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Marinus Swanepoel, "Scholarly Communication: the quest for Pasteur's Quadrant." *Proceedings of the IATUL Conferences*. Paper 11.
<http://docs.lib.purdue.edu/iatul/2011/papers/11>

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SCHOLARLY COMMUNICATION: THE QUEST FOR PASTEUR'S QUADRANT

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Abstract

The scholarly communication system is sustained by its functions of a) registration, b) certification or legitimization, c) dissemination and awareness d) archiving or curation and e) reward. These functions have remained stable during the development of scholarly communication but the means through which they are achieved have not. It has been a long journey from the days when scientists communicated primarily through correspondence. The impact of modern-day technological changes is significant and has destabilized the scholarly communication system to some extent because many more options have become available to communicate scholarly information with. Pasteur's Quadrant was articulated by Donald E Stokes in his book *Pasteur's Quadrant Basic Science and Technological Innovation*. It is the idea that basic science (as practiced by Niels Bohr) and applied science (as exemplified by Thomas Edison) can be brought together to create a synergy that will produce results of significant benefit, as Louis Pasteur did. Given the theory (fundamental understanding) we have of scholarly communication and given how modern-day technological advances can be applied, a case can be made that use-inspired basic research (Pasteur's Quadrant) should be the focus for current research in scholarly communication. In doing so the different types of digital scholarly resources and their characteristics must be investigated to determine how the fundamentals of scholarly communication are being supported. How libraries could advocate for and contribute to the improvement of scholarly communication is also noted. These resources could include: e-journals, repositories, reviews, annotated content, data, pre-print and working papers servers, blogs, discussion forums, professional and academic hubs.

Keywords: scholarly communication, scholarly publishing, Pasteur's Quadrant/ Models, academic writing

Introduction

Generally speaking librarians would agree that information and communication technologies have been, and still are, a destabilizing force in libraries. Worthy of mention is not only the wealth of information, the variety of tools and numerous services available in cyberspace, all of which came about in the last couple of decades, but also the changed way in which libraries do business [Hazen, 2007]. Libraries, specifically academic libraries, played a significant role in the arena of scholarly communication in the past, especially as far as the functions of dissemination and access, preservation and curation is concerned. However, the influence of information and communication technologies has also impacted scholarly communication in a disruptive manner, not in terms of its basics/functions but rather in terms of its format or presentation and market forces. Chodorow [2000] is quite frank about it: "Our system of scholarly communication is in trouble. Its economy has changed, and its technology is changing." Depending on how libraries position themselves during this period of disruption, we might or might not see libraries lose ground in the role they have to play in the scholarly communication process. There is also the potential/possibility that libraries may significantly increase their role.

Scientific journals have been distributed to readers in print since their beginnings in 1665 [Hunter, 2007]. However, for the last 15 years or so electronic delivery has not only coexisted, but grown alongside the print medium. Today, many if not most academics prefer the electronic delivery to print. Further evidence of this trend is that by 2007 40% of the content in Elsevier's Science Direct database was e-only content [Hunter, 2007].

Apart from the use of information and communication technologies in improving and streamlining the processes it is clear that the current scholarly communication system is still very much the same as it has been over the last couple of hundred years. The functions and processes remain essentially the same. Rosendaal and Geurts [1997] already indicated more than 10 years ago that this tactical/mechanical transformation will only improve the existing system, while a strategic or structural transformation to the scientific communication network is needed.

Given that there is a need to change/improve the scholarly communication system, this study is meant to identify some pointers as to where attention should be focused to find the areas that would potentially produce the most benefit when changing it.

Methodology

The hypothesis of this brief study is that indications of potentially significant change and improvement in the current scholarly communication system can be found in exploring the application of Pasteur's quadrant.

The methodology to determine that is as follows: After briefly looking into the theory of Pasteur's quadrant, scholarly communication is explored to determine the breadth and scope rather than depth thereof. This is done by a reconnaissance of scholarly communication through the creation of a framework and by looking at the functions performed by the scholarly communication system. Another exploration, this time to survey the manifestations of scholarly communication from a technological point of view, is presented. This is done with the purpose of identifying aspects that could benefit from closer scrutiny through the lens of Pasteur's quadrant. This will be supplemented with a number of characteristics applicable to information and communication systems.

