

A tale of two 'opens': intersections between Free and Open Source Software and Open Scholarship

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Abstract

There is no clear-cut boundary between Free and Open Source Software and Open Scholarship, and the histories, practices, and fundamental principles between the two remain complex. In this study, we critically appraise the intersections and differences between the two movements. Based on our thematic comparison here, we conclude several key things. First, there is substantial scope for new communities of practice to form within scholarly communities that place sharing and collaboration/open participation at their focus. Second, Both the principles and practices of FOSS can be more deeply ingrained within scholarship, asserting a balance between pragmatism and social ideology. Third, at the present, Open Scholarship risks being subverted and compromised by commercial players. Fourth, the shift and acceleration towards a system of Open Scholarship will be greatly enhanced by a concurrent shift in recognising a broader range of practices and outputs beyond traditional peer review and research articles. In order to achieve this, we propose the formulation of a new type of institutional mandate. We believe that there is substantial need for research funders to invest in sustainable open scholarly infrastructure, and the communities that support them, to avoid the capture and enclosure of key research services that would prevent optimal researcher behaviours. Such a shift could ultimately lead to a healthier scientific culture, and a system where competition is replaced by collaboration, resources (including time and people) are shared and acknowledged more efficiently, and the research becomes inherently more rigorous, verified, and reproducible.

Introduction

"Information wants to be free." – Stewart Brand

It is the best of times, it is the worst of times, it is the age of wisdom, it is the age of foolishness, it is the epoch of belief, it is the epoch of incredulity, it is the season of Light, it is the season of Darkness, it is the spring of hope, it is the winter of despair, we have everything before us, we have nothing before us. Departing from the words of Dickens, in short, when it comes to the state of scholarship, we are at a crossroad where existing and imagined infrastructures overlap, compete and displace one another. At the heart of that struggle lies our evaluation, valuation, use and operationalisation of “openness” in scholarship: what it was, what it is, what it can be. To each of those three, multiple legitimate answers exist. That multiplicity is the topic of the present article.

Since the 1980s, some of the key developments in academia have been based around Free and Open Source Software (FOSS) and Open Scholarship, as part of a wider and pluralistic Open Society movement (Şentürk 2001; David 2008). FOSS has been highly successful in a number of ways in society, and there is much that could be learned from this and applied more broadly to academia, particularly in context of an ongoing renewed interest in Open Scholarship. Contrasting FOSS and Open Scholarship together will provide reciprocal insight into these highly dynamic concepts and their relative successes or acceptance to date (Willinsky 2005; 2006; Grubb and Easterbrook 2011; Levin and Leonelli 2017; Lahti et al. 2017).

Specifically, in this article we will address four key themes in the four sections below:

- First, we will discuss notions of ‘openness’ in FOSS and Open Scholarship, and how these constitute and concern one another. This section describes the history of FOSS over the last several decades, and the resurgence in ‘open research practices’ within modern academia. We additionally explore the contested understandings of Open Scholarship or Open Science, and the inherent complexities this creates with respect to FOSS.
- Second, we ask which aspects of FOSS and Open Scholarship can be transferred between each other. This section primarily deals with three issues: first, shaping communities of practice between FOSS and Open Scholarship; second, the fundamental principles and values behind both, such as ‘gift-giving’; and third, questions about the roles of commercial players in each space.
- In the third section, we discuss what we can learn about systems of reward, value, and reputation by comparing the two ‘opens’. Many problems within modern scholarship can be

traced towards a defective system of reputation accrual and reward. What can Open Scholarship learn from FOSS in this regard?

- In the fourth section we ask how ‘openness’ intersects with issues around reproducibility and data sharing. Many fields of modern research are undergoing what is often termed a ‘reproducibility crisis’. This section will look into how FOSS and open data intersect with Open Scholarship to address this critical issue.

Understanding notions of ‘openness’ in software and scholarship

A large intersection exists between the principles and philosophies that underly FOSS and Open Scholarship. Due to their historical overlap, we can investigate the co-production that generated both in their current multitude shapes. We recognise movements of convergence as well as divergence in their shared history. For example, software and data accessibility (e.g., availability, inspection, and re-use) are now considered prerequisite for making full research environments transparent and rigorous enough to reproduce results (Ghosh et al. 2012; Sandve et al. 2013; Millman and Perez 2014; Hocquet and Wieber 2018). Many modern data collection and analysis workflows, including preparation and dissemination of publications, rely on a range of essential software or Web-based tools for which powerful FOSS solutions already exist (e.g., [R](#), [Python](#), [Julia](#), [GNU PSPP](#)). The combined ability to independently reproduce and refute research is one of the critical elements for most of the scientific enterprise (Popper 1959). Openness in research software and data promises to help close the digital divide and enhance the democratic globalisation of research participation (May 2006; Fuchs and Horak 2008; Packer 2009), and are critical to healthier socio-cultural and political discourse (Merton 1942). As the foundations behind FOSS tend to be more thoroughly studied and understood, understanding its history can help to elucidate modern concepts of scholarship and their future co-evolution (Bretthauer 2001; Weber 2004) (Figure 1).

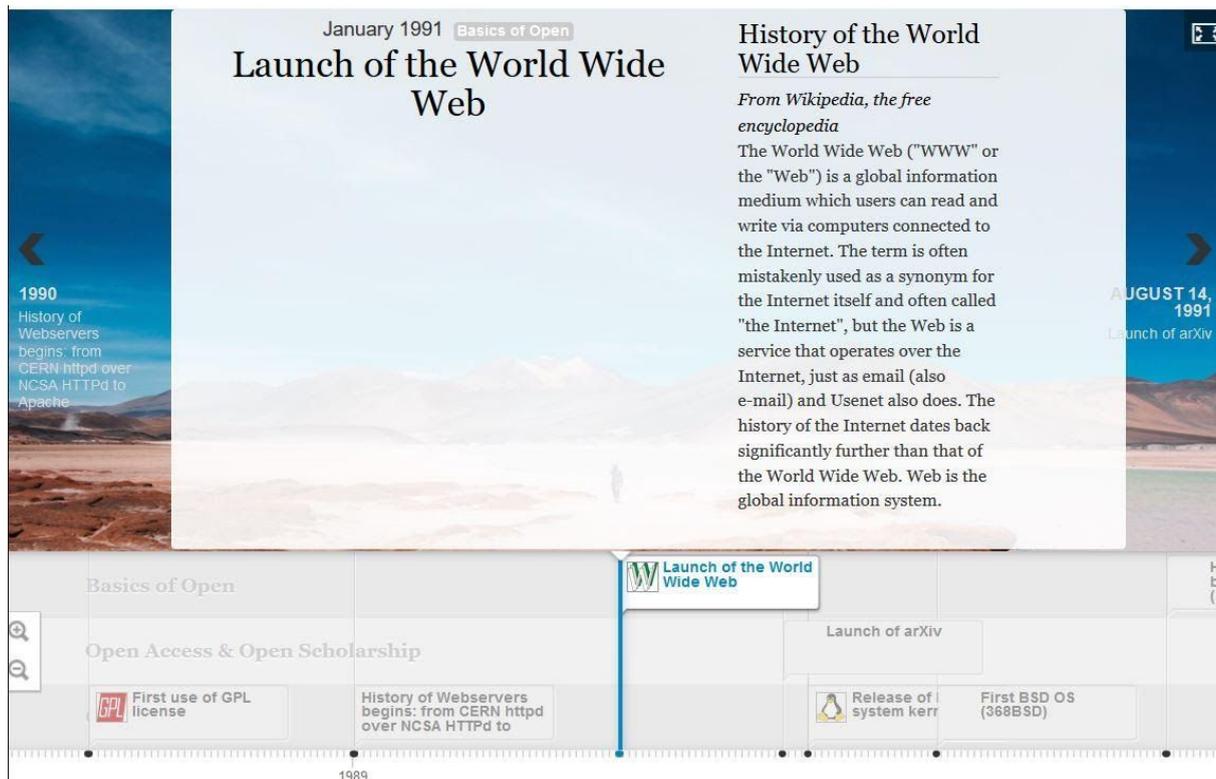


FIGURE 1 - Timeline: Parallel Evolution of Open Source and Open Scholarship (see <https://blog.flavoursofopen.science/timeline/> for interactive version)

A brief history of the Free Software and Open Source movements

The origins of 'free' software are closely tied to the development of the first mass-produced computers in the 1950s, bundled together as packages by IBM. The adoption of time-sharing mainframes, and the development of standardized operating systems and programming languages for such infrastructures (leading from Multics to Unix and the C language, in the late 1960s and early 1970s), created an environment in which source code for academic computing could be shared: repetitive work was left to machine and know-how could be quickly passed over. However, the Free Software movement itself was launched in [1983](#) (see the original announcement by Richard Stallman [here](#)), followed by the launch of the [GNU project](#) based around the free operating system GNU (1984); most importantly this represented the first FOSS organized manifesto. The purpose here was to produce a novel software system by sharing the general code knowledge, which was until then primarily covered by intellectual property. The idea of intellectual property rights was incompatible

with what the founders called [fundamental freedoms](#)¹, which created a new set of values around encouraging the ability to run, study, change, adapt, and redistribute software without restriction. Since 1985, the movement has been overseen by the non-profit [Free Software Foundation](#). The GNU project and a definition of Free Software were created as a result of this, becoming the *de facto* manifesto for the movement. The [GNU General Public License](#) (GPL) was first used in 1989 by the GNU developer team to broadly distribute software released as part of the GNU project. GNU is probably one of the most common and known cases of ‘copyleft’. The current version (GPLv3), released in 2007, is still widely used today, in 2019.

In 1998, the [Open Source Initiative](#) (OSI) was launched as an offshoot of the Free Software movement. As part of the OSI, Eric S. Raymond [outlined](#) his issues with the term “Free Software”, particularly in its ambiguity regarding either pricing or licensing. He advocated for its replacement “Open Source” as a label to describe reusable software and the culture surrounding this. Much of the motivation for Open Source was based on strategic rebranding of technical ‘excellence’ and pragmatism in software production to make it more compatible with commercial interests around commodification of source code, including through consultation services (Lerner and Triole 2000). Now, FOSS has become an almost ubiquitous part of modern society, although dedicated projects seem to be largely focused in North America, China, and western Europe, with relatively little documented activity across Central America, SE Asia, and Africa (Mombach et al. 2018). Even now, after more than 20 years since the inception of the OSI, the definition of Open Source remains contested. Technology is undergoing an extreme rate of growth, and definitions require constant adaptation to new areas that technology is developing; this makes it difficult to establish a global definition that can cover many different fields and interests.

A key component uniting both Open Source and Free Software is that people, in principle, have a natural right to share, re-use and modify source code, and should therefore be clearly granted this right. This is different from the right to contribute, and is legally enforced through explicit conditions around licensing and copyright, embedded within the [Open Source Definition](#). Open Source focussed more on the development/production side with a more effective “bazaar” model (Raymond 2001) for collaborating, which does not explicitly guarantee Free Software’s fundamental freedoms. The bazaar is considered an almost utopian, decentralised form of democratic organisation in contrast to the typical “cathedral” of centralised production. Stallman [summarised](#) this divergence as “Open Source is a development methodology; Free Software is a social movement.” This is also often

¹ “The freedom to run the program as you wish, for any purpose. The freedom to study how the program works, and change it so it does your computing as you wish. Access to the source code is a precondition for this. The freedom to redistribute copies so you can help your neighbor. The freedom to distribute copies of your modified versions to others. By doing this you can give the whole community a chance to benefit from your changes. Access to the source code is a precondition for this.”

alluded to in the widely known slogan from Stallman, “‘free’ as in ‘free speech,’ not as in ‘free beer.’” This is equivalent to free as in ‘libre’ rather than free as in ‘gratis’, in many languages; or ‘to be free’ versus ‘to be for free’. The acronyms FOSS or FLOSS (free/libre open source software) are able to encompass all aspects of the Open Source and Free Software movements. Now, Open Source, without the moral load associated with the word “free”, is the standard term used to refer to this class of software, and is now ubiquitous in the global computing landscape — including within scholarly research.

The interwoven histories of Open Access and Open Scholarship

Scholarship, scholarly identities, and the politics and process of scholarly communication have a rich, non-linear, inconsistent, region- and discipline-specific history (Csiszar 2016; 2018). The typically institutionalised forms that dominate modern scholarship, came about as part of a shift towards increasing ‘citizen science’ through the 19th century (Shapin 2011). This was followed by the explosion of global scholarship in the post-Second World War years, leading to increased growth of the higher education sector, diversification of academic roles and career paths, increasing international participation in research, and increasing dissemination of academic outputs through scholarly journals and books (Fyfe et al. 2017). Together, these factors led to an intricately evolving sociopolitical relationship between the ‘public’ and scholarship (Merton 1973; Geiger 2017; Neylon 2018). Scholarly practices of sharing precede the origins of scholarly journals, based around early forms of scholarly communication, such as witnessing experiments, and later, the exchange of letters between scientists, as the first form of so-called ‘virtual witnessing’ (Shapin 1984). These early forms of sharing were highly exclusive and catered only to a small and local elite. Over the course of the centuries following the scientific revolution, the ‘public’ character of science changed. This was primarily due to a shift in who is considered to be included in that ‘public’, informed by an evolution of the ‘social contract of science’ that increasingly placed science inside society, as opposed to esoterically hovering above it (Gibbons 1999). A consequence of this was that many more people became legitimate members of the public of science, whose voices were considered worthy of participation and inclusion (Gibbons et al. 1994).

