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THE DUAL FUNCTION OF OPEN ACCESS SCHOLARLY COMMUNICATION

An *arXiv* Case Study

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KEY WORDS

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ABSTRACT

This paper proposes that the system of scholarly communication and publishing must be tailored to the new technological (Internet) and social (Open Access) realities. It addresses, in particular, the need to revise and adapt the mission of academic journals so that they meet the new needs of science and society. The paper distinguishes between their research function and their institutional function and, using an example from arXiv, illustrates how these two functions may be fulfilled by subject-based repositories and scholarly journals, respectively.

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1. Introduction

Digital technology and the Internet have had a strong impact on various sectors of society, as well as on science (European Commission, 2016a). In scholarly communication, the advent of the Internet has been crucial to the emergence of a movement known as Open Access (OA), which advocates universal and cost-free access to all scholarly articles—those, at least, that have been financed with public or non-profit funds.

Accordingly, the public research organizations and agencies of some economic powers, such as the European Union, the United States, the United Kingdom, and China,[1] have mandated that research groups benefitting from their support must publish their articles under Open Access conditions.

The OA movement maintains that all Internet users should have the right to read, download, print, copy, search, link, distribute, crawl, mine, and reuse articles published in peer-reviewed academic journals that report the results of publicly funded research.[2] Two pathways to reach the dream of full OA have been identified: green OA and gold OA. The gold approach to OA calls for converting only those journals that currently require a subscription for online access. Green OA, on the other hand, advocates a different approach: that all researchers deposit their manuscripts in an Open Access digital repository, once they have been accepted by a journal and regardless of whether the journal itself is OA[3]. These two approaches are compatible, of course, and could be implemented simultaneously.

A digital scholarly repository[4] is an online, open access archive for collecting, preserving, and disseminating intellectual output, usually peer-reviewed research papers and documents. There are basically two kinds of repositories for open access articles: Subject-based Repositories (SR) and Institutional Repositories (IR). An SR is a repository dedicated to a specific discipline—high-energy physics, for example—while an IR is a repository set up by a university or research center to exhibit its researchers' results. In both cases, scholars self-archive their manuscripts as the final step in their research efforts (Harnad, 2001). Most funding agencies (see footnote 1) currently require that researchers deposit the peer-reviewed version into the SR or IR immediately after its acceptance by the journal[5]. They do allow access to be restricted for a specified period of time, however, to protect the rightful commercial interests of publishers, who count on recovering their investment through library subscriptions to the journals they manage. As a general rule, this is a 6-month embargo, but it is usually extended to a maximum of 12 months for journals in the social sciences and humanities.

This paper proposes that the system of scholarly communication and publishing must be tailored to the new technological (Internet) and social (OA) realities. The emergence of online scholarly repositories means that the mission of scholarly journals must be revised and adapted to the new needs of science and society. As we will see, it is urgent that a distinction be drawn between the research environment and the public dissemination environment. Our objective here is to point out a deficiency or limitation in today's OA policies but without presenting a definitive solution to the problem. Since this will be a complex solution, it must be discussed by the numerous actors involved in the transformation of scholarly communication.

2. Background

Let us describe the situation in scholarly communication prior to the Internet. The founding of scholarly societies in the seventeenth century shifted science from the private to the public realm. This was the beginning of what we could call *science as institution*; it was accompanied by the appearance of scholarly

[1] European Commission (2016b), NSF (2015), RCUK (2013, 2015), Kaiser (2015), Van Noorden (2014).

[2] See the Budapest Open Access Initiative (February 14, 2002), the Bethesda Statement on Open Access Publishing (June 20, 2003), and the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (October 22, 2003).

[3] For a detailed explanation of all things OA, see Suber (2012) and Eve (2014).

[4] A list of most of the world's digital repositories may be viewed at https://v2.sherpa.ac.uk/opendoar/ .

[5] Researchers normally deposit the peer-reviewed version (i.e., postprint), not the formatted and paginated version published by the journal (i.e., version of record).

journals, such as *Journal des Sçavans* and *Philosophical Transactions*, the purpose of which was to disseminate the results obtained by researchers belonging to these societies. Prior to that time, science was primarily a private, individual activity, and there was no systematic way to formally publish the scientist's discoveries[6]. Moreover, scientists of that era tended to be secretive (Nielsen, 2011). Over time, the peer review process emerged (Biagioli, 2002), and these journals came to have a dual function.