Pasteur's quadrant

Donald Stokes [1997] describes in his book *Pasteur's Quadrant*, how research with only fundamental understanding in mind is exemplified by the research of Niels Bohr in physics, while the research by Thomas Edison on electricity is the prime example of research with only use in mind.

The argument is that because applied research and basic research have different goals it makes these two types of research conceptually distinct [Stokes, 1997]. At its core basic research seeks to broaden our understanding of a phenomenon while applied research is focused on a need or problem, expressed by an individual or a group.

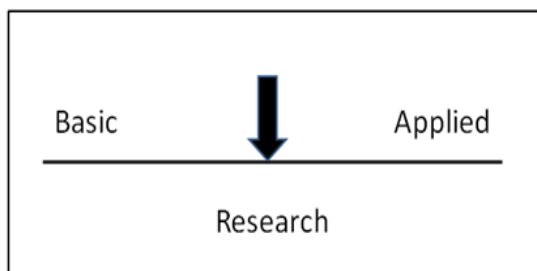


Figure 1: The continuum of research [Stokes, 1997]

Apart from this distinction between basic and applied research, Stokes also observes that basic and applied research are at the opposite ends of a continuum (see Figure 1) and that any one research project would have elements of both, some more than others. Pasteur's quadrant would have a perfect balance of the two.

The best of both (research for fundamental

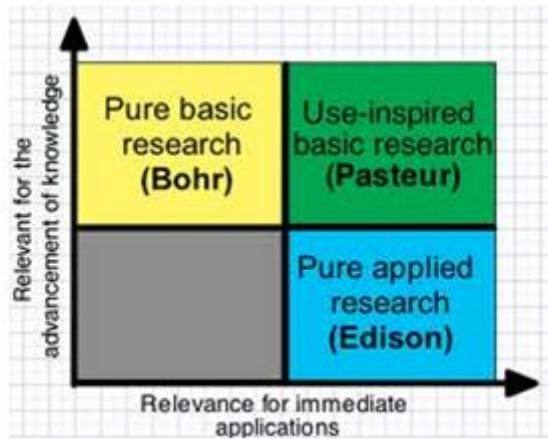


Figure 2: Quadrant model of scientific research [Stokes, 1997]

fundamental understanding is less likely to result in specific applications. On the other hand research undertaken to solve a problem concerning a specific application is less likely to result in more fundamental understanding. However, the one doesn't exclude the other, for technology and research are interrelated and impact one another.

Scholarly communication: a framework

There appears to be some confusion as to the difference between scholarly communication and scholarly publishing. In simplistic terms one could say that scholarly communication encompasses both public and private (scholarly) communication while scholarly publication refers to documents being made public.

According to Borgman [2007] one could also distinguish between formal and informal scholarly communication, the difference being that formal scholarly communication is meant to be available to a wide audience over an extended period of time while informal scholarly communication is that which is accessible to a restricted audience and often transient and ephemeral in nature.

Scholarly communication includes many types of public and private communication and these

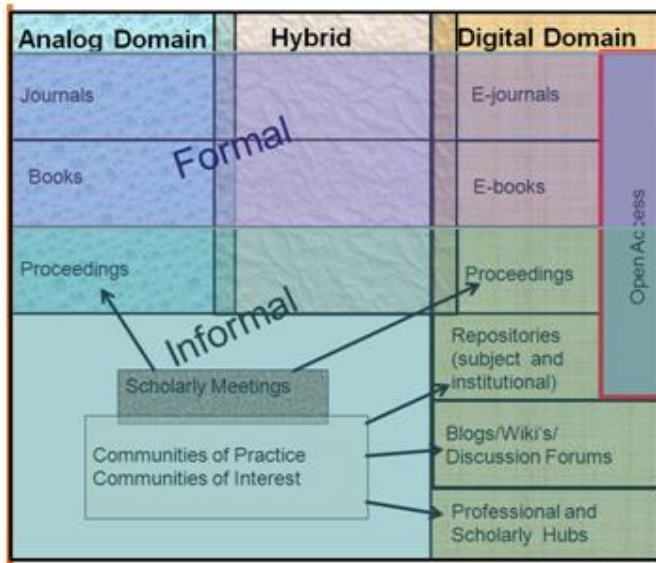


Figure 3: The manifestations of scholarly communication

understanding and research for use) is visible in Pasteur's fundamental understanding of the fermentation process and how to use that knowledge to control fermentation to limit spoilage. Pasteurization as a process came about because of Pasteur's ability to combine understanding and use. Hence the term: Pasteur's Quadrant.

