A three-phase model proposal for the evolution of scientific communication: from first print periodicals to current electronic communication system

Proposta de modelo trifásico para a evolução da comunicação científica: dos primeiros periódicos impressos ao sistema de comunicação eletrônica atual

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ABSTRACT

Scientific communication has undergone deep transformations, since the emergence of Internet. Aiming to provide further thought on the evolution of scientific communication, this paper features a historical overview of the scientific communication advances over the last twenty years through a three-phase model for the evolution of the electronic journal and the preprints services, and presents Brazilian contemporary panorama for scientific communication. The three-phase model presented in this work is an adaptation of that one proposed by Tenopir et al. (2003) to describe the patterns of journal use by scientists since 1990. The early evolutionary phase followed the emergence of the first digital journals and the creation of repositories in the Web for publishing preliminary versions of scientific literature on the author's initiative; by that time, most academics reproved electronic publishing initiatives. From 1996 and forward, in the consolidation phase, electronic journals were commonly identical to their print counterparts; the acceptance of the electronic format began to increase, and preprint services got underway in several disciplines. The advanced evolutionary phase started with the world discussion on open access to scientific information. The comparison of the current electronic journal with that viewed by enthusiasts in the first years of the 1990s shows that some aspects still remain to be improved in electronic formal and informal communication, towards effective dissemination of scientific information.

Keywords: scientific communication; electronic journal; e-publishing; open access; information dissemination.

RESUMO

A comunicação científica tem experimentado transformações profundas, desde a emergência da Internet. Como fomento à questão da evolução na comunicação científica, este artigo apresenta uma perspectiva histórica dos avanços na comunicação científica ao longo dos últimos vinte anos, por meio de um modelo de três fases para a evolução do jornal eletrônico e serviços de preprints, e fornece elementos que descrevem o panorama atual para

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a comunicação científica no Brasil. O modelo trifásico apresentado neste trabalho é uma adaptação daquele proposto por Tenopir et al. (2003) para descrever os padrões de uso de jornais pelos cientistas desde 1990. A fase evolucionária inicial seguiu a emergência dos primeiros jornais digitais e a criação de repositórios na Web para publicação de versões preliminares de trabalhos científicos por iniciativa do autor; àquele tempo, acadêmicos tradicionais reprovavam iniciativas de publicação eletrônica. De 1996 em diante, na fase de consolidação, os jornais eletrônicos comumente consistiam em cópias idênticas de suas versões impressas; a aceitação do formato eletrônico começou a aumentar, e os serviços de preprints disseminaram- se em várias disciplinas. A fase evolucionária avançada iniciou-se com a discussão mundial sobre o acesso livre à informação científica. A comparação do jornal eletrônico corrente com aquele imaginado pelos entusiastas nos primeiros anos da década de 1990 mostra alguns aspectos que podem, ainda, ser melhorados na comunicação formal e informal, visando a efetiva disseminação da informação científica.

Palavras-chave: comunicação científica; jornal eletrônico; publicação eletrônica; acesso livre; disseminação da informação.

INTRODUCTION

Social communication comprises the exchange of information between individuals by means of a common signal system, e.g., speaking, writing or through gestures. Scientific communication, specifically, is a component of social communication that has currently undergone profound transformations:

- Mikhailov defined that scientific communication is "the combined process of presentation, delivery, and receipt of scientific information in human society" (Mikhailov et al., 1984). The processes implicated in scientific communication – the basic mechanism for the existence and development of science – can be described as: the direct dialogue among scientists about research or development in which they are engaged;
- the visits to colleague's laboratories, scientific or technical exhibitions;
- the oral presentation by scientists in lecture halls;
- the exchange of letters, preprints, and off prints of publications;
- the preparation of research results and development for publication, including the choice of the form of publication (letter to the editor of a journal, manuscript for deposit, article in a journal, report, presentation, patent claim, rationalization proposal, survey, monograph, or textbook) and the place and time of publication;
- the editorial/publishing and typographic processes;
- the distribution of scientific publication;
- the library/bibliographic activity and manuscript work; and
- the scientific information activity, that comprises the collection, storage, searching, and distribution of scientific information (Mikhailov et al., 1984).

