All data generated by the Human Genome Project were made freely and rapidly available on the Internet. This changed and accelerated medical discovery and spurred innovation globally: It facilitated the discovery of more than 1,800 disease genes, finding suspect genes in a matter of days instead of years, and more than 2,000 genetic tests for human conditions; more than 350 biotechnological products are currently either on the market or in clinical trials. According to a study, the $14.5 billion US investment in the project has created new jobs, drugs and expanding bio-genetics industries. In its entirety, the project created an economic impact of $966 billion and $59 billion in federal tax revenue.*

Open Access

Open Access stands for unrestricted online access to research in general[5]. Open Access is mostly associated with journal publications, but can be applied to all forms of published research output, including peer-reviewed and non peer-reviewed academic journal articles, conference papers, theses, reports, book chapters, monographs, and data. Generally Open Access of research results enables faster and wider diffusion of knowledge by digital means, and is thus one of the foundations of Open Science.

In 2004, the Ministers of Science and Technology of the then 30 OECD countries, and of China, Israel, Russia, and South Africa recognised the significance of comprehensive Open Access policies. The European Union has been actively pushing Open Access since 2006, including it in the 7th Framework Programme. The current Framework Programme Horizon 2020 makes Open Access a mandatory practice for funded research, to improve the circulation of information and the

[3] Ostrom, Elinor. *Governing the commons: The evolution of institutions for collective action*. Cambridge University Press, 1990.

[4] European Commission. European Research Area and Innovation. (2015). at http://ec.europa.eu/research/conferences/2015/era-of-innovation/index.cfm?pg=home ; European Commission. Innovation Union. (2014). at <http://ec.europa.eu/research/innovation-union/index_en.cfm

[5] Budapest Open Access Initiative: http://www.budapestopenaccessinitiative.org/

transfer of knowledge in the European Research Area (ERA) and beyond. Even though Open Access is fast becoming the norm of scientific publishing, there is the need for concerted policy action and interventions[6].

Open Access publishing is now widely accepted as the best model of disseminating research publications. Open Access platforms such as arXiv for pre-prints and the Public Library of Science (PLOS) have already overtaken traditional journals in several research fields. Whereas arXiv is funded as infrastructure, PLOS charges for article processing (about $ 1,500 for PLOSone[7]). These examples point to different approaches to Open Access: With the Green route, research output is self-archived, e.g. at an institutional repository or a personal website. The Gold route enables researchers to publish their papers directly Open Access. Publishers often charge article processing charges (APC) for Gold Open Access. With he Platinum route the journal grants free access for authors and readers, but is usually funded by other public subsidies.

The oligopoly of academic publishing

Academic publishing is a multi-million dollar business dominated by just a few major publishing houses with high profit margins. Publishers such as Reed-Elsevier, Wiley-Blackwell, Springer, and Taylor & Francis increased their output particularly since the mid 1990s and the rise of the digital era. In 2013 the top five publishers account for more than 50% of all scientific papers published and indexed by Web of Science.

*Many critics say publishers simply take publicly funded research and sell it back to the taxpayers. It is estimated that in Austria the public sector spends about 65 to 70 million Euro per year for the acquisition of academic publications. Therefore, the consolidation of the scientific publishing industry through transparency and contract re-negotiation should lead to the re-allocation of existing resources to OA. ***

Currently prevalent copyright and business models as well as market-dominating positions of a few large content or information providers generally inhibit Open Innovation in the distribution of research output. Therefore it will be of utmost importance to reform the funding of a high-quality publication system. A sustainable transformation will include the establishment of new publishing funds, the concerted and transparent negotiation of publishing contracts, monitoring and training activities, new quality evaluation strategies, and the creation of, and participation in, international infrastructures. Furthermore, with a transition from Open Access to Open Science, issues of licences and re-usability of Open Access publications and data will have to be clarified.

Open Research Data

Data are produced in scientific research processes and are the basis for reasoning, discussing and proving research outputs. They can be figures or have another quantitative format, and they can also be qualitative materials such as protocols, transcripts, field notes, or digital content such as audio or video. Opening research data towards unrestricted access for re-use and re-distribution is the goal of Open Data. Within an open definition[8] there are 3 priorities:

- Availability and Access: The data must be available as a whole and at no more than a reasonable reproduction cost, preferably by downloading over the internet. The data must also be available in a convenient and modifiable form, including meta-data.
- Reuse and Redistribution: The data must be provided under terms that permit reuse and redistribution, including the intermixing with other data sets.

