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Openness, Web 2.0 Technology, and Open Science

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ABSTRACT This article begins by examining the dimensions of open science including the ethics of science and the peer review system before defining open science in terms of 'wiki science' or 'science 2.0'. The article then briefly scrutinizes the future of open science, commenting upon the nature of open distributed knowledge systems and new models of production and innovation based on peer-to-peer systems.

Introduction

Open science is a term that is being used in the literature to designate a form of science based on open source models or that utilizes principles of open access, open archiving and open publishing to promote scientific communication. Open science increasingly also refers to open governance and more democratized engagement and control of science by scientists and other users and stakeholders. Sometimes other terms are used to refer to the same or similar conceptions of science, such as 'wiki science' or 'science 2.0', that focus on 'technologies of openness' that promote not only more effective forms of scientific communication but also increasingly the deep sharing of large databases ('linked data' [1] and 'cloud computing' [2]). In this brief presentation, first I touch on the related dimensions of openness in science, focusing on epistemology, ethics, review, economics and governance of open science, before attempting a definition, and finally I address the question of the future of open science.

Dimensions of Open Science

Science is traditionally regarded as an open endeavor. The P2P Foundation's discussion of open science begins by recognizing that not only is science traditionally an open enterprise but that the Internet potentially increases and extends the openness in new ways:

> Openness is arguably the great strength of the scientific method. At its core is the principle that claims and the data that support them are placed before the community for examination and critique. Through open examination and critical analysis models can be refined, improved, or rejected. Conflicting data can be compared and the underlying experiments and methodology investigated to identify which, if any, is more reliable. While individuals may not always adhere to the highest standards, the community mechanisms of review, criticism, and integration have proved effective in developing coherent and useful models of the physical world around us. As Lee Smolin of the Perimeter Institute for Theoretical Physics recently put it, 'we argue in good faith from shared evidence to shared conclusions'. (http://p2pfoundation.net/Openness_in_Science)

Openness is also an essential aspect of the ethics of science. Scientists by virtue of their professional status and membership of scientific communities are bound by expectations to openly share their work and to make public their methods and procedures as much as the data or results. Perhaps most importantly, scientists should be open to criticism and participate in the review of scientific

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work. David Resnik in *The Ethics of Science* emphasizes this aspect when he writes: 'Science's peer review depends on openness. Openness prevents science from becoming dogmatic, uncritical and biased' (Resnik, 1998, p. 58).

The virtue of open science in so far as it draws on commons-based peer production is increasingly seen as a mode or system of production structured by large-scale collaboration, driven by motives other than profit. In this regard, Benkler & Nissenbaum (2006, p. 394) write:

> Commons-based peer production is a socio-economic system of production that is emerging in the digitally networked environment. Facilitated by the technical infrastructure of the Internet, the hallmark of this socio-technical system is collaboration among large groups of individuals, sometimes in the order of tens or even hundreds of thousands, who cooperate effectively to provide information, knowledge or cultural goods without relying on either market pricing or managerial hierarchies to coordinate their common enterprise. While there are many practical reasons to try to understand a novel system of production that has produced some of the finest software, the fastest supercomputer and some of the best web-based directories and news sites, here we focus on the ethical, rather than the functional dimension. What does it mean in ethical terms that many individuals can find themselves cooperating productively with strangers and acquaintances on a scope never before seen?

Yet the system of peer review, while the core practice of science, is also open to abuse, and there are many scholars questioning its purpose: 'Is it a filter, a distribution system, or a quality-control process?' (Wagner, 2006). Peer review evolved from a set of practices in the eighteenth century, especially in medicine. It was not associated with the first issues of the *Philosophical Transactions of the Royal Society*, one of the first journals, established in 1665, although peer review has a history in early Arabic scientific studies of medicine where physicians were required to take duplicate patient notes. It is really only in the twentieth century that peer review, as the process of subjecting scholarly work to the scrutiny of one's peers, has become the institutional cornerstone of the scientific system and its ethical basis, even though the process itself has come in for increasing criticism. Expert and anonymous peer review has been open to allegations of bias and suppression, and has been criticized for its slowness, which has led some to advocate for dynamic and open peer review and open peer commentary.[3]

