Fermilab-Print-01-001

The Place of E-Prints in the Publication Patterns of Physical Scientists

Kate Manuel

ABSTRACT. E-prints, electronic equivalents of paper preprints used by scientists for rapid, informal communication of research, have recently proliferated. Empirical research on e-prints has not, however, been commensurate with increasing numbers of e-print servers, scientists authoring e-prints, or researchers accessing e-prints. This study examines a sample of e-prints randomly selected from three e-print servers to ascertain e-print authors' type and country of employment, level of collaboration, citation of other e-prints, level of publication in traditional, peer-reviewed or letters journals, and eventual transformation of e-prints into refereed publications. *[Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <getinfo@haworthpressinc.com> Website: <http://www.HaworthPress.com> © 2001 by The Haworth Press, Inc. All rights reserved.]*

KEYWORDS. E-prints, preprints, scientific communication, electronic publishing, scholarly publishing

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This research was funded by a 1999-2000 CSUH Faculty Support Grant. The author would like to thank former colleagues at CSUH, especially David Merignollo, research assistant for this project, and Lynn LaFleur, interlibrary loan coordinator, for obtaining numerous bibliographic items not available locally.

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INTRODUCTION

Preprints, manuscripts of articles yet to be published (Lim 1996), have figured prominently in scientists' informal communication of research since the 1970s (Peskin 1994). In the late 1980s and early 1990s, scientists–notably Paul Ginsparg and colleagues at Los Alamos National Laboratory (LANL)–began posting preprints on the Internet (Ginsparg 1997). In their new, electronic environment, preprints came to be called e-prints, and they enjoyed quicker dissemination, wider distribution, and lower costs than paper preprints. Many scientific and professional societies presently maintain e-print servers. The LANL server itself has recently experienced some 60,000 daily user connections to its more than 100,000 e-prints (*Web Server Statistics* 2000). Several events in 2000 heightened public interest in e-prints: the Universal Preprint Service Initiative (Van de Sompel and Lagoze 2000), later known as the Open Archives Initiative (*http://www.openarchives.org*), was announced with the goal of establishing "interoperability standards supporting the search and retrieval of e-print papers from all disciplines" (Luce 2000, 184); efforts to integrate e-print archives through citation linking were begun (Ginsparg et al. 2000); Chemical Abstracts Service began indexing selected e-prints (Tomaiuolo and Packer 2000); and Chemweb.com (*http://preprint.chemweb.com*) began hosting e-prints for chemistry (Guterman 2000).

E-prints have been frequently mentioned in the literatures of librarianship and of science since 1990, but treatments of them have chiefly been descriptions of particular e-print servers' policies and performance, or speculations about e-prints' potential impact on scientific publishing. Gregory Youngen's study (1998) of the frequency with which articles indexed in *Science Citation Index* cite e-prints and Stephen Harter and Taemin Kim Park's study (2000) of journal editors' views on publication of papers previously posted on the Internet are among the few studies of e-prints that ground their conclusions in empirical research. Although Bob Hanisch (1994) called for study of the metrics of e-prints, especially the frequency with which e-prints are transformed into peer-reviewed journal articles, in 1994 at the E-Print Archive Forum of the American Physical Society, there has, heretofore, been little quantitative research on how e-prints fit into the publishing activities of the scientists authoring them. This is somewhat surprising, since scientists' formal and informal communicative behaviors have traditionally been well studied by librarians and other researchers. Librarians, in particular, have been interested in understanding how scientists produce and communicate research because this information can be used to facilitate patrons' retrieval of scientific information. Knowledge of how scientists communicated in the pre-electronic

preprint environment has not yet, however, been re-examined in light of the proliferation of e-prints.

THE PROBLEM

Scientists produced paper preprints for distribution to colleagues as a way of coping with delays inherent in publication in a print-on-paper environment. The costs of producing and mailing paper preprints kept the number of preprints distributed low. One study of preprints found that although over 50% of authors distributed at least one preprint prior to publishing an article, the median number of copies of a preprint distributed was six, with only 1/6 of authors sending out over 25 copies of a preprint (Crawford, Hurd, and Weller 1996, 68).[1] The limited distribution of paper preprints kept communication within narrow circles of researchers mutually known to be working on particular topics,[2] and some libraries played an important role in acquisition and accessing of preprints. E-prints, however, can be distributed more quickly, more widely, and at less cost than paper preprints. Their availability on e-print servers expands the range of potential readers and removes the need for library collections of preprints.[3] In fact, e-prints are so successful in communicating scientific research quickly and inexpensively that some have wondered whether e-prints could, for at least certain types of scientific authors reporting certain types of research, take over journal articles' roles as fosterers of scholarly dialog and as communicators of scholarly research results to large communities in timely fashion.[4] No longer vehicles for dialog or communicators of research, journal articles would be left to certify authors' reputations for purposes of retention and promotion (Guterman 2000; Stankus 1999, 21)[5] and to archive past research (Dow 2000).[6] This altered view of journal articles' purpose is conveyed by one physics editor quoted in Stephen McGinty's *Gatekeepers of Knowledge* as saying:

> . . . in physics, nobody except a student at a place where you didn't really have active physicists would ever learn anything from a physics journal. That's just where papers eventually were published so that [they] would look official and somebody could get tenure. All of the real action was occurring first in . . . [e-prints]. (1999, 100)

Some champions of e-prints even describe the traditional journal publication system as a "Faustian bargain" between scientists-authors, who simply want to share their findings as expeditiously as possible, and publishers, who have thus far profited from science's communicative norms (Harnad 1997).[7]

Central to discussion of e-prints' relationship to peer-reviewed journal articles are the questions of (1) which scientific authors produce e-prints, (2) how e-prints fit within the broader publishing behaviors of their authors, and (3) with what frequency e-prints become peer-reviewed journal articles. While physics and mathematics are commonly described as accepting of e-prints (Lim 1996, 22; Luzi 1998, 132; R. Youngen 1996), other scientific disciplines have been less welcoming. It is often said, for example, that "e-prints are not compatible with the culture of chemistry" (Guterman 2000).[8] In addition to disciplinary differences in the degree to which scientists produce e-prints, one might also expect differences based upon scientists' employment within academia, research laboratories, or industry, as well as upon the frequency with which scientists publish generally. Finally, although some have suggested that large numbers of e-prints will not be transformed into journal articles, others claim that virtually all e-prints eventually become articles in peer-reviewed publications. Marianne Burke, for example, expresses fear that "[s]ome researchers may forego seeking journal peer review in favor of rapid dissemination through exclusively electronic mechanisms" (2000, 23), and Bert TePaske King envisions the appearance of "final form" e-prints, papers that are "not published, either out of rebellion against traditional peer review . . . or out of isolation from it" by, for example, authors already possessed of tenure (1994).[9] Others claim that most e-prints are "uploaded in conjunction with journal submission" (Perry 2000); that "all those papers in Ginsparg's archive eventually appear in paper journals" (Harnad 1995, 290);[10] and that "peer-respect" controls quality as well as traditional peer review by discouraging posting of poor quality e-prints (Berrie 2000).[11]