[6] Consultation on Science 2.0 (Open Science) by the European Commission, the area where respondents felt there was the greatest need for action was OA to publications and data, where 63% of those responding felt the need for more work and interventions. https://ec.europa.eu/digital-agenda/en/news/final-report-science-20-public-consultation
[7] Publication costs PLOS http://blogs.plos.org/plos/2015/09/plos-publication-costs-update/
[8] Open definition http://opendefinition.org/

- Universal Participation: Everyone must be able to use, reuse and redistribute - there should be no discrimination against fields of endeavour or against persons or groups. For example, 'non-commercial' restrictions that would prevent 'commercial' use, or restrictions of use for certain purposes (e.g. only in education), are not allowed.

The pursuit for Open Data in research has to be regarded in the broader context of the Open Data movement. In 2013, for example, the G8 leaders signed a treaty stating that all government data should be released openly by default (UK Cabinet Office 2013). To tackle societal challenges such as climate change, it is essential to create large data sets and initiate meta-studies based on data from various sources. Only then collaborative cross-domain comparison, analysis and interpretation of unpredictable phenomena becomes feasible.

However, the majority of research fields has not yet implemented open data policies. Challenges of data sharing are widely discussed, since cultures of data creation and sharing differ immensely between research fields. Biomedical research and earth sciences, for example, have different priorities and data protection issues to cope with, and they follow different rules of standardisation. Furthermore, opening data is a very laborious process and one that has not yet been sufficiently appreciated in scientific credit and citation systems, nor sufficiently reflected in awareness of alternative licensing models, such as Creative Commons[9]. Unlocking the full potential of open research data would also mean creating access for text- and data-mining without copyright infringement.

Besides accurate data management planning, operating open research data will have to follow several principles, such as transparency of sources and formal responsibility, integrity and quality, interoperability, and operational efficiency[10]. Open research data management is currently becoming a legal requirement, driven by several research funding policies. However, we are only at the beginning of defining the necessities for sustainable open research data projects and infrastructures. To ensure that projects funded by the European Commission can partake in opening up research data, the Commission has launched an Open Research Data Pilot[11] to learn about obstacles and issues concerning data management in Horizon 2020.

In 2013, the Research Data Alliance (RDA) was founded by the European Commission, the US National Science Foundation and National Institute of Standards and Technology, and the Australian Government's Department of Innovation. The RDA is organised in working groups and in plenary meetings where over 3,000 individuals and organisations share their insights and develop and discuss policies, standards, and ethical dimensions of data sharing[12].

With open research data being the next hot topic on the Open Science agenda, we will see overlapping issues with big data and e-infrastructures, such as preservation and versioning, findability, standardisation, interfaces, the necessity of linked open data and meta data, data access protocols, new types of information asset registers, quality control, and data sets being integrated in current or new reward systems.

Open Methods

The objective of Open Methods is to make clear accounts of the methods used freely available via the Internet, to enhance the scientific process. Scientific blogging and commenting culture are core practices in this regard. Open annotation, open bibliographies and reference management already

[9] http://creativecommons.org/
[10] A very useful list of principles of open data operation can be found in the "OECD Principles and Guidelines for Access to Research Data from Public Funding", published in 2007 http://www.oecd.org/sti/sci-tech/38500813.pdf
[11] Fact Sheet Open Data Pilot: https://www.openaire.eu/opendatapilot
[12] Research Data Alliance: https://rd-alliance.org/

point to the collaborative dimension – sometimes called crowdsourcing - of opening science in the making. Open Notebook science is making the research project available online as it is recorded, similar to a lab notebook. Such an online notebook thus could comprise project plans, protocols and other workflows, experimental setups, raw data, interpretations, and memos. It holds a thorough documentation of sources and their accessibility, problem formulation and research design, and even acknowledgements of failure.

