

Module 1: Open Principles

Estimated time to complete: 60 minutes

Estimated saving time: xxx

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[IDEA: ONCE TEXT IS COMPLETE; CREATE AUDIO RECORDING FOR ALL OF THIS FOR EACH MODULE, and release as a podcast]

BEFORE YOU START

Science is everywhere, science is all around us. This is your last chance. After this there is no turning back. You take the blue pill, the story ends, you wake up in your bed, and believe whatever you want to believe. You take the red pill, you stay in Wonderland, and we show you how deep the rabbit hole goes.

Did you know that the Internet and the World Wide Web were both originally designed for research purposes? Scientists wanted a fast, easy, and low-cost way for sharing data with each other, and hence the Internet was born. Now, the Internet dominates almost all aspects of our daily lives, and yet has somehow deviated from this original purpose. Now, science seems to have gone almost backwards compared to every other enterprise - Open Science is the movement to bring modern research back into line with this original digital intent, while reasserting fundamental scientific principles back to the endeavour.

Did you also now that this is so important, that it is even in the United Nations Declaration on Human Rights?

[Insert quote from Article 27 here]

You have probably landed here because you have a nagging feeling that something about the way modern science is conducted and shared is not quite right. This module will hopefully shed some light on those feelings, and help you to understand the state of the present system, and its discord within intrinsic human and scientific values and principles. This is the start of your own journey to become an *awesome* researcher and a *champion* in your field.

[INSERT INTRODUCTORY VIDEO HERE]

Introduction

Welcome to Module 1 of the Open Science MOOC: Open Principles. This is the first of 10 core modules to give you a solid grounding in all things Open Science. This module has been developed in the open through collaboration by an international team of Open Science wizards.

You, yes you, are in the middle of a profound global scientific revolution. To innovate in a field frequently implies moving against prevailing trends, structures, and cultural inertia. **Open Science** is no different. The fact that *you* are here, reading this now, means that you probably have an interest in the impact that Open Science can have on improving research cultures, and have noticed that something is not quite right about the “status quo” in modern research.

This module will introduce to you the guiding principles, values, and practices of ‘Open Science’, some of the potential barriers to these, and the positive impact that integrating openness into your daily research work can have on you. This module is not designed to be a ‘one size fits all’ approach, but rather a foundational plan that incorporates questions around the varying and dynamic dimensions, interpretations, and goals of Open Science across different communities.

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Who is this module for?

Designed primarily for students and researchers at the graduate and undergraduate level, this module can also serve as training material for postdocs and more senior researchers. We want to help make openness universal and for all, not just a select few. This aims to be a cross-disciplinary module covering all research branches, including Engineering, Medicine, Biosciences, Mathematics, Social Sciences, Humanities, and the Arts.

Right from the beginning, we have recognised that ‘science’ can be off-putting to research fields that don’t consider themselves to be ‘scientific’. This is why we have set a highly inclusive standard, and right from the very beginning of this project have had people from across the *whole* spectrum of scholarly research, and related disciplines like tech, publishing, and librarianship, involved in developing and scoping the project. We use the term ‘Open Science’ given that this seems to be the phrase that global changes are coalescing around. But recognise that terms such as ‘Open Research’ or ‘Open Scholarship’, although less widely used, might capture what our intention is here a bit better.

The point is, irrespective of your background, **you are very much welcome here.**

“Open Science describes the practice of carrying out scientific research in a completely transparent manner, and making the results of that research available to everyone. Isn’t that just ‘science’?!”
- Mick Watson (source)

Melanie Imming, & Jon Tennant. (2018, June 8). Sticker Open Science: just science done right. Zenodo. <http://doi.org/10.5281/zenodo.128557>

Specific learning objectives for this module

1. Understand the ethical, legal, social, economic, philosophical, and research impact arguments for (and against) Open Science.
2. Set up a personal profile for defining your impact: Measure the social and academic attention for the full range of your research processes and outputs.

What is Open Science?

None of us is as smart as all of us. - Kenneth H. Blanchard.

The term ‘Open Science’ has not yet a universally accepted definition, but usually refers to one core theme: **Increasing knowledge availability as a public good**, typically with critical research principles such as credibility, reproducibility, and verifiability thrown in in some combination. Many other terms are being used synonymously with Open Science, such as Open Research, Open Scholarship, Science 2.0, and eScience.