OBJECTIVES

This study explores the institutional settings of authors posting e-prints, the place of authors' e-print production within the context of their recent publications; and the degree to which authors transform e-prints into publications in peer-reviewed journals. Specifically it seeks to assess:

- the relative percentage of e-print authors employed by academic institutions, research laboratories, and industry;
- the relative percentage of e-print authors working in various countries;
- the frequency with which authors collaborate in producing e-prints, including the frequency with which authors engage in international collaborations in producing e-prints;

- the degree to which e-prints cite other e-prints or traditional, peer-reviewed sources;
- the frequency with which e-print authors have recently participated in traditional, peer-reviewed publishing; and
- the percentage of e-prints transformed into peer-reviewed journal articles, as well as the time interval between e-print and journal article.

Whenever possible, attempts are made to relate findings to what is known of scientists' publishing in the print environment. It is hoped that these findings and the conclusions drawn therefrom will be of some help in the practice of librarianship, as librarians assist patrons in locating e-prints' information, as well as in laying groundwork upon which further discussion of the emergent phenomenon of e-prints can draw.

METHODOLOGY

This is essentially a bibliometric study in that it focuses on "extrinsic facts about publications," like the time and place of publication, the author's identity and affiliation, the literature cited, etc. (Paisley 1989, 707). One hundred e-prints were selected from each of three different e-print servers or bibliographic databases for a total of three hundred e-prints. The decision to limit the sample size to three hundred e-prints was strictly the result of funding available for this project. Attempts to create a weighted sample, proportionately representative of the various characteristics of e-prints and their authors, were deemed unfeasible, as these characteristics were precisely what was unknown–in any empirical sense–when the study began. These three hundred e-prints mark a beginning to this line of research, and further, similar studies are needed to ascertain exactly how representative this sample is of all e-prints and e-print authors.

The e-print servers or bibliographic databases were:

- MPRESS/MathNet.preprints, *http://MathNet.preprints.org*, for mathematics;
- LANL's ArXiv, *http://www.arXiv.org*, formerly xxx (*http://xxx.lanl.gov*), especially the part of it that formerly supported the Chemical Physics Preprint Database (*http://www.chem.brown.edu/chem-ph.html*), for chemical physics/physical chemistry;[12] and
- SLAC/SPIRES HEP (high energy physics) Database, *http://www-spires.slac.stanford.edu/spires/hep/*, from the Stanford Linear Accelerator Center, for high energy physics. SPIRES is not an e-print server in the

sense of hosting complete electronic texts of e-prints; rather, it is a subject-focused database of high energy physics literature that links to full text of e-prints or bibliographic entries at other servers. E-prints listed in SPIRES were included in this sample because SPIRES is commonly mentioned in discussions of scientists' ability to access e-prints (cf. Youngen 1998), because SPIRES represents access to e-prints in ways more characteristic of traditional bibliographic control than MPRESS or ArXiv (Crawford, Hurd, and Weller 1996), and because it was thought that these differences in e-print hosting and distribution might relate to characteristics of e-prints and authors.

Overall, these three e-print servers or bibliographic databases were selected for study because they provide access to materials from disciplines or fields variously accepting of e-prints and because their e-print distribution or citation mechanisms were organized upon different models. High energy physics, along with astronomy, has long been highly accepting of preprints and e-prints. Only one of these two, high energy physics, was selected for study, as it was thought that the findings from one field might be characteristic of the other. Looking at high energy physics e-prints cited in the SPIRES database also provided the opportunity to examine e-prints accessed through one model of an e-print distribution system, an "umbrella" bibliographic database referencing e-prints on many other servers. Mathematics e-prints were included because mathematics as a discipline has been fairly accepting of e-prints. Because mathematics scholarship can be less dominated by work done at big research laboratories in the United States and other scientifically oriented countries, it might also be more reflective of e-prints' potential opening of opportunities to scientists from other places. MPRESS further represented an e-print distribution mechanism on a somewhat different model than either ArXiv or SPIRES. While SPIRES is fundamentally a bibliographic database focused on high energy physics and ArXiv relies upon author-supplied information in providing posting capabilities for various disciplines, MPRESS attempts to cover all of mathematics and relies upon authorial posting, but also furnishes some bibliographic structure by providing browsing categories. Findings of this study may not be completely generalizable to e-prints found on other servers, but they do provide a basis for comparison.

Although a weighted sample was not possible, as few characteristics of e-prints and their authors were known when the study began, the study did not simply examine the first 100 e-prints that appeared on the screen of the e-print servers or bibliographic databases. It was thought that doing so would lead to examination of only more recently posted e-prints and that the results might not be characteristic of earlier e-prints. Instead, estimates of the approximate

size of each archive were used in selecting every xth paper from it. In practice, this method meant somewhat different things in selecting e-prints from these distribution mechanisms. When the sample was compiled, in December 1999, MPRESS contained 19,000 e-prints, of which the sample examined every 190th e-print, or .53% of the total MPRESS listings. With ArXiv/Chemical Physics Preprint Database, there were 1,000 chemistry-related e-prints, of which the sample examined every 10th e-print, or 10% of the total. SPIRES included over 300,000 bibliographic citations–not all of which were to e-prints. Only e-prints were included in the sample, though, and when, for example, the 3000th listing in SPIRES was not for an e-print, the next subsequent e-print listed was added to the sample and the count forward continued from the record that was not an e-print. The e-prints selected represented postings over 10 years, ranging from 1989 to 1999. Not all e-prints were listed by their servers or citation databases in exactly reverse chronological order, though, and samples did not evenly distribute themselves over this 10 year span. MPRESS listings, in particular, deviated from reverse chronological order–leading to what seems to have been over-representation of older e-prints in that portion sample. Transformation of these e-prints into articles in peer-reviewed publications was tracked via searches in *Science Citation Index/Web of Science* (*SCI/WOS*) to see what percentage of e-prints became journal articles. Not all e-prints are intended to become journal articles; some represent conference presentations and are published in conference proceedings. Using this methodology, only publications in materials indexed by *SCI/WOS* would be found, resulting in some under-counting of the numbers of e-prints published in some fashion. The number and types of documents cited by the e-prints, as well as the number of co-authors, were determined by examination of the e-prints themselves.