Perhaps the biggest innovation in the history of scholarly research was that of the printed journal in the 17th Century, which became the primary vehicle for communicating research and defining increasingly specialised scholarly communities (Potts et al. 2017; Hartley et al. 2019). This extended the physical college into a virtual college (Sztompka 2007; Csiszar 2018), coinciding with emerging scientific practices around working collaboratively to advance knowledge as a common good for society, rather than for personal or institutional gain (David 2004; Lahti et al. 2017). Journal articles

have only slightly evolved since their origins, ideally now containing sufficient documentation of research processes such that others can build upon or repeat that research. Despite the advent and enormous growth of Web-based technologies that permit more effective and low-cost methods of sharing and dissemination, greater epistemic diversity in scholarship, and increased democratisation of academic knowledge (Owen, Macnaghten, and Stilgoe 2012; Cowley 2015; Hartgerink and van Zelst 2018; Hartgerink 2019; Tennant 2018b; Martin 2019), scholarly journals and journal articles remain largely as isolated and low-tech digital versions of their printed analogues. Appearance of these new technologies catalysed the modern Open Access (OA) movement, which, similar to FOSS, primarily focuses on providing unrestricted access to research articles (Guédon 2008; Suber 2012; Tennant et al. 2016) and helping to increase the global/public circulation of research information beyond professional scientists (Adcock and Fottrell 2008; Laakso et al. 2011; Bacevic and Muellerleile 2018). OA undoubtedly has its origins as a grassroots, community-led initiative as an alternative or complement to typically subscription-based proprietary publishing ventures (Willinsky 2005). Now, it has become widely adopted at various policy levels by universities, governments, and funding bodies; often aligned with the impact or 'excellence' agendas of these institutes (Finch et al. 2013; Vessuri, Guédon, and Cetto 2014; Moore et al. 2017; Katz, Allen, et al. 2018).

The early history of the Internet involved a number of academics based at either private or public research institutes (e.g., Tim Berners-Lee, Grace Hopper, Elizabeth Jake Feinler, Sally Floyd, Lawrence Lessig, and Linus Torvalds), suggesting that the ideals that underpin much of FOSS have their origins from within scholarship itself. Others suggest that "Open Science" and the idea of scientific knowledge as a common good has its origins as far back as the late sixteenth and early seventeenth centuries (David 2004; 2008; Shapin 2011; Martin 2019). While it is difficult to identify whether Open Source or Open Scholarship came 'first' due to their dynamic histories, both draw from the notions of common goods (and specifically digital common goods that are non-rivalrous) (Ostrom et al. 2002; Frischmann, Madison, and Strandburg 2014), and unrestricted participation and sharing based on the underlying values of equity and sustainability, among others. Compared to FOSS, Open Scholarship is practically more complex (Mirowski 2018); the former only relates to software development (including infrastructure, governance, legal and funding issues), whereas the latter regards the entire process of scholarship, including research articles, grant proposals, data, software, educational materials and methods, and research evaluation (Katz, McInnes, et al. 2018; Tennant, Beamer, et al. 2019); of which sharing the outputs from is now widely implemented and even mandated within many areas of scholarship (Vincent-Lamarre et al. 2016).

Many of the more-recent Web-oriented developments remain in direct tension with traditional methods of scholarly publishing. Here, commodification and privatisation of research has become

the *de facto* norm for much of the industry, which relied on exclusionary business models to support itself. Because of this, some actors in the private sector, as well as a number of professional academic societies, have even taken active stances to subvert, co-opt, or even stop progress towards more inclusive and open systems (Posada and Chen 2018; Tennant 2018a). The hyper-competitive reward system only seems to have exacerbated this, instead promoting secrecy and individualism rather than any form of collective collaboration for knowledge generation (Merton 1968). This tension appears to be prevalent in North America and western Europe, with some regions such as Latin America seeming to have made much stronger progress towards having scholarly research produced there made accessible for the betterment of wider society (Packer 2009; Alperin and Fischman 2015; Ochoa and Uribe-Tirado 2018; Debat and Babini 2019). Current trends in OA and Open Scholarship cannot therefore be considered as isolated ‘movements’, but instead as intersecting with a complex array of questions, such as whether scholarly processes and outputs should be able to be subject to privatisation or commodification (e.g., through copyright and patents). Such issues have also been prominent in debates within FOSS communities, and can help to frame one of the core issues of the present scholarly communication system. This complex plurality exists especially with respect to synthetic modern understandings of openness, and presents the scope for which an integrated understanding of FOSS culture can be potentially leveraged in scholarship.

A resurgence in ‘open research practices’

Particularly during the last three decades, notions of ‘openness’ and ‘open’ have seen a surge in attention among a variety of research-related stakeholder groups. While undoubtedly having a much longer and richer history, the onset of what can be considered a modern understanding of Open Scholarship can probably find its origins within OA. Taking the *Budapest Open Access Initiative* (BOAI) as a point of genesis for the term itself (Chan et al. 2002), a wide array of stakeholders ranging from technologists and librarians to researchers and educators have established their individual and peer group’s perspectives on the multifaceted notions of ‘openness’ in scholarship. Policymakers and research funding agencies on local, regional, national and international levels have taken note of the emerging trend and began to issue reports, guidelines, and policy documents that further shaped the conditions of openness (Moedas 2015; Union 2017; 2019; Participants of African Open Science Platform Strategy Workshop et al. 2018). The agenda of ‘open’ is “extending [...] into all areas and activities of the academy, impacting its core missions of teaching and research, as well as the systems and processes that are critical to individual and institutional success.” (Corrall and Pinfield 2014, p.293).

In principle, OA is highly distinct from traditional, subscription-based publication business models. Subscription-based research articles have a strange duality in which they are published, but are largely inaccessible and restricted to the public due to financial, copyright, and licensing constraints. Although the ideas behind OA certainly pre-date the advent of the Web, the potential of digital technologies and their associated workflows, relatively low cost and increased efficiency of copying, transmitting, and storing documents, catalysed the widespread development of OA. These all flew in the face of the subscription model, which, even in digital environments, relied on resource-based constraints by creating the illusion of scarcity in production and dissemination. Fundamental in the origins of OA were the unconditional free public availability for reading, as well as unconstrained re-use so long as original sources were attributed; often equated with the Creative Commons Attribution (CC-BY) license (Suber 2007b; 2012; Tennant et al. 2016). As citation or attribution is a norm in scholarly research, this requirement is not typically considered to be a restriction and is fully compatible with standard practices. Since BOAI, most policy and technology developments have focused specifically on OA to research articles, as this is seen as where the most value is perceived to lie within scholarship, both in terms of industry revenue and in research evaluation criteria at sub- and supra-national levels. And while at least two similarly-foundational declarations – the [Bethesda Statement on Open Access Publishing](#) (2003), along with the [Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities](#) (2003) – widened the declarative scope of open access to other elements of scholarly output at around the same time, we just now see increasing uptake and accompanying developments on a wider-scale in, for example, the fields of open access book publishing, open education (including Open Educational Resources, OER), and the larger and underlying topic of open infrastructure for science and scholarship.

Accompanying OA, a range of ‘open research practices’ are now commonly called upon as potential methodological improvements to major issues around reproducibility, publication bias, questionable research practices, and more efficient or rigorous research workflows (Watson 2015; Levin et al. 2016; Crick, Hall, and Ishtiaq 2017; Masuzzo and Martens 2017; McKiernan 2017; Bowman and Keene 2018; Fraser et al. 2018). This includes a diverse range of practices such as pre-registration and registered reports (Nosek and Lakens 2014; Nosek et al. 2018), sharing of code and data (Barnes 2010; Levin 2015; Mons 2018), and opening up the peer review process in different ways (Morey et al. 2016; Ross-Hellauer 2017; Tennant et al. 2017). As research has become progressively computational, demands for FOSS have simultaneously increased as part of the complete scholarship environment. However, we must also be careful not to attribute too much power to openness. Sociologist of science Harry Collins already demonstrated that sharing everything that can be shared is still insufficient to produce, for instance, replicable research (Obels et al. 2019). There is a lot to science that cannot be made explicit and thereby cannot be shared on paper or digitally; known as

tacit knowledge and tacit expertise (Collins 1992; Derksen and Rietzschel 2013; Penders, Holbrook, and de Rijcke 2019).

Regional variations in uptake of open research practices are noteworthy. In Latin America (Arza, Fressoli, and Lopez 2017), “Open Access” (aka Ciencia Abierta/Acceso Abierto) seems to have become more widely adopted with the advent of SciELO in 1997 (Packer 2009) and Redalyc in 2002 (López et al. 2008). Other regions, including western Europe and North America, have a more diverse and fragmented history of making OA the norm, with correspondingly diverse economic and social tensions (Barić et al. 2017). The European Commission (EC) issued an OA pilot in 2007, which became a mandate in 2013; however, in spite of this, much of Europe still seems to be continuously struggling with the political and economic dimensions of OA (Johnson 2019). Some European countries, such as Croatia, have strong national and governmental support for a ‘diamond’ OA model (Stojanovski 2015), and are very much demonstrating leadership in this space more akin to progressive initiatives across Latin America. Elsewhere in Europe, infrastructure initiatives such as [OPERAS](#) are helping to make great progress for non-profit OA, similar to Latin America, while most STEM publishers, funders and policymakers in western Europe and North America seem reluctant to engage with equivalent and more sustainable initiatives, despite common perceptions of being where the world’s ‘best’ research takes place. In 2018, the Technical Advisory Board for the African Open Science Platform released a strategy paper on how “to put African scientists at the cutting edge of contemporary, data-intensive science as a fundamental resource for a modern society” (Participants of African Open Science Platform Strategy Workshop et al. 2018). These regional examples are by no means exhaustive, but serve to illustrate the fact that Open Scholarship, in its various forms, has now become a heterogeneous global phenomenon, with an incredibly complex suite of political, socio-cultural, and technical dimensions (Debat and Babini 2019; Tennant, Beamer, et al. 2019).

Contested understandings of Open Scholarship (and ‘Open Science’)

It is not our goal here to present a consensus definition of ‘open science’ or ‘open scholarship’, as we do not believe we have the common authority to do so. We recognise that openness in scholarly research has become a dynamic and evolving spectrum of principles, values, and practices (Willinsky 2006; Nosek et al. 2015; Moore 2017; Chan et al. 2019; Tennant, Beamer, et al. 2019), rooted in the philosophy of unrestrained participation and the Commons (Suber 2007a; Bosman et al. 2017; Martin 2019). Some researchers now even self-identify as ‘open scholars’ or ‘open scientists’ as a result of this. It is noteworthy that these diverging extensions of the web of meanings and corresponding applications neither happen in congruous, simultaneous and/or uniform manner, nor

do they encompass the same object of identification. It also is unclear what specifically makes one an 'open scientist' or 'open scholar' (or not), what the differences or similarities between the two are, and who has the moral authority to define what underpins this (and Open Scholarship in general).

Shortly after the turn of the Millennium, Şentürk (2001) described "open science" as a solution to 'closed' and structurally exclusive modes of science, comprising three core characters: multiplex ontology; multiplex epistemology, and methodological pluralism. As far as we are aware, this remains the earliest introduction of "open science" into the scholarly literature, and yet remains curiously uncited by virtually all of the subsequent literature on 'open science'. Here, there was a strong original humanist focus on the role of science in global politics, cultures, social democratic relations, and even with an impact on human rights. During the 2000s and early 2010s, Open Science, as Titus Brown states, could be understood as "...the philosophical perspective that sharing is good and that barriers to sharing should be lowered as much as possible. The practice of Open Science is concerned with the details of how to lower or erase the technical, social, and cultural barriers to sharing" (Brown 2016). This socio-cultural philosophy echoed the work of (Şentürk 2001), and was reflected in later works including Michael A. Peters' review of existing Open Science approaches (Peters 2010), and the now often-cited "Five Schools of Thought" of Open Science by (Fecher and Friesike 2014)². Concepts of 'freedom', akin to 'Free Software', have been rarely discussed in the context of scholarly communication (Alperin et al. 2017).

During the last few years, Open Science has often come to be understood in a relatively narrow sense; see Lahti et al. (2017) for an exception. Earlier notions of Open Science emerged as an "umbrella term that encompasses almost any dispute about the future of knowledge creation and dissemination" (Fecher and Friesike 2014). While the use of "Open Science" varies substantially across disciplines, most recent literature usually remains limited to the domain of STEM-based research, often overlooking important initiatives in the arts, humanities and social sciences. The primary focus connecting all disciplines is the widespread uptake of new technologies and tools, and the underlying ecology of the production, dissemination and reception of knowledge from a research-based point-of-view. The term 'open science' implicitly seems only to regard 'scientific' disciplines, whereas 'open scholarship' can be considered to include research from the arts and humanities (Eve 2014; Knöchelmann 2019), as well as the different roles and practices that researchers perform as educators and communicators, and an underlying open philosophy of sharing knowledge beyond research communities.