The first function was related to researchers sharing findings with each other. Journals were an efficient complement to researchers sending each other letters and private preprints[7] (Willinsky, 2005: 189-207) and supported research by giving it broader dissemination to a scholarly audience. Thus, we will refer to this as the *research function* of journals. With the increase seen in the number of researchers, universities, and research centers following World War II, there was a formidable increase in the number of articles published, as well as a higher degree of specialization (Solla Price, 1963; Guédon, 2001: 20, 23). As a result, the leading journals began to filter articles and select them on the basis of ever more exacting standards of quality, and this, in turn, made it easier for researchers to locate high-impact articles. Thus, the impact of any given scholarly article depended on the impact factor[8] of the journal in which it was published.

This brings us to the second function, which was related to the role of journals in various institutions. Since the leading journals published the best articles, supposedly, researchers were eager to read and get published in those journals. Moreover, institutions and research evaluation committees placed a higher value on researchers who were publishing in those journals and gave them preference for grants, tenured positions (i.e., stable employment), promotions, awards and honors, greater funding, etc. The political, military, social, and economic power that science had demonstrated during and after World War II spurred scientometric/bibliometric studies (Solla Price, 1963; Guédon, 2001: 20, 23) for measuring researchers' performance that, in turn, became a tool used by science policy makers for allocating human and financial resources to the various fields of research. We will call this social and political dimension of the journals' function their *institutional function*.

We are considering functions of a general nature—in this case, the research function and the institutional function—because we are describing journals from a broad perspective. Journals have fulfilled other important, specific functions throughout their history (Roosendaal and Geurts, 1997): *registration*, which allows claims of priority; *certification*, which establishes the validity of an article; *awareness*, which enables scholars to keep abreast of new findings; and *rewarding*, which rewards authors for their performance based on citation metrics. Roosendaal and Geurts's registration and awareness functions are subtypes of our research function, whereas certification and rewarding are subtypes of our institutional function.

In this article, we are particularly interested in the certification function because, while awareness is meaningful in the context of an academic audience (i.e., the peers), certification is for the benefit of the much wider audience of society as a whole, including businessmen, politicians, and R&D officers. This is because to certify something is to uphold its truthfulness—not only from the epistemic perspective but also from the standpoint of its applicability (in industry, society, and the military, for example). If an article has passed peer review and been published in a leading journal, it has survived the harsh scrutiny of peers. In other words, if leading experts in the field have accepted it, then (for now, at least) it has entered into the broad array of knowledges recognized by the scientific community. A journalist would be justified in

[6] Note that the word *publish* means *to make public*.

[7] A preprint is currently understood as a scholarly paper ready to be considered by a scholarly journal but not yet published. A preprint has not yet undergone peer review, while a postprint is a paper that has passed peer review (Harnad, 2003).

[8] Journal impact factors were created in the 1950s for the purpose of *measuring* science and those who were doing it (Garfield, 1955). The impact factor claims to indicate the impact a given journal has had in the scientific community in a given year; it is obtained by taking the total number of times the journal in question was cited during the previous two years in other journals analyzed and dividing that number by the total number of articles published by this same journal during the same period of time. There are, however, other kinds of impact measures.

reporting a discovery that has been published in a high-impact journal, for example, but it would be patently irresponsible for a journalist to report a discovery based on an article that had been rejected (or not even evaluated) by the peers. Popular science newspapers and magazines do, in fact, abide by this standard when communicating science in the mass media.

Broadly speaking, the publication of a paper in a refereed journal constitutes officialization (i.e., institutionalization) of the research findings, and this is crucial for obtaining recognition and prestige within one's scholarly community. The peer review process continues to be important in the sense that it represents a line of demarcation between what we may call *official science* or *institutional science* (e.g., the science that somehow is approved to be taught in schools and disseminated in newspapers) and the "science" that is still under scrutiny. Publishing in a refereed journal is the equivalent of establishing a boundary between "what is known" and "what is still under investigation."

As Guédon (2004, p. 316) has pointed out, journal rankings have continued for branding purposes: "journals matter only to differentiate between peer-reviewed articles and non-peer-reviewed publications and to provide symbolic value […], journals contribute to the impact of individual articles by their prestige—a dimension generally associated with the notion of 'impact factor'." Librarians, journalists, R&D administrators, teachers and, of course, other researchers trust a high-impact journal (one that is frequently cited) more than a low- or no-impact journal (one that is seldom if ever cited).