Formal scientific communication through scholarly journals exists since the 17th century. The documentation and dissemination of concepts through scientific works of accepted genre, as extensions of the seventeenth century scientific letters, appeared in 1665, with the first two scientific periodicals – the Journal des Sçavans (Paris) and the Philosophical Transactions of the Royal Society of London –, both published by scientific societies (Meadows, 1998).

In a natural way, scientific periodicals started to assign the role of acknowledgement of discoveries' authorship and to present information in a form of an indexed article (Schauder, 1994). Until nowadays, scientific periodicals continuous to be an important part of the scientific acknowledgement system (Cronin; Overfelt, 1995), and the assessment by experts of material submitted for publication – the peer review system – has remained as a useful quality control tool and a critical component of the editorial process and scholarly communication, adding value to the process of scientific communication through results validation.

A historical perspective of scientific communication

The last years of the 20th century have known a reaction to the restriction of the traditional system of

scientific communication. Many investigators and other actors have criticized the delay between submission and publication of works, which somehow reveals the inability of the traditional system to attend the increasing capacity demand for recent scientific progresses dissemination, as a result of the global expansion of research and development. The increasing specialization within all disciplines caused this exponential growth of information and brought about further expansion of new journal titles until the flood of new periodical literature began to spur the notion of 'information overload'.

By that time, the debate was still about:

- the obligation of depending on the editors for achieving diffusion of research results to the largest scale (Bachrach et al., 1998);
- the requirement of subscription or 'pay-per-view';
- the strictness of the peer review system;
- the high manuscript rejection rates;
- the tendency of system to focus on the quantity of output, favor sanctioned institutions and renamed authors, suppress new ideas and endorse traditional research methods (Harnad, 1998; 2000); and
- the price of journals increases causing cancellations by libraries, which, in turn, are followed by new price increases (Case, 2001).

The concern about developing new forms of formal and informal communication among scientists and the appearing of innovative approaches for accessing research and development results emerges from this scenery, together with the new information technologies' emergence, particularly Internet.

Since Internet presents the potential to disseminate information worldwide almost instantaneously, this newly emerged communication channel changed the way research used to be performed and the researchers' collaborate process. Other Internet properties like the multimedia ambient, the interactive media, the facility of establishing cooperation despite the time and geographic distances, and its applicability for both informal and formal communication provided additional elements to the debate on new forms of scientific communication.

With this new channel of communication, new opportunities appeared for scientific communication in such a way that cooperation among scientists has changed and the barriers between formal and informal literature started to fade, resulting in a continuum of collaborative and interactive work (Borgman, 2000; Kling; McKim, 2000).

This paper features a historical overview of the scientific communication advances, and proposes a three-phase model for the evolution of the electronic journal over the last twenty years, highlighting Brazilian current situation for scientific communication. Comparing the attributes of the current electronic periodical with that seen by enthusiasts in the first years of the 1990s, this study points out some aspects that still can be improved in electronic journal, towards effective dissemination of scientific information.

A three-phase model proposal for the recent evolution of scientific communication

The evolution of scientific communication over the past twenty years essentially encompasses the development of the electronic journal, which will be described in a perspective of the three-phase model proposed by Tenopir et al. (2003) to describe the patterns of journal use by scientists since 1990, with adaptations, as explained below.

The early evolutionary phase

Lancaster meticulously documented the basis of the increase in library costs in 1978, and saw "paperless information systems" as a possible solution to the problem (Lancaster, 1978). However, the real beginning of the electronic journal (or 'e-journal') is to be found in the late 1980's.