One should also consider that the motivation for research will have an impact on the outcome: research to cultivate

can be plotted on a continuum ranging from formal to informal but to demarcate the exact borders with reference to these characteristics is not feasible.

For the purpose of providing an overview of the scholarly communication arena the following graphic representation in figure 3 serves well. The primary classification is based on whether the message is paper based (analog), both analog and digital (hybrid) or digital. Since it is the digital domain that has given rise to the open access movement, open access is situated within that domain. There were open (free)

publications in the analog domain before the advent of the digital, but the emphasis was on free. With open access, as it is understood today, the emphasis is on (universal) access rather than on the fact that it is free.

Functions of scholarly communication

There seems to be some difference of opinion on what to name the different functions of the scholarly communication process, however there is general agreement on the understanding of what the functions are.

Registration

The function of registration is to allow the researcher the opportunity of notifying other interested parties of his/her ideas. This is the act of staking a claim, in a manner of speaking; giving notice of being the first to have this idea/insight. Essentially it allows for claims of precedence of scholarly discovery [Van de Sompel, Payette, Erickson, Lagoze and Warner 2004].

Certification

This relates to the expectations of legitimacy and authority by the research community. In general terms it can be said that it refers to the peer review process by which a piece of work is given "the stamp of approval" or being certified as to its validity. Borgman [2007] views registration as part of certification and names this function: legitimization.

Dissemination and awareness

This function can simply be viewed as publicity but it is also called communication and diffusion, awareness and transparency. It is also argued that dissemination is the main purpose of scholarly communication for research can only have meaning, in a functional sense, if it is communicated to a broader audience [Borgman 2007].

Archiving

Traditionally libraries and archives took responsibility for access, preservation and curation of records. The purpose of this function is to preserve scholarship for future readers and researchers. The methods of doing this have changed as the medium of the records has changed. For example preserving monographs in the library requires different skills and technology than curating a digital data archive.

Rewarding

Roosendaal and Geurts [1997] also alludes to rewarding being a function of the scholarly communication system. The reward is seated in being referenced by other scholars and being published in a certain class of journal [Van de Sompel et al. 2004]. It is also important in academe for promotion and tenure.

Manifestations of digital forms of scholarly communication

Despite the increase in the variety of other forms of scholarly communication, the number of scholarly journals is increasing at a steady pace of around 3.5 % per year. This has been the case since the 1700s [Waltham 2010]. It seems that the scholarly journal is still the preferred vehicle for scholarly communication and that the standard unit of such a "message" is still the scholarly article. Björk, Roosr and Lauri [2008] calculated the total number of refereed articles published in 2006 as 1 350 000 by 23 750 journals.

Table 1: New models of digital scholarly communication

That is not to say that there has been significant innovation in the creation of new forms of scholarship and scholarly works. On the contrary a study by Ithaka in 2008, commissioned by the Association of Research Libraries, proved that there has been significant movement in this area. The purpose of this study was to scan for new models of scholarly works and to identify as many examples from as many disciplines as possible [Maron and Smith, 2008]. A summary of

Type of digital resource	% of digital scholarly resources	Distinguishing characteristic	Examples
E-only journals	23%	Strongly resemble traditional print journals	http://www.ecologyandsociety.org http://www.atmospheric-chemistry-and-physics.net/home.html
Reviews	5%	Reviews published daily, not organized in volumes and numbers	http://bmcr.brynmawr.edu/ http://f1000.com/
Preprint and working papers	5%	Low barriers for publication	http://arxiv.org/ http://www.ssrn.com/
Encyclopedias, dictionaries and annotated content	12%	Wide participation but retain expert editorial vetting	http://planetmath.org/ http://plato.stanford.edu/
Data	20%	Scientists can contribute and harvest data	http://www.rcsb.org/pdb/home/home.do http://ebird.org/content/ebird/
Blogs	7%	Extremely low cost, informal and responsive	http://www.realclimate.org/ http://peasoup.typepad.com/
Discussion forums	11%	Easiest to use and a great tool for connecting to others in the discipline	http://www.h-net.org/ http://www.h-france.net/subscribe.html#posting
Professional and scholarly hubs	17%	Wide range of content types	http://www.alzforum.org/ http://www.ibmsonline.org/BoneKEy/tabid/78/Default.aspx

the results showing the eight principal types of digital scholarly resources found is shown in table 1.