3. Internet and Online Repositories

Having emerged in the 1960s, the Internet began to be used by United States universities in the 1970s and 1980s[9]. As early as 1991, physicists developed an SR (Ginsparg, 1996) so that they could exchange preprints immediately and did not have to wait for the articles to be published in traditional physics journals. This became a successful cultural practice among physicists, the repository having two objectives: (a) to speed up the process of sharing knowledge with peers (*awareness*) and (b) to establish the priority of discovery (*registration*). Prior to the advent of the World Wide Web, preprint exchange was part of the physics culture (Till, 2001, Harnad, 2003) but not customary in other disciplines. The preprint exchange culture is, in a sense, a continuation of the distant practice of exchanging letters that was so commonplace among scientists (i.e., natural philosophers) prior to the mid-seventeenth century when scholarly societies and their associated journals came into being. The aforementioned repository, currently known as *arXiv*, contains more than 2,011,228 e-prints[10] and receives roughly 180,000 new submissions[11] every year. The tremendous success of *arXiv* has prompted scientists in some other fields to join in the practice of exchanging preprints in this manner. Thus, *arXiv* has become a kind of *e-agora* where physicists, mathematicians, computer scientists, quantitative biologists, and statistics scientists currently self-archive and exchange preprints (Larivière et al, 2014).

Nowadays, *arXiv* is a daily meeting place (Sismondo, 2016) where knowledge is exchanged in the form of preprints. With different sections for different kinds of subjects and specific protocols for self-archiving, it serves as a "market of ideas" (Delfanti, 2021), so to speak, where scholars deposit the products they want to show (and exchange with) their peers. In physics, therefore, *arXiv* is the proper place to fulfill the *research function* of scholarly communication. Following *arXiv*'s example, the use of SRs has been promoted[12] in other fields (Hoy, 2020), as well, to encourage the free exchange of preprints and thereby fulfill the research function.

This paper aims to show that, with the Internet and OA, a transition has begun that should lead us to create a clear separation between the *research function* and the *institutional function*. As the *arXiv* example below shows, the SRs rather than the journals must

[9] http://www.internetsociety.org/internet/what-internet/history-internet/brief-history-internet. (Last accessed on August 19, 2021)

[10] http://www.arxiv.org/. (Last accessed on August 19, 2021)

[11] https://arxiv.org/help/stats/2020_by_area/index#:~:text=The%20current%20submission%20rates%20(i.e.,%2Dmat%20(16198)%3A%209.1%25. (Last accessed on August 19, 2021)

[12] Since IRs have no special relevance to our subsequent considerations, they will not be considered in this paper.

fulfill the research function, whereas the institutional function should remain in the hands of the journals. Digital technology and the Internet are imposing a new logic on communications that should inspire us to consider a new organizational and logical model for scholarly communication.

4. Case Study. The *arXiv* 's Research Function

As a concrete example, we will now recount in some detail a debate among physicists on the *arXiv* platform. This debate took place through the exchange of new versions of their preprints—manuscripts not yet submitted to a journal—as they were depositing them in this repository. Thinking that their preprints were not yet mature enough to be submitted to a physics journal, these physicists were seeking to exchange ideas with their peers via *arXiv*.

The crux of this matter, however, is that their debate did not begin with preprints deposited on *arXiv*; it had already started with an article published in the prestigious journal *Nature* and with other physicists on *arXiv* who had immediately called into question the results reported in that article. At the end of this story, we will explain why we believe that the initial submission of this article to *Nature* was not an accident but rather was related to the distinction we are making here between the research function and the institutional function.

On 23 February 2006, an article entitled "Counterfactual quantum computation through quantum interrogation" (Hosten et al., 2006) was published in *Nature*. This article presented a complex experimental set-up in which, according to the authors, a computer could perform computations counterfactually—that is, it could give the result of an algorithm lodged in its interior without actually having executed the algorithm (i.e., without any photon or electron interacting with it). Counterfactual quantum computation was accomplished by putting the computer in a superposition of "running" and "not running" states, and then making the two histories interfere. This astounding quantum phenomenon was nothing new: in a May 1998 *arXiv* preprint, Richard Jozsa (1998) had suggested this possibility, based on a *gedankenexperiment* proposed by Elitzur and Vaidman (1993). Jozsa's article was published more than a year later, in September of 1999, in the journal *Chaos, Solitons and Fractals* (Jozsa, 1999)[13]. In July of 1999, however, just prior to the article's appearance in this journal, Jozsa posted a new *arXiv* preprint jointly authored with biologist Graeme Mitchison, in which they set limits on counterfactual computation[14]. Mitchison had read Jozsa's first *arXiv* preprint and had contacted him before the article came out in *Chaos, Solitons and Fractals*. Mitchison had chosen to substitute quantum computation for his neurobiology research between 1999 and 2001 and, during that time, he published a series of articles (first on *arXiv* and later in journals) on the application of quantum counterfactuality in medical X-ray dosimetry.