Throughout this MOOC, we consider ‘Open Science’ to be fully inclusive of all of these terms, all scholarly research disciplines, and to reflect the wider process of organised knowledge creation (Bartling and Friesike, 2014).

Ironically, the only current peer-reviewed research article to systematically attempt to define Open Science is paywalled, so we do not include here. Sigh.

FOSTER defines Open Science as: “The movement to make scientific research, data and dissemination accessible to all levels of an inquiring society.”

Open Science can broadly be viewed as a way of enhancing scientific progress through sharing of knowledge and methods, wider collaboration, and increased rigour and is indirectly already postulated as part of our/researchers’ collective core values and **Good Scientific Practices**. Research can only thrive if it is shared and built upon.

Often, the usage of Open Science seems to be based around three core things: *Processes* (e.g., collaboration, reproducibility), *Products* (e.g., Open Data), and *Values* (e.g., freedom, equity). This seems to form a chain reaction, where values drive a process, which in turn defines the products of research.

Therefore, some of the key, value-based goals of the Open Science community include:

- **Freely available access to all outputs of the whole research process;**
- **Equity and inclusive participation in research;**
- **Diverse and creative interpretations of scientific results;**
- **Rigorous, transparent, and responsible evaluation of research processes and outcomes;**
- **Collaborative re-use of research outcomes, reducing costs, waste and redundancy;**
- **Comprehensive research practices incentivised through more diverse reward systems;**
- **Accelerated research discovery, innovation and public impact; and**
- **Increasing reproducibility of research results, enhancing trustability and integrity.**

If these things are all true, then we have to ask of ourselves: *Why isn’t all publicly-funded science practised this way?*

It seems that Open Science is often communicated as an *alternative* to many modern or traditional scientific methods. We argue that Open Science is an *enhancement* of the traditional process, using new knowledge, skills, and technologies to improve how the process and outputs of research are communicated. It is based on fundamental human values around **inclusivity**, **freedom**, and **equity**, embedded as foundational elements to the research process, rather than as an afterthought. These human values are what distinguish ‘Open’ science from much of the way modern research is viewed and practised. We also believe that virtually everyone who comes into research already has these fundamental values as part of who they are. However, often they become divergent from the way in which the academic system forces them to work. We want to change that.

These foundational elements of traditional research communication, peer-reviewed research articles, are acting as an important mechanism to summarise and communicate research.

[add here reference to “new peer review models” and refer to the resp module]

Open Science helps to make research articles more rigorous, verifiable and reliable. This helps to enhance public trust in the scientific community and endeavour. In modern society, this has never been more important.

Open Science is subject to the most rigorous peer review because the process never ends. - (Woelfle et al., 2011).

Perhaps one of the most important aspect of the Open Science movement in recent years has been the drive behind the liberation of research papers from behind paywalls to be freely available to anyone. This has largely been based on the principle that humans deserve to have access to scientific knowledge, and benefit from that.

[insert act 27 of the UN declaration on human rights here]

Number of articles (A) and proportion of articles (B) with OA copies, estimated based on a random sample of 100,000 articles with Crossref DOIs. Piwowar et al. (2018)

Still today (2018), most research papers remain locked behind expensive paywalls and critical research data remains hidden away on hard-drives, methods remain scantily documented, research results cannot be reproduced, and researchers are often evaluated on senseless criteria [refs for all these claims].

These are just some examples of typical practices that contribute to what might be viewed as ‘closed science’; or bad (unethical) scientific practices.

Open Science is about changing these research practices through a cultural/paradigm shift. This shift in research culture is often referred to as the **Scholarly Commons**, which seeks to explore and redefine what a modern scholarly communication ecosystem should look like. (See also the Principles of the Scholarly Commons.

[Create infographic for scholarly commons]

Accomplishing a cultural shift on a global scale is **NOT EASY**. Fundamentally, it is usually mainly done through the spread of shared cultural norms and values that are interpreted and celebrated in hundreds of local institutions: in your department, school, laboratory, university, professional association, publishing effort, open software platform developer company, or funding agency. It is a complex, multi-dimensional paradigm to comprehend. Each of these organizations fits itself into the cultural practices that members decide will work best for them to become active in performing the cultural work of Open Science. Culture change *must* start from the ground up. Open Science principles illuminate this ground.