² A sixth school was recently proposed as an addition here, community and inclusion, noting that the principles of diversity and inclusivity are key and should be embedded in notions of Open Scholarship (Tennant, Beamer, et al. 2019).

This fragmented understanding is perhaps best illustrated in one of the most commonly-used graphical representations of Open Science from the EU-funded [FOSTER project](#) (Figure 2). Here, Open Source is significantly considered as a ‘third level’ element within Open Science, rather than of equivalent importance to OA or Open Data. Any public-facing element is also almost entirely absent, for example via Citizen Science, whereas other organisations such as the OECD include this within their classifications of Open Science (OECD 2015). Furthermore, the linking of the various ‘open concepts’ together in a hierarchy exposes (not just pictographically) that there is very little horizontal connection between them. Instead, this represents a fairly fragmented landscape within the ‘umbrella’ of Open Science. Also, ‘open science’ seems to be a linguistic particularity which is mainly confined to English and French speaking academe, since in many other languages, terminology employed to denote “science” (e.g., “Wissenschaft” in German or “Wetenschap” in Dutch) is more general than in English (Tennant, Beamer, et al., 2019, sec. 4.2.2). Similar to the overtaking of ‘Free Software’ by ‘Open Source’, ‘Open Science’ seems to be the most popular and widely used compared to its research or scholarship alternatives; albeit, the three are often used interchangeably and in overlapping senses in discourses.

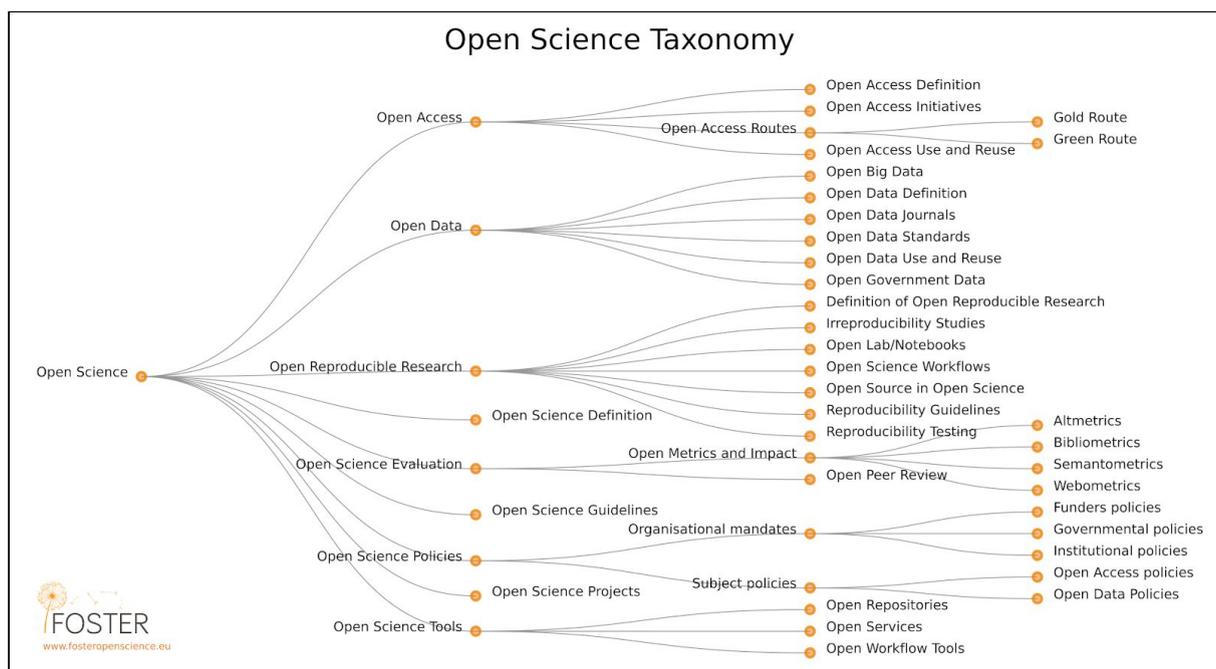


Figure 2. An Open Science Taxonomy, from FOSTER (Pontika et al. 2015).

Emphasizing this evolving notion of Open Science, (Vicente-Saez and Martinez-Fuentes 2018) as part of a systematic review where seventy-five studies were analyzed, defined it as “...transparent and accessible knowledge that is shared and developed through collaborative networks”. (Watson 2015) made the compelling argument that ‘open’ research practices are no different from *good* scientific

practice, akin to views that FOSS leads to the development of *better* software. Watson here also stated that “software should be (and in fact is) driving the open-science movement”. This would suggest that open science is perhaps nested within the FOSS movement, as opposed to being subsidiary to it as implied by FOSTER. Irrespective of these ontological differences, the general consensus appears to be that Open Science is a commitment towards specific practices that lead to the public sharing of research outputs, and that this is a *good* thing leading to *better* science. Open Science then is about the process of knowledge production and then how that knowledge is shared; something overlapping with, and fundamental to, FOSS. Although not explicitly stated, the core concept around such practices creating more openly inclusive research environments aligns itself with the philosophies of earlier advocates of Open Science (Şentürk 2001; Peters and Roberts 2015). However, even socio-cultural terms such as ‘liberty’ are still used in their practical, rather than philosophical, sense (Frankenhuis and Nettle 2018); and the wider humanist and political sentiments that underpinned early concepts of Open Science (e.g., based around fundamental freedoms), and indeed Free Software, appear to be almost absent.

Taking these described tendencies as a line of further evolution, more and more scholars acknowledge the similarities and overlaps in the network of scholarly practices encompassing research, education, communication, and engagement. These practices have an underlying ‘open mindset’ against the backdrop of digitization and its impact on academia, thus re-transforming the understanding of Open Science towards what often is termed “digital” and/or “Open Scholarship” (Peters 2010; Veletsianos and Kimmons 2012; Peter and Deimann 2013; Eve 2014; Weller 2014; Peters and Roberts 2015; Pomerantz and Peek 2016; Cronin 2017).

To compound this taxonomic complexity even further, ‘openness’ in scholarship is often used at a number of different scales; for example, lab groups or teams, individuals, and institutions (Tennant, Beamer, et al. 2019). Thus, ‘Open Scholarship’ is often applied indiscriminately to mean very different things, but with the same blanket terminology applied. Linked to the diachronic shift in the meaning of Open Science away from the more philosophical underpinnings of ‘openness’ in academia as discussed by, for example, Peters and Roberts (2015), and towards a narrower and more pragmatic frame of reference, the widespread and often-synonymous usage of Open Science and Open Scholarship has added to this confusion. The terms themselves can be off-putting or exclusive due to the often dogmatic or purist way they are discussed (in particular on social media) as a seeming solution to all of science’s problems. By associating open research practices with ‘good’ research, the implication is that researchers who are not involved in open research are doing ‘bad’ research. While this may be partially true, in that open research tends to be more rigorous and transparent (Watson 2015), it creates a tension between those who either do not sympathise with,

or are unable to commit to such practices. Very few researchers or ‘open science advocates’ appear to have been critically reflective on *how* such sharing and transparency are implemented, and on the potential unintended consequences this might have for different sub-communities (Bacevic and Muellerleile 2018; Tennant, Beamer, et al. 2019; Düwell 2019), especially within a hyper-competitive ‘publish or perish’ academic environment. The lack of common understanding also means that people often end up having the same conversations about very different things, or simply talking past one another. For example, with ‘open peer review’, there are more than one hundred existing definitions (Ross-Hellauer 2017), many of which are competing or with a different frame of reference, as with debates around open peer identities and open review reports. The language of openness may also be deliberately co-opted for non-open purposes if not precisely defined. The term “openwashing” – derived from “greenwashing”, where vendors rush to label their products “green” in environmental terms in order to increase sales – refers to practices considered deceptive insofar as they purport to be open but do so only to make themselves more attractive and in reality do not adhere to a majority of the principles of openness (Watters 2014; Weller 2014).

Katz, Allen, et al. (2018) asserted that “Open scholarship is perhaps the most broad term we can use; it includes open science, open humanities, and open research, and can be defined as opening products such as articles, data, software, educational resources, or more broadly, opening the process of scholarship.” Arguing for an integrative and inclusive framework, Veletsianos and Kimmons defined Open Scholarship as taking “three major forms: (1) open access and open publishing, (2) open education, including open educational resources and open teaching, and (3) networked participation, [...which] refers to scholars’ uses of online social networks to share, critique, improve, validate, and enhance their scholarship.” (Veletsianos and Kimmons 2012, p.168). Tennant et al. (2019) echoed this understanding as a framework in a living strategy development document for Open Scholarship, defining it as “the process, communication, and re-use of research as practiced in any scholarly research discipline, and its inclusion and role within wider society” (Tennant, Beamer, et al. 2019), attempting to reinject the notion that the function of scholarship cannot be divorced from its social imperative.

If one accepts a broad, flexible, and diverse definition for Open Scholarship, this in part alleviates the question of who has the authority to determine a single definition, and across a hugely complex array of disciplines, cultures, and stakeholder groups. The foundational [Open Definition](#), from the Open Knowledge Foundation, defines ‘open’ as “...anyone can freely access, use, modify, and share for any purpose (subject, at most, to requirements that preserve provenance and openness).” However, this is not specifically geared for scholarship, legally encoded, or enforced should the definition be subverted; for example, if licensing constraints prohibit re-use or modification via

non-commercial or non-derivative clauses. Presently, there is no institutional equivalent in Open Scholarship to either the Free Software Foundation or Open Source Initiative to provide oversight on this. The ambitious [Open Scholarship Initiative](#), launched in 2014, is one such potential candidate, and has been historically supported by UNESCO and a variety of foundations, institutes, and proprietary actors, including many of the large scholarly publishers. While the Open Scholarship Initiative is broadly representative of the scholarly communication ecosystem, it also includes commercially motivated actors who arguably the Open Scholarship (or at least Open Access) movement started as a 'rebellion' against, and continue to operate a number of 'anti-open' marketing and business practices (Posada and Chen 2018; Tennant and Brembs 2018). The Open Scholarship Initiative does not attempt to define 'Open Scholarship', but more considers it to be a spectrum only comprising practices and processes on a range from more to less open (Hampson 2018), thus opting for flexibility over precision.

There are two main competing approaches towards this lack of consensus. First, given the diversity of principles, practices, and outputs involved in Open Scholarship, a single, unified, comprehensive and widely-accepted consensus definition is probably not sufficient (or even desirable); unless such a definition readily embraces this diversity (e.g., as the Open Scholarship Initiative seems to do). Second, there remains a need to rigorously define and enforce the philosophy, values, and principles of Open Scholarship, and explore how these underpin the practices, and to have consensus reached on this within the scholarly community. This would address the lack of common understanding, which has impeded the widespread adoption of the strategic direction and goals behind Open Scholarship, prevented it from becoming a true social 'movement', and separated researchers into disintegrated groups with differing, and often contested, definitions and levels of adoption of openness (Tennant, Beamer, et al. 2019). Rebecca Willen has also identified that there might be two, perhaps three, different sub-movements that intersect in different ways, involving 'open science', 'replicable science', and 'justice-oriented science'³. A potential consequence of having multiple competing approaches is that the future of Open Scholarship remains insecure, potentially and inadvertently increasing the strength of commercial or proprietary players in this space, and becoming entirely divorced from any sort of value- or philosophy-driven basis.

Alternatively, it could be the case that now, open research is diffused in such a wide variety of ways that there cannot plausibly be a single, cohesive community and set of practices that define it. This would represent the absorption of 'open' research into 'traditional' research, and part of a successful

³ Rebecca Willen, Justice oriented science, open science, and replicable science are overlapping, but they are not the same

<https://rmwblogg.wordpress.com/2020/02/29/justice-oriented-science-open-science-and-replicable-science-a-re-overlapping-but-they-are-not-the-same/> (retrieved 05/03/2020).

trend towards 'better' research overall. Instead, Open Scholarship, Open Research, and Open Science might best be thought of as overlapping/intersecting 'boundary objects' (Moore 2017) that represent this inherent diversity. The position of FOSS within any such schema depends on whether one regards it purely in a practical sense, or in a more fundamental and philosophical manner. Such might be preferential to avoid compounding these ontological issues further with legal and technical aspects associated with software, data, and other scholarly outputs. As Şentürk (2001) originally prescribed, the pluralism in concepts of 'openness' in scholarship (and/or science) might be where its power lies, in that different communities can understand and adopt it in different ways depending on their inherent social norms and research processes.