In their joint article, Mitchison and Jozsa claimed that, if a computer's measurement could be either in the state |0> or in the state |1>, then only one of these states could be determined counterfactually with almost absolute certainty. This preprint, which they had posted on *arXiv* in July of 1999, was published two years later (May of 2001) in the *Proceedings of the Royal Society of London*[15].

In the *Nature* article, Hosten et al. (2006) claimed that the limitations set by Mitchison and Jozsa were not valid and concluded that it was indeed possible to counterfactually determine any computer's state, whether |0> or |1>. Adding drama to their assertion, they conducted an experiment with four states accessible to the computer (|00>, |01>, |10>, and |11>) and, in what appeared to be a counterfactual process, they were able to ascertain each and every one of the four computer states without needing to make the computer run. By publishing their article in a high-impact journal such as *Nature*, Hosten et al. had endowed it with a symbolic value it would not have gotten by being posted on *arXiv*. It is very important to note the social

[13] It is important to note that, while Jozsa's finding was openly and immediately shared with the world on *arXiv*, it took more than a year for the journal to publish it.
[14] See Mitchison & Jozsa (1999).
[15] See Mitchison & Jozsa (2001).

visibility they acquired from being published in *Nature*[16].

On 10 June 2006, Mitchison and Jozsa responded to Hosten et al. by publishing a preprint on *arXiv*[17], in which they argued that it was impossible to obtain more than one outcome counterfactually, even though their explanation and the mathematical notation they utilized were of no help in clarifying the matter. Hosten et al. replied immediately, on 14 July 2006, this time by posting a preprint on *arXiv*, and a heated exchange ensued over the following weeks. On 27 July, Mitchison and Jozsa added a short text at the end of the 10 June preprint, identifying this preprint as version 2. Hosten et al. did the same on 6 August, creating a version 2 of their previous preprint. There were no further exchanges between these authors until several months later, on 3 January 2007, when Mitchison and Jozsa created a version 3 of their *arXiv* preprint. The dispute ended in a draw, however, since they could not agree on a definition of the concept of counterfactuality in quantum mechanics. Hosten et al. arrived at a quantum-philosophical *realistic* approximation that supported counterfactuality, while Mitchison and Jozsa argued a more *orthodox* interpretation that excluded counterfactuality.

Meanwhile, a new actor had made his entrance into the dispute: on 20 October 2006, Lev Vaidman posted a preprint on *arXiv* that became a decisive factor in the evolution of this debate[18]. In his preprint, followed by two subsequent versions on 21 December 2006 and 2 January 2007, Vaidman acknowledged the subtlety of the Hosten et al. experimental set-up but, like Mitchison and Jozsa, argued that counterfactual computation for all possible outcomes was impossible. Moreover, and more importantly, Vaidman shifted the debate toward analysis of the so-called "weak measurements" in quantum mechanics. Given that, among his Philosophy of Physics colleagues, Vaidman is a well-known proponent of the Many-Worlds interpretation of quantum mechanics, arguing this interpretation was most likely his philosophical objective in challenging the Hosten et al. article. Under this interpretation, it was not at all a counterfactual phenomenon but rather the result of a process involving creation and annihilation of parallel quantum worlds.

Hosten and Kwiat, apart from the other collaborators who had published with them in *Nature*, responded to Vaidman on *arXiv* with a preprint[19] dated 19 December 2006 in which they analyzed the "weak measurements" and claimed that Vaidman's conclusions stemmed from a particular interpretation of "weak measurements." It took Vaidman only two days to respond with his version 2, on 21 December; a short time later, on 2 January 2007, he posted the definitive version 3 of his *arXiv* preprint. It could be said that the direct debate over counterfactual computation concluded on this date, pending new theoretical or experimental subtleties relative to the "weak measurements."