According to some sources, the very first electronic journal was "New Horizons in Adult Education" – a refereed journal focused on current thinking and research within adult education and related fields, published two or three times each year, launched by the Syracuse University Kellogg Project from 1987 (Hugo; Newell, 1991; Suber, 2007). Additionally, there are indications that the second electronic journal to appear was "Newsletter on serials pricing issues", from

the American Library Association, in 1989 (Tuttle, 1991), followed by the "Postmodern culture" (Johns Hopkins University), the "Psycolloquy" (American Psychological Association) and the "Public-Access Computer Systems Review" (University of Houston), all launched in 1990 (Bailey Jr., 1992; Miran; Medeiros, 2001). In the initial phase of development, electronic journals were innovative, characterized by the absence of a printed version and distributed by e-mail, ftp or gopher.

Additionally, the early 1990's saw the creation of repositories in the web for publishing preliminary versions of gray scientific literature (preprints) on the authors' initiative (self-publishing) – the e- prints archives. The first e-print archive, ArXiv, launched in August 1991 and used among high-energy theoretical physicists at the Los Alamos National Laboratory (Ginsparg, 1994), is still online and currently provides access to 406,884 e-prints in the fields of Physics, Mathematics, Non-linear Science, Computer Science and Quantitative Biology.

However, the first studies on usage and acceptance of electronic journals show that most academics viewed electronic publishing as experimental, at best. According to writings of Kling and Covi, a scholar who was facing a choice between publishing in a print journal and publishing in an electronic journal faced a choice between legitimate (but perhaps slow) publication, and more rapid publication in electronic journals that were viewed as of lesser quality or even not serious journals (Kling; Covi, 1995). The widespread notion was that print journals were better able to assure appropriate readership than electronic journals, with few exceptions (Kling; Covi, 1995).

In response to the first publishing experiments, Ann Okerson wrote a paper discussing several critical questions about the electronic journal and detailing possible directions that could be taken (Okerson, 1991).

In the paper, she described two interesting visions of electronic journals. The first vision delineates the subsequent evolutionary phase with exactness: in the majority of cases, electronic journals would mimic the current paper journal format, which means that the refereed content found in print journal would be replicated in the online site. The second vision suggests dramatic change in the whole process of scholarly communication, that would become instant, global, and interactive (Harnad, 1990). This visionaries' electronic journal would open windows onto ideas attached as supplementary files, footnotes, sounds, and visual matters – writing would not be confined to any place or time or group whilst paper distribution would take place secondarily.

The consolidation phase of the electronic channel for scientific formal and informal communication

The book "Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing", edited by Ann Shumelda Okerson and James J. O'Donnell, launched in 1995, makes publishing history (Okerson; O'Donnell, 1995). It was based on an e-mail discussion held in the summer and fall of 1994 about scientific journals and their future, and suggested a radically decentralized scholarly publishing model, in which scholars self-publish their works, which then may or may not be peer-reviewed (Brent, 1995; Okerson and O'Donnell, 1995).

In the consolidation phase, through collaboration with scholarly and professional societies, preprint services got underway in several disciplines, although still in the early stages of planning.

From 1996 and forward, possibly as a response to the recent debate on the future of scientific communication, headed by enthusiasts like Paul Ginsparg, Steven Harnad, Andrew Odlyzko, and Ann Okerson, many print journals started to produce electronic editions of their content. During this second stage of the evolution of scientific communication, the majority of electronic journals were close copies of their printed journals. Articles on paper were scanned and made available as bitmap files after the publication of the original articles.

At that point in time, scientists started to recognize electronic journals as alternatives to print journals (Harter, 1998; Tomney; Burton, 1998). In spite of that, peer group pressures (Gomes; Meadows, 1998), technical barriers and lack of knowledge (Bishop, 1998) disturbed the acceptance of electronic journals in the evolving phase.

From 1991 to 2000, there has been an incredible increase on the number of electronic journals (Table 1).