Horace Judson (1994) argues that in conjunction with transition from exponential growth of the sciences to a steady state, and the appearance and development of electronic publishing and electronic collaboration, we are witnessing the structural transformation of science based on 'declining standards and the growing, built-in tendency toward corruption of the peer-review and refereeing processes'. He also acknowledges that the peer review and refereeing systems that have evolved are 'social constructs of recent date'. Open peer review indicates that the nature of electronic media of scientific communication may also offer some extension of the peer review system. The first journals employing these more open systems began to appear in the 2000s. While peer review is taken as the principal mechanism that enshrines the value of community self-evaluation ('criticism' in the Kantian sense) and offers the means for 'quality improvement' (in today's language) that constitutes the essential openness of scientific communities, the ideal and process is not immune to change, criticism and revision. In some ways the development of the peer review system echoes the history of science and the movement from the 'small science' era of Boyle's 'invisible college' of the seventeenth century, to the professionalization of science in the eighteenth century, through to its disciplinary formations in the nineteenth century, the scientific nationalism of the twentieth century, concluding with the 'big science' of the late twentieth century (Wagner, 2007). Today we face another major historical periodization or transition, with the rise of global and open science (Peters, 2006) that involves the possible end of science superpowers (Hollingsworth et al, 2008) and the beginning of a more articulated open system based on open source models of intellectual property and large-scale international collaboration.

Increasingly, international scientific organizations stress open science as an efficient means of addressing scientific problems of global significance that spill across borders. Thus, Paul A. David (2003), writing on 'The Economic Logic of "Open Science"', indicates:

> 'Open science' institutions provide an alternative to the intellectual property approach to dealing with difficult problems in the allocation of resources for the production and

> distribution of information. As a mode of generating reliable knowledge, 'open science' depends upon a specific nonmarket reward system to solve a number of resource allocation problems that have their origins in the particular characteristics of information as an economic good ... [While 'the collegiate reputational reward system' creates conflicts over cooperation] open science is properly regarded as uniquely well suited to the goal of maximizing the rate of growth of the stock of reliable knowledge.

Five major forces are structuring the emergent science system in the twenty-first century, all pointing toward a new openness for science built upon the complexity and dynamism of open systems communications and 'deep sharing': networks, emergence, circulation, stickiness (place), and distribution (virtual) (Wagner, 2007). The emergence of global and 'open science' has been matched by calls for the global governance of science from European science agencies. For instance, the report of the Expert Group on Global Governance of Science (European Commission, 2009) to the Science for the European Commission notes:

> The call for open access and for greater openness in research has been led by scientists and scientific organisations, but has also met with institutions and systems of science that act to resist change. Debates about openness in scientific research and science communication illuminate broader concerns about science's place in society and its own responsibilities in rethinking its practice and culture.

Janez Potocnic, European Commissioner for Science & Research, in the foreword to *Open Access – opportunities and challenges* (Potocnic, 2008) published jointly by the European Commission and UNESCO, suggests the new set of relationships between open science and intellectual property:

> We live in a digital age that has opened up unprecedented opportunities for the dissemination of scientific knowledge. Sharing this knowledge efficiently is crucial for the future of Europe ... I strongly believe that we must work towards solutions that offer the research community rapid and wide dissemination of results. At the same time, I am convinced that there must be fair remuneration for scientific publishers who invest in tools and mechanisms to organise the flow of information and the peer review system.

One of the most pressing questions that confronts global science and questions of its governance is 'Toll Access or Open Access?' Richard Sietmann (2008), in 'Quo Vadis, Knowledge Society?', a contribution to the Commission's handbook, puts it this way:

> Should scientific and technical information obtained with taxpayers' money in public institutions or on the basis of publicly funded projects be a free commodity? Or is it 'a commodity, which, as an information product or service, is traded and sold, and in other words has a market'?

Defining Open Science

There have been many attempts to define 'open science', sometimes referred to as 'Science 2.0' or 'wiki science'. OpenWetWare wiki defines Science 2.0 in the following terms:

> The internet is undergoing a major change – from an original environment in which individuals post static information to a new environment where anyone can dynamically and collaboratively create, edit, and disseminate content.

The emergence of Science 2.0 or Open science has been noted by M. Mitchell Waldrop (2008), writing for the *Scientific American*, in 'Science 2.0 – is open access science the future?', where he makes the following points:

- Science 2.0 generally refers to new practices of scientists who post raw experimental results, nascent theories, claims of discovery and draft papers on the Web for others to see and comment on.
- Proponents say these 'open access' practices make scientific progress more collaborative and therefore more productive.
- Critics say scientists who put preliminary findings online risk having others copy or exploit the work to gain credit or even patents.

- Despite pros and cons, Science 2.0 sites are beginning to proliferate; one notable example is the OpenWetWare project started by biological engineers at the Massachusetts Institute of Technology.