As we have seen, although the issue arose with the Hosten et al. article in *Nature*, it was debated entirely through *arXiv* preprints. Vaidman sent his preprint to the journal *Physical Review Letters*[20] *(PRL)* the same day he posted its version 1 on *arXiv* (20 October 2006), but the article was not published until some months later on 18 April 2007. Vaidman, Hosten, and Jozsa remained in contact by email[21] following their preprints exchanges on *arXiv*. Mitchison and Jozsa, on the other hand, did not publish their preprints in any journal, though later they did do research on the "weak measurements." Both Mitchison and Jozsa posted *arXiv* preprints on "weak measurements" that were later published in journals[22]. Although Hosten and Kwiat did not publish their preprints in any journal, either, they did continue their research on the "weak measurements;" in 2008, they

[16] For example, *Science Daily* (https://www.sciencedaily.com/releases/2006/02/060223084147.htm), *Discover Magazine* (https://web.archive.org/web/20190301063516/http://blogs.discovermagazine.com/cosmicvariance/2006/02/28/paul-kwiat-on-quantum-computation/#.XHjSqFjP1TY), *The Chronicle of Higher Education* (http://www.chronicle.com/blogs/wiredcampus/the-weird-world-of-quantum-computing/2029), and the *Chicago Tribune* (on Sunday, September 8, 2016, according to *The Chronicle*). [Last access to all the above links: August 19, 2021]

[17] See Mitchison & Jozsa (2006).

[18] See Vaidman (2006).

[19] See Hosten & Kwiat (2006).

[20] See Vaidman (2007).

[21] Personal communication from Vaidman.

[22] See Mitchison, Jozsa & Popescu (2007), Jozsa (2007), Mitchison (2008), and Aberg & Mitchison (2009).

jointly published an article in *Science*[23] for which there was no preprint in any SR.

As we pointed out above, the Hosten et al. article had acquired symbolic value by being published in a high-impact journal such as *Nature*. That value, in turn, derives from the journal's impact factor: the greater the impact factor, the greater the symbolic value. When his article was published in *Nature*, Onur Hosten was a doctoral student at the University of Illinois at Urbana-Champaign.[24] He obtained his PhD in 2010 and was subsequently contracted by Stanford University, where he remained until 2018. Since, at that time, Vaidman, Mitchison, and Jozsa were secure in their contracts as scientists with their respective universities, it is reasonable to think that Hosten was under considerably more pressure than they were to publish in *Nature*, as opposed to starting a discussion on *arXiv*. Thus, whether intentionally or not, Hosten gave the institutional function precedence over the research function, in that publishing in a preeminent journal like *Nature* represented (and still represents) the surest way to obtain post-doctoral fellowships, grants, and tenured positions. The veteran physicists, however, responded to Hosten not through *Nature* but through *arXiv*, that being the best way to exchange ideas (i.e., the research function).

5. Discussion

Only Vaidman published an article related to this debate in a journal. The exchange of *arXiv* preprints was very productive, however, and gave clues as to the lines along which research would develop ("weak measurements"). Hosten's article in *Nature* (which is where the debate originated) and Vaidman's in *PRL* reflected very little of the debaters' clever arguments, however. Much information of interest was lost in the abyss between the *research physics* of *arXiv* and the *institutionalized physics* of *PRL*. In fact, in his *PRL* article, Vaidman cited three *arXiv* preprints[25] that figured in the debate but were never published in any journal. As for those *arXiv* preprints that had been subsequently published in journals, Vaidman opted to cite the journal version, undoubtedly for branding reasons. It has become routine procedure among physicists to cite *arXiv* preprints only when there is no corresponding journal version. For instance, Kuperberg (2002) noted that "one of the most important papers in quantum algebra is a still-unpublished *arXiv* article by Maxim Kontsevich."[26]

Another important consideration is that *Nature* targets a heterogeneous and interdisciplinary audience while *PRL*'s readers are specialized in physics. It is most likely, therefore, that many of those who read the *Nature* article (or its abstract) were convinced by Hosten et al.'s experimental proof but ignorant of Vaidman's decisive contributions in *PRL*. By the same token, since *PRL* is geared toward a more diverse audience of physicists, those who read only *PRL* could miss important contributions on a particular problem that are published in one of the more specialized journals, such as *Physical Review A*, *Physical Review B*, and *Physical Review C*. To the researchers, journalists, members of the general public, and other individuals who read Hosten's original article in *Nature* but did not see Vaidman's response on *PRL*, the content of Hosten's article was certified knowledge, in the Roosendaal and Geurts sense of the word. In other words, to those readers, it was knowledge accepted by the author's peers and, therefore, knowledge that could be confidently disseminated in society (i.e., to businesses, the general public, politicians, R&D administrators, and the like). On the other hand, to those who read both articles (i.e., *Nature* and *PRL*), Hosten's results were not certified but rather still in the research phase, for Vaidman had apparently succeeded in refuting them.