These 300 e-prints represent the work of 820 unique authors, whose affiliations, countries of work, and recent publishing activities in traditional, peer-reviewed publications were also studied. The sample of chemical physics/ArXiv e-prints yielded 255 authors; mathematics/MPRESS, 185; and high energy physics/SPIRES, 380, with a single high energy physics e-print accounting for 101 of the 380 authors. Because the rest of the high energy physics/SPIRES articles in the sample were not so heavily multi-authored, findings are consistently expressed in terms of the sample with and without the authors of this e-print. *Science Citation Index/Web of Science* (*SCI/WOS*) was used to search authors' affiliations, countries, and recent publications.

The sample was assembled in December 1999, and all data compilation occurred in a six month period between January and June 2000. A Microsoft Access database designed for this purpose was used for tabulating data. The *Web of Science* version of *Science Citation Index* was used for searching.

Bibliometric survey is a research technique common in librarianship and one that serves well, by being unobtrusive and having stable, easily obtainable measures, when the topic studied focuses on the results and products of research (Qin, Lancaster, and Allen 1997). Of course, a common criticism of quantitative methods is that by "emphasizing . . . communication through the published literature," they "perpetuate a 'rationalized' view of science" (Edge 1979, 112). Admittedly, the present study contributes little to understanding why particular, individual authors post research results as e-prints. This is an important issue, but given the present state of research on e-prints, establishing broad metrics describing the publishing patterns of e-print authors seemed a sound first course.

FINDINGS

1. *The relative percentage of e-print authors employed by academic institutions, research laboratories, and industry.*

On two of the three e-print servers, fewer e-prints were authored by persons employed in industry than by persons employed in research centers or laboratories or in academic departments. When multiple affiliations were listed for an author, the first affiliation only was recorded, on the assumption that it constituted the primary affiliation. For high energy physics/SPIRES, excluding the exceptionally multi-authored e-print, of the 279 authors, 14 (5.01%) were employed in industry; 138 (49.46%) were employed in research centers or laboratories; and 125 (44.8%) were employed in academic departments. Including the extremely multi-authored e-print, of the 380 high energy physics/SPIRES authors, 14 (3.68%) were employed in industry; 141 (36.84%) were employed in research centers or laboratories; and 224 (58.9%) were employed in academic departments. The affiliations of 3 of the 279 or 380 authors, 1.07% or .79% respectively, could not be tracked. For mathematics/MPRESS, of the 185 authors, 31 (16.76%) were employed in industry; 20 (10.81%) in research centers or laboratories; and 131 (70.81%) in academic departments. Affiliations for a significant number of authors–31of 185 (16.76%)–could not be tracked in SCI or on the Internet. For chemical physics/ArXiv, of the 255 authors, 6 (2.35%) were employed in industry; 92 (36.08%) in research centers or laboratories; and 158 (61.96%) in academic departments.

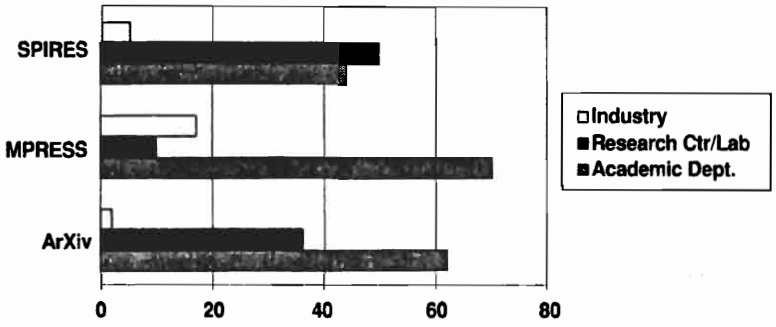
One might have predicted that researchers working in industry, or even in research centers or laboratories, where requirements of publishing for tenure are not operative, would be more likely to rely upon e-prints for rapid communication of research results than scientists in academic departments (Guterman 2000; Meadows 1998, 191). This was not the case, however, and perhaps should not have really been expected, as much industry-based research focuses upon the development of new products and applications and is deliberately not shared/communicated. On two of three e-print servers, researchers in industry made up the lowest percentage of authors. Further, only in high energy physics/SPIRES, and only then when the e-print with 101 authors was excluded, did the percentage of e-print authors in research centers or laboratories exceed that of authors in academic departments. Overall, it seems as if academic authors, despite lingering concerns about electronic publishing's place in retention and promotion decisions, are nevertheless publishing e-prints (see Figure 1).

2. *The relative percentage of e-print authors working in various countries.*

E-prints on all three servers were authored by scientists then working in countries around the world (Table 1). (Attempt was not made to determine country of birth or naturalization, merely the country in which the scientist/author then worked.) Although the majority of electronic preprint distribution systems are located in the United States (Lim 1996, 22), many of these systems are mirrored in other countries (Halpern 2000, 42), and a large number of user hits on these servers are reported to come from developing countries (Blume 2000).[13] Most e-prints are, however, authored by researchers working in "first world" or "developed" countries. One factor accounting for the paucity of e-print authors from developing countries is undoubtedly the emergence of "bigger science," which concentrates larger numbers of resources (workers, equipment, and money) in fewer, more specialized research centers (Crawford, Hurd, and Weller 1996, 2). The fact that few countries or regions have a particle accelerator, for example, serves to keep small the pool of authors of experimental high energy physics papers. Also, despite e-prints' commonly being credited with making invisible colleges more accessible and easily joined (Crawford, Hurd, and Weller 1996, 100), "third world" settings have historically proven ill-suited for the expansion of research networks because of the relative lack of resources and contacts (Crane 1972, 58). Enthusiasts who describe e-prints as an " 'ultrademocratic' approach to information production and distribution" (Harnad 1993) should be aware that while e-prints may represent a "more equitable and efficient" model of disseminating research results to scientists worldwide (Van de Sompel and Lagoze 2000), e-prints have not yet fundamentally democratized the production of information.[14]

The countries Germany, Israel, Japan, Russia, and the United States each account for over 10% of e-print authors on any of these e-print servers. Austria, France, Italy, Mexico, Sweden, and the United Kingdom each account for over 4% of authors on at least one of these servers. The remaining authors are

FIGURE 1. Author Affiliation by Employing Institution (in Percentages)



distributed widely among 30 other countries. Of African countries, only Algeria and South Africa display e-print authorship. These findings reflect the prominence of the United States, Europe, and Japan in high energy physics (Crane 1972, 64), of Asian countries in physics generally, and of Asian and Eastern European countries in chemistry and physics (Dore et al. 1996, 594).