As these new web 2.0 technologies develop, science can use and modify these new tools directly, as in, for example, the way biological research has developed with OpenWetWare, that is a wiki where researchers share expertise, information and ideas in biological science and engineering. Science 2.0 is based on the expectation that these new technologies will change how scientists communicate their work and the way in which research is done. Web 2.0 in relation to open access publishing promotes live publishing, removes price barriers to communication, improves collaboration between authors, researchers, readers and publishers, and promotes a paradigm change in approach and openness (Nikam & Babu, 2009).[4]

Recently, the Organizing Committee of the International Symposium on Science 2.0 and Expansion of Science (S2ES 2010), in its call for papers, prefaces its remarks in the following way:

> The term Science 2.0 has been used with different but related meanings. It is usually related to Web 2.0-enabled scientific activities, specifically Web 2.0 [Shneiderman, 2008], but it has also been related to the expansion of science by means of new concepts and theories (Second Order Cybernetics [Umpleby, 1991, 2006, 2009], and the Systems Approach), or new modes of producing knowledge. (Gibbons et al, 1994)[5]

This presentation emerges from some thinking about the nature of openness as a philosophical concept (Peters, 2009d) that I develop in a book called *The Virtues of Openness*, co-authored with Peter Roberts (2010). In terms of my current thinking, philosophy of open science rests on five interrelated propositions. I state them baldly here without justification or argument. They are, if you will, 'observations' or working hypotheses to be confirmed (or falsified). Each of these propositions has a complex and contested history in philosophy and science. The aim here is to scope the philosophy of open science rather than to defend these seven propositions:

1. Openness to 'experience' – this might be given a Baconian, inductive and empiricist reading with an accent on the pragmatics of the experiment (Peltonen, 1996).
2. Openness to criticism – an extension and naturalization of the Kantian account of Reason given in the first critique which provided the tools for rational self-critique.
3. Openness to interpretation – historically connected to self-expression, freedom of expression, rights to free speech and the other academic freedoms on which the university is built.
4. Openness to the Other – an ethical stance that in the present technopolitical era can be construed in terms of institutionalized peer production, free sharing of knowledge and collaboration to create the intellectual commons.
5. Open science communications technologies – this historically contingent feature, itself an episode in the history of modern science, refers to the development of open source and open access models of science based on the logic of distributed knowledge systems and an ethic of sharing, peer review, cooperation and collaboration.
6. Openness=freedom – this specifically links to items 3 and 5 above, and relates to use, reuse and modification of data and information, as the basis for creativity (the Creative Commons argument) and innovation.
7. Open science governance – I would like to give this feature a radical Republican interpretation (after Polanyi's [1962] 'the republic of science') based on peer review extended to all levels of the professoriate and also to users, including the public.

I cannot begin to substantiate these propositions in such a brief presentation. I have commented on various aspects of this 'philosophy' in a number of related papers (Peters & Besley, 2006; Peters, 2008, 2009a, b, c), but let me make some preliminary observations. Openness to experience can be read as a form of pragmatism (radical empiricism) both as a critical method and a theory of truth as expressed in the works of James, Pierce and Dewey and encapsulated in the belief that experience is always ongoing, open-ended, and unfinished. In *The Critique of Pure Reason* (1781), Kant is concerned to restrain, discipline and prevent pure reason from going beyond the limits of possible sensory experience (see also Settle et al, 1967). Openness to interpretation is one of the key distinguishing features of phenomenological inquiry and hermeneutics (and the hermeneutical reduction) that aims to reflect on one's own pre-understandings, frameworks, and biases as a starting point for investigation. I have chosen to give the proposition in 3 above a particular interpretation that conforms to the P2P (peer-to-peer) definition.[6] Equally, I could easily give a Levinasian ethical interpretation based on the primacy of the face-to-face relation or a Gadamerian interpretation. Hans-Georg Gadamer, in particular, emphasizes openness to the Other, including the non-western Other, and proposes an ethics of openness and dialogue – a 'hermeneutical ethics' that arguably provides an ethical model for global science (see also Toulmin 1972, 1982, 2002; Heelan, 1991).