The argument may also be applied to the popular (i.e., non-academic) magazines and newspapers *Science Daily*, *Discover*, the *Chronicle of Higher Education*, and the *Chicago Tribune* (see footnote 16), which echoed the article published in *Nature*. If one of their readers (e.g., an

[23] See Hosten & Kwiat (2008).

[24] https://www.linkedin.com/in/onur-hosten-83618658. (Last access: August 19, 2021)

[25] The three preprints Vaidman cited were Mitchison & Jozsa (2006), Hosten et al (2006b), and Hosten & Kwiat (2006).

[26] Maxim Kontsevich's paper is "Deformation quantization of Poisson manifold, I," *arxiv.org/abs/q-alg/9709040* [Deposited on September 29, 1997]. It was published later, in December 2003, in *Letters in Mathematical Physics* 66 (3), pp. 157-216.

ordinary, science-loving citizen) were to read the news in these magazines and newspapers without being aware of Vaidman's response, then that reader would be convinced that, in the future, there could be computers that perform complex calculations counterfactually[27], whereas Jozsa, Mitchison, and Vaidman had shown through powerful arguments that this may not be the case. To put it more simply, *Science Daily* and *Discover* readers will be convinced that there could be counterfactual computers in the future when, in reality, there were serious doubts in the minds of various experts. In this case, the results published in *Nature* did not reach the sizeable newspaper and television audiences—but could have done so. If the line between research science and institutional science was arbitrary and blurred *before* the emergence of OA, it is even more so today.

6. Recommendations

Journals should revise their publishing model. Rather than simply carrying out the peer review process to select individual articles for publication, journals should provide state-of-the-art information, a critical account, and a unified narrative of what has happened thus far with regard to a particular scientific problem. This narrative should include the most important articles and perhaps abstracts or excerpts of the rest of the articles on that problem that have been posted on *arXiv* but not published. Some early promoters of *arXiv* suggested a model of this type more than a decade ago. For instance, *Geometry and Topology*[28] was an overlay journal that took a similar kind of approach: "in heavily arXived areas of research, journals are a *de facto* second layer of the permanent literature, with the *arXiv* as the first layer" (Kuperberg, 2002). Paul Ginsparg (1996), the founder and head of *arXiv*, foresaw this: "Any type of information could be overlayed on this raw archive [*arXiv*] and maintained by any third parties." Both of these quotes echo the separation that we are proposing between the research function and the institutional function. SRs such as *arXiv* could handle the research function, whereas the journals would be responsible for the institutional function. As has been pointed out by Ginsparg (2007), *arXiv* is the place where researchers can "share preliminary findings, solicit community feedback, and stake priority claims," and he added that the "underlying idea [of *arXiv*] is to replicate in some on-line form the common experience of going to a meeting or conference, and receiving from a friend/expert some informal recent research thought, an instant overview of a subject area." In fact, most high-energy physicists admit using *arXiv* as their primary daily information source (Nielsen, 2011; Delfanti, 2016).

Hosten's article passed *Nature*'s "closed" (formal, institutional) peer review[29] but did not survive the "open" (informal) peer review on *arXiv*. This analysis, based on an example drawn from *arXiv*, shows the importance of the preprint exchange culture and proposes that journals be converted to institutional and political[30] platforms for (*a*) the interdisciplinary transfer of knowledge; (*b*) the evaluation of a researcher's professional career; (*c*) making strategy

[27] Remember, a counterfactual calculation is a calculation that the computer has not *actually* performed but does have the ability to perform, potentially. In other words, apparently no energy (i.e., neither electrons nor photons) has flowed through its circuitry. We have put "actually" in italics because, in this context, speaking in terms of what is *real* is rather problematic, of course. Our experts are all in agreement that the computation does occur (i.e., this is a fact) and that the computer does perform the calculation; there is disagreement, however, with regard to the computer's operating status. Hosten et al. argue that the computer is "not running," so to speak, when it performs the calculation, whereas Jozsa, Mitchison, and Vaidman maintain that, even though no photons are observed flowing through the computer's circuitry, the computer is "running" (in one of the possible worlds or histories, in quantum terminology) when it performs the calculation.