What aspects can be transferred between FOSS and Open Scholarship

FOSS and Open Scholarship as communities of practice around collaboration and sharing

Communities form an essential part of FOSS (Katz, McInnes, et al. 2018). Here, software development and re-use is inherently communal and ideologically democratic based on its core methodologies, and self-organised either hierarchically or modularly. Version control systems allow developers to independently make changes to a copy of the code and share the changes with collaborators. Remarkable momentum towards more open collaboration models has been powered by [Git](#) (and GitHub). This modern, distributed version control system allows decentralized development of large-scale FOSS projects. It was initially developed by Linus Torvalds to facilitate Linux kernel development and has subsequently been widely adopted by the FOSS community. While harder to learn and use than earlier popular systems, such as SVN and CVS, Git similarly enables efficient collaborative workflows, and also adds additional support for decentralized development. This process allows developers to copy the initial code repository, work independently on a 'fork' of it, and then share the changes or the full changed version on platforms such as GitHub, GitLab, Bitbucket, or Sourceforge. It has proved to be a highly effective participation system for software, leading to the rapid popularisation of such practices and development of FOSS projects.

Part of the success of FOSS was that the methods and products were proven viable alternatives, practically and commercially, to proprietary software. Another major part is that, in theory, anyone who shows an interest in a project is able to collaborate and contribute code, write documentation,

add examples or tutorials, discuss, and provide feedback. This means that, even in expert-driven and software-intensive projects, there is a relatively low barrier to entry (particularly when using Web interfaces to the version control system) even for those with non-coding skills, as there is substantial value in, and appreciation for, generalist skills in documentation and communications. Increased participation also helps to divide up the labour required for larger projects, opening up new working environments and group formation and governance structures based around a shared sense of collective participation and authority (O'Mahony and Ferraro 2007; Palazzi et al. 2019). FOSS can also be thought of as a powerful method for social, community-driven or peer-to-peer dynamic learning, where the distinction between users, testers (or reviewers), and developers is more blurred than in a proprietary environment.

Collaboration in FOSS projects is essentially continuous and iterative as a progressive form of verification. The underlying assumptions for this type of process are very much idealised: public disclosure of bugs and issues that get resolved sequentially, usually by a core team plus external volunteers, until a piece of software is released, with the 'principle of many eyes' helping to increase the validity and verifiability of work. A consequence of this is a further assumption that this process also results in *better* software (Kelty 2001); or an alternative viewpoint that perhaps only 'better' software is worth being shared under a FOSS license (Pauliuk et al. 2015). Research projects are typically distinct from this, with 'releases' coming primarily in the form of research articles at discrete moments in time. These articles and their content are largely immutable, save for post-publication processes such as retraction or applying a corrigendum. 'Testing' as a form of quality control is usually conducted through peer review, which remains a highly-regarded yet curiously understood process at the heart of scholarship (Tennant and Ross-Hellauer 2019). These practices are slowly and tentatively beginning to change; for example, with preprint reviews in some disciplines like Meta-Psychology.

Much of this sharing and collaborative FOSS culture was driven by reciprocal motivations around sharing and repurposing, also sometimes called 'hacking' (Orr 2006; Coleman and Golub 2008). When applied specifically to software, [hacker culture](#) leads naturally to FOSS as a community of practice, as the freedom to re-use and modify (i.e., 'hack') is built into the software through licensing requirements. Raymond (2001, p. 31) puts hackers at the heart of a gift-giving culture: "You become a hacker when other hackers call you a hacker. A "hacker" in this light is somebody who has shown (by contributing gifts) that he or she has technical ability and understands how the reputation game works. This judgment is mostly one of awareness and acculturation, and can only be delivered by those already well inside the culture." This 'gift-giving' culture strongly emphasizes the ideology that underpins the FOSS community, that sharing is intrinsically valued as part of wider hacker culture

and in which reciprocity is key⁴. It is essential that scholars understand how to apply these successful collaborative practices from FOSS development, especially now that much scholarly research is becoming increasingly reliant on computation. This has the potential to improve the efficiency, diversity, productivity, and reliability of research processes, decoupled from any formalised journal-bound peer review system (Heller, The, and Bartling 2014; Frassl et al. 2018; Tennant, Bielczyk, et al. 2019)

Here, however, it is important to clarify some important differences between participating in FOSS and Open Scholarship activities. These differences lie in the process more than the product. For products, granted the adoption of similar licenses (e.g., those that are Open Definition compliant), there is no substantial difference in the 'openness' for OA, Open Data, and FOSS; although in some jurisdiction, like the US, data cannot be subject to copyright. Users are typically able to access the products without restriction, and, according to the license, able to derive works from and redistribute these products. There are, however, residual issues in that just because something is 'open' does not make it accessible and immune from other inequities and ethical concerns that might influence its access and usability (Nicol et al. 2019). On the process side, it is the way that products are accessible for collaboration during development that differs. With FOSS, it is typical that a small, core group of people starts openly developing a software product; however, this depends on the scale of the project, and it can range from individual, networked, to large corporate or governmental ventures. Other people can participate in (and leave) the effort over time, contributing as they wish. Development iterates over multiple cycles and releases, and the product is available from the very beginning of the process. This method is very much idealised, and best practices can include aspects such as using open repositories, version control, and issue trackers; but such collaborative practices are neither strictly inherent to FOSS, nor are they limited to it. The production of knowledge goods that is based on sharing both resources and outputs, performed by loosely

⁴ A study in 2002 (N=81) showed that participation in FOSS can be broadly divided into internal factors that are not easily influenced, such as intrinsic motivation and altruism, and external rewards, such expected future returns, skill expansion, and personal needs (Hars and Ou 2002). Additional factors included peer recognition and self-marketing (both extrinsic), and community identification (intrinsic). Contrary to the proposed stance of openness for the greater good. Interestingly, only 16% of the participants rated high on altruism. Another survey based on closed and open-ended items of (N=110) FOSS contributors (Baytiyeh and Pfaffman 2010) revealed that intrinsic motivation factors, including the belief to be working for the greater good, providing something valuable to others, and the belief of helping others are the strongest factors motivating individuals. These motivators are followed by extrinsic (external) human capital factors such as learning new skills, tools, strategies, and methods, and factors related to increasing own academic and personal success. A further study (Bagozzi and Dholakia 2006) of (N=402) active Linux User Groups participants, who completed a survey based on the Theory of Planned Behavior and the attitude-theoretic model, found that the strongest factors to contribute with active participation to FOSS are social identity (identification with the movement, cognitive and affective social identity), attitudes, and perceived behavioral control (i.e., the perceived difficulty in actively participating given norms and rules).

connected individuals who collaborate in a decentralized, modular and often non-hierarchical way has been identified as a new way of organizing production. Yochai Benkler coined the term “commons-based peer production” for this mode of development and identifies projects such as Wikipedia and OpenStreetMap as examples (Benkler 2006). Through this lens, it becomes clear that the use of open licenses might be a necessary condition for the success of peer production endeavours such as FOSS, Wikipedia and OpenStreetMap, but it is not sufficient. Rather, a sustainable community of contributors is required for such efforts.

On the contrary, the process for Open Scholarship activities is mostly closed - as with more traditional ways of conducting research. Exceptions do exist where the actual outputs from a research project are software or models (e.g., [Astropy](#), [NEURON](#)). Scholars can join a collective effort, produce several research artefacts, and open them up at the time of publishing (i.e., the process is closed, but the products are open) (Masuzzo and Martens 2017). Although new approaches have been proposed lately, such as post- and open-publication peer review where authors publish a "to be reviewed" version of their manuscript and its revisions (Ross-Hellauer, Deppe, and Schmidt 2017; Tennant et al. 2017), we mostly only see snapshots of research artifacts in the open, and not their full and tracked development process⁵. One example is where the process itself is more exposed, for example by using electronic laboratory notebooks (Myers et al. 1996), or registered reports (Nosek and Lakens 2014). These are still not as accessible to participation or collaboration as a typical FOSS workflow, but provide more of a window into the process of the research itself (Obels et al. 2019). Recently, the concept of a ‘Massively Open Online Paper’, or MOOP, was proposed to attempt to reflect a more FOSS-style workflow within scholarly manuscript writing (Tennant, Bielczyk, et al. 2019), presenting new collaborative opportunities for peer-to-peer learning and interactive knowledge generation in an authoring environment (Heller, The, and Bartling 2014). Such exceptions aside, Open Scholarship in its current form is more similar to proprietary software companies who decide to render their products Open Source while keeping the participation process exclusive.

For Open Scholarship it seems that intrinsic motivations might play a stronger role than extrinsic ones when it comes to participation within some communities. A survey of 300 participants (Oreg and Nov 2008) among FOSS developers and Wikipedia authors (that is, both code and knowledge contributors) revealed that software developers tend to place greater emphasis on reputation and self-development motivations, whereas knowledge contributors place greater emphasis on altruistic

⁵ One exception to this is many papers where the first author is involved, where calls for research happen openly in social media websites and the resulting papers are available from the beginning in publicly shared documents (e.g., as was the process for the present article). Such a process of collaborative authoring and editing is now simple and popular using Google Docs (or other similar applications), which was enhanced when the Open Source reference manager Zotero was integrated with it.

motives. Yet, extrinsic factors should not be underrated, in particular those related to human capital; this is especially the case as, unlike much of FOSS development, in many fields a large quantity of research is funded by the public. This presents a strong ethical case for making the outputs, at least, of research publicly accessible. Once it is empirically demonstrated that Open Scholarship activities build stronger peer networks and help build one's reputation and resume, extrinsic factors (e.g., promotion processes) might encourage otherwise less motivated scholars. The Open Access citation advantage is a powerful example of such (Norris, Oppenheim, and Rowland 2008; Swan 2010; Wagner 2016; McKiernan et al. 2016).

The extent to which intrinsic factors are more powerful than extrinsic factors remains yet to be fully illuminated for the wider case of scholarly knowledge diffusion. Scholarly communities should be aware of the social contexts surrounding knowledge transfer (Gibbons 1999; Morgan et al. 2018), and use this to create the best cultural environment and shared values possible to attract these motivations of scholars. Given some documented effects of openness such as wider readership and access (Levin 2015), boosting collaboration and transparency (Peters and Roberts 2015), democratisation of science (Brown 2016; Tennant 2018a) and promoting accountability and responsible research (Resnik 2006), ideally all stakeholders involved in the process of scholarly communication can and should be supportive of this trend, both in principle and in actions. However, that is not always the case. As outlined in the Foundations for Open Scholarship Strategy Development document (Tennant, Beamer, et al. 2019), a number of challenges and threats to this ideal still remain. This includes acknowledging the limitations of 'openness', the appearance and inclusivity of the community, and possible disincentives to sharing and open collaboration. There are also direct threats that openness brings to be mindful of; for example, potential mis-use of publicly shared genomic data to discriminate against marginalized communities. However, much of the existing research indicates that Open Scholarship is more aligned with fundamental incentives for researchers (e.g., visibility, collaborations, reputation, career advancement, grant awarding) (McKiernan et al. 2016). Therefore, there is space for additional insight into the potential motivators and barriers for the uptake of, and attitudes towards, open research practices.

Leaving the classic self-determination theory of intrinsic and extrinsic motivation aside, other studies have also shown how social identity and altruism might play a role in engaging with Open Scholarship, but also that tool support is important. An exploratory study of self-archiving practice and inhibitors among computer scientists (Graziotin 2014) found that authors often infringe the copyright transfer agreements of the publishers when self-archiving and stop self-archiving when they discover they are infringing. Lack of automation and time required were found to be the strongest factors inhibiting self-archiving of publications and sharing of datasets. This study called for

tools from the FOSS community for facilitating author-based self-archiving that take authorship rights into account; we remain unaware of any such initiatives at the present, however. Similar research has identified widespread copyright infringement of scholarly articles (Green 2017; Jamali 2017), and there are a number of ongoing legal cases in this space (Chawla 2017; Manley 2019). Together these indicate that more awareness and support are needed for researchers regarding the legality and restrictions associated with licensing and copyright of scholarly works (Gadd, Oppenheim, and Proberts 2003; Gadd and Troll Covey 2019).

Altogether, this suggests that there are complex barriers to enter an Open Scholarship mindset and to take up associated practices. Open research activities carry norms and culture that some individuals might find hard to understand even before engaging with them. This would seem to manifest itself in an apparent divergence between the attitudes towards (generally positive) and practices of Open Scholarship (Ross-Hellauer, Deppe, and Schmidt 2017; Smith et al. 2017; Zhu 2019). What emerges from this is that research cultures are not simply binary (i.e., open versus closed), nor are they confined to the realm of software or scholarship. Openness is pluralistic and context-dependent, reflecting values and principles, practices and processes, and outputs; which themselves are not discrete but form a complicated feedback loop with external and internal constraints. Although intrinsic motivation can be important, identifying with the community of practice is also key here (Eghbal 2016). Extrinsic motivators, such as money, prestige, patents, citations (i.e., 'incentives') may lead us away as a community from open research practices. However, extrinsic and intrinsic motivations are complex and interrelated. For example, Ryan and Deci suggest that both types of motivation can be traced to basic human needs for autonomy, competence and relatedness (Ryan and Deci 2000). Such tensions between motivations and practices can manifest themselves between selective communication of knowledge, an inherent willingness to share, and the strange duality of scholarly research articles often being simultaneously public and not publicly accessible (Hilgartner 2012; Levin et al. 2016).