In that course of time, peer-reviewed electronic journals increased from 26% to 43% of total, which strengthens the notion that peer review was still considered the best available approach for quality assurance in scientific communication. In other words, the number of peer-reviewed electronic journals increased well over 550 times between 1991 and 2000. Although peer review has declared imperfections, some specialists admit that there is no viable alternative, whether on paper or on the electronic airwaves (Harnad, 1986, 1998).

Table 1. The growth of electronic publishing, peer review and charge requisition from 1991 to 2000.

Item considered	Number per year							
	1991	1992	1993	1994	1995	1996	1997	2000
Total number of electronic journals and magazines	27	36	45	181	306	1,093	2,459	5,451
Peer-reviewed electronic journals	7	15	29	73	139	417	1,049	3,900
Electronic journals and magazines that charge for access	2	2	6	29	72	168	912	-(1)

Data obtained from the Directory of Electronic Journals, Newsletters and Academic Discussion Lists and the Directory of Scholarly Electronic Journals and Academic Discussion Lists. (1)Missing value.

Digitization was definitely the major responsible for the dramatic rise in number of scholarly electronic journals from 1996 to 2000. Still in 1999, Wells found 387 'free' electronic journals, defined as "independent, electronic scholarly journals, that is, those that are available through the Internet, usually the World Wide Web, free of charge to the reader, and publish academic articles, usually peer reviewed" (Wells, 2007).

Coming back to the data presented in Table 1, it can be observed that the number of electronic journals/ magazines that charge a fee for access rose from 7% to 37%, in the first seven years. It clearly denotes that, if this number had continued growing at that rate and if a revolutionary movement had not occurred, around 2010 we would undergo an overload of electronic journals that no library would attend. Similarly to the 'library crisis', the payment for electronic access would be a great-unresolved question and a new impasse in scholarly communication would be generated.

In Brazil, the first electronic scientific journal was The Journal of Venomous Animals and Toxins including Tropical Diseases, launched in 1995. Published by the Center of Studies on Venomous Animals of the São Paulo State University (Unesp), its initial fascicles were distributed in diskettes (Souza, 2002, p.41). In parallel, the Nucleus of Biomedical Informatics (NIB) of the State University of Campinas (Unicamp) initiated a pioneer project of electronic scientific publication, with the development of the 'Virtual Hospital', a resource of medical information in the Internet. The Virtual Hospital was followed by the foundation of the e*pub – the Group of Electronic Publications in Medicine and Biology –, which was responsible for the development of electronic journals like the Online Journal of Plastic and Reconstructive Surgery, the first purely electronic Brazilian scientific periodic, and the Journal of the Cardiology Society of the São Paulo State.

A more recent and significant national initiative for the improvement of the scientific research communication was the Scientific Electronic Library Online (SciELO), a program that celebrates ten years of existence. The SciELO was implemented in the beginning of 1997 as a cooperative project between the Latin-American and Caribbean Center on Health Sciences Information (BIREME/PAHO/WHO) and the State of São Paulo Research Foundation (FAPESP). The first year was dedicated to developing a methodology to publish full-text journals on the Web, and the editors of ten Brazilian journals that comprised the first SciELO Brazil collection participated actively. The SciELO Brazil portal started operating publicly in 1998. As from 2002, the project has also been supported by the National Council for Scientific and Technological Development (CNPq) of Brazil. Promoted by the BIREME and supported by the CONICYT Chile, the SciELO progressively developed as a network of open access journal collections, extending its activities to the Caribbean countries, Portugal and Spain, using the same methodology to publish online journals and provide links in the internet, as well as to follow up the performance of individual articles, journals and collections.

The advanced evolutionary phase

In the advanced phase of the evolution of scientific communication, the number of available titles increased in the Internet, and the integration of this medium into the scientist's information habits turned out to be significant. Starting in 2000, this stage was characterized by the several initiatives taken in support of the open access to scientific information, at the same time the first 'Open Access' journals appear.