These different modes of scholarly communication are a certain indication that the key issue, mentioned in 2002 by Frey, De Roure and Carr, is no longer an insurmountable problem: "A key issue for Chemists making use of the Grid will be the support it can provide for distributed

collaboration. This includes video, multimedia as well as the traditional need we have for visualization.” There is ample proof among the examples of the various digital scholarly models listed above that these issues have, at least from a technical point of view, been resolved.

Attributes of information technology systems

A look at the literature to see what information technology and systems (being part of the Edison quadrant) are bringing to the table identified the following characteristics [Vasconcelos, Sousa, and Tribolet, 2007] for consideration along with the theory on scholarly communication (the Bohr quadrant).

- Usability – user’s ability to utilize a system effectively
- Performance – responsiveness of the system, the time required to respond to stimuli or the number of events processed in some interval of time;
- Reliability – ability of the system to keep operating over time;
- Availability – proportion of time the system is up and running;
- Security – system’s ability to resist unauthorized attempts at usage and denial of service while still providing its services to legitimate users;
- Functionality – ability of the systems to do the work for which it was intended;
- Modifiability – ability to make changes to a system quickly and cost effectively;
- Variability – system can be expanded or modified to produce new architectures that differ in specific, preplanned ways;
- Subsetability – ability to support the production of a subset of the system;
- Conceptual Integrity – vision that unifies the design of the system at all levels (ability of the architecture do similar things in similar ways);
- Building simplicity – ability to implement the defined architecture;

Future directions: accelerators and brakes

The move towards open access appears to be an ongoing trend even if Rolands, Nicholas and Huntington predicted in 2004 that: “... a significant shift towards open access is, in the short to medium term, highly unlikely.” Waltham [2010] determined that the 9% publishers offering an open access as an option to authors in 2005 had increased to 30% in 2008 and that of the estimated 1,350,000 journal articles published in 2006, 19.4% percent are freely accessible. That is a sizable portion of scholarly publishing and with the Directory of Open Access Journals now reaching 6 285, and growing, this trend seems to be continuing.

New electronic publishing models based on self archiving have the potential to revolutionize scholarly communication, rendering it more efficient and effective [Correia and Teixeira, 2005].

It seems that the marriage of the commercial economy of publishers with the gift-exchange culture of the academy is being irreparably damaged. Scholars give their research findings to publishers at no cost and publishers then sell it back to them (to universities) at exorbitant prices. This is exacerbated by the anomaly in the scholarly publishing market, namely that both supply and demand has risen sharply [Chodorow, 2000].

Academe is notoriously slow to embrace change. The resistance to embrace the many other ways, apart from the traditional journal article or conference paper, in which scholarly and scientific discovery is communicated in professional assessments, is a big stumbling block [Roman, 2011]

Pasteur's quadrant applied

Keeping the quest for Pasteur's quadrant in mind, there is a need to identify the most desirable characteristics from the new forms of scholarly communication that can be presented as the product of a marriage between the theory of scholarly communication and the application of information technology and systems. The following noteworthy positive aspects of the different manifestations of scholarly communication can be distilled from table 1:

- Familiarity - no big departure from how it was done in the past and the ability to do similar things in similar ways.
- Immediacy - new material being made available all the time.
- Accessibility - low barriers to participation by contributors and users.
- Control - peer review and editorial vetting.
- Reciprocity - the gift-exchange culture remains in place.
- Responsiveness - communication and in particular feedback is fast.
- Inexpensive - no big investment required.
- Scalable - volume of information (number and length of submissions) not be limited.
- Neutrality of format - it just needs to be digital.
- Universal access - anywhere where access to the Internet is available.