The Future of Open Science

Rich text, highly interactive, user generated and socially active Internet (Web 2.0) has seen linear models of knowledge production giving way to more diffuse open-ended and serendipitous knowledge processes, and new models of open science have challenged expanded protection of intellectual property (IP). Increasingly, global science carried out through the Internet promoting enhanced scientific communication and 'linked data' enables novel kinds of science and engineering collaboration (Peters, 2006; Olson et al, 2008). Open source initiatives have facilitated the development of new models of production and mass innovation. The public and non-profit sectors have called for alternative approaches dedicated to public knowledge redistribution and dissemination. Distributed peer-to-peer (P2P) knowledge systems rival the scope and quality of similar products produced by proprietary efforts. Certainly, the speed of diffusion of open source projects is an advantage, and successful projects have been established, especially in software and open source biology. Open access science has focused on making peer-reviewed online research and scholarship (including digitized back issues) freely accessible to a broader population. Open science demonstrates an 'exemplar of a compound of "private-collective" models of innovation' that contains elements of both proprietary and public models of knowledge production (von Hippel & von Krogh, 2003; von Krogh & von Hippel, 2003). But does the expansion of a patenting culture undermine the norms of open science and does the intensification of patenting accelerate or retard the development of basic and commercial research (Rhoten & Powell, 2007)?

The open science economy plays a *complementary* role to corporate and transnational science and implies a strong role for governments. Increasingly, portal-based knowledge environments and global science gateways support collaborative science (Schuchardt et al, 2007). Cyber-mashups of very large data sets let users explore, analyze, and comprehend the science behind the information being streamed (Leigh & Brown, 2008; Leigh et al, 2008). The World Wide Web has revolutionized how researchers from various disciplines collaborate over long distances, especially in the life sciences. Interdisciplinary approaches are becoming increasingly powerful as a driver of both integration and discovery (with regard to data access, data quality, identity, and provenance) (Sagotsky et al, 2008). National science reviews and assessments (bibliometrics and webometrics) focus on the formative role in developing distributed knowledge systems based on quality journal suites in disciplinary clusters with an ever finer mesh of in-built indicators (Besley, 2009; Peters, 2008).

The long future of open science is difficult to predict, but clearly there will be more change in the next 50 years of science than in the last 400 years, with biotech industries and genomic sciences emerging with the most economic and ethical significance. At the same time, supergrid computerization of science is taking place with spectacular information growth, combinatorial libraries, multiple competing hypotheses in a matrix, and deep real-time simulations. 'Wikiscience' and science 2.0 lead to perpetually refined papers with mass authors, the growth of 'amateur' and backyard science, and distributed instrumentation and experiment; linked-up data sharing, thanks to minimal transaction cost, will yield smart-mob science. As Kevin Kelly reminds us, the Internet is already made up of one quintillion transistors, a trillion links, a million emails per second, 20 exabytes of memory. It is approaching the level of the human brain and is doubling every year, while the brain is not.

Notes

[1] 'Linked data' is 'a term used to describe a recommended best practice for exposing, sharing, and connecting pieces of *data*, *information*, and *knowledge* on the Semantic Web using *URIs* and *RDF*' (Wikipedia, original emphasis).

[2] 'Cloud computing' is '*Internet*-based *computing*, whereby shared resources, software and information are provided to computers and other devices on-demand, like a public utility.' It 'describes a new supplement, consumption and delivery model for IT services based on the Internet, and it typically involves the provision of dynamically *scalable* and often *virtualized* resources *as a service* over the *Internet*' (Wikipedia, original emphasis).

[3] Open peer review (OPR) began trial in 1996 when a number of journals, including the *Journal of Interactive Media in Education*, began experimenting with it. This was followed by *PLoS Medicine*, published by the Public Library of Science, and *Atmospheric Chemistry and Physics*. *Nature* launched its own experiment in 2006 with mixed success. *Philica*, an online journal launched in 2006, published all articles immediately, which are then reviewed after publication by reviewers on a voluntary basis. *Biology Direct* is another journal that experiments with OPR as an alternative to traditional blind peer review. Open Peer Commentary is another innovation in the review process that promotes expert commentaries on published articles.

[4] See the following science blogs for a discussion of the advantages and current difficulties facing Science 2.0: http://www.spreadingscience.com/our-approach/what-is-science-20/ and http://openwetware.org/wiki/Science_2.0/Brainstorming

[5] 'The purpose of the Organizing Committee of the International Symposium on Science 2.0 and Expansion of Science (S2ES 2010) is to bring together researchers and designers from the three perspectives of the proposed New Science in order 1) to share their reflections regarding each of these three perspectives, 2) to analyze what is common among them, and 3) to identify the ways how they complement each other.' 'S2ES 2010 (*www.sysconfer.org/s2es*) will be held in the context of The World Multi-Conference on Systemics, Cybernetics, and Informatics: WMSCI 2010 (*www.sysconfer.org/wmsci*) in Orlando, Florida, USA on June 29th-July 2nd, 2010.'

[6] http://p2pfoundation.net/Openness

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