It is incumbent on the Open Scholarship community to develop and coordinate strategies for transitioning to OA, Open Data, and FOSS in academia that encompass social and cultural issues (Tennant, Beamer, et al. 2019). We should strive for an Open Scholarship in which science as a vocation is supported, and foundational ideals around 'hacking' and 'gift-giving' are allowed to find new spaces. Communities that can affect and support such principles of Open Scholarship can be cultivated around this, while at the same time allowing those with more external motivations to be supported by revised incentive structures. Maybe a complementary lesson here is that Open Scholarship advocates should try to align communal and individual incentives, so that people who are extrinsically motivated still end up doing what remains best for everyone else.

As we saw with the FOSTER taxonomy, vocational aspects of scholarship are almost completely absent, more with a focus on communication of outputs. The taxonomy implicitly neglects the role that connectivity (i.e., cooperation and collaboration) might have to achieve greater efficiency, impact, and influence (Gunnarsson 2019). Therefore, in the future, it seems like it might be useful to think of Open Scholarship in two fundamental ways, as with FOSS. One element would focus on production and participation (e.g., collaboration through sharing), and the other based on dissemination (e.g., due to licensing constraints). This exposes two different viewpoints on what constitutes being ‘fully open’, while also embedding core values around equal and free participation, while implicitly rejecting proprietary or exclusive systems.

Integrating FOSS practices into scholarly workflows

One key assumption embedded within open source communities and hacker culture is that the best software is the best because it works, and fulfils its intended purpose. Other aspects can also include appreciation of efficiency or style of the code, as well as a sense of ‘playful cleverness’, with values extending beyond just software or scholarly communities. The fundamental elements of Open Education and FOSS seem to underpin developments in a number of modern initiatives, leading to values-based communities, open collaboration, re-use, and sharing, and cross-pollination of ideas and practices, and a truly interdisciplinary and inclusive approach to scholarship (Heller, The, and Bartling 2014; Katz, McInnes, et al. 2018; Tennant, Becker, et al. 2019). There are now a number of noteworthy examples of communities of practice coming together, and attempting to collaborate upon different aspects of Open Scholarship, irrespective of the seeming tensions with current incentives. They are leveraging rare traits within scholarship, such as open development, networked collaboration, strong, value-based frameworks, and inclusivity, as a sort of counter-culture to traditional research processes (Moshontz et al. 2018). Such developments come during a critical time when there is increasing capture and enclosure of vital components of the global scholarly infrastructure by private entities, which has further consequences on inclusive participation and epistemic diversity, particularly against researchers from the ‘global south’ (Posada and Chen 2018).

Examples of these communities include [The Carpentries](#), the [Software Sustainability Institute](#), and indeed the broader research software community (Hettrick 2016). [Open Journal Systems](#), created by the Public Knowledge Project and launched in 2001, is FOSS for the management of peer reviewed journals, and released under the GNU general license (Edgar and Willinsky 2010). As of 2010, around half of the journals it supports were based in the developing world, demonstrating the value of FOSS publishing services for increasing global participation within scholarly communication. The [Collaborative Knowledge Foundation](#) offers FOSS services that reduce costs while increasing

interoperability and flexibility in the scholarly publishing process, while avoiding vendor lock-in associated with equivalent proprietary systems (McGonagle-O'Connell and Ratan 2019). These two examples represent major attempts to reform proprietary scholarly publishing models and adopt more Web-native functionalities (Morris 2009; Peters 2010), while also helping to retain security in the future of open and community-controlled scholarly infrastructures (Bilder, Lin, and Neylon 2015; Joseph 2018).

In addition, many elements from FOSS workflows have great potential to be more widely adopted by research communities to help increase the efficiency and productivity of research, based around several key elements (Ghosh et al. 2012; Millman and Perez 2014):

1. Version controlled workflows, for tracking data collection, analysis runs, manuscript writing, peer review, and up-scaling collaboration;
2. Automated execution and continuous integration, where the code, data, and full computational environments are inherently reproducible, and proposed where possible in-browser or via peer-to-peer networks;
3. Continuous testing to detect and remove errors and bugs prior to peer review;
4. Readability with the so called 'clean-code' philosophy, where well written and documented codes are easy to access at different coding levels based on existing standards for self-documentation; and
5. Developing infrastructure capacity for tools and procedures essential to research workflows.

These benefits could help to define a successful new community development model based around sharing, collaboration, and innovation, one which is already increasingly being adopted by the software industry who, among the many advantages, see it as an economic improvement. Other communities have already taken up parts of these practices as a way to improve research and help to make it more fundamentally reproducible, particularly in computational contexts (Sandve et al. 2013). These ideas are quickly spreading between academia and coding communities; for example, many software companies today are selling their expertise more than the code or the code subscription. Users can freely access the code and verify the robustness of the latter, improve it for specific cases when necessary and make sure all elements are in place for better company performances. One of the key aspects here that underlines the community is that research is a process that continuously evolves, and is therefore not captured and defined appropriately with just discrete outputs (i.e., peer reviewed journal articles). Research projects could contain numerous components and 'releases', akin to version control and FOSS, with an emphasis on the value of the

process and documentation. This could create a tendency for projects to become more distributed, and interactive collaboration to be recognised as a fundamental and more widely-valued trait (Heller, The, and Bartling 2014).

Regardless of self-identified membership of the “Open Scholarship Community”, one could argue that performing any (or a combination of) the multitude of practices associated within Open Scholarship, contributes to its political and practical goals. Open Scholarship, as a practice, will thus greatly exceed Open Scholarship as a community. A vast proportion of researchers already contribute to FOSS, use version control systems, share data, use open notebooks, share preprints, yet elect not to identify as open scholars or open scientists. Indeed, there is no reason why they should, as they are most likely not doing these things because it gives them a sense of identity, but are doing it because it enables them to perform and share their scholarship in more efficient and effective ways.

This divergence could present problems, especially in the context of governance issues. Open Scholarship will become dominated as a community based on self-identification, rather than automatically based on research practices. Those who more readily identify as open scholars may attempt to govern people who do not, irrespective of whether they are committed to open practices. Those who do not self-identify as open scholars, yet commit to open practices, will most likely be uninterested in trying to govern those who do identify, creating a potential skew in the governance of the ‘community’. Consequently, this is also where Open Scholarship falls short of being defined as a single, organic ‘movement’, as it appears to lack common or shared values, strategic coordination, well-defined goals, and any form of governance or community structure (Tennant 2018). This issue is similar to FOSS, in that democratic values and inclusivity appear to be core, underpinning elements to Open Scholarship, but it remains unclear if these are upheld in practice, and whether these practices are inherently ‘better’ for scholarship.

Integrating FOSS principles and values into scholarly communities

So, to what extent can the principles of FOSS ‘hacker culture’ and Open Scholarship be further aligned as communities of practice? One fundamental element that FOSS, OA, and Open Scholarship all have in common is that they believe that the outputs of the wider process of organised knowledge creation, including intellectual properties that they represent, deserve to be a public, rather than proprietary, property (Willinsky 2006; Bartling and Friesike 2014). They are also based around the simple fact that existing work is there to be used (for what diverse purposes) and built upon, both as developers and/or researchers “standing on the shoulders of giants”. For Open

Scholarship, there has been relatively little explicit work into the underlying principles (with the exception of the dozens of declarations and charters aimed at OA), and especially regarding those that are universally accepted. A recent review of Open Science demonstrated that it can help to advance diversity, justice and sustainability in the psychological sciences (Grahe et al. 2019). Beyond this, OCSDNet is almost unique in this space, in that it proposes seven principles for Open and Collaborative Science as part of its [Open Science Manifesto](#). Here, it outlines the importance of representation and inclusivity within Open Science, and the importance of these in challenging the core values of more traditional forms of science. Principle 6 also states: “It incentivizes inclusive infrastructures that empower people of all abilities to make, and use accessible open-source technologies”, thereby embedding FOSS within the principles of open and collaborative science. Similarly, the Vienna Principles for scholarly communication have a strong focus on Open Science, based around 12 principles including accessibility, discoverability, and reusability (Kraker et al. 2016). Finally, the Scholarly Commons was designed to embed strong principles in the wider landscape of research communication, without an explicit focus on Open Scholarship (Bosman et al. 2017).

However, within the Free Software movement, the principles of freedom were much more deeply encoded from the outset than they appear to be for Open Scholarship or Open Science, which both appear to be more similar to Open Source in their current focus on pragmatism; with the exception of the OCSDNet and Vienna Principles. The result of this for software communities is that, by being based on essential freedoms, this helped to promote social aspects such as frictionless sharing and co-operation - factors that are increasingly important in a digital world. Often a moral basis is argued for OA around fundamental rights of access and re-use, akin to arguments made for democracy. Similarly, a parallel argument is that Open Scholarship is a more efficient or effective way of performing and communicating research than traditional forms. Whether an increasing adoption of open practices is more due to the ideological or pragmatic arguments between software and scholarly camps remains elusive. In both, familiarity with open practices might be because they are both inherently *better* practices and lead to *better* outputs, rather than being because they align with the principles and values associated with a particular movement (i.e., Free Software).

Although FOSS and Open Scholarship might have similar foundations (i.e., around ideas of free sharing and common goods), the differences in the pace of technological and cultural changes between the two mean that ‘openness’ seems to have made more impact in the software world than in research. There are a number of key differences here between software and research that might explain this distinction in uptake rates between open practices, and the translation of values and principles into practices:

1. The core issue of incentives around open research practices. The strong core principles and values of Open Scholarship practise that lead to 'better' research, and more advantages for individual recognition, is still set against what is often termed a 'publish or perish' culture in modern academia. This tension pitches the values of high quality scholarship against other systems of value such as citation-based metrics or journal brands (Alperin et al. 2018; McKiernan et al. 2019), which are often in control of proprietary vendors and directly tied to career advancement or financial recognition.
2. The consequences of FOSS can be seen almost immediately in improved software, while observed changes in research due to Open Scholarship practices manifest themselves in less tangible ways or after a longer period of time (McKiernan et al. 2016).
3. Differences in support and training for 'open' skills between the software and scholarly research environments. Much of the infrastructure and technology for scholarly communication has been outsourced to either publishers or other third-party vendors, rather than within research institutes or academies themselves. This means that hard skills required to learn how to do open scholarly communication are difficult to acquire from within academies, which makes translation of the practices from the underlying principles problematic.
4. Temporal duration; FOSS has become normative across global software communities, whereas diffusion of Open Scholarship practices appears to be more recent in many aspects and develop at a slower pace.
5. The communication within the Open Scholarship community, and how this translates to the wider scholarly community. If Open Scholarship is treated as something distinct than just 'good' scholarship (Watson 2015), then this creates a divide and tension between different camps.

A relevant question to better understand these causes is whether or not open research is equivalent to 'better' research, based on either the values, practices, or principles. Does sharing code and the coding environment, being more inclusive, making the work OA, all make research better? What if it can be reproduced, because it solves a particular problem, leads to an innovation, or makes a big jump forward in a field (Sandve et al. 2013; Fanelli 2018)? This depends on several factors. Firstly, many of these common notions of openness do not translate well beyond empirical research disciplines, and can be better considered as a 'boundary object' (Moore 2017). Critically, this depends on subjective perceptions of what is seen as 'better' or 'higher quality' research. If sharing data and software environments, detailed and rigorous analytical/methodological protocols, and other elements can be considered to increase the rigour, reproducibility, and accountability for research then it is difficult to argue against openness increasing intrinsic research quality.

Furthermore, adopting such practices allows individuals and communities to automatically adhere to the coupled principles and values of openness, and thus become included as part of the Open Scholarship community by default, irrespective of whether or not one openly identifies as such. If one considers science and research to be self-correcting, which often is assumed, then openness is necessary for others to repeat and verify, and thus, enable correcting to function at a system-wide scale (Ioannidis 2012). Open Scholarship as a process can potentially become relatively decentralised, distributed, and a peer-to-peer process of production, based on strong scientific principles and rigorous technological infrastructure; rather than a competition for spurious measures of success.

Thus, it appears there is a substantial place for refining the core values of Open Scholarship/Science, in particular around collaboration and participation; or perhaps even refining two separate ‘camps’ again based around different concepts. For example, Open Science already appears to be well understood to be more equivalent to Open Source in its pragmatic, process and output focus (Levin and Leonelli 2017; Masuzzo and Martens 2017). Similarly, on the intersections of education and technology, many elearning and ed-tech proponents also advocate for Open Source-based solutions for supporting teaching and learning at higher education institutions.⁶ The OCSNet and Vienna Principles seem to provide a strong basis from which to work on this, and to begin generating a more coherent discourse around open scholarly practices, challenging the issues with the present incentive system, and creating a fairer academic advancement system. Both the FOSS and scholarly communities are vast and heterogeneous, and there is no singular adherence to any particular set of values or organisation; and yet, the FOSS community has achieved great things. Ultimately, this foundation could be refined to be a more effective narrative based on the inherent motivators for different stakeholder groups; for example, how openness can catalyse technological innovation and economic growth (for industry and policymakers), or how openness can challenge unethical conduct while increasing the reliability of research through a more effective and collaborative creation method. In time, we would likely see such more effective communication, based around a combination of principles and practices, close the ‘apathy gap’ and resistance towards openness through appealing to a sense of common interests among stakeholder groups.