3. *The frequency with which authors collaborate in producing e-prints, including the frequency with which authors engage in international collaborations in producing e-prints.*

The average number of co-authors per e-print varies by disciplinary field, suggesting that differences in the research and publishing cultures of mathematics, chemical physics/physical chemistry, and high energy physics are reflected in e-prints' authorship. Mathematics/MPRESS displays the lowest number of co-authors per publication, while high energy physics/SPIRES displays the highest. For chemical physics/ArXiv e-prints, the number of co-authors ranged from a low of 0 to a high of 9 with an average of 1.65. For mathematics/MPRESS, the low is 0, the high 4, and the average 1.335 co-authors. For high energy physics/SPIRES, the low is 0, the high 15, and the average 5.29 for the sample excluding the e-print with 101 authors. If this e-print is included, the high is 100 and the average 30.45.

These findings conform to earlier findings of disciplinary differences in co-authorship in the print environment. Mathematicians have tended to work alone, or occasionally with 1 to 2 other people (Meadows 1998, 108), although mathematics "has lately been seeing a dramatic increase in joint-authored papers" (Walsh and Bayma 1996, 346). Chemical physics also has seen an in-

TABLE 1. Author Affiliation by Country, in Percentages

Country Name	ArXiv	MPRESS	SPIRES
Algeria	.39%		
Argentina	2.75%	1.62%	1.07%
Armenia			.358%
Australia		.54%	
Austria		5.95%	
Belgium	.39%		
Brazil			1.43%
Canada		3.78%	1.43%
Chile	.39%		
China	2.75%	.54%	2.5%
Colombia			.358%
Czech Republic		2.7%	
Denmark			.358%
Finland	.39%	1.62%	
France	8.24%	2.7%	9.67%
Germany	7.45%	23.24%	14.33%
Greece			1.07%
Hungary	.78%		.358%
India	1.18%	.54%	1.07%
Israel	13.73%	4.87%	
Italy	3.14%	4.87%	4.3%
Japan	3.53%	.54%	14.69%
Mexico	4.31%		.358%
Netherlands	1.18%	1.62%	
Norway		.54%	
Poland	.39%	1.62%	.358%
Portugal		.54%	
Romania			2.37%
Russia	7.06%	2.16%	11.11%
South Africa			.358%
South Korea			2.87%
Spain	3.92%	.54%	.358%
Sweden	4.31%	1.62%	
Switzerland	.78%	.54%	2.15%
Taiwan		1.08%	
Ukraine		.54%	
UK	3.14%	4.32%	4.65%
USA	32.55%	15.67%	17.2%
Vietnam		.54%	
Unknown		15.67 %	4.3%

crease in the number of multiple-author papers over the twentieth century (Bahr and Zeman 2000, 411), although it displays nowhere near the degree of collaboration characteristic of high energy physics, where hundreds of collaborators and co-authors are the norm (Crawford, Hurd, and Weller 1996, 20; Walsh and Bayma 1996, 347). In fact, the sample of high energy physics e-prints selected from the SPIRES database seems somewhat unrepresentative of high energy physics publishing in that only one e-print had a large number of authors (see Figure 2).

A number of e-prints do display international collaborations in authorship. International co-authorship is highest in MPRESS with 27 out of 100 e-prints (27%) having co-authors from different countries. In ArXiv, 24 out of 100 e-prints (24%) display international co-authorship, while 11 out of 100 (11%) SPIRES e-prints have co-authors from multiple countries.[15] The fact that all three e-print servers display international collaboration in over 10% of their papers can be related to recent increases in international collaboration (National Research Council 1997, 19) and in the percentage of papers published with authors from more than one country (Walsh and Bayma 1996, 347-348). The higher degree of international co-authorship in mathematics e-prints is probably reflective of the "dramatic increase" in the number of jointly authored papers, nearly all collaborations of remote colleagues, that Walsh and Bayma (1996, 347) have noted for mathematics. Again, however, it must be noted that the countries involved in international co-authorship are invariably First World or developed ones (see Figure 3).

4. *The degree to which e-prints cite other e-prints or traditional, peer-reviewed sources.*

E-prints do not yet seem to have exactly the same research standing as peer-reviewed publications, as e-print authors themselves are not citing large numbers of e-prints. E-print authors' citations are still primarily to articles in peer-reviewed publications. ArXiv e-prints had a low of 0 citations to other e-prints, a high of 4, and an average of .35. For MPRESS, the low was 0, the high was 5 and the average .286. For SPIRES, the low was 0, the high was 10, and the average was .57. The fact that high energy physics e-prints displayed the highest number of citations to e-prints is not surprising, given the importance and early acceptance of e-print communications in high energy physics. It is interesting to note that e-prints' citations do conform to Eugene Garfield's finding that a scientific article has, on average, 15 citations (1979, 2). Too much significance can probably not be attached to these findings, however, for two reasons. First, the totality of published information which e-print authors could be citing still contains more traditional book and journal publications than e-prints. Secondly, e-print authors planning to publish their work in jour-

FIGURE 2. Average Number of Co-Authors per E-Print

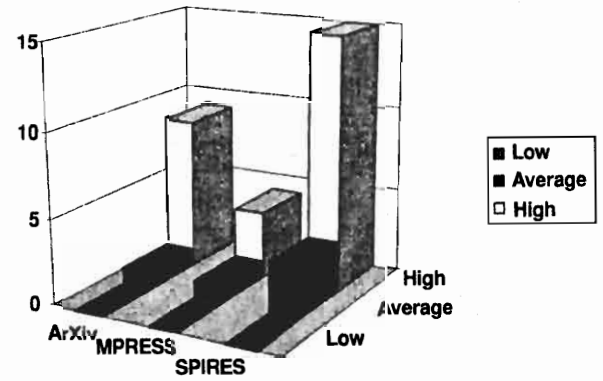
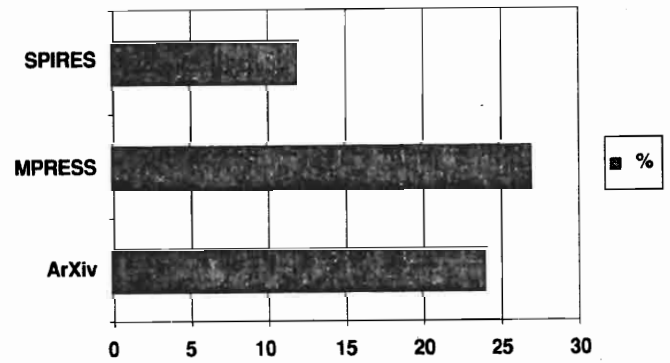