Besides distributed collaboration, Open Methods help to reduce experimental errors, shortcuts, and therefore falsification. Inspired by open-source software creation Open Methods create (digital) research objects that should be findable, accessible, interoperable and reusable (FAIR). Social media, registries and online tools for Open Methods support researchers in exchanging knowledge. Zenodo[13] or DataCite[14] are such exemplary open research material repositories that give objects a permanent identifier (DOI) to be cited. Several digital video repositories allow the visual documentation of methods. Open Notebook frameworks support the workflow documentation in personal repositories.

The extent to which methods in the making can be opened up differs between research fields and their epistemic cultures. Today advocates of open methods are mostly to be found in data-intensive or experimental sciences that follow clear protocols or workflows, but recently researchers in digital humanities and social sciences have experimented with elements of Open Methods. With recognition and reward systems being established for open methods in the future, we will see increasing activity in this dimension of Open Science.

Open Education

Digital resources and the Internet are transforming pedagogy. Open Education not only creates access to education, it makes use of open content, such as open educational resources and places an emphasis on the learner's network[15]. Open resources include freely distributable textbooks and teaching materials, such as filmed lectures, readings, problem sets, but also interactive user forums. Open courses could be collaboratively designed in cooperation with students. New digital education platforms support the cooperation with open libraries, archives and memory institutions.

Massive Open Online Courses (MOOCs) have been challenging traditional teaching since 2008 as a new form of interactive distance mass education. The European MOOC Scoreboard lists more than 1,700 online courses, with Spanish and British providers leading the field, and with most MOOCs dedicated to science and technology education[16]. A study shows that the primary objective of institutions running MOOCs is to increase visibility and reputation besides reaching out to new students and improving teaching[17].

With the market entry of several commercial providers associated with US Ivy League universities in 2012, the imminent shift from higher education to a technology enhanced content industry was heavily debated. It was feared that such disruptive innovation with its freemium business model – students get the content free of charge, they just have to pay for certificates – would endanger original objectives such as community–centeredness, open structures and learning goals.

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[15] Weller, Martin. Battle for Open. Ubiquity Press Limited, 2014.

[16] MOOC Scoreboard 2015: http://openeducationeuropa.eu/en/news/almost-1700-courses-listed-new-european-moocs-scoreboard

[17] Institutional MOOC strategies in Europe: status report based on a mapping survey 2014 http://www.eadtu.eu/documents/Publications/OEenM/Institutional_MOOC_strategies_in_Europe.pdf

In Europe MOOCs are still not commercialised to such an extent, but we are facing implications from copyright rules on Open Educational Resources (OER) if copyright reforms will not fix issues of educational exceptions throughout Europe[18]. Besides copyright issues, support for OER is constantly increasing. UNESCO members have committed to supporting them within the Education 2030 Framework for Action[19].

Open Evaluation

Traditionally the scientific publication and funding systems provided important basic services: access and evaluation. As the number of scientific publications continually grows, evaluation and impact assessment for selection will only become more important. However, traditional peer review and bibliometrics based on article citation in its present state cannot cope with all dimensions of Open Science in terms of validity and transparency.

In an Open Evaluation environment, we find written peer reviews, numerical ratings, usage statistics, social web information and citations in combination with participatory elements from social media. Reviewers' identities could be authenticated and reviews themselves be gathered in a credit system.

The Altmetrics movement is currently developing a range of novel indicators to complement traditional measures by adding other research objects and output – such as research data - to assess impact. Several online Open Access platforms, such as PLOS or F1000Research[20], are already experimenting with new forms of post-publication peer review. Besides invited reviewers, this involves voluntary evaluators, who comment or blog their review after publication. In this respect, the review is an on-going process, a transparent community effort. Challenges of such an approach include incentives for participation and uncertain reviewer expertise. Advocates of post-publication review claim that research outputs (and its authors) that do not manage to create interest is already a sign of poor quality, and therefore does not pose a problem.

With peer review becoming an on-going open process, it will be important to reflect those new forms of peer production in knowledge creation appropriately. It might lead to opening up funding proposals for discussion and lead the way for new indicators of collaboration.

A fundamental necessity for the transition towards Open Evaluation within Open Science is the identifiability of researchers and their research output. Therefore independent digital identifiers such as ORCID[21] are significant to distinguish and link researchers and their research objects, such as books, datasets, equipment, articles, media stories, citations, experiments, patents, reviews, and notebooks.

