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Scientists' Use of Journals: Differences (and Similarities) Between Print and Electronic

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Abstract: Studies conducted over the last three decades demonstrate that scientists read widely from scholarly journals. Scientists use these journals primarily for research and current awareness. Reading of scholarly articles has increased to approximately 110 to 120 articles per person per year, and a growing amount of these readings come from preprints and other separate copies. Scientists are also reading a greater percentage of new articles. In fall 2000 we surveyed scientists at Oak Ridge National Laboratory to repeat a survey conducted in 1984. The primary aim of the recent survey was to identify the impact of electronic/ digital journal alternatives on information seeking and reading patterns of scientists. Nearly one-third of journal articles read now come from electronic journals or digital databases. Evidence suggests that scientists are reading from a broader range of journals than in the past, influenced by timely electronic publishing and by growth in bibliographic searching and interpersonal communication as means of identifying and locating articles. Although the scholarly journals system has changed dramatically in the past few decades, it is evident that the value scientists place on the information found in scholarly journal articles, whether electronic or print, remains the same.

1. INTRODUCTION

Journal literature has proven repeatedly to be one of the most important communications channels for scientists of all types, whether they work in universities, industry, or government laboratories (Ref. 1). Convenient access to journal literature has historically been important for scientists and—although they read less on average—for engineers as well.

The distribution of journals has changed in the last decade, however. In addition to more traditional journal titles becoming available in digital forms from many fee-based electronic full text systems, new distribution channels such as electronic preprint and e-print servers, listservs, and free access from scientists' Web sites supplement traditional print journals. At the same time, there is a growing feeling among many librarians and scientists that journals are in crisis due to rising subscription prices. That crisis, combined with an increasing number of digital

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alternatives, may be expected to lead to greater use of alternative sources for journals or, perhaps, to less use of journal articles altogether.

In 1982 a study was performed by King Research, Inc. (KRI) for the U.S. Department of Energy (DOE) Office of Scientific and Technical Information (OSTI) to investigate the value of information generated from DOE research and development (R&D) funding and the contribution that the Energy Data Base makes to this value (Ref. 2). The study results were widely disseminated and the study methods replicated in several environments. The positive results led OSTI and others to question whether the methods and models employed could be used to determine the extent to which libraries, information analysis centers, and other intermediary services contribute to the value of information. This further investigation was funded under a grant from the National Science Foundation with partial contribution by OSTI (Ref. 3). One part of this 1984 study involved surveys of scientists and other professionals located at three nuclear energy sites: Oak Ridge National Laboratory (ORNL), Rocky Flats and Rockwell Energy Systems Group.

A component of this 1984 survey involved examination of journal information seeking and reading patterns. With the evolution of electronic journals, we felt that replicating the 1984 survey in the year 2000 would provide a useful means of assessing the effects of electronic journals and digital databases on the aforementioned patterns. This was done by re-surveying scientists and other professionals at ORNL. In particular, we asked about amount of reading of scholarly journals and posed a series of questions concerning the last article read. In addition to demographic information, we asked some questions about the awareness and use of preprint services (i.e., the Los Alamos National Laboratory [LANL] e-print archive [arXiv.org] and the Department of Energy PrePRINT Network).

In this paper we compare the pre-electronic journal patterns (1984) with recent patterns (2000) regarding amount of reading, source of articles read, how they were identified, age of articles read, and the time scientists and others spent identifying and locating articles, obtaining them, and reading them. A distinction was made in the 2000 survey between readings in electronic sources and print sources.

2. DESCRIPTION OF INFORMATION ENTITIES MENTIONED

2.1 Oak Ridge National Laboratory

The Oak Ridge National Laboratory (ORNL) was established in 1943 in Oak Ridge, Tennessee, for wartime weaponry research. Today it employs approximately 1,500 scientists and engineers whose R&D efforts support the national and international goals of the Department of Energy. The purpose of ORNL is fourfold: to discover and provide quality energy sources, to improve and protect the environment, to participate in maintaining national security, and to create and promote scientific and technical knowledge to ensure the leadership of the United States in the scientific community.