FIGURE 3. Percentage of International Co-Authorship of E-Prints

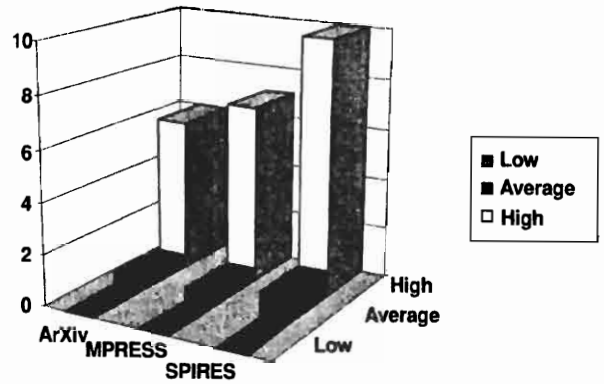


nals that discourage the citation of e-prints may consciously minimize their use of others' e-prints as sources (see Figure 4).

5. *The frequency with which e-print authors have recently participated in traditional, peer-reviewed publishing.*

E-print authors seem to be active participants in traditional, paper publishing. This includes not only publications in peer-reviewed, scholarly journals

FIGURE 4. Average Number of Citations to Other E-Prints per E-Print



but also publications in letters journals, traditional, rapid communicators of non-peer-reviewed research findings and a communicative venue with which one might expect e-print authors to dispense. In the period 1998-1999, the author of an ArXiv e-print produced a low of 0, a high of 49, and an average of 5.38 non-e-print publications. Of these publications, a low of 0, a high of 10, and an average of .66 were in letters journals. MPRESS authors produced a low of 0, a high of 26 and an average of 1.6 non-e-print publications, with a low of 0, a high of 2, and an average of .097 of these in letters journals. For SPIRES, excluding the e-print with 101 authors, there were a low of 0, a high of 62 and an average of 5.4 non-e-print publications, with a low of 0, a high of 33, and an average of 1.95 of these in letters journals. Inclusion of the SPIRES e-print with 101 authors yielded a low of 0, a high of 62, and an average of 9.39 non-e-print publications per author, with a low of 0, a high of 33, and an average of 4.4 of these in letters journals.

Concern that large numbers of e-print authors might be opting out of the peer review system by posting results strictly to e-print servers seems unfounded, at least at present. Certainly some e-print authors are publishing nothing, at least for limited time periods, in peer-reviewed and letters journals. Other e-print authors continue to be active contributors to traditional publications. These authors' submissions to refereed scholarly and letters journals, however, are not necessarily the particular pieces of research represented in particular e-prints, whose individual contents may never be subjected to peer review or transformed into traditional articles. Nevertheless, it is significant that many of these authors continue subjecting at least some of their research

results to peer review. In fact, the average e-print author engages in what seems a fairly healthy level of publication activity in traditional publications. Over a two year period, many have produced far more than the one to two publications that previously characterized the output of an entire career (Crane 1972, 35). Indeed, the average ArXiv and SPIRES author, even when the e-print with 101 authors is excluded from calculations, produced slightly more articles over a two year period than were reported by Meadows in 1998 as characterizing the out-put of a three year period. [The SPIRES authors are perhaps themselves atypical of scientists generally in that high energy physics is characterized by having a relatively large population of theorists who contribute prodigiously to the total publication output of the field.] Meadows noted that scientists produce on average 5.1 articles in a three-year period and 8.6 in a five-year period (1998, 86).[16] It seems not unreasonable to say that production of e-prints is simply part and parcel of the general escalation of publishing productivity per researcher in the sciences.[17] In fact, the high level of publishing productivity of these authors probably corresponds to their high level of co-authorship. As Bahr and Zemon state, "The greater the number of collaborators, the greater the potential for increased productivity"; while a chemist working alone or with another author can write four papers in five years, a chemist working with more than 12 collaborators can write over 14 articles (2000, 413) (see Figures 5 and 6).

6. *The percentage of e-prints transformed into peer-reviewed journal articles, as well as the time interval between e-print and journal article.*

Predictions that 90%, or "virtually all," e-prints are later published in peer-reviewed journals seem, from the evidence of the e-prints in this sample, to be overly optimistic. Many e-print servers, like ArXiv, allow authors to annotate their e-print submissions with subsequent information relating to their publication in peer-reviewed journals; that is, authors can later add notes to their e-prints indicating that their contents have been submitted to, accepted by, or published as articles in particular journals. The authorial annotation system seems, as will be seen, unreliable–as many authors do not return to update the publication information on their e-prints once their articles are published. Because the author was aware of this situation at the beginning of the research project, a decision was made to track the publication of all e-prints' contents in peer-reviewed journals by doing author searches in *Science Citation Index/Web of Science* (*SCI/WOS*) rather than to relying upon publication information provided by the author or the e-print server. One limitation of using *SCI/WOS* to do this, though, is that e-prints appearing in publications not indexed by *SCI/WOS* would be missed, making it appear as if these e-prints

FIGURE 5. Average Number of Publications per E-Print Author (1998-1999) (SPIRES Sample Does Not Include the E-Print with 101 Authors)