Committing to memory the concept of 'Open Access', it was first properly defined in 2001, at a meeting that took place in Budapest, promoted by the Open Society Institute, a group of open access activists (even though at the time they didn't all use the term 'open access' yet). Out of that meeting came the so-called 'Budapest Open Access Initiative' (BOAI) and open access was defined in that initiative as follows (Budapest Open Access Initiative, 2002):

> By 'open access' to this literature [primarily peer-reviewed journal articles, as mentioned earlier in the Initiative], we mean its free availability on the public internet, permitting any users to read, download, copy, distribute, print, search, or link to the full texts of these articles, crawl them for indexing, pass them as data to software, or use them for any other lawful purpose, without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. The only constraint on reproduction and distribution, and the only role for copyright in this domain, should be to give authors control over the integrity of their work and the right to be properly acknowledged and cited.

From BOAI, two basic strategies were established in order to make research articles freely available on the Internet: the self-archiving, which means the deposit of authors' refereed journal articles in open electronic archives; and the instigation of a new generation of journals committed do open access, and the assistance to existing journals that elect to make the transition to open access.

In April 2003, fifteen months later the BOAI, the 'Bethesda Statement' was proclaimed from a one-day meeting of scientists, funding agencies, librarians, scientific societies and publishers. The essence of open access' definition in the Bethesda Statement remained the same, but it focused more on actual legal and practical consequences (Open Society Institute, 2005).

Yet in 2003, the Max Planck Society in Germany, convened a meeting on "Open Access to Knowledge in the Sciences and Humanities" and produced the 'Berlin Declaration on Open Access', resulting the inclusion of the humanities in the discussion. This declaration considers that open access is real open access if:

- the article is universally and freely accessible, at no cost to the reader, via the Internet or otherwise, without embargo;
- the author or copyright owner irrevocably grants to any third party, in advance and in perpetuity, the right to use, copy, or disseminate the article, provided that correct citation details are given; and
- the article is deposited, immediately, in full and in a suitable electronic form, in at least one widely and internationally recognized open access repository committed to open access and long-term preservation for posterity (Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities, 2003).

After these innovative initiatives, many other movements around the world occurred in support of Open Access. In January 15, 2004, on the campus of the Pontificia Universidad Catolica de Valparaíso (PUCV) in Valparaiso, Chile, a workshop was held on the possibilities of electronic publication, in which 120 delegates from 15 countries participated, which resulted in the drafting of the Valparaiso Declaration for Improved Scientific Communication in the Electronic Medium. Few months later, in Brazil, participants at the 2nd International Digital Libraries Symposium in Campinas, on May 21, 2004, issued a statement in support of open access (Suber, 2007). The next official documents supporting the open access initiative in Brazil were the "Declaration of Salvador - Commitment to Equity" and the "Salvador Declaration on Open Access: the developing world perspective", which were produced during the International Seminar on Open Access for Developing Countries (Salvador Declaration on Open Access: the developing world perspective, 2005). In December 2005, as an initiative of researchers, librarians and São Paulo's citizens signed up a declaration

supporting open access to scientific information (Acesso..., 2005). In 2006, participants in the Convention on Biological Diversity in Curitiba, March 31, adopted a statement endorsing open access for biodiversity data. Little time after, Florianópolis declared support to open access, during a symposium of the National Association of Research and Postgraduate in Psychology (IBICT, 2006) whereas attendees of the 2006 iCommons iSummit, in Rio de Janeiro, released the Rio Declaration on Open Access (Suber, 2007).

At present, the Directory of Open Access Journals, DOAJ – a systematic service that covers free, full text, quality controlled scientific and scholarly journals – includes at the present 2602 journals (at the time of writing this paper), covering several subjects and languages (Directory of Open Access Journals – DOAJ, 2007). A survey on this directory reveals 203 Brazilian journals that currently provide open access to scientific information. Interestingly, from these 203 journals, 178 belong to the SciELO collection.