The power of modern web technologies enables instantaneous sharing and global collaboration in an unrestricted fashion. The digital era is transforming the way in which research is performed, and the limitations of the print era are largely gone. With this, new issues arise which include the complexities of knowledge capture and communication. The framing of these complexities as a ‘Commons’ integrates the political, social, economic, and philosophical dimensions around knowledge generation and sharing.

Open Science gives rise to a new set of standards, tools, principles, and practices to revolutionise the way we perform and disseminate research knowledge. And we are going to need all of this, if we want to help shape our world for the better.

For example, the United Nations has recently set a number of critical Sustainable Development Goals.

UN Sustainable Development Goals

The question to you is, *do you believe that science can help progress towards reaching these goals?* Hopefully, your answer is a resounding **YES**. But if so, you must also acknowledge that much of the way we often currently practise science in a ‘closed’ manner means that we are not doing the best that we can to achieve this.

Open Scientists share objects to gain network effects for their work

“Because we have to coordinate with one another to get anything out of our shared free time and talents, using cognitive surplus isn’t just about accumulating individual preferences. The culture of the various groups of users matters enormously for what they expect of one another and how they work together. The culture in turn will determine how much of the value that we get out of the cognitive surplus will be merely communal (enjoyed by the participants, but not of much use for society at large) and how much of it will be civic.” - Excerpt From: Clay Shirky. *Cognitive Surplus*[Link to original source text?].

Building on a civic culture of sharing, Open Science creates new and value from every object (idea, data, method, software, results) that is openly shared, releasing the inherent value of the research process. Some of this new value accrues to the researcher who shares, some goes to the benefit of all researchers working in the same arena who reuse these objects, and some goes to researchers who can open up new research from the collective resource that these objects now enhance. This last value is the ultimate promise of Open Science: a shared surplus of research objects that can be openly mixed, mined, and melded into new, synthetic knowledge.

McKiernan (et al., 2016) demonstrate the advantages of open sharing for increasing citations, impacts, and ultimately the careers of researchers. What the ‘open’ researcher does to increase the holdings of the open corpus in their field adds a civic choice to these advantages. Growing the open research ecosystem helps every researcher on the planet, while simultaneously making a conscious objective towards making research a public and societal good. Thus, even within traditional systems of research(er) evaluation, the practice of Open Science is inherently beneficial to the individual.

Adding new research findings or experimental methods to an open repository/platform tends to be as easy (or easier) than sharing within a closed collection (such as a for-profit publisher). Open sharing scales better, particularly when it uses open standards-based platforms, such as the Open Science Framework. It also tends to be less fragile, since it can be migrated or ported into new platforms and spread across multiple locations. Openness adds to discoverability and access, and contributes to reproducibility.

The potential of openness is virtually unlimited in scope!

Even as the value of, for example, a telephone exchange increases with each new telephone connection, the addition of a new data set, or a null result paper, or a specific finding, builds numerous interconnections with the rest of the global research corpus. These interconnections (and their “network effects”) can lead to the generation of new knowledge, and they can serve as a mirror and a measure to reveal how each new bit of content solves (or critiques) a specific issue, and also potential problems with the newly added object. Rapid open review opportunities arise as well as increased recognition and opportunities for new collaborations.

Many of these network effects will take place on the internet at a planetary scale. The interconnections made possible by Open Science build capacity for the free movement of objects and ideas directly linked back to their authors. This capacity for the almost instant and free global access to research products on the open web is anathema to markets that need to claim ownership and restrict access in order to capture profits from these. Distributed data protocols such as the Interplanetary File System and other emergent technologies will reduce the cost of hosting science objects to a near zero margin. Open licenses make sharing research knowledge durable and its reuse legal.

As Cameron Neylon said at the metrics breakout of the *Beyond the PDF* conference some years ago [when exactly?], *reuse is THE metric*. Reuse reveals and confirms the advantage that open sharing has over current, market-based, practices. Reuse validates the work of the scientist who contributed to the research ecosystem. Reuse captures more of the inherent value of the original discovery and accelerates knowledge growth. Open Science is a science knowledge and data reuse accelerator. Its network effects help make reuse available, and, in time, inevitable. However, active, open reuse has not been a part of science culture for most scientists today, and the cultural changes that can help Open Science realize the goal of widespread reuse is a major challenge we face. [where does the quote end? Reference?]