⁶ See e.g. the [IndieWeb for Education initiative](#) and associated activities, and the [Mozilla Foundation’s involvement](#) as two examples of overlapping fields of activity between research labs, scholars’ writing desks, the seminar room and/or lecture hall, and HE’s IT departments in which FOSS can play an integral role to foster Open Scholarship.

The role of commercial players

As we have discussed above, commercial players play an important role in both FOSS and Open Scholarship. In the latter, we have seen how they contribute to both our understanding and practices of openness, and maintaining the present system of evaluation and reputation. However, many of the commercial aspects of the wider scholarly communication ecosystem remain in direct conflict with any notions of openness. As a key example, traditionally many scholarly publishers operated around a subscription-based business model that has created an oligopolistic 'market' structure (Bergstrom et al. 2014; Armstrong 2015; Larivière, Haustein, and Mongeon 2015; Shu et al. 2018; Tennant and Brembs 2018), particularly based on explicitly anti-competitive practices such as non-substitutability, micro-monopolies, and non-disclosure clauses. This is clearly in violation of fundamental freedoms associated with openness, as many of these vendors actively prohibit sharing through mechanisms such as copyright and creating the illusion of artificial scarcity in order to preserve revenues. Such rights are mostly signed away by authors in exchange for publication, and for remuneration of these primary investors and value creators to be effectively nil, despite scholarly publishing being one of the most profitable industries that exists. A general lack of transparency has meant that the commercial elements of the system are able to maintain great power and control over the flows of knowledge and finances in scholarly communication (Björk 2016; Björk et al. 2018).

This tension has been one of the driving forces behind the entire modern push for Open Scholarship, with demands for a new, modern, open scholarly infrastructure (Bilder, Lin, and Neylon 2015; Joseph 2018; Okune et al. 2018; McGonagle-O'Connell and Ratan 2019). Now, there exist two major camps: the non-profit side, comprising services such as those via the Joint Roadmap for Open Science Tools ([JROST](#)); and the proprietary side, with alternatives offered by publishers such as Elsevier and Springer Nature (via Digital Science) and service providers like Clarivate Analytics. A major criticism of the latter is that the services they offer around data and analytics represent their ownership of key elements of scholarly infrastructure that create lock-ins for users and their workflows (Posada and Chen 2018; Tennant and Brembs 2018; Campfens 2019). The result of this has been that, despite the best intentions of Open Scholarship, much of the infrastructure it relies on has now been captured by commercial entities and subject to market control as a system of organised competitiveness (Odlyzko 2013; Anderson and Squires 2017). The scholarly publication process now primarily exists to reward and regulate a reputation economy (Hyland 2015; Lariviere and Sugimoto 2018), and thus poses one of the greatest single threats to modern scholarship (Brembs, Button, and Munafò 2013; Brembs 2018).

Similar to FOSS, commercial absence represents a key problem that key elements of open scholarly infrastructure do not receive adequate sustainable funding and commitment for essential projects and services (Chang, Mills, and Newhouse 2007; Chengalur-Smith, Sidorova, and Daniel 2010), something with which Open Educational Resources also struggles (Wiley 2007). Most recently, in the Open Scholarship space, this struggle has been illustrated with discussions around the sustainability of communities and arXiv-like platforms based around the Center for Open Science. Initiatives like SCOSS, while invaluable, are currently far too small-scale to support the number of projects that require longer-term financial support.

Often it is the case that many of the people engaged in FOSS and maintaining its infrastructure operate from within large commercial organisations, rather than being committed to such projects full-time. Within the wider realm of scholarship, we know that there is 'enough money within the system' to support an almost total 'flip' to a more open system, especially regarding OA (Björk and Solomon 2014; Schimmer, Geschuhn, and Vogler 2015). However, this does not appear to have manifested in a way that is disruptive, or affordable to many researchers and institutes around the world (Barić et al. 2017; Green 2017; 2019), and may now even be creating a second financial crisis, akin to the serials crisis, through hyperinflation of charges for OA and a lack of price sensitivity (Khoo 2019). Furthermore, this highlights the problem that such forms of 'closedness' are often more difficult to see because they are more about violating principles than any specific practices, with the unintended consequence that 'openness' can actually lead to new forms of enclosure (Tkacz 2012; Mirowski 2018). It might be the case that substantial intervention is now required from public administration bodies in parallel with the mobilisation and strategic coordination of research communities around these issues, seeing as this involves the transfer of billions of euros/dollars of public funds each year to commercial entities (Di Cosmo 2006; Tennant, Beamer, et al. 2019).

Systems of valuation in academia, and the role of open practices

In the preceding sections, we touched upon the issues of reward, evaluation, and assessment systems in modern research cultures. We also discussed how open research practices tend to lend themselves towards 'better' science, in that the research is more rigorous, accountable, and easier to build upon. This section will address the problem of how to make these open research practices aligned with the things that are valued (i.e., incentives) in order to make them more widely-accepted and adopted behaviours and practices. This presents a major challenge for academics (and academies) in how they can adapt and evolve into a system that is defined more by fundamentals of

Open Scholarship (e.g., re-use, sharing, and collaboration). Indeed, such strategic implications around openness are only now just beginning to be explored within some communities (e.g., AI) (Bostrom 2017), and represent major challenges in defining ‘value’ in [open] scholarly research.

What elements of scholarship are currently most-valued?

At the present, few of the things which we might use to define ‘better’ scholarship (whether ‘open’ or not) are what we seem to value in terms of how research is evaluated or rewarded (Alperin et al. 2018; Schimanski and Alperin 2018; McKiernan et al. 2019). The former concept is based around things such as sharing of knowledge, ideas, and outputs, rigorous and reproducible research, and transparency; yet, current systems of reward rarely value these things, and are instead largely based on proxies for ‘prestige’ or ‘quality’, or arbitrarily based on things that can be measured, without considering the inherent value in what those things actually measure. At present, the primary reward system for professional advancement in academia in many STEM fields seems to be focused on peer-reviewed articles published in reputable scholarly journals and conference proceedings, author position/order, and perceived value of a publication venue. Current evidence suggests that citation-based metrics, including the h-index and journal impact factor (Bornmann and Daniel 2007; Lariviere and Sugimoto 2018), drive this system of evaluation (at least in North America and parts of Europe), along with factors such as the journal rank or brand that a particular piece of research is published in. This complex system of value transfer is often generalised under concepts of ‘research impact’ or ‘excellence’ (Vessuri, Guédon, and Cetto 2014; Moore et al. 2017).

What is often mistaken in this context is that, while such journals and other measures of success or reputation might be of comparative use (simply because they can be measured), this does not actually make them a useful or objective measure of reputation or prestige itself. What we know is that these current proxy measures of research quality, credibility or legitimacy not only perform poorly, but in fact often seem to correlate better to the opposite (Brembs, Button, and Munafò 2013; Brembs 2018). Journals, as the primary vehicle of communication for scholarly research in many disciplines, play a prominent role in this, forming the basis of the reward system, the distribution of prestige among communities around journals, where the attainment of having a piece of research published in such a peer reviewed venue is deemed to be of higher value than the inherent value or role of that piece of research for society. This intersection between journals as both vehicles of communication and of prestige lies at the heart of many problems in modern scholarly research.

At present, many elements of the peer review system are routinely exploited and (curiously) poorly understood (Tennant and Ross-Hellauer 2019). Peer review is often anonymous, unrewarded, and

yet in high demand, and often in the control of commercial, third-party entities (Fyfe et al. 2017). This is further exacerbated by the fact that peer review, in its current journal-coupled implementation, is considered to be a necessity for virtually all forms of scholarship, irrespective of the diversity of processes that lead up to it, and it has been commonly criticised (Tennant et al. 2017; Ross-Hellauer 2017). Chief among all of these criticisms, are the fundamental issues that it remains virtually unknown how peer review operates as a quality control mechanism, whether it actually performs to the expectations with which it is regarded, or what actually even happens as part of the process. Some research has even shown that peer review barely changes the quality and content of research between the preprint and final published versions of articles (Klein et al. 2018; Carneiro et al. 2019); and yet, it remains almost universally highly regarded as the process which assigns most value to a piece of scholarly research.

Other knowledge generation systems, including FLOSS and Wikipedia, have more continuous 'review' systems that allow for greater differentiation of value, and on a more granular basis, than a binary state of 'peer reviewed' and 'non-peer reviewed' that continues to define research (Tennant et al. 2017). Non-peer reviewed work is often referred to as 'grey literature', and some researchers and communities explicitly state that they will not even read or use such works, and many journals forbid its citation in peer reviewed articles. This represents an unusual implication, as just because something has been 'peer reviewed' or not, does not mean that it should be treated any more or less critically as a responsible method of scholarship; especially when that review process remains concealed. Only recently has any progress been made in measuring the quality of peer review and reviewers themselves (Bianchi, Grimaldo, and Squazzoni 2019), aided by some publishers opening up their data on peer review (Bravo et al. 2019). However, given that critical information about peer review is typically kept private by publishers, it is hard to gauge reviewer and review quality, and yet curiously its use remains almost ubiquitous and held in high-regard (Callaham and Tercier 2007).

Any renewed understanding of 'impact' for Open Scholarship should encourage recognition of an increased diversity of research practices and outputs rather than those confined to peer reviewed research papers (Fecher and Friesike 2014). However, relevant and necessary changes in reward or 'incentive' structures are typically lagging behind this understanding at virtually all levels, including policy, institutional, and practical levels (Levin et al. 2016). The continued use of inappropriate metrics and proxies for value has contributed to a hypercompetitive culture widely known as 'publish or perish', and represents a vastly unscientific approach towards research evaluation. Social movements such as the [San Francisco Declaration on Research Assessment](#) (DORA), launched in 2013, have attempted to implement a new broader form of research evaluation, showing that demand for evaluation reform is increasing (Hicks et al. 2015; Ioannidis et al. 2019). Nonetheless, the

continued primary focus on journal articles as the point of most value in scholarship has relegated other essential components of research cycles, including software, materials, teaching, infrastructure, public engagement, and data, to be considered as 'second class' value objects and processes. This value distribution is now also becoming codified into policies as a new norm within Open Scholarship, where OA to research articles has undoubtedly had the biggest focus in the last 3 decades (Piwowar et al. 2018), but despite great progress has not been accompanied by concurrent changes in the evaluation system. This is peculiar as research articles could not exist without many of these other components, and yet they are consistently undervalued in terms of socio-cultural appreciation, evaluation, and recognition for funding (Alperin et al. 2018).

Alternative metrics: the alternative to what?

Present evaluation systems are dominated by metrics based on citation counts (Wagner 2016; McKiernan et al. 2019). Citation, in its rawest form, is usually an acknowledgement of an intellectual debt (Garfield 1979), and a hierarchical genealogy and network of ideas, dependent on a number of factors. Citation is an incredibly varied practice, and can represent an incredible array of different positive and negative relationships; yet, mostly because they are something that can be counted and are readily available from a number of sources, cumulative citation counts and a number of equally context-devoid metrics dominate valuation discourses and practices. Data regarding these metrics and indicators are typically maintained by commercial bibliometric databases, such as the Web of Science and Scopus, that, in turn, also contribute to setting the baseline for incentivisation.

Scholarly research is peculiar in that citations only between articles seem to have any form of currency, and not between different networks of objects, despite the principle and practice being essentially the same. For example, principles for software citation now also exist as a reflection of this (Smith, Katz, and Niemeyer 2016). Citation typically links recognition (as measured by citations) with reputation; this becomes problematic in the often dogmatic association of this reputation in one way or another to career and funding structure (i.e., success), which leads to cycles of self-reinforcement (more grants, better publications, thus more grants; i.e., the Matthew Effect) (R. K. Merton 1968; 1988). Not only is this a misuse of the purpose of citations and a failure to understand what they are conceptually, it also misappropriates them in assuming that every citation is of equal value, as in a form of economic currency (Wouters 2014; Penders 2018).

The problem with using such a simplistic metric to measure impact and reputation is that it reinforces tendencies of risk aversion, lack of data transparency and many others, thus negatively affecting the Open Scholarship environment (Haustein, Bowman, and Costas 2015; Benedictus,

Miedema, and Ferguson 2016; Wilsdon 2017; Wilsdon et al. 2017). This has led to the search for “Alternative Metrics” (popularly known as ‘altmetrics’) that can more accurately capture the diversity inherent within the wider publishing ecosystem beyond citations and peer reviewed articles (Priem et al. 2010). Examples of such metrics include mentions or shares on blogs, media reports, white papers and other indicators of a wider discussion or use of a given piece of research beyond traditional journal outlets.