The energy programs at ORNL are focused on new strides in energy technology and the research of fossil, nuclear, and biomass energy. They are the largest energy-related R&D program among the DOE national laboratories. ORNL's environmental programs, in support of the DOE's

ecological mission, are concerned with environmental technology, assessment, and maintenance. National security is promoted in the nuclear science division of ORNL primarily through the management and responsible handling of nuclear materials and through its leadership in promoting international awareness of nuclear material safety and stewardship. The remaining scientific and technical functions of ORNL support the energy, environmental, and nuclear sciences. They encompass such fields as materials science, computer science, life science, neutron science, and the social sciences.

2.2 Los Alamos National Laboratory ArXiv.org E-Print Archive Service

Los Alamos National Laboratory's arXiv.org e-print archive, developed by Paul Ginsparg, was implemented in August 1991 to facilitate free sharing of research information by electronic distribution and archiving of research papers. Authors are encouraged to submit their own papers for distribution, and subject-related listservs notify interested participants of recently submitted research papers. Paper topics include mathematics, computer science, physics, and neuroscience.

2.3 Department of Energy PrePRINT Network

The Department of Energy PrePRINT Network, available in January of 2000, is an aggregate site for scientific and technological preprints in digital form. Unlike LANL's arXiv.org, the Network does not archive these preprints but only links to those Web sites where they may be found. It does, however, notify (via e-mail) those interested in particular subject areas about newly submitted electronic papers at various Web sites. Subject areas in the PrePRINT Network include mathematics, physics, materials, biology, environmental sciences, and chemistry. Networked servers come from professional scientific and academic institutions and organizations.

3. LITERATURE REVIEW

Working scientists in all types of settings recognize the value and importance of journal literature. A readership study done in 1993 for Hodges Library at the University of Tennessee and four studies conducted from 1994-1998 for companies show that readership of scientific scholarly journals by science professionals is considerable (i.e., 188 average readings per year per university scientist and 106 readings for scientists elsewhere) (Ref. 1). Even more notable is the amount of time these scientists spend reading the scholarly articles: an average of 182 hours per university scientist and 88 hours per scientist elsewhere per year.

Other studies report similar results. Meadows (1974) found that medical researchers read approximately 7.4 professional papers per week (approximately 380 per year) and engineers read approximately 1.5 per week (approximately 75 per year) (Ref. 4). Pinelli et al. (1989) observed that engineers read an average of 6.7 articles per month (approximately 80 readings annually) (Ref. 5). Studies of time spent reading show average times ranging from 2.2 hours per month for engineers (approximately 26 hours per year) to 24 hours per month for cancer researchers (approximately 288 hours per year). The median of all averages of reading time is 11.7 hours per month or 140 hours per year per scientist (Ref. 6, Ref. 7, Ref. 8).

There is abundant evidence that scholarly journals are not only widely read by working scientists but are used extensively in scientific work as well, whether that work be teaching, research, administration, or other activities. Rogers (2001) notes that of all Ohio State University departments surveyed, the biological and medical sciences faculty and students are the greatest users of electronic and print scholarly journals (Ref. 9). Olsen examined journal-reading habits for professors of chemistry, sociology, and the humanities and found that academic readers unanimously find journal literature to be "indispensable" to their work. They read journals for many reasons, including gathering background knowledge on a topic, current awareness, and looking for specific facts or items. Chemists use literature the most frequently: 62% read journals daily (Ref. 10).

When preparing to do research in an unfamiliar area, readers use retrospective literature as well as current articles. They scan or browse through vast amounts of material, using these articles to trigger new ideas. Olsen found that scientists interact with the literature for "learning, creative thinking, and analytical thinking," leading her to conclude that "good software design that facilitates searching, scanning, and browsing are crucial elements in electronic publications" (