Limitations of Open Science

Despite the more or less obvious benefits of Open Science practice, there are a range of reasonable concerns and therefore necessary limitations and exceptions to be identified, discussed and implemented in a highly discipline-specific manner. These include and are not limited to: - personal data of and information about individuals - any sensitive information (re bioengineering, medical information, ...) - geomapping data of endangered species (flora & fauna)

Another important aspect to note (as has always been) is that each OA dataset requires a clear description of the context in which the data was raised, so that scientists who make use of the freely accessible data apply it in a meaningful analysis and reasonably transferred context.

History of Open Science and Open Cultures

Science wants to be Open by default.

The earliest form of Open Science can perhaps trace its origins back the 17th century, and the origin of the academic journal. [CITE FYFE etc HERE] This was catalysed by an increasing demand for the wider dissemination of scientific knowledge with the wider public. In the 1660s, Robert Boyle, the “father of chemistry,” broke with the practices of alchemy in his early writings, e.g., *The Sceptical Chymist*, and promoted open experimentation (following Roger Bacon’s model). Previously, alchemists occulted their methods and their knowledge died with them. What might have been called “open alchemy” became “natural philosophy” and then “science.” Science was born open.

Although difficult to pin down exactly, the origins of what many call the modern ‘Open Science movement’ was probably catalysed by increasing frustration, debate, and distress regarding the impacts of ‘closed science’ (e.g., barriers such as subscription paywalls) and commercialisation on knowledge dissemination. Indeed, one of the rallying cries of the Open Science movement is that taxpayers who already paid to fund research should not be having to pay again to read the results. The term Open Science itself appears to have been coined by Steve Mann in 1998.

In the last two decades, there has been an explosive growth in the development of different aspects of scholarly infrastructure - the core, underpinning aspects of a well-functioning research machine. Much of this is a blend of non-profit and commercial services, which are now variably integrated, but has created a strange and complex new system of ways to perform and communicate research.

From this, what might be becoming a little more clear is that Open Science is about systemic change. It challenges the way research is conducted, at a practical and cultural level, the way it is evaluated, and the ways in which scientific knowledge is disseminated. Much of this is ingrained into research culture through self-reinforcing local governance systems, which are often imposed through external capitalist pressure. For example, the ‘*publish or perish*’ mantra is a direct consequence of these pressures, which in turn are linked to the evolving neoliberal agenda imposed by modern research institutes.

So now, if this makes sense to you, it might seem like Open Science is in almost direct conflict with a capitalistic culture. This conflict is not new to science. In the 1940s, sociologist Robert Merton articulated some of the results of his sociology of science research as a set of four norms: principles that described the underlying ethos of science. Each of these norms is sharply divergent to how a free marketplace operates. You can read about the norms here. One of Merton’s norms was “communism,” (this is sometimes re-worded as “communalism”).

Quoting Merton’s original 1942 article: “‘Communism,’ in the nontechnical and extended sense of common ownership of goods, is a second integral element of the scientific ethos. The substantive findings of science are a product of social collaboration and are assigned to the community. They constitute a common heritage in which the equity of the individual producer is severely limited.” Originally published as “Science and Technology in a Democratic Order,” *Journal of Legal and Political Sociology* 1 (1942): 115-26; later published as “Science and Democratic Social Structure,” in Robert K. Merton, *Social Theory and Social Structure*.

It is good to remember that Open Science principles rearticulate science norms that were historically considered to be integral to science itself. Open Science reaffirms the right of the community to access the substantive findings of science. As the findings of science belong to the entire community, any attempt by individuals or corporations to capture these for profit is a practice based on a notion of equity that is foreign to, and contrary to, how science is meant to operate.

Open Science really hit the mainstream around 2016 due to a number of possible reasons. A combination of political activity and grassroots community-led initiatives really put it on the map, and now everywhere you go in science, openness is all around in one way or another.

For example, there has been a strong focus on Open Science in the last few years in Europe, with one of the biggest developments coming from this being the European Open Science Cloud (EOSC).

[Give examples of more countries' OS activities here - NOT JUST EUROPE] [Include recent developments from Africa and Indonesia]

Differences in understanding and interpretation

As mentioned above, there does not seem to be a single accepted definition of what Open Science is. Ask one person, and they will tell you it is about making datasets and research papers public. Ask another, and they will tell you about a vision for a 'radical' transformation of scholarship, where all processes and outputs are instantaneously public. The extent to which different communities and disciplines have embraced and adopted Open Science practices is extremely variable. However, what is clear is that 'Open Science' in one form or another is taking off across the entire research domain, from Arts, Humanities, and Social Sciences through to Maths, Engineering, and Physical Sciences.