Citizen Science

Open Science is about participation; likewise Citizen Science is open to impulses and participation of non-scientists in the research process. Citizen Science is much more than science communication or PR. It is certainly not about counting how many hundred thousand amateurs

[18] Roadmap Communication on the modernisation of EU copyright rules , October 2015: http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_cnect_001_cwp_communication_copyright_rules_en.pdf
[19] Education 2030: Governments commit to an educational future that includes OER: http://www.oeconsortium.org/2015/11/education-2030-includes-oer/
[20] http://f1000research.com/
[21] https://orcid.org/content/initiative The Austrian Science Fund FWF will mandate the use of an Open Researcher and Contributor ID (ORCID) as part of its grant application process starting from 1 January 2016.

have already joined GalaxyZoo[22] to help analyse images from the Hubble Space Telescope, or how many are tracking birds or counting bees, or playing protein-folding games online.

Supported by collaborative technologies, Open Science can do more than just using citizens as brain-workers, it involves citizens in the research design, in the analytical process, and in dissemination and exploitation activities. Furthermore, citizens can act as funders e.g. via crowdfunding and evaluate research results. Citizen Science adds important dimensions to the democratisation of science and responsible research and innovation. There is broad consensus that participatory approaches could foster active engagement instead of passive audiences and co-shape science and technology development. Moreover, Citizen Science provides many opportunities for children and students to be involved in scientific practices.

Nowadays, science policy and research organisations are facing the challenges of how to realise which forms of citizen involvement. Most importantly, they could learn from existing grassroots movements. Many have already opened up traditional forms of knowledge production, such as the Do-it-yourself-movement in Synthetic Biology, the open source software and hardware communities, local activists protecting honey bees, or literature communities collectively annotating romanticist literary works. We can learn from them about incentives and infrastructures, and how they can be translated into sustainable social spaces. Once again attention has to be drawn to skill sets necessary to plan, conduct and govern participatory research.

Citizen Science is a priority of the EU Digital Agenda, and it is mentioned throughout several organisational and thematic sectors of Horizon2020. Support is granted i.e. through design and piloting of Collective Awareness Platforms for Sustainability and Social Innovation (CAPS), with a strong orientation towards information and communication technologies. However, for relevant technology and methods development it will be important to search for already existing projects and infrastructures, such as inter-institutional repositories of political data, repositories of the collaborative curation of cultural heritage materials, or platforms for advocating patient communities' research objectives in public health, and learn from them.

Furthermore, visibility platforms and registries for Citizen Science projects are good for providing an overview of activities; however such platforms only rarely meet the objectives of Citizen Science projects themselves, as they are locally or thematically networked. Rather than collecting facts about such projects, it would be more important for capacity building to open channels for reflecting experiences and discussion.

Infrastructures for Open Science

Besides their technical dimension, research infrastructures can be regarded as catalysts of interdisciplinary research and enablers of trust in the scientific process[23]. The policy shift from discipline-specific database environments towards a networked knowledge space has already resulted in many achievements: CLARIN[24] fosters the development of integrated and interoperable language resources and tools, EUDAT[25] connects many of Europe's leading scientific data centres, GÉANT[26] links researchers via a European backbone network, and more. Already being complemented in policies of EU member states, joint scientific infrastructures are regarded as a fundamental enabling technology for the European Research Area and the digital economy.

[22] http://www.galaxyzoo.org/
[23] Horizon 2020 Consultation Report: Open Infrastructures for Open Science http://cordis.europa.eu/fp7/ict/e-infrastructure/docs/open-infrastructure-for-open-science.pdf
[24] http://clarin.eu/
[25] http://eudat.eu/
[26] http://www.geant.org/

With regard to Open Science activities, it will be important to align national e-infrastructures initiatives with Open Science priorities and other national strategies, and to embed them in international frameworks. On a European level, the vision of an **Open Science Cloud** is currently being discussed. Europe already has substantial cloud infrastructures for researchers, but they operate largely as separate entities. The initiative of an open collaborative platform for the management, sharing, analysis, reuse, and preservation of research data and other research objects also gives rise to interesting economic considerations. Both the information and infrastructure industries could gain from their cooperation with research organisations. At the moment, the optimal supra-national organisational format for the operation of such an Open Science cloud is being discussed, and a call is being prepared. It will be important to map the need of researchers, but also determine what is already working fine, in order to plan for innovative collaboration and enhancement of existing cloud infrastructures, the avoidance of duplication, and interoperable standards.

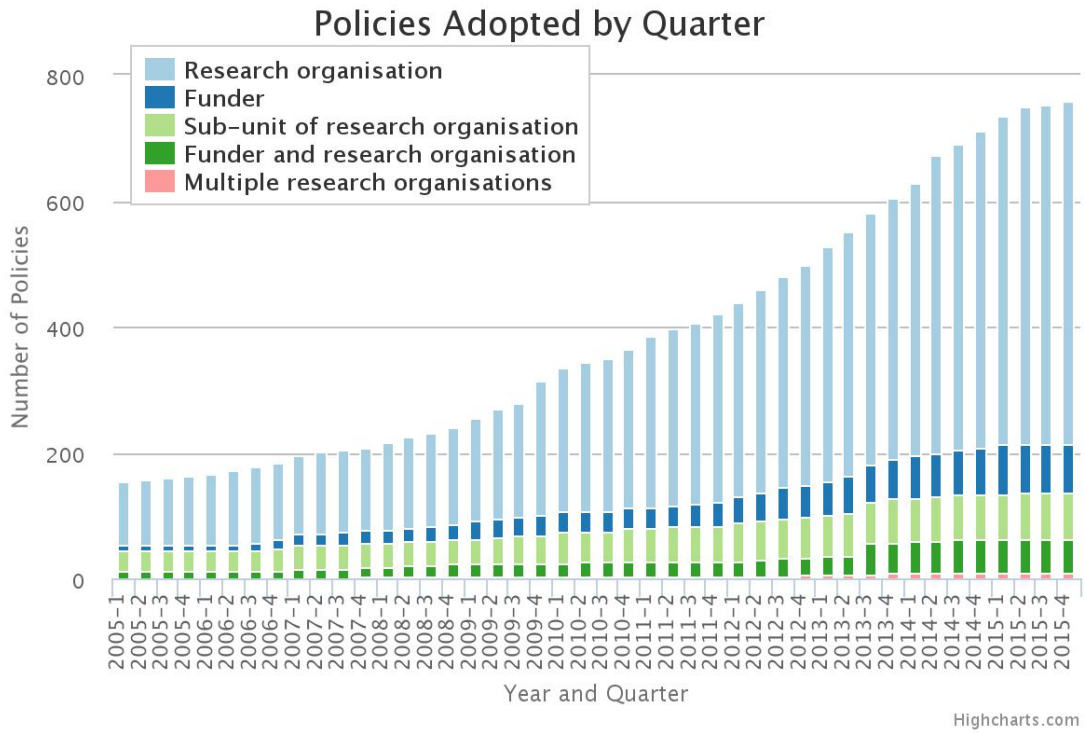

Figure 1 ROARMAP (Dec 2015)[27] Registry of Open Access Repository Mandates and Policies (ROARMAP) is a searchable international registry charting the growth of open access mandates and policies adopted by universities, research institutions and research funders that require or request their researchers to provide open access to their peer-reviewed research article output by depositing it in an open access repository.

[27] http://roarmap.eprints.org/

Open Science in Austria

Surveys from 2013 and 2014[28] show the great support Open Access gets from scholars of all fields and age groups in Austria[29]. Today Austria is an acknowledged Innovation Leader in implementing Open Access, acting at the forefront together with the Netherlands, the United Kingdom and Germany, in line with organisations such as the Wellcome Trust, the US National Institutes of Health (NIH), or the Max Planck Society. The **Austrian Science Fund** FWF has been instrumental in promoting Open Access in Austria, but also internationally, since 2003. Therefore the Austrian model is now regarded as role model of best practice for other European funding institutions[30]. Only recently have the FWF and the Austrian Library Consortium (KEMÖ) signed an agreement with the Springer Verlag Group that allows Austrian research institutions' affiliates to publish with Open Access in more than 1,600 journals from 2016 onwards.

Universities Austria (then the Austrian Rectors' Conference) has already signed the Berlin Declaration for Open Access in 2004. Furthermore, in its Strategy2020, the Austrian Council for Research and Technology Development has called for Open Access to all publicly funded research results already in 2009[31].

In 2015 the **Open Access Network Austria** OANA brought its mission to a first conclusion: a set of recommendations for the implementation of a stringent Open Access policy in Austria has just been published[32]. The network comprises all Austrian public universities, several other research organisations and the main science and research funding institutions. This is a unique constellation, since the research landscape in Austria is rather fragmented, and it is indeed neither common for its proponents to address politics and industry with one voice, nor to work together to develop a policy framework. Furthermore, the network serves as a contact point and source of information for scientists and research. Recommendations for a national Open Access strategy include the goal to make all publicly funded research publications available via unrestricted Open Access by 2025.

The Austrian Federal Ministry of Science, Research and Economy – respecting the autonomy of research organisations – is planning to mainstream Open Access policy in its performance agreements with Austrian universities[33].

Open Access to research data is also gaining importance in Austria. A recent report documents open research data requirements in the Austrian research landscape[34]. Therefore, the launch of the **E-Infrastructures Austria[35]** platform in early 2014 marks another important milestone in the

[28] See: Buschmann, K. / Rieck, K. (2015). *Bericht zur 2. Informationsveranstaltung des Open Access Network Austria (OANA)* http://www.oana.at/veranstaltungen/veranstaltung-21012015/

[29] See great need for Open Access: FWF Survey 2013: https://www.fwf.ac.at/en/news-and-media-relations/news/detail/nid/20150114-2101/?tx_rsmnews_detail%5Bref%5D=l&cHash=ce76a9578129fd3e652596d1accf034d

[30] "It commissions scientific studies and surveys to explore Open Access issues and funding models. FWF adopted the Principles on the Transition to Open Access to Research Publications initiated by Science Europe. It supports Europe PubMedCentral (EPMC), arXiv, Open Access Publishing in European Networks (OAPEN) Foundation, and DOAJ; pays for one third of costs of Austria's partnership with SCOAP3, negotiates with publishers (IoP Publishing, Taylor & Francis, and Springer) to lower subscription/licensing fees for journals and to get rebates for APCs; and publishes the Open Access testimonials of scientists to promote Open Access to gain public support." http://www.pasteur4oa.eu/sites/pasteur4oa/files/resource/FWF-OA-Policy-Case-Study-7-Nov-2015-final.pdf p1

[31] RFTE (2009). *Strategie 2020*. http://www.rat-fte.at/tl_files/uploads/Strategie/090824_FINALE%20VERSION_FTI-Strategie2020.pdf

[32] http://dx.doi.org/10.5281/zenodo.34079

[33] See: Buschmann, Rieck, 2015: 2; Bauer, B. (2014). *Open-Access-Kooperationen in Österreich: Open Access Network Austria und E-Infrastructures Austria – aktuelle Entwicklungen seit 2012.* AGMB-Jahrestagung in Mannheim 2014. GMS Med Bibl Inf 2014; 14(3): Doc22. doi: 10.3205/mbi000319

[34] Bauer et al (2015) Researchers and their data: results of an Austrian survey https://phaidra.univie.ac.at/detail_object/o:407513

[35] https://www.e-infrastructures.at/

evolving Austrian Open Science movement. Its objective is to coordinate and further develop nationwide repository infrastructures for digital research objects and educational materials. Open Research Data will form an important part in the fast growing Austrian "data ecosystem"[36].

The Austrian Open Science landscape in research might be fragmented, but is very active, as several examples will show: The Directory of **Open Access Journals** lists 51 Austrian journals; the Directory of **Open Access Repositories** likewise lists 22 Austrian repositories by November 2015[37].

Austrian researchers have already twice received the Open Humanities Award. Bernhard Haslhofer (then University of Vienna, now AIT, award 2013) built an open-source web application called **Maphub**[38] that adds commenting, zooming and geo-referencing to digitised historical maps. In 2014, the award went to Rainer Simon (AIT) and others for their project **SEA CHANGE**[39] which makes open geographic metadata available for historic documents.

The platform **citizen-science.at**[40] connects and displays Austrian Citizen Science projects. In 2015, it organised the first Citizen Science conference in Vienna. It provides a database for all Citizen Science projects in Austria and a valuable resource for education purposes, especially in secondary education.

The **Genom Austria** project is initiating a public dialogue on the role of genome sequencing for human life[41]. It emphasises the importance of diverse genome sets and invites participants not only to make their genome visible to open research, but also to discuss socio-cultural and ethical implications.

The Ludwig Boltzmann Society has hosted the **Open Innovation in Science** project since 2014. As a pioneer, the project aims at expanding knowledge transfer between science and society, based on collaborative innovation processes. Within this framework, the Citizen Science project Tell Us![42] aims at crowdsourcing the identification of relevant research questions in health research. Another component of this project is the training lab LOIS, the first education programme to train Open Innovation methods along the whole research process in health research, starting in 2016.

The Austrian Chapter of **Open Knowledge** (foundation) – a global non-profit network that promotes the sharing of knowledge – actively contributes to building awareness and capacity by connecting and consulting relevant stakeholders and organising meetings and workshops.

[36] Berger, H. et al. (2014). *Conquering Data in Austria: Technologie-Roadmap für das Programm IKT der Zukunft: Daten durchdringen – Intelligente Systeme*. p46-48
[37] https://www.openaire.eu/oa-austria ; https://doaj.org/search ; http://www.opendoar.org/find.php?cID=15&title=Austria
[38] http://maphub.github.com/
[39] http://pelagios-project.blogspot.co.uk/
[40] Citizen-Science.at
[41] GenomAustria - http://genomaustria.at/

[42] Tell Us! - https://www.redensiemit.org/

Figure 2 *Word cloud created by Katja Mayer with WORDLE from Horizon 2020 Science with and for Society work programme 2016-2017*

Policy Implications

"Open means anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness)" Open Definition

Sharing the output of publicly funded research is recognised today by most OECD countries as an enabler of better quality, increased collaboration, and new forms of exchanges between science and society, all of which leading to higher social and economic impacts of science. The transition to Open Science requires countries to strengthen regulatory frameworks and both human and technical capabilities. Open Access and digital research infrastructures are currently in the spotlight: digital libraries, online repositories, databases, inter-institutional international networks, to name a few. International policy co-ordination is key to the success of Open Access and e-infrastructures. Furthermore, several OECD countries, such as the US, Australia, Chile, China, and several European countries are already preparing policies to promote Open Research Data and Open Education[43].

At the Competitiveness Council[44] in May 2015, the European Commission once again highlighted Open Science as being fundamental to an innovative European Research Area (ERA). The official move from "Open Access" to "Open Science" in European research and innovation policy seems only logical, adding a broader picture and tapping into the all-encompassing potential of the openness paradigm for shaping robust and sustainable science in society relations. However, openness now has a market value and will be subject to tensions and necessary negotiations. To **determine future directions** of Open Science and for a **smooth transition**, all stakeholders are requested to invest some effort into designing policies together. A participatory approach – as chosen by the European Commission – is therefore suited best. A prerequisite for a successful implementation of Open Science will thus be to understand that its actors do not always share the same incentives, expectations or objectives. An effective strategy works with this **diversity** and

[43] OECD Report Open Science: Making Open Science a Reality. 2015
[44] May 2015 Competitiveness Council http://era.gv.at/object/document/1817/attach/st09385_en15.pdf

builds it into its agenda, whether on transnational, national or institutional level; whether as research organisation, NGO, policy maker, funding agency or capacity builder.

In Europe, Open Science affects all aspects of **Horizon 2020**, but also forms the foundation of the research related aspects of the **European Digital Single Market** initiative[45]. To learn about benefits and constraints of Open Science from stakeholder's perspectives, there are pilot projects in operation. They are encouraging the creation and application of open data management plans within project proposals; besides, with platforms like OpenAIRE or EUDAT2020[46], stakeholders are assembled to address challenges of opening research data. The project FOSTER facilitates Open Science training in the European research area. Policy makers understand how important human capital and skill development is for the vision of responsible open research and innovation to succeed. With the establishment of a European **Open Science Policy Platform**[47], the European Commission will seek advice on policy coordination, implementation and monitoring.

Open Science and the advancement of Open Access to publications and research results will be one of the priorities of the **Dutch Council presidency of the European Union in 2016**. Besides renegotiating transparent contracts with scientific publishing houses, emphasis will be on the legal necessities and modifications to existing legal frameworks to make copyright legislation better suited for Open Science, with special regard to the question of re-usability of copied or recorded materials.

Open Science Priorities

With the transformation of the public research system to Open Science, we need to understand Open Innovation not as being about either commercial or open matters. It is precisely the synergy of commercial and alternative markets for knowledge that Open Innovation strives to achieve. This needs comprehensive coordination and collaboration of stakeholders with often diverging goals and needs. The success of Open Innovation is therefore tied to policy's capability to manage and guide complex negotiation processes.

Policy priorities for Open Science include:

Fostering Incentives

- Promoting existing Open Science best practices and creating visibility for open research practices
- Rewarding bottom-up commitment and Open Science practices by inducing a paradigm shift in research funding and performance measures and credit structures
- Facilitating spaces and time for interdisciplinary and transdisciplinary collaboration
- Encouraging Open Innovation by initiating experimental open spaces for science in society activities
- Minimising bureaucratic requirements

Training

- Including Open Science in education programmes and in performance contracts with higher education and research organisations
- Developing Open Science training formats in line with field-specific needs
- Fostering and rewarding open research practices throughout all career levels and research cycles

[45] Digital Single Market for Europe http://ec.europa.eu/priorities/digital-single-market/
[46] EUDAT2020 http://www.eudat.eu/
[47] https://ec.europa.eu/research/swafs/pdf/pub_open_science/new_policy_initiative.pdf

Mainstreaming Open Access

- Pursuing a coordinated Open Access policy effort (see OANA recommendations[48])
- Supporting the shift from Open Access publications to Open Access to research data and educational materials

Coordination and Alignment of National and European Policies and Roadmaps

- Strengthening national commitment to Open Science in research and innovation by developing comprehensive Open Science policies, and by bringing all stakeholders together in a transparent forum, e.g. by transforming OANA into an Open Science network Austria
- Monitoring the implementation of Open Science as a cross-cutting thematic priority in all relevant research and innovation programmes; avoiding unnecessary redundancies or un-coordinated parallel actions; advocating consonance in national actions such as the Austrian ERA Roadmap, *"Digitales Österreich"*, *"Allianz für Responsible Research"*, "Open Innovation Austria", and so forth

Open Infrastructures

- Understanding national research infrastructures from a European perspective and aligning it with clear requirements and roadmaps
- Developing supra-national governance structures for open infrastructures
- Bringing stakeholders together to work with existing e-infrastructures such as ACOnet, universities' ZIDs, high-performance computing infrastructures such as the Vienna VSC, the Austrian Centre for Scientific Computing, GRID, West-Cloud
- Broadening national participation in a European Open Science cloud besides existing infrastructures
- Actively engaging in international processes of standardisation and interoperability

Legal frameworks

- Sensitising researchers and research administrators for legal considerations and open licences in relation to research integrity
- Promoting institutional frameworks for open interdisciplinary collaboration
- Adapting legal frameworks to requirements of Open Access publishing and Open Research Data, as well as Open Educational Resources.

"New knowledge is created through global collaborations involving thousands of people from across the world and from all walks of life". Carlos Moedas May 2015[49]

Notes

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[48] OANA Recommendations: https://zenodo.org/record/33178#.VkWwur8gxzU
[49] http://europa.eu/rapid/press-release_SPEECH-15-5243_en.htm

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* See http://report.nih.gov/nihfactsheets/ViewFactSheet.aspx?csid=45 and study released by United for Medical Research from Battelle: http://www.battelle.org/media/press-releases/updated-battelle-study-genetics-and-genomics-industry

** See Larivière V, Haustein S, Mongeon P (2015) The Oligopoly of Academic Publishers in the Digital Era. PLoS ONE 10(6): e0127502. doi:10.1371/journal.pone.0127502; and
Reckling, Falk (2015) Die öffentlichen Kosten wissenschaftlicher Publikationen in Österreich 2013. Version 1.0 http://zenodo.org/record/18338#.VmLsYmQrIy4