Using deductive reasoning, relationships between the functions of scholarly communication and the positive characteristics of new forms of scholarly communication can be identified. Likewise relationships between the characteristics of information technology systems and the positive characteristics of new forms of scholarly communication can be identified. These are presented in table 2.

Theory of scholarly communication (Bohr's quadrant)	Pasteur's quadrant	Characteristics of ICT systems (Edison's quadrant)
Registration Certification Dissemination and awareness Archiving Rewarding	Responsiveness Control Familiarity Immediacy Accessibility Neutrality of format Scalable Universal access Reciprocity Cheap	Security Reliability Conceptual Integrity Usability Performance Availability Modifiability Variability Subsetability Building simplicity

Table 2: Relationships between the three quadrants

In order to return to the original format, the alternative presentation of these relationships is produced in quadrant format. This is also to show those elements identified with potential to significantly change and improvement the current scholarly communication system, see figure 4.

<p>Theory of scholarly communication (Bohr's quadrant)</p> <p>Registration Certification Dissemination and awareness Archiving Rewarding</p>	<p>Pasteur's quadrant</p> <p>Immediacy Accessibility Neutrality of format Universal access Control Reciprocity Responsiveness Scalable</p>
	<p>Characteristics of ICT systems (Edison's quadrant)</p> <p>Usability Modifiability Performance Variability Reliability Subsetability Availability Conceptual Integrity Security Building simplicity Functionality</p>

Figure 4: Pasteur's quadrant as it relates to scholarly communication

Conclusion

This paper started out with the hypothesis that indications of potentially significant change and improvement in the current scholarly communication system can be found in exploring the application of Pasteur's quadrant. Indeed use-inspired desirable characteristics were identified and it would be interesting to see what would develop should that become the focus of research to improve the scholarly communication system. It would therefore be fair to say that, should the power of Pasteur's quadrant be true, the pursuit of the following characteristics in bringing about a new scholarly communication dispensation would move the current one to the next level:

- immediacy,
- accessibility,
- neutrality all format,
- universal access,
- control,
- reciprocity,
- responsiveness,
- scalability

It might also serve libraries well to focus on these while they are trying to help bring about changes and improvements in the current scholarly communication system through various actions and initiatives. In 2009, Bourg, Coleman and Erway formulated a call to action for libraries with reference to scholarly publication. The call to action required that libraries:

*Commit to continual study of the ever-changing work patterns and needs of researchers; with particular attention to disciplinary and generational differences in adoption of new modes of research and publication.

*Design flexible new services around those parts of the research process that cause researchers the most frustration and difficulty.

*Embed library content, services, and staff within researchers' regular workflows; integrating with services other units provide (whether on campus, at other universities, or by commercial entities) where such integration serves the needs of the researcher.

*Embrace the role of expert information navigators and redefine reference as research consultation instead of fact-finding.

*Reassess all library job descriptions and qualifications to ensure that training and hiring encompass the skills, education, and experience needed to support new modes of research.

*Find ways to demonstrate to senior university administrators, accreditors, and auditors the value of library services and resources to scholarship; while providing services that may seem invisible and seamless to researchers.

*Engage researchers in the identification of primary research data sets that merit long-term preservation and access.

*Offer alternative scholarly publishing and dissemination platforms that are integrated with appropriate repositories and preservation services.

It is quite obvious that by answering this call to action libraries will solidify the role they have to play in the scholarly communication process. Whether it is for libraries to take the leading role in bringing about change in the scholarly communication system is an argument and discussion for another day.

The future of scholarly communication depends to some extent on whether technological determinism or social construction will be the determining force. Should social construction (the belief that social and cultural forces determine technical change) be the determining force, change will be much slower than what technology allows for. Should the opposing view of technological determinism (the belief that social and cultural changes are determined by technical forces) win the day, it will to some extent be a vindication of the power and potential in Pasteur's quadrant: scholarly communication practices and mechanisms one could hardly imagine today.

However it could be fairly safe to say that it will be neither one nor the other. This view is supported by Borgman [2007] who states that a combination of "...information, technology, and subject expertise will help build the human capacity necessary for digital scholarship." Also Roosendaal and Guerts [1997] are of the opinion that whatever scholarly communication system is arrived at, it will only be effective and efficient if each configuration appeals to the research community.

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