There are two ways too look at this. First, some might argue that the power of a definition lies in its precision, and helps to avoid distortion of those definitions - what some might, in this case, call "open washing". Second, flexibility in the definition, and its understanding and interpretation, lead to increased familiarity with a concept as a 'boundary object'. For the latter, and for Open Science, this means that while it might be interpreted differently across different communities with a variety of norms and practices, the foundational understanding that Open Science is good for public access to knowledge is universally accepted.

There are also geopolitical differences that shape our understanding of Open Science. For example, in Europe, and much of the developed world, Open Science has an inherently market-oriented language that promotes economic value, productivity, and competition, above all other factors. However, for many of those in the 'global south', Open Science is more about fostering community-building through knowledge sharing, and nurturing social networks around new technologies and infrastructures.

Principles of Open Science

Now, there are no rules about Open Science, and no one individual or organisation is setting the agenda. However, what is commonly recognised is that Open Science is underpinned by specific, core principles and values. In recognition of this, there are now around 100 charters and declarations to do with data sharing and scholarly communication and publishing, and hundreds more advocacy organisations that make openness a significant part of their mission.

Note that often you will find things described as Open Science, but that do not seem to embrace these principles. These things are probably not 'true' Open Science, but more just attempting to surf the wave or join the bandwagon as a PR stunt. Such things are often called 'open washing'.

Open & Collaborative Science Manifesto

Open and Collaborative Science Manifesto. This video describes the 7 principles that constitute a more open and inclusive science in development. CC BY Source

This above video from OCSDNet is absolutely critical in framing the principles of Open Science. It outlines the importance of representation and inclusivity within Open Science, and the importance of these in challenging the core values of traditional science. They propose **seven principles** for Open and Collaborative Science:

- **Principle 1:** Enables a knowledge commons where every individual has the means to decide how their knowledge is governed and managed to address their needs.
- **Principle 2:** It recognizes cognitive justice, the need for diverse understandings of knowledge making to co-exist in scientific production.
- **Principle 3:** It practices situated openness by addressing the ways in which context, power and inequality condition scientific research
- **Principle 4:** It advocates for every individual's right to research and enables different forms of participation at all stages of the research process.
- **Principle 5:** It fosters equitable collaboration between scientists and social actors and cultivates co-creation and social innovation in society.
- **Principle 6:** It incentivizes inclusive infrastructures that empower people of all abilities to make, and use accessible open-source technologies.
- **Principle 7:** It strives to use knowledge as a pathway to sustainable development, equipping every individual to improve the well-being of our society and planet.

Another widely-known vision for the future of scholarly communication is the Vienna Principles.

Vienna Principles

The Vienna Principles, now in handy infographic form!

Community values in Open Science

Including diversity, inclusivity, fairness, equity, social behaviour, accountability, ethics and responsibility.

How do we use Open Science approaches in the context of retooling our institutions to benefit actual living and breathing humans (scientists and nonscientists)? How can we use Open Science to enable as many people who have the interest and talent to pursue science for it's own sake and to generate knowledge that is broadly useful for society, and not just elite institutions, venture capital firms or global megacorporations? - Alex Lancaster (source).

I am, somehow, less interested in the weight and convolutions of Einstein's brain than in the near certainty that people of equal talent have lived and died in cotton fields and sweatshops. - Stephen Jay Gould.

The global landscape of Open Science

The production of research knowledge is inherently geopolitical, as emphasised by The Knowledge Gap. There are strange forces at play that influence representation, mechanisms of distribution, dimensions of power, and structural inequalities throughout the global scholarly communication system. These all contribute towards a complex, and fragmented, global Open Science landscape.

To see Open Science as a historically produced discourse, we need to first abandon the notion that openness is always inherently positive and/or neutral. We then need to revise and contextualize openness within their particular historical legacies, contexts and sociopolitical struggles. Denisse Albornoz (Source).