Creating a new prestige economy based on open principles

If new metrics are employed and become prominent in assessing quality of research, it could potentially kick start a new set of biases within scholarly publishing. One way to circumvent this to an extent is to responsibly employ a combination of quantitative metrics and qualitative assessment (Hicks et al. 2015; Wilsdon et al. 2017), so the system becomes less dependent upon metrics; for example, similar to the Research Excellence Framework in the UK. The most important factor while choosing these metrics are the values which we want them to reflect (e.g., responsibility, trust, consistency), and how this is reflected in scholarly practice. To complicate matters further, Open Scholarship includes multiple contribution roles, such as authors, publishers, data analysers, software developers, reviewers, and editors, with a range of complex network interactions. To generate a robust framework for measuring impact and therefore reputation, different metrics and indices would be required to reflect this participant diversity (Nichols and Twidale 2017). Thus, any future appropriate valuation system has to capture the inherent diversity in dimensions between the practitioner, the practice, and the output.

As Cronin notes for the realm of Open Education, “complexity resides in determining and negotiating the value of open practice at an individual level, and structural and cultural barriers to openness persist within higher education” (Cronin 2018); but this surely also holds true for other dimensions of Open Scholarship. Thus, the question raised is how to measure reputation and impact within Open Scholarship. This critical factor has also received relatively little attention in the FOSS space (Hu, Zhao, and Cheng 2012), especially when compared to participation motivations. In FOSS, reputation is generally gathered based on one’s ability to be a good coder, and the practices that come with that in an openly participatory environment (Kelty 2001). In this way, it is similar to academia in that prestige functions as its own sort of capital, and drives an ‘economy’ based on reputation. However, a study in 2016 demonstrated that additional factors such as past reputation based on positive evaluations, social network effects, and other demographic traits were important in defining reputation within an Open Source community (Cai and Zhu 2016). Furthermore, such positive reputations tended to lead to greater success and performance as a group, thus re-emphasising the

collaborative basis for reputation building. Applying this to Open Scholarship, it seems that there is therefore a substantial amount of scope in realising it as a community-based movement focused on gift-giving (Feynman 1974), especially around the tools that allow others to create, akin to FOSS, rather than a commercially-governed system focused primarily on outputs. This would help to realign the focus of where the value lies most in research, exposed around the general process of collaborative creation, and not just purely focused on outputs.

This renewed view of reputation accrual through collaboration and sharing can also have a secondary benefit, in that issues to do with appropriate authorship and accreditation⁷ can be resolved by having explicit and tangible guidelines for contributing to research projects. This is because the concept of authorship shifts radically from being something bound to an article, to something in which attribution is fundamentally transparent and easy to resolve, as well as dynamic based on ones' contributions, irrespective of what they might be. Thus, Open Scholarship workflow could seek to find new ways of quantifying or measuring contributions as different forms of 'impact' on research, including how the wider community interacts with processes and outputs. For example, these can be simple things borrowed from FOSS, such as project stars, forks, commits, and watchers (e.g., via GitHub). Each of these help to expose value in a different way, based on how content is perceived and digested by the wider community.

This would have several effects. First, credit could be obtained and granted for more than just authorship of research papers. Second, through valuation of a greater diversity of processes and outputs, these things become more widely incentivised. Third, the alignment of wider recognition would bring the reward system in line with that of Open Scholarship, and thus 'better' research or best research practices. It ultimately would mean that research that does not follow convention can be rewarded, thus fostering diversity, freedom of exploration, and creativity (Frankenhuis and Nettle 2018b). Prestige and reputation thus would return to principles of "good" scholarship, and not be outsourced to inappropriate and proprietary measures. Elements of such a system can already be seen in a range of digital platforms that leverage the power of networked communities to gain a deeper understanding of people and processes (Tennant 2018b). The bottom line is that the right measures of reputation across all levels of Open Scholarship could incentivize the right motivation. For this to happen, a broad exploration of altmetrics must ensue to ensure a substantial shift in how impact and reputations are measured.

However, this focus on incentives, and in particular metrics, as a mechanism for cultural change towards openness could also have dangerous and unintended consequences. While there is little

⁷ [CRedit](#) - CASRAI.

doubt that rewards should be provided for more diverse forms of process and sharing beyond published articles, there is a risk that such evaluation procedures, and an increasing focus on 'alternative metrics', could lead to greater monitoring of researchers (and thus less freedom, innovation, and creativity), while still suffering from the same bureaucratic misuse as the impact factor does (Kansa 2014). One thing that OA, and Open Scholarship, has failed to do is to fully understand the significance and impact of such an entrenched paradigm that couples reputation, evaluation, and funding systems together, and how to alleviate or reform this. Goodhart's Law is commonly paraphrased as "When a measure becomes a target, it ceases to be a good measure." Through this, there is a further danger that some measures of openness can become used primarily as signalling mechanisms.

If the focus remains on individual researchers adopting the principles and practices of Open Scholarship, the present evaluation system exerts a conservative pressure, invoking resistance to change. This is distinct from many parts of FOSS, where individuals could more easily form communities to help to fix elements of the system and solve problems, without explicit needs for substantial infrastructural or institutional support; indeed, there are many organisations that already provide financial support for individuals to create, contribute, and maintain FOSS. This creates a duality in which FOSS communities involve both individuals as part of their jobs, alongside groups of extrinsic contributors. Engagement with FOSS projects can be monitored and evaluated (e.g., through GitHub activity), which provides portfolio material for acknowledgement and credit as incentives for career progression. In this way, engagement with FOSS is built into the community through existing reward systems. Software development is more dynamic and independent of the institutional layer that the research community is rooted in.⁸

By comparison, Open Scholarship still remains largely constrained by institutional forces that control academia (e.g., the reputation economy). Virtually every relevant paper or report in the last two or three decades on the future of scholarly communication has criticised the current academic reward system. Recent research in North America is beginning to shed some crucial light into the extent of this (McKiernan et al. 2019), and provides the basis for strategic moves to evaluation reform - a requirement for a reflexive and transformative move towards Open Scholarship. Transferring credit, credibility, and legitimacy within conservative networks from one infrastructure to another is incredibly difficult, and compounded in this case by the coupling of the evaluation system with the reward system. Initiatives such as the [Transparency and Openness Promotion \(TOP\) Guidelines](#) are promising in this space, by ranking/scoring journals according to different 'openness' criteria, and

⁸ When FOSS is embedded in institutional structures, these structures do not exhibit the same conservative pressure as academic equivalents, i.e. software developers can be requested to specifically produce open source software and can build reputation precisely for that openness.

thus incentivising journals to adopt increasingly open criteria. For example, journals and publishers are scored positively for enabling data citation and transparency, having transparent code and materials, adopting open science badges and registered reports, and encouraging replications.

Reproducibility and data sharing

This final section will look at the intersections between data sharing, FOSS, and issues around research reproducibility. What exactly constitutes replication, reproduction, replicability, or reproducibility, is often not very clear. This terminology is extremely complex, since many competing definitions are often used simultaneously. Here, we consider reproducibility to describe any measure that is taken to increase the verification of research results, which usually involves data sharing and thus falls under the banner of ‘Open Science’ (Baker 2016; Munafò et al. 2017; Wallach et al. 2018). Reproducibility is perhaps one of the strongest pragmatic aspects that unites FOSS with Open Scholarship, being inherent to the efficiency and reliability of research (Sandve et al. 2013; Munafò et al. 2017; ter Riet, Storosum, and Zwinderman 2019).

Research that lacks openness to facilitate reproducibility can be compared to only making compiled source code available, where reverse engineering is one of the ways needed to reproduce software (at the mercy of the methods section). Open Scholarship is more equivalent to sharing the source code itself, allowing for immediate reproduction. This raises a key question over whether or not research can really be called “scientific” if it cannot be reproduced, computationally or otherwise. This is not equivalent to saying that research is ‘wrong’, just that it is unverified. In scholarly research, peer review is usually taken to signal verifiability, but in most cases does not actually indicate this as the process is concealed, and often focused on reviewing text rather than data and code. In software environments, computational reproducibility is now becoming more frequently considered throughout all stages of the research development pipeline, when executed efficiently; for example, with strong community management, good documentation, and using container technologies (Boettiger et al. 2015). FOSS can help to facilitate transparency and reproducibility of experiments within a specific environment, as the entire process is exposed and ‘forkable’.

In the last decade in Europe much attention has been given to construction of research infrastructures (RIs) and e-infrastructures, initiatives where research communities can identify a governance body to plan policies, best practices, and digital services to be adopted by scientists to improve scientific workflows. Many researchers now perform their work in these “digital laboratories” (e.g., tools, services, standards, models), that are dependent on shared digital services for experimentation (e.g., virtual research environments, RIs, thematic services, workflow engines).

They use these to perform experiments that lead to the creation of new digital objects such as research data (e.g., time series, sensor data, maps) and research software (e.g. R scripts, executable workflows, scripts). RIs can support reproducibility and openness of research results. Computer scientists make use of digital resources to perform their experiments, ranging from their laptops, to the Internet itself, cloud resources, and shared on-line services or software as a service solutions. These practices generate increasingly more data, a critical factor of scholarly research, yet not so much in pure software. RIs (and advanced virtual research environments) are devised exactly to enable a common (possibly online) environment where software can be executed in a shared, agreed on, trusted (certified?), platform (with again different degrees of complexity: plugged-in, embedded, web services, dynamic deployment, etc.). RIs take on board the cost of keeping a "common ground" of execution for scientists of a community with other benefits: economy of scale, big data close to processing facilities, encouraging common practices in software development, mitigating the obsolescence effect of software.

Here, software is the scientific product and runs in shared digital laboratories that are common to researchers. However, while FOSS might lead to better software and more efficient research, it alone does not necessarily lead directly to reproducible research. In other words, software alone is insufficient for reproducibility, but sharing software without the associated computational environment is a minimal requirement for reproducible research. Reproducibility is also affected by factors such as operating systems, inputs, parameter ranges and data availability, and experimental testing environments (Sandve et al. 2013; Millman and Perez 2014). For example, some widely-used R packages work differently in different versions of R. While FOSS, such as R or JASP, is not sufficient for open research and reproducibility, it certainly does promote these features. JASP, for example, provides users with the option to import/export and sync data with an Open Science Framework (OSF) account; an option that, at a minimum, facilitates and implicitly encourages such virtues and practices. Commercial alternatives like SPSS are more about the enclosure of services and communities. Within the scholarly ecosystem, reproducibility is focused on how the software is being used rather than being an intrinsic property of the software itself. Thus, reproducibility manifests in several different forms within the software-scholarship ecosystem.

Alongside FOSS, Open Data is now becoming an increasingly important and core aspect of Open Scholarship. This refers to the sharing of data, permitting others to analyse and reach the same conclusions for a piece of research - thus allowing research reproducibility - or to enable cumulative science by making data available; for example, for meta-analyses, and providing opportunities for new and originally unintended research. With this in mind, the fundamental elements underpinning research reproducibility are complete within an Open Scholarship system - articles, data, software,

and all relevant research environment data are exposed and executable to help increase fundamental reproducibility.

The major tension here is that what is often considered to be best for research is mis-aligned with what is considered to be best for individuals or communities, as measured through evaluation criteria. Data sharing policies for journals and funders can be complex and difficult to enforce (Sholler et al. 2019). In the field of Industrial Ecology, for example, one recent paper stated “[editors of journals]...should consider asking authors for a major revision of manuscripts whose claims are not reproducible because of lack of documentation, data, or software. This would encourage authors to document their scientific claims with higher transparency and reproducibility.” (Pauliuk et al. 2015). However, this focuses only on one element of reproducibility (i.e., results), and there are other concerns such as analytical, computational, and methodological reproducibility that should be considered. All of these are complex concepts in themselves, both philosophically and in terms of practical implementation, and they add additional dimensions or barriers to the adoption of ‘open research practices’. For researchers then, it makes sense to consider these aspects prior to initiating a research project itself, rather than post hoc. This is, of course, bearing in mind the limitations associated with personal data or commercially sensitive data, such as those generated when collaboration between academia and industry is involved. These categories of data cannot be made open or public by default (unless anonymised or embargo periods have passed). Data sharing can in some cases be seen as a burden for researchers, who may be unprepared for the challenge of creating, treating and sharing data for external consumption rather than private use. Many funders and institutes now require research projects to have a data management plan, and these could be easily extended to a more holistic ‘reproducibility plan’, that outlines how the data, software, articles, and all other relevant methods and outputs will be documented and shared to increase reproducibility and potential for re-use.

As part of the Open Data movement, the increase in the implementation and promotion of the FAIR principles (Findable, Accessible, Interoperable and Reusable) (Wilkinson et al. 2016) has stimulated the sharing of data that is more suitable for reuse. FAIR data is different to Open Data, as according to the FAIR principles it is not simply enough to share only the data itself, but that metadata should be included too; about, for example, how interviews were conducted, laboratory set-ups and experimental conditions, as well as which configurations and software versions were used. Only when this metadata is included will the data be actually functionally reusable. It should be noted that the FAIR principles should not be equated with Open Data, as “Accessible” means that there should be metadata available about a dataset, while the data itself could remain behind a barrier.

These FAIR principles stimulate sharing data/software using digital repositories. A range of generalist or discipline-specific data (or 'object') sharing platforms or repositories now exists, including Figshare, GitHub, Zenodo, the Open Science Framework (OSF), 4TU.ResearchData, and Dryad; although of these examples, only the latter four are built on FOSS. Often, the value of these services is focused around 3 categories:

1. Opening data increases trust, verifiability, re-use value, fraud detection, and reproducibility of research (Munafò et al. 2017);
2. Opening data tends to lead to more citations (Piwowar, Day, and Fridsma 2007; Piwowar and Vision 2013);
3. Opening data can lead to increased innovation and economic growth (Zuiderwijk et al. 2014; Moedas 2015).