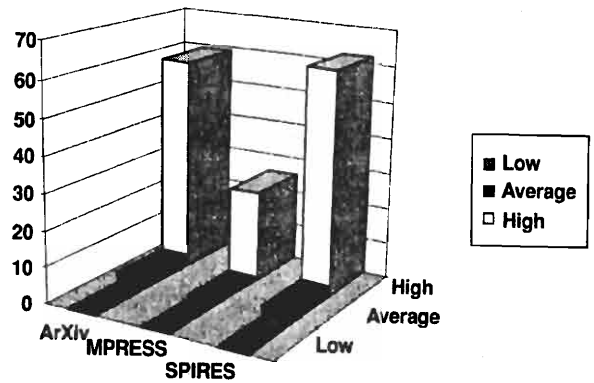
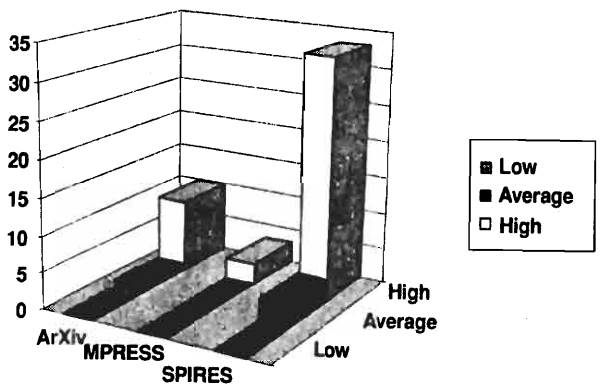


FIGURE 6. Average Number of Publications in Letters Journals per E-Print Author (1998-1999) (SPIRES Sample Does Not Include the E-Print with 101 Authors.)



never resulted in print publications. In all of the discussions below, statements that e-prints "carry notes" or are "marked as" submitted to, accepted by, or published in particular journals reflect information given on or with the e-print itself, while statements about their actual publication are based upon searching for the e-print's author/content in *SCI/WOS*.

Of all ArXiv e-prints, 50% have been published in peer-reviewed publications; 13% carry notes stating that they have been submitted to peer-reviewed publications but have not yet been published; 15% carry notes stating that they have been accepted by peer-reviewed publications but have not yet been published; and 22% have no corresponding peer-reviewed publication. Sixty-seven of these 100 e-prints were posted prior to 1999 and thus have had a longer time within which to appear in peer-reviewed publications. Yet of these 67, 37 (55.22%) have been published in peer-reviewed publications, while eight (11.9%) are still noted to have been submitted, seven (10.44%) are still noted as accepted, and 15 (22.38%) have no corresponding peer-reviewed publication. Considering only the e-prints with peer-reviewed equivalents, 21 of the articles appeared within the same calendar year as the e-print's posting; 17 appeared in the calendar year following the e-print's posting; and one appeared two calendar years after the e-print's posting. Interestingly, 10 of the e-prints were posted subsequent to the publication of the journal article. These 10 e-prints post-dated their articles by 1 to 7 years, with an average of 3.6 years, and are serving to abstract prior, reported research rather than to announce recent findings. It is, unfortunately, far from uncommon to find an e-print still carrying the note that it has, for example, been "Submitted to *Physica D*" when the peer-reviewed publication actually appeared in the *Journal of Physics A*.

Of the MPRESS e-prints, 44% of the total had been transformed into peer-reviewed publications, while 56% had not. Seventy-three e-prints were posted prior to 1999 and of these 39 (53.42%) had been published as peer-reviewed articles, while 34 (46.57%) had not. (MPRESS e-prints are not annotated by their authors with notes indicating that they have been submitted or accepted by various journals.) For the e-prints with peer-reviewed equivalents, nine of the articles appeared within the same calendar year that the e-print was posted, 10 appeared within one calendar year of the e-print's posting, eight within two calendar years, and one within three calendar years. Only one article preceded its e-print, and then by one calendar year. A large number of MPRESS e-prints, 12 of the 100 (12%) were, unfortunately, by authors who could not be located at all in *SCI/WOS*–making it hard to be sure whether they had not been published in peer-reviewed publications, or whether their authors simply publish consistently in journals not indexed by *SCI/WOS*. This is undoubtedly related to the fact that MPRESS is the server with the lowest concentration of postings from the United States, Asia, and Western Europe, whose authors more commonly publish in journals indexed by *SCI/WOS*. MPRESS displays the highest levels of materials from Central and Eastern European countries.

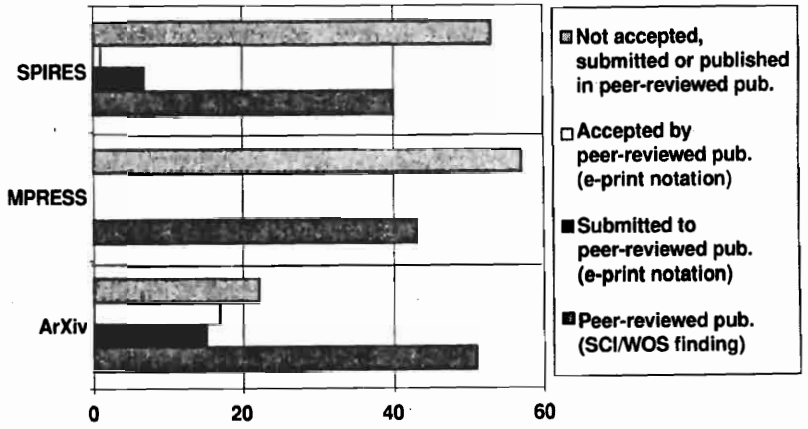
Of the SPIRES e-prints, 40% had peer-reviewed equivalents; 7% were marked as submitted; 1% were marked as accepted; and 52% had no peer-reviewed equivalents. Seventy-two e-prints had been posted prior to 1999, with 37 (51.38%) having been transformed into articles; four (5.55%) still marked as submitted; and 31 (43.05%) having no peer-reviewed equivalent. For the e-prints with corresponding peer-reviewed articles, 23 of the articles had appeared within the same calendar year that the e-print was posted; 13 articles appeared within the following calendar year; and one article within the following two calendar years, while one article preceded its e-print by one calendar year. Again, one could find e-prints annotated, for example, as "submitted to *Nuclear Instruments and Methods in Physics Research A*" when the article actually appeared in *Nuclear Physics B*–although this occurred far less frequently than with ArXiv e-prints.