TODO *Add content from here https://zenodo.org/record/1407488#.W5sqPuj7RPZ*

The different dimensions of Open Science

Open Science, just like ‘regular science’, is a complicated construct. Thankfully, a lot of great work has already been performed to help frame the different contexts of Open Science. One of the most commonly used is the Open Science taxonomy from FOSTER, shown below:

FOSTER Open Science taxonomy

FOSTER Open Science taxonomy

The different aspects of this will be explored through different modules in this MOOC, but here it is worth highlighting just some of the core concepts:

- **OPEN DATA:** Open data is the process of sharing both the original, raw and the treated or processed data online. This helps others to redo your experiments, and re-use it for additional purposes, helping to verify and accelerate research discoveries.
- **OPEN ACCESS:** Allows anyone to access and re-use research published in journal articles without payment or restriction.
- **OPEN PEER REVIEW:** This is a highly dimensional concept, including aspects to do with publishing review reports, revealing the identity of reviewers, and making peer review a more continuous and collaborative process.
- **OPEN METHODS:** Where the process of the research has been documented in a sufficient detail to allow others to *repeat, reproduce, or replicate* the work.
- **OPEN SOURCE:** Most modern science relies on code and software, and Open Source is about providing free access and re-use rights to this to maximise its utility.

Other critical aspects of Open Science include **Public Engagement with Science**, **Open Educational Resources**, and **Open Advocacy** - all of which will be covered in later modules!

Modules covered throughout this MOOC

Another popular framing device is the ‘Open Science schools of thought’, by Benedikt Fecher and Sascha Friesike:

1. The **Infrastructure school**, which is concerned with how the architecture of new technologies can help to make a more efficient research enterprise;
2. The **Public school**, regards the accessibility of knowledge creation to a wider audience;
3. The **Measurement school**, concerned with alternative methods of assessing scientific impact development;
4. The **Democratic school**, based around fundamental rights of access to knowledge; and
5. The **Pragmatic school**, concerning the role of collaborative research for more efficient knowledge creation and dissemination.

Recently, the Foundations for Open Scholarship Strategy Development added a 6th to this, the Community and Inclusion school.

How Open Science impacts you

[GO TO TASK 1: Defining how Open Science affects you]

Changes in research evaluation

The world of research evaluation is slowly changing. While there is generally little empirical evidence, it is generally accepted that research evaluation is almost entirely contingent on getting research articles published in ‘high impact’ journal venues.

One consequence of this, is that other elements of the research process, are seen as less important. This includes Open Science, which can be viewed as risky or detrimental to the career choices of an individual research, and in particular those who are already disadvantaged/marginalised, or at an earlier stage in their career.

Perhaps a much bigger consequence of this, however, is that we essentially have a system where researchers are rewarded for how many papers they publish, and the brands associated with the venue of publication, which can be detrimental to the value of shared knowledge.

Things are changing, though. It is becoming more widely realised that these publication-based incentives are detrimental to the research process, and the health of research culture. For example, this comes from an advertisement for a professorship at the Ludwig Maximilian University, Munich, and is the first time that Open Science was made an explicit part of hiring criteria:

“Our department embraces the values of Open Science and strives for replicable and reproducible research. For this goal we support transparent research with open data, open material, and pre-registrations. Candidates are asked to describe in what way they already pursued and plan to pursue these goals.”

Having Open Science as a core value in research departments sends a strong message for a shift in research cultures.

[Mention stuff from the EC here] [Also EURODOC statements]

Potential impact on your career

Creating your digital profile

- ORCID
- Publons - note Clarivate caveat (integrate with ORCID) - make this optional
- ImpactStory (integrate with ORCID)

[GO TO TASK 2: Developing your digital researcher profile]

Barriers to Open Science

Open Science reflects the intentions of the researchers themselves, and is thereby subject to cultural bias. Open Science is not a perfect system by any means, and operates a hierarchy between different barriers. For example, Open Access seeks to remove barriers such as price for readers and re-use permissions, but often fails to address barriers such as connectivity or language, and also in cases erect new barriers, such as author-facing costs.

This is something which the Open Science movement is becoming more and more aware of, especially regarding the risks and impacts that progress towards Open Science can have, particularly on marginalised demographics or already higher-risk communities. Some of the major barriers towards Open Science include:

- Forcing junior researchers to share their data at point of first publication, potentially compromising their future research based on those data;
- High article processing charges (APCs) for publication, that discriminate against those without financial privilege;

- Other geopolitical factors include resistance to sharing due to fear of persecution, and knowledge misuse or appropriation.
- Evidence. Researchers are generally conservative to adoption of new approaches, until there is sufficient evidence that they are superior than traditional methods.