Equally significant, the Registry of Open Access Repositories – ROAR (2007), a service that promotes open access to the research literature pre- and post-peer review through author self-archiving, registers a number of 853 e-print archives: the majority content is Research Institutional or Departmental (437 repositories). With 50 repositories registered in ROAR, Brazil is among the nations that report the greatest number of repositories, occupying the 4th position of the ranking, just after the United States, the United Kingdom and Germany – 210, 93 and 78 repositories, respectively. From the Brazilian registered e-prints, only five are Research Institutional or Departmental archives. This data advertises that Brazilian scientific community has still not assimilated institutional repositories.

Another electronic service that provides a list of open access repositories around the world that wholly embraces the concept of open access to full text resources, excluding electronic journals - the Directory of Open Access Repositories – OpenDOAR (2006) - currently registers 852 repositories, and places Brazil in the 7th position, with 25 repositories reported, after the United States (250), Germany (110), the United Kingdom (94), Australia (51), the Netherlands (44), France (31), Sweden (30), and Canada (29). The analysis of data obtained from both ROAR and OpenDOAR shows that half of the Brazilian digital repositories really correspond to electronic journals archives.

Current view for scientific communication

Plenty of positive aspects associated to electronic journals, particularly those adopting Open Access policies, are acknowledged worldwide:

- Electronic publication can maximize the research results' impact thus promoting a change of roles in publication system and giving researchers the deserved acknowledgment. Regarding the impact of electronic journals, Lawrence registered that online articles are cited 4.5 times more often than offline articles (Lawrence, 2001), when considering articles within each year, and averaging across all years from 1990 to 2000.
- Information can be much more up-to-date and easy to find in Internet than could be achieved with paper.
- Foment institutions are interested in changing the view about scientific publication, in a way that financed researches could be as accessible as possible. Open Access could, this way, maximize access to scientific research, increase research's progress, impact, productivity and rewards. One of the core advantages of digital format, for the foment institutions, is its capacity for searching, which results in reducing lost time with duplicated efforts worldwide.
- With the ease of communication provided by electronic mails, a much greater feedback is achieved through the Web, favoring interactivity.
- Links are considered a mainstay of the hypertext format. Papers can link to those they have cited and, more interestingly, articles can be linked to those that cite them.
- Virtual reality, animation, interactive mathematical charts, and supporting data can present a deeper look into the results, adding value to digital scientific communication. That means that online journal can publish data, programs, animations, and multimedia components that no print journal can publish.

The proliferation of electronic journals continues to be phenomenal. The latest edition of the LISU Annual Library Statistics of 2006 reports that, of the more than 188,500 serials listed, 45,000 are available exclusively online or in addition to a paper counterpart (Creaser; Maynard; White, 2006).

By the way, there has been an increase this year in the number of periodicals available in CD-ROM, after a slight fall three years ago (Creaser; Maynard; White, 2006). >From those 45,000 periodicals, almost 7,000 are now published in CD-ROM, what denotes a search for alternative systems of scientific communication.

Based on a search of the 2002 online edition of Ulrich's International Periodicals Directory (2007), Tenopir et al. (2002) detected approximately 15,000 active, peer-reviewed titles, of which 12,000 were available electronically, and the majority of the electronic journals were still replicas of traditional print journals (Tenopir et al., 2003). Considering that the number of serial titles listed by Ulrich for the year considered was of 164,000, it is easy to find that 9.15% of the world' serial titles used peer review by that time.

Consistently with that reasoning, 80% of the peer-reviewed titles were then electronically available, which means that the electronic media has been legitimated for scientific communication and many electronic journals have achieved credibility.

The current consensus seems to be that, although there are problems with peer review, it is unlikely to be abandoned, but may be opened up. Some works propose a reform to peer review in order to encourage innovation without sacrificing quality control, particularly by developing new ways to undertake it online (Till, 2000). Publicly identified reviewers, readers and editors should post comments and authors would prepare a final version and submit it for publication in the archives of the desired journal.

However, much of the peer-reviewed literature is still unavailable through open access publishing. For instance, the number of journals listed in DOAJ in 2005 constituted only 7% of the world's peer-reviewed titles listed by Ulrich (Kirsop; Chan, 2005).

Calling attention to the Library and Information Science and through a survey of the electronic journals presently indexed at the DOAJ, it can be extracted that, from the 764 titles indexed, 71 are issues related to this field of knowledge. An analysis of the course of indexing of these journals, in the period of 1991 to 2006, reveals two major peaks (Table 2).

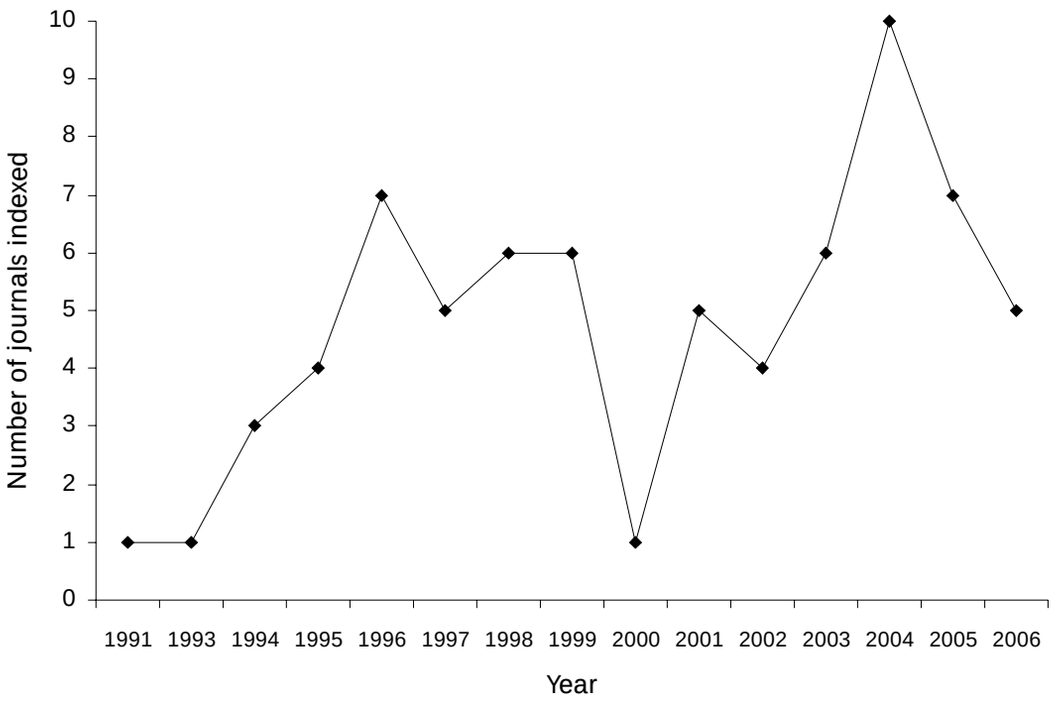

Table 2. Indexing of Journals on Library and Information Science in the Directory of Open Access Journals (DOAJ), from 1991 to 2006.

The boom of electronic journals on Library and Information Science observed in 1996 could be a repercussion of the discussion directed by the core group of enthusiasts on e-publishing (e.g. Paul Ginsparg, Steven Harnad, Andrew Odlyzko, and Ann Okerson), well known for their provocative writings.

The next prominent peak of electronic journals on Library and Information Science indexed in DOAJ, distinguishable in the year 2004, can be related to the important initiatives on Open Access that took place in 2003, starting with the BOAI, and followed by the Bethesda Statement on Open Access Publishing and the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities.

With respect to the adoption of the electronic media for scientific communication, a recent survey shows a significantly high acceptance of electronic journals and repositories, and an unwillingness to return to print versions only (Rusch-Feja; Siebeky, 1999). According to Swan and Brown (2005), a vast majority of authors (69%, among those who have never published in open access journals), if required to deposit copies of their published articles in one or more repositories, declared that would do so willingly (Swan; Brown, 2005). This data reinforce the acceptance of the electronic repositories by scientific community.

Moreover, a great number of journals – over 90% – give permission for authors to self archive their papers (Sherpa, 2006). However, self-archives still do not include many audio or video files, which represent less than 10% of digital objects available in the electronic repositories (Swan; Brown, 2005).

Although Internet has modified traditional information organization on a scale never seen before and instigated new scientific communication models, some questions remain not solved. Has Internet really revolutionized access to scientific communication? Have we achieved the place visionaries of the electronic journal described? With regard to scientific communication, are today's matters different from those sixteen years ago?

Visionaries of electronic journals dreamed that scientific ideas would be sprouted precisely when it is ready, criticized via the Internet, and put out immediately for open peer commentary or wide examination.

Unfortunately, electronic scientific communication has not reached that place. Not yet. The multimedia potential of Internet has been poorly used to advantage; the electronic journal frequently uses a conventional peer review system; the great majority of electronic journals still mimiks their print versions in design, conception, content delivery; and there also remains a significant gap between a manuscript submission and publication.

From the scenario Ann Okerson described for the evolution of scholarly journals (Okerson, 1991), most predictions have become true in this advanced phase of the evolution of scientific communication: computer equipment and user-sophistication are currently pervasive, but not ubiquitous; electronic and paper versions are available for serious academic journals; subscription model decreases whereas license and single-article models expand; some journals transfer their electronic versions to commercial owners, but access costs are low; secondary services re-think roles at the same time as other indexing services strengthens; new niches are created; publishers without electronic delivery shrink; and Copyright Law is being revised. Just one of Okerson's predictions seems not to correspond to reality in the early years of the 20th century: the occurrence of stratification of richer and poorer users, universities, and nations.

Although there was a hesitation that with information converted to digital formats, scholars in developing countries would be disadvantaged, some thinkers argue that electronic journals would be a tool for further breaking down the barriers to democratic research, in view of the fact that it is still cheaper for these researchers to get one computer with Internet access than to subscribe to many journals (Ginsparg, 1996; Neal, 1997).

Open access or not, the current electronic journal has still to surpass some barriers, like:

- the connectivity barriers: billions of people do not have access to the digital technology, and millions of serious scholars are offline;
- the censorship barriers: as a matter of fact, many schools, employers, and governments want to limit what you can see;
- the language barriers: most online literature is in just one language, a good number in English, and machine translation is very weak;
- the handicap access barriers (most sites are not accessible to handicapped users); and
- Web sites can change their URLs or disappear altogether, in such a way that information could be lost.

CONCLUSIONS

Information produced in the context of research and development constitutes a public good, since it most frequently counts on public financial resources: consequently, access must by guaranteed to all who need it. Therefore, open access electronic journals, together with institutional and thematic digital repositories, will continue strong. Electronic repositories do not substitute scientific periodicals' role, but complement them, taking advantage of the Internet benefits and promoting rapid diffusion of research results.

Of course, formal and informal systems of scholarly communication have to transcend several barriers. Researchers from some disciplines still have not accepted electronic channel as a legitimate means for scientific communication, and only when all those obstacles are overcome, the electronic journal will reach the place visionaries described for scientific communication in the electronic age.

Rather than just recreating a print journal in exact format, it is expected from editors that electronic journals shall innovate with the use of multimedia (e.g. moving images and sound), enrich the communications format (e.g. through inclusion of embedded software, datasets, etc.), use new navigational models (e.g. incorporating hyperlinks), increase user involvement and interaction, and develop new distribution formats (e.g. continuous addition of articles instead of serialization in volumes and issues).

The scientific communication advances all over the world during the last twenty years can be analyzed through the three-phase model perspective presented by Tenopir et al. (2003) with adjusting. Formal systems of scholarly communication, in developing countries like Brazil or in the most prosperous nations still have to transcend several barriers until the electronic journal and eprints services reach the place visionaries described for scientific communication in the electronic age.

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