Some e-prints' transformations into peer-reviewed publications may perhaps have been missed because the e-print served as the basis for a section of an article dealing with a broader or different topic, or because the article appeared in a journal title not indexed in *SCI/WOS*. The finding that only 50-60% of e-prints (far from 90% or "virtually all") have corresponding peer-reviewed articles seems fundamentally right, however, in light of earlier findings reported for e-prints, preprints, and grey literature generally. Hrvoje Galic of the Stanford Linear Accelerator Center is on record as saying that 52.7% of 8,093 high energy physics-phenomenology e-prints were published, as were 55.3% of 8,640 high energy physics-theory articles, 51.3% of 1,595 high energy physics-lattice articles, and 46.4% of 1,963 general relativity and quantum cosmology articles (Crawford, Hurd, and Weller 1996, 71-72).[18] One study of producers of "grey literature" found that 16% of authors did not intend to follow grey literature publications with formal publications (Artus 1994, 301), while another study found that just under 50% of Society of Automotive Engineers' (SAE) preprints were published in normal *SAE Transactions* (Auger 1989, 70).[19] Six to 12 months seems like a reasonable time frame within which to expect an e-print's contents' appearance as a peer-reviewed journal article.[20] An earlier study of psychologists presenting papers at the American Psychological Association conference similarly found that 60% of the published papers had appeared within six to 12 months of preprint distribution in conjunction with the conference (Menzel 1966, 66)[21] (see Figures 7 and 8).

CONCLUSIONS

As estimates place the number of e-prints posted annually at 12,000 (G. Youngen 1998, 449), it would be premature to conclude too much from find-

FIGURE 7. Percentage of E-Prints Transformed into Peer-Reviewed Publication, All Years



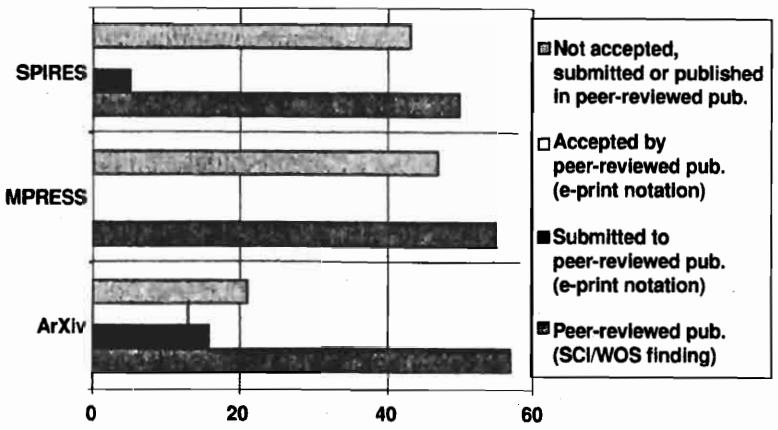
ings based on a sample of 300 e-prints, a mere 2.5% of annual e-print output.[22] Additionally, this was a random sample, and a weighted sample might have been more beneficial in assessing the behavior of representative e-print authors. Nevertheless, certain trends emerging from these findings deserve mention. Because these findings correspond to what was known of preprint authorship, or predictable of e-print authorship, it seems safe to conclude that:

- e-prints are not being transformed into peer-reviewed journal articles at a rate higher than that at which preprints were transformed. That is, only 50-60% percent of e-prints directly and clearly result in journal articles.
- because not all e-prints are submitted to or approved by peer-reviewed publications, there probably are grounds for worrying that e-prints could, potentially, leave "bad versions" of papers accessible in the public arena (Lim 1996, 26). This is not to say that all e-prints that do not result in peer-reviewed publications represent "bad" science; authors may choose to make the e-prints' contents the basis for sections in publications on broader topics, may re-direct their research interests, or may be prevented by external circumstances from following up on research. However, while scientists currently researching in an e-print's field may be well equipped to detect "bad" research, e-prints are also accessible to students, researchers in other fields, and the public, "who are in [no] position to judge [e-prints'] acceptability" (Meadows 1998, 204) but must instead rely upon the peer-review process to screen information for them.

- any peer-reviewed articles resulting from an e-print can be expected to appear within 6-12 months of the e-print's posting.
- e-prints often result from collaborations, including international collaborations, but that e-prints are not yet being produced in large numbers by authors from developing countries.
- notes on e-prints indicating the journal to which an article was submitted or by which an article was accepted do not always correctly indicate the journal in which the article was actually published. Bibliographic control of e-prints is currently limited (Carroll and Cotter 1994, 6).
- e-prints do not seem to be lessening the amount of traditional, peer-reviewed publications because e-print authors often publish extensively, even if they do not always transform particular e-prints into peer-reviewed journal articles.

A fundamental question raised by the global accessibility of e-prints on servers concerns the boundary between formal and information communication, a distinction that has been at the heart of most studies of scientific communication (e.g., Griffith 1990, 40).[23] Those concerned about e-prints' proliferation often emphasize e-prints' status as informal, non-peer-reviewed communication (Dow 2000, 152), and journal articles' status as formal, peer-reviewed communication (Van de Sompel and Lagoze 2000). Otto Kinne, for example, cautions that e-prints are "fine for speedy, low cost communica-

FIGURE 8. Percentage of E-Prints Transformed into Peer-Reviewed Publications, Pre-1999 E-Prints



tion of an informal sort" but the boundaries of formal and informal should not be blurred (1999, 316), with non-peer-reviewed e-prints' being substituted for peer-reviewed journal articles. Unfortunately, the distinction between formal and informal communication is being rendered obsolete by electronic forms of self-publication,[24] which effectively "'whitewash[]' this intrinsically 'grey literature' so that it becomes public/published the day it leaves the author's desk" (Dallman, Draper, and Schwarz 1994, 3). What this will mean for the continuation–or metamorphosis–of peer-reviewed publications and e-prints is an open question. Perhaps methods of peer-review for e-prints will be implemented. In any case, continued scholarly attention needs to be paid to the blurring of this boundary; the changing publication forms and roles that result therefrom;[25] and the resultant, emerging paradigms of scholarly and scientific publishing.[26] Many phenomena related to these changes remain under-explored, especially upon an empirical basis.

NOTES

1. In the pre-electronic environment, even the most widely distributed pieces of grey literature, including preprints, had a characteristic print run of a few hundred (Posnett and Baulkwill 1982, 124).

2. One study of preprints found that 3 in 4 authors mailed preprints to colleagues working in the same research areas (Crawford, Hurd, and Weller 1996, 68). As Quinn notes, "Originally preprints were of very limited circulation, usually to a group which could communicate verbally within itself about the preprint, and provide feedback to the author. Now preprints are distributed very nearly as widely as the final publication" (Quinn 1995, 27). In fact, one could say that e-prints are more accessible than articles in expensive scholarly journals with low subscription rates or restrictive interlibrary loan policies.

3. Crawford, Hurd, and Weller had noted by 1996 that a number of libraries were discontinuing paper preprint collections in light of the emergence of e-print servers (1996, 70).