However, as well as these, there are several worrying and ongoing trends that reflect more systemic issues within Open Science, and scholarship more generally:

- That Open Science is introducing more metrics to ‘incentivise’ researchers to work harder, at the cost of true productivity and creativity, and not always in their best interests;
- That new gate-keepers are consolidating these metrics, and using them to define the future of research, ending up with a system operating more like a business than an exploratory venture;
- The increasing capture of research and infrastructure by commercial, for-profit entities, reflecting the increasing neoliberal market organisation around science and higher education;
- These same entities often having a parasitic relationship with researchers, who provide labour, services, and content for free to help them build profits;
- A lack of job stability or security and resources, which acts against innovation or any form of risk-taking;
- A lack of consideration of the social and cultural real-world benefits of research; and
- The fact that most historical research still remains locked away from access or re-use.

Based on this, it is interesting to ask why such dangerous trends seem to grow from seemingly good intentions based on positive core principles and values. It might be easy, based on the above, to become extremely pessimistic, or even antagonistic, towards Open Science. However, as with any movement or new way of doing things, it is down to each of us to carefully balance the potential drawbacks and benefits, and the wider consequences and contexts of these.

Moving away from tradition and the status quo

While the core principles underlying Open Science are often focussed around accessibility, in practice there is often a trade-off within this hierarchy, and often with unforeseen consequences. Much of this is not due to the intentions of Open Science, but more about the difficulties in reconciling the different stakeholder viewpoints, which often leads to inherent conflict and complications around developments.

[Include: lobbying, resistance to shifting away from impact factor, resistance to openness, co-opting of OA and Open Science by publishers. Need to add this section to TOC.]

It is perfectly natural for researchers and industries that have made themselves successful or profitable based on a particular set of practices to resist any disruption towards that. Let us take two primary examples for this.

1. Moving research evaluation away from journal brands and the impact factor.
2. Moving away from a subscription model to one where all information is freely available.

[EXPAND]

Open Science and reproducible research

There is an enormous overlap between Open Science and reproducible research. Now, traditionally, much of the research process, as well as the outputs, remain hidden or closed from public scrutiny. Open Science attempts to expose some of this process; for example, by recording and documenting ‘failed’ reactions, highlighting repeated experiments and their variants, and revealing thoughts, ideas, and comments that were part of the process but wouldn’t make into a final research paper.

All of these elements can be documented as part of a ‘lab notebook’, and comes with an important implication: **The aspects of research that did not produce favourable results are just as important as those which do.**

Here, the intersection of reproducibility and Open Science becomes centred around one thing: **Freedom and Liberation.** As Frankenhuis and Nettle, (2018) describe, the practices of Open Science are liberating to individuals because they:

1. Enable transparent and comfortable exploration of data;
2. Reward quality, which is under our control, rather than outcomes, which are not;
3. Reduce the demand for “positive” results required for career advancement;
4. Cultivate a flexible and open mindset;
5. Enable a more constructive and collaborative research climate; and
6. Generates more accurate information that is ultimately more accessible.

Therefore, one could easily argue that Open Science is aligned with concepts of academic freedom, by liberating individuals from the constraints of the closed system.

Making Open Science part of your daily research workflow

As you might now see, Open Science impacts almost every aspect of the typical research workflow. There are a number of tools, services, platforms, and practices for you to engage with, and this will likely differ for each individual, lab group, or community.

There are no set rules though. Open Science gives you the freedom to explore processes that work best for you, your research, and the impact that can have on your wider community. Below is just one combination of examples of tools that can make your research workflow more open all the way from an initial grant proposal through to research assessment.

Rainbow of Open Science Practices

Kramer, Bianca, & Bosman, Jeroen. (2018, January). Rainbow of Open Science practices. Zenodo. <http://doi.org/10.5281/zenodo.1147025>

Where to go from here

Hopefully now you have come to see the importance of Open Scientific principles, values, and practices as a fundamental part of modern science. Open Science is an umbrella term for a range of ideals, values, practices, and principles, all of which are integrated together:

Intersections of Openness

Intersections of Openness: Open Access, Science, & Education. By Abby Elder, CC BY 4.0 International License. Source

The **learning outcomes** from this should be:

- You will now be able to describe the ethical, legal, social, cultural, economic, and research impact arguments for and against Open Science.
- After deciding which platforms/tools/services are most useful for yourself and your community, you will be able to develop a personal profile for showcasing their research profile and outputs.
- After reflecting on the status of Open Science within their research group or lab, you will help to devise concrete ways to locally improve open practices.