[28] The current web page for the journal *Geometry and Topology* is http://msp.org/gt/. Thanks to the WayBackMachine tool, from the Internet Archive project (https://archive.org/), we can see what this journal's web page was like in the year 2005: https://web.archive.org/web/20051107205514/http://www.maths.warwick.ac.uk/gt/. On this page we can read the following: "All Geometry and Topology Publications are deposited in the arXiv."

[29] We call it closed (as opposed to "open") because, normally, a journal's peer review process is carried out by only three referees. At that time, however, *Nature* had conducted some "open peer review" trials; see *Nature* (2006) to read skeptical conclusions, and Koonin et al. (2006) to read encouraging conclusions.

[30] The word 'political' is here used in the sense of the Greek word 'polis', namely, for the citizens (=the city).

decisions in scientific policy; and (d) ensuring that only painstakingly scrutinized and certified science becomes popularized.

It must be emphasized that there was no deficiency in *Nature's* peer review process; rather, it was an extraordinarily ingenious problem that called for a very specific expert. If Hosten et al. had *first* communicated their research and results via *arXiv*, Vaidman's response would have appeared sooner, and *Nature* would have been more cautious.

SRs eliminate delays in the dissemination of results among experts (awareness), though the presentation of those results to the so-called *global village* (McLuhan) should fall to the leading journals (certification). In this scenario, the journals would still hold great sway, politically, because they would still be managing information that attracts the attention of large sectors of public opinion—including that of businessmen and politicians. Thus, articles deposited in SRs would have local impact in a specific discipline, and articles published in journals would become part of the "Great Conversation" (to use an expression similar to Oakeshott's, so often mentioned by the Richard Rorty).

Sandewall's slogan (2004) would endorse the research function of refereed journals: "We ought to think of scientific publication as a function that is internal to the scientific community […], papers are published by scientists for scientists." On the other hand, Moore's slogan (2006) would support the institutional function of the refereed journals: "a judgment of the scientists, by the scientists, for the people."

As we have stated, in very recent years, many countries have approved guidelines and policies favorable to OA (see footnote 1). These policies advocate Open Access to academic articles that are based on publicly funded research, with two primary objectives: to facilitate the exchange of knowledge among researchers and to make scientific results available to the taxpayers who funded the research through the taxes they paid. The problem with this indiscriminate support of Open Access, however, is that it fails to differentiate between certified and non-certified content. In reality, these policies foster *awareness*, but ignore *certification* issues. Thousands of articles stored on journal websites and in subject-based and institutional repositories will be available to the general public (e.g., the taxpayers); what will not be available to them, however, is a clear standard of reliability for those articles and information as to whether an article published in *Nature* has been refuted on *arXiv*, or vice versa. Take a physics article published in *Nature*, for example; that article would have been reviewed by three formal referees, appointed by the journal. But suppose that journal review was actually a *second* review and the article had been reviewed or critiqued *first* by an innumerable and indeterminate host of physicists on *arXiv*—informal referees, appointed by no one. How could a taxpayer know that?

7. Conclusion

Our objective was to show that, just as the printing press did in its day, the new technologies can help us critically rethink and improve scholarly communication and knowledge transfer by separating the science production phase from the science presentation-dissemination phase. The conclusion is that, while the journals' peer review process is still important for institutional purposes (i.e., the external function of scholarly communication), it must be revised and adapted to the new epistemological and social (OA) needs and to the new technological tools (Internet). We have shown that SRs such as *arXiv* are the best way to address the internal function of scholarly communication.

While science policies aimed at fomenting OA might be proceeding in a good direction,[31] the consequences have not yet been comprehensively analyzed. As we have seen, current OA policies do address the awareness aspects but not the issues and arguments regarding certification that have been raised here. We have argued that the awareness aspects should be handled through subject-based repositories (SRs), while the refereed journals should be responsible for the certification

[31] There is a debate about the impact that OA policies could have on the publishing industry—for example, how they could affect employment in this sector—but these considerations are beyond the scope of this article. To understand the impact of OA on the publishing industry, see Suber (2012) and Eve (2014).

aspects. OA policies must tackle this issue in cooperation with the stakeholders who are impacted, if they wish to succeed in completing the conversion of scholarly communications from in-print to online versions.

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