The above highlights that open data, similar to FOSS, enables repurposing, refinement, and re-use by others, potentially far beyond the originally intended purposes. Extending beyond reproducibility, this openness enables the creation of value both in academia and outside; for example, in industry.

Similar to what has happened for OA, there is now a growing concern that Open Data too is being 'hijacked' by commercial organisations, who increasingly offer a range of research data services including repositories and management plans for researchers or research institutes as part of service packages (Posada and Chen 2018). This is part of a growing trend within the publishing sector, towards recognition of the commercial value behind such data. As such, this presents a new challenge for the public sector in that solutions and infrastructure around data sharing and storage might need to become more widely supported by non-commercial entities, including government-backed institutes. Therefore, these issues around data sharing also factor into core principles around reproducible research, research funding, as well as the incentive/reward system that governs how research is produced and communicated.

Computational reproducibility is not necessarily something simple to learn. One thing which is generally agreed upon is that computers and software are foundational to many aspects of modern research. Yet, despite this, computational reproducibility does not appear to receive due attention or credit in the training of researchers, or in the process of daily research. For undergraduate research teachings, where computational reproducibility is compromised in comparison to other software; for example, SPSS is seemingly often preferred to R, where code and environments can be more easily reproduced. Therefore, the uptake of code sharing seems to be slower in reaching some research fields. Generally, computational reproducibility and reliability are not considered perhaps as much as

they should be, given the impact that they can have on comprehensibility and reliability of research results. The same can perhaps also be said often for data processing and management, with both data and software often being relegated to ‘second class citizens’ with little documentation, organisation, testing, version control. However, there are now many good examples of academic projects that try to improve this by promoting community standards, code review, and software such as Bioconductor and rOpenSci (Boettiger et al. 2015; Forero 2019).

A question that arises from this is whether FOSS and Open Data are prerequisites for reproducibility and Open Scholarship. This opens up additional issues by exposing research processes, for example allowing auditing of the methodologies, allowing attempts at reproducibility as part of the peer review process, and opening up participation in research processes to those beyond those with access to proprietary data/software (thus tending towards ‘citizen science’). It also motivates or encourages different forms of ‘talent’ within scholarship, something which can only be exposed through transparency and inspection of the entire research process. Such transparency, in theory, also facilitates more productive criticism, evaluation, and diversity in forms of peer review. As such, this element of Open Scholarship has many parallels to the latter development of the FOSS movement (David 2008; Vermeir and Margócsy 2012; Lahti et al. 2017).

Limitations and future research

In this article, we have highlighted the substantive cross-over between Free and Open Source Software and Open Scholarship, in the contexts of common understanding, communities of practice, underlying principles, issues around reputation and incentives, reproducible research, and the role of commercial players. Given the enormous complexity surrounding both software and research, this is a non-exhaustive analysis. Likewise, we also did not consider additional overlaps with wider ‘open culture’, such as the dynamic histories behind Open Education and Open Educational Resources, Open Governments, Open Policy, Open Pharmaceuticals, among others. This explicit limitation in scope allowed us to focus on critical issues that remain pervasive within modern software and research cultures.

By comparing FOSS and modern scholarship, we have exposed the enormous potential for greater integration of the shared underlying principles and practices, based fundamentally around collaboration, to become more normative within scholarly cultures. However, we recognise that both in FOSS and Open Scholarship, code, data and other outputs are not value-free. Algorithms, programmes and more, allow interventions in public life. The values inherent in openness need to be carefully balanced with other values (e.g., human rights, conservation, population health). One of the

central lessons Open Scholarship can learn from FOSS in this regard is that there is a need for a critical study of the ethics of openness.

To bring the benefits of FOSS and Open Scholarship synergies to life and make them work for the global scientific community, it is necessary to actively source input from all world regions. In a western-centric/dominant academic ecosystem, so far the most under-represented stakeholders amongst the research community seem to come from Latin America, Africa and parts of Asia. Much progress is being made these days on embracing ICT on all societal levels testing innovative approaches and therefore much can be learned from those experiences in order to design an FOSS-based open scholarly infrastructure. In principle, this involves embedding viewpoint and demographic heterogeneity within the core of the future of Open Scholarship.

Based around this, future research could look into the personality traits, attitudes, and intrinsic and extrinsic motivators that seem to drive the Open Scholarship community, and look at the factors that catalyse participation in the practices. A potential arena of consideration here would be comparison of scholarly communities with that of Wikipedia. The latter is undoubtedly a highly successful project and one of the most visited domains in the world, and yet Open Scholarship is in relative infancy. A further technology that could possibly capture most of the necessary values in research cycles and Open scholarship environments is Blockchain. Given its decentralized and transparent nature and appending of attributes such as immutability and provability to digital goods that circulate within it, it is a potential candidate for future academic systems. Blockchain technology can also work with consensus mechanisms to democratize how pieces of research are validated, how scientific reputation is measured and through research tokens, and potentially incentivize more credible knowledge creation (Leible et al. 2019). Several studies over the years have attempted to understand what motivates individuals to contribute to FOSS. To our knowledge, the body of knowledge on the motivation for performing Open Scholarship activities is lacking. If we assume a similarity between the two phenomena, we can draw some parallels from the former to understand the latter. By comparing Open Scholarship communities to FOSS, Wikipedia, Blockchain, and other large and decentralised communities, some of the dissonance between participation and incentive systems in research might be exposed.

A further critical question to examine at what point during the scholarly process should it become 'open', to what extent, and to benefit whom. At the present, much of scholarship ultimately ends up being public at some stage, but only in the sense of not being secretive (Kelty 2001); however, from this it often ends up being privatised or obfuscated in ways that are not beneficial to wider society. There is also likely an enormous 'file drawer' problem with many aspects of historical scholarship, and little in the way of understanding the scope of this at the present, or how to potentially resolve

it. This is related to the wider issue of who scholarship is supposed to serve. If it is for the wider benefit of society, so that the maximum number of people can exploit and use it, then it has to be as rigorous and reliable as possible (Merton 1942). It clearly does also not meet this need if scholarly works are owned by private entities that actively prohibit its sharing and re-use. Thus, there is a direct tension here between Open Scholarship and organisations that maliciously violate fundamental freedoms underpinning this. However, without a solid principles-based foundation to Open Scholarship, and one that is widely accepted and enforced, then such violations will continue unchecked.

Conclusions

Open Scholarship might seem like a relatively new research term and paradigm, but it has deep historical roots in the very foundations of scholarship. Openness in one form or another has been part of the scientific ideal for centuries now. However, in the present way it is being discussed and often implemented, it could paradoxically lead to a more enclosed, monopolistic scholarly system dominated by 'siloes'. It seems that Open Scholarship, if based more on morality around freedom, would align itself more closely with Mertonian norms (Bowman and Keene 2018). In this way, Open Scholarship parallels FOSS in that it challenges proprietary systems as well as exclusive methods of scholarly knowledge production. However, two key distinctions exist between FOSS and Open Scholarship. The first is the inherent diversity and fragmented nature of the wider scholarly community, which makes any sort of monistic understanding of 'openness' difficult. The second is that the principles, values and respective 'freedoms' for Open Scholarship do not seem to have been as rigorously identified and implemented as in software communities. It is likely that the intersection between these two factors, combined with an overlaid homogenised system of research evaluation, is likely responsible for the relative slow growth of the Open Scholarship movement, which in turn has allowed the unintended capture of many elements of the space by proprietary entities.

If we consider Open Source to be more about processes and methodologies, and Free Software more of a community-driven ideological movement (with some overlap), which of these best describes Open Scholarship? It seems that at its roots, Open Scholarship is a combination of both. Often it is described as a more efficient, effective way of doing research, injecting more transparency and rigour/reproducibility into the process. Other times, it is described as an issue of equity and social justice. However, at least part of this divergence or ambiguity is due to the fact that Open Scholarship seems to encompass a diverse myriad of practices, outputs, and principles, which have not been connected together into a single, unified and unambiguous understanding. Thus, it appears

that there is also no clear cut boundary - either in terms of principles/values, practices, or outputs - between 'open' scholarship and 'closed' scholarship.

We can finalise this article by using two salient examples of how openness has failed to become normative in scholarly research. The first of these is the existence of the 'pirate' platform Sci-Hub, which provides illicit access to some 70 million paywalled research articles. Whether or not anyone agrees to the existence of this platform morally or legally is moot, given that it does exist, and exists purely for the reason that there is a fundamental access problem in scholarly research. The second example is the Wuhan Coronavirus, which became a global health emergency in the first months of 2020. The outbreak of this virus catalysed the rapid data sharing and publication of results by researchers around the world, essentially deploying what are considered 'open research practices' in order to combat the threat of the virus. This event shows that the tools and infrastructures for Open Scholarship now readily exist, as do the moral and practical reasons for using such services, and it is simply the imperative of researchers to actually commit to them (Kupferschmidt 2020).

The solution: A fully-open mandate

For the first few years of its existence, the Internet had the potential to form the technical and institutional basis for a new system of 'openness' in science. We believe that it has failed to achieve this for several reasons:

1. Evaluation metrics have not sufficiently changed from the pre-Internet world, and reputation and success are conflated;
2. Abuse of copyright (i.e., used counter to its initial intentions);
3. 'Closed' scientific practices, from the pre-Internet world, have been institutionalised.

Much of this can be ascribed to the increasing commercialisation of science, which often seems to stand in contrast to the agenda of science itself. Most metrics used are for short-term evaluations, whereas openness in science only offers a better diffusion and quality of science in the long-term.

We believe that the pragmatic way to reverse this problem is the formulation of new national and supra-national mandates, which could be based around the Foundations for Open Scholarship Strategy Development (Tennant, Beamer, et al. 2019). Governments and funding bodies should provide modern, sustainable and technically interoperable infrastructures based around existing established repositories, and all their associated functionalities (e.g., persistent identifiers, standardised metadata, research data repositories, usage metrics), with immediate, unrestricted,

and full access to all research outputs.⁹ If implemented, this would simultaneously solve the major outstanding issues with reliability, affordability, and functionality that global scholarship systems face and are in urgent need of fixing. We know that there is ‘enough money in the system’, currently being largely wasted on redundant services for commercial publishers, that would more than adequately finance this shift. The benefits of doing so would be immense, increasing the globalisation capacity of research, new services and infrastructures to be built on top of a huge knowledge database in order to, for example, help serve the UN Sustainable Development Goals. We also know that such services readily exist, as exemplified by case studies like the Coronavirus. This mandate would help publicly-funded research to speed up with respect to the relatively faster industry cycles, boost innovation and development in research, and enhance university-industry partnerships. Ownership and the value of research would be retained by the institutes that funded and created it, and dissemination and evaluation would no longer have to be out-sourced to commercial third-parties. The problems of ‘predatory journals’ would be diminished overnight as a side-effect, as there would be no incentives to publish with commercial third-parties anymore. Commercial vendors would then actually have to compete fairly by providing real value-added services beyond the red herring of ‘prestige’.

To achieve this system, governments would need to simultaneously defund or depower the existing systems, including the highly profitable elements that exist within it, while constructing the new sustainable open scholarly infrastructures. But by having national funders working more closely with institutes (and research libraries), this would overcome the labour-intensive methods of mandating researchers to be more open, by more efficiently providing them with the tools and services to automatically do so. Critical infrastructure components including AmeliCA, OPERAS, SciELO, COAR and others are already running on limited finances and are highly effective. As another side effect of this mandate, it would prevent openness in scholarship from only being superficially addressed, or even corrupted by proprietary systems.

The capture of key elements of the open scholarship system by commercial players is not because they add any inherent value to the scholarship process, it is simply because they have the financial capacity to acquire such services. This amplifies the ‘prestige’ or ‘validation’ that these companies often distribute through their products in the eyes of public and academic institutes, while simultaneously alleviating the responsibility of public institutes and funders to fulfil the mandates given to them. Such ongoing privatisation of the research process is clearly not in the spirit of science and scholarship as fundamental to creation of learning and development of a commons around

⁹ For a supranational open framework, see e.g. the European Open Science Cloud, <http://doi.org/10.5281/zenodo.3610132>

knowledge. Finally, by adopting a more commons approach to knowledge generation similar to FOSS, we expect that scholarship becomes an inherently more inclusive process, with equitable access and participation embedded in it as a core and fundamental value. Will the *glass house* of Open Scholarship be to *ivory towers* what the bazaar was to the cathedral in Open Source?

Author contributions

JPT conceived of the idea for the project, which was collaboratively written as a MOOP. All co-authors provided text, edits, ideas, and discussion for this paper, which was written in the open and collaboratively using Google Docs. It received hundreds of contributions as part of an iterative and organic procedure.

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Disclaimer

Most of the authors of this manuscript grew up in a western context and are therefore potentially biased towards particular understandings of systems. Any additional information that helps us to fill any gaps in this manuscript are highly welcomed.

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