4. Even with recent advances in print publishing, many scientists still find the delays of print publication problematic. Chemist Henry Rzepa, for example, writes, "[E]ven with all the advances in publishing that have occurred over the past few decades, it can still take up to a year for the printed form of scientific journals or books to become available. Supplementary data associated with the original research may take longer to appear" (Rzepa 1996, 253). See also Perry (2000); he describes the peer review process as "extremely slow," with the publication of theoretical papers on high temperature superconductivity taking over one year.

5. See Doty, Bishop, and McClure (1991) for thorough discussion of inextricable linkage between formal and informal communication, scientific norms, and rewards.

6. Pfander and Martin thus describe publications as serving the purposes of (1) communicating results of scholarly research to large communities in timely fashion, (2) fostering communication, and (3) gaining recognition for their authors (2000, 27).

7. Harnad, interestingly, acknowledges the allocation of influence and prestige as functions of journal articles but suggests that this is less significant to scientists/authors than "reach[ing] the eyes and minds of one's peers" (Harnad 1995, 78).

8. See also Gould and Pierce (1991) on the importance of pre-prints within various scientific disciplines.

9. Peter J. Stand, a chemist at the University of Utah and editor of *The Journal of Organic Chemistry* worries that widespread use of preprint servers would undermine the peer-review system (quoted in Guterman 2000). Criticism of PubMed Central centered on its "threatening to disrupt the established methods of evaluating research for publication" (Blume 2000). Cf. Bederson (1994); Holtkamp (1994); and McGinty (1999, 72). See also Brent, who writes, "Considering the incredible pressure to publish, the amount of junk scholarship that finds its way even into existing paper publications, and the incredible oversupply of publications that defies the heroic efforts of scholars to keep up with their discipline, I am not terribly comfortable with Harnad's optimism" (1995, 280).

10. See also Odlyzko (1999, 391), who claims, "Even the physicists who rely on Ginsparg's preprint server continue to publish most of their papers in established print journals" and Halpern (2000, 42). Crawford, Hurd, and Weller similarly state that "e-prints are still preprints and virtually all are submitted to refereed journals for traditional publication" (1996, 70), while Tomaiuolo and Packer write that "[m]any of the preprints, after all, become published articles" (2000, 55).

11. The notion that posting one's work on e-print servers where anyone can view it is the "ultimate peer review" (Blume 2000) and keeps the quality of e-prints on par with that of traditional peer-reviewed research is commonly expressed. See, for example, Doyle (2000); Ginsparg as quoted in Lim (1996, 27); and Boyce (2000, 404). Rzepa particularly credits the fact that data can be posted along with the e-print as a check on authorial conduct (2000). Ginsparg claims that "[i]n 'e-print archives,' researchers communicate exclusively via research abstracts that describe materials otherwise suitable for publication" (1997, 86). Grounds for this belief can, perhaps, be found in resources like the *Japanese Journal of Applied Physics,* which has foregone refereeing in favor of quick publication. "One would expect that this would result in a large number of low quality papers that would be rarely cited, yielding low impact factors, but this has not turned out to be the case. The self-discipline in submitting only high quality papers on the part of the Japanese scientists involved . . . is remarkable" (Stankus 1992, 201).

12. Use was made of the Chemical Physics Preprint Database despite the fact that some have described "[t]his effort [as] essentially a failure as few authors submitted" (Bachrach 2000). The majority of authors in the sample from the Chemical Physics Preprint Database/ArXiv had institutional affiliations with Departments of Chemistry or Chemical Research Centers. In any case, physical chemists and chemical physicists seemed a sub-disciplinary grouping divergent enough from high energy physicists to be studied separately.

13. The LANL ArXiv server, for example, is mirrored in 15 countries (Halpern 2000). Charlotte Bell and Keith Ruskin, two anesthesiologists at Yale University School of Medicine, for example, report that 20% of hits on their GASNet site come from developing countries (Blume 2000).

14. For more on the "democratizing" potential of e-prints, see Crawford, Hurd, and Weller (1996, 14), Doty, Bishop, and McClure (1991), Dow (2000, 149), Eysenbach (2000, 499), Guterman (2000), Kinne (1999, 317), Langer (2000), Pikowsky (1997, 41), and Valauskas (1998, 46). Others voice more reservations about the supposed "democratization" brought by e-prints; cf. Quinn (1995, 22) and Walsh and Bayma (1996, 345 and 357).

15. See Kreitz, Addis, Galic, and Johnson (1997) on the "strong tradition" of international collaboration in high energy physics.

16. Meadows also adds "article equivalents" to these figures, with there being an additional 3.9 article equivalents in a 3 year period and 3.8 in a 5 year period. Article equivalents by e-print authors were not tracked in this study, but it seems reasonable to predict that production of article equivalents by e-print authors be at a similarly high level.

17. See Meadows (1998, 18). Meadows explains that "the amount of research information in circulation is growing rather more rapidly than the size of the associated research community," meaning that the average author is producing more work.

18. Galic speculates that the rest probably end up in books or proceedings.

19. See also Meadow (1998, 139 and 166) and Posnett and Baulkwill (1982, 124). Kelly (1998, 69) reports a finding that 51% of 2,391 meeting abstracts later appeared as full articles.

20. Stevan Harnad, one of the most enthusiastic e-print proponents, suggests a nine month interval between an e-print's posting and acceptance of the final draft of an article version (Harnad, 1999).

21. Of course, it must be remembered that it can take over 12 months for a published article to be incorporated into an abstracting and indexing service (Crawford, Hurd, and Weller 1996, 4).

22. The larger the sample analyzed, the higher the statistical reliability of the results (Braun, Glanzel, and Schubert 1985, 7).

23. Griffin thus writes, "The formal-informal distinction is an extremely useful one" (1990, 42).

24. See also Crawford, Hurd, and Weller, who write, "An e-print of the future will possess features of both informal and formal formats now in use" (1996, 110), as well as Eysenbach (2000).

25. Ginsparg, for example, has already begun describing e-prints as "formal" communications and contrasting them to "informal" bulletin board postings (1994, 392).

26. Harnad writes that with ability of author to self-archive work, all earlier forms of publication become obsolete (1999). See also Crawford, Hurd, and Weller on the "No Journal" and "Unvetted" models of publishing (1996, 26-27) and Bradley (1999) on e-prints as one of three new paradigms for publishing.

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