- Using the guidelines published by their research laboratories, departments, or institutes, you will be able to help identify the policies for career progression and assessment, publishing and open access, data sharing, and intellectual property.
- You will be able to further collaborate with colleagues and international peers to develop a shared definition of Open Science.

From these, what you will hopefully now have are the foundational best practices and knowledge needed to engage in Open Science. Some small, tangible steps you can take to make a real difference here include:

1. Whenever possible, use and cite existing public data;
2. When you can, share your research data through a trusted online repository;
3. Make sure to release source code and scripts used for your analyses, including the environment needed to run them;
4. Post free copies of your research articles online however possible;
5. Share preprints of your research articles online, ideally at the time of journal submission; and
6. If you can, choose an Open Access journal to publish your research articles.

These are adapted from (Masuzzo and Martens, 2017), and just scratch the surface of the full power of Open Science. To learn more, visit the remaining 9 modules! This is the perfect chance for individuals, such as yourself, to take action and seize the initiative to become a champion in your research field.

Open Science is the future, and it will replace closed science. I encourage you to embrace it. -
Mick Watson.

Further reading

There is so much potential reading material out there that it would take years of continuous reading to get through it all. Here are some select favourite selected research articles on the topic that help to go into things a little deeper. All of them are free to access and re-use, of course!

- Open Science is a research accelerator (Woelfle et al., 2011).
- Open Science: The Evolving Guide on How the Internet is Changing Research, Collaboration and Scholarly Publishing (Bartling and Friesike, 2014).
- Open Science: one term, five schools of thought (Fecher and Friesike, 2014).
- From Open Science to Open Innovation (Chesborough, 2015).
- Winning Research Grants with Open Science (Grigorov et al., 2015).
- Promoting transparency in social science research (Miguel et al., 2014).
- Promoting an open research culture (Nosek et al., 2015).
- When will ‘Open Science’ become simply ‘science’? (Watson, 2015).
- Do you speak Open Science? Resources and tips to learn the language (Masuzzo and Martens, 2017).
- Early-career researchers’ perceptions of the prevalence of questionable research practices, potential causes, and Open Science (Starmer et al., 2017).
- Making Science Transparent By Default; Introducing the TOP Statement (Aalbersberg et al., 2018).
- Defining success in Open Science (Ali-Khan et al., 2018).
- Open Science is liberating and can foster creativity (Frankenhuis and Nettle, 2018).

- Digital Open Science-Teaching digital tools for reproducible and transparent research (Toelch and Oswald, 2018).

Development Team

- Gareth O'Neill, Language Lubber
- Bruce Caron, Culture Work Architect
- Jo Havemann, #ResearchinAfrica Highlighter
- Jon Tennant, Dinosaur Whisperer.

Additional tools and services

- The FOSTER Open Science Training courses are an excellent series for developing your Open Science skills. Each course takes about 1-2 hours to work through and you'll receive a badge upon completion. The courses include practical tips on getting started with Open Science as well as providing information on discipline specific tools and resources you can use.
- The Joint Roadmap for Open Science Tools, a community working link together existing Open Science platforms and services into a unified infrastructure.
- The Open Research Glossary, designed to help provide some insight into some of the language surrounding 'Open Scholarship'.
- The Berkeley Initiative for Transparency in Social Sciences (BITSS) have an excellent MOOC on Transparent and Open Social Science.
- The Scholarly Communication Super Collection at ScienceOpen contains more than 1000 research articles, thematically organised on the topic. Most of these are also Open Access.
- Why Open Research? is a fantastic website by Erin McKiernan, providing illustrations and information that help to support a strong case for Open Research.
- The Foundations for Open Scholarship Strategy Development, a document that aims to agree on a broad, international strategy for the implementation of open scholarship that meets the needs of different national and regional communities but works globally.
- Open Science: Sharing Your Research with the World - A MOOC hosted by TU Delft through edX.
- This incredible visualisation of the Open Science landscape by Mark Hooper. Mark was also the one who designed the original logos for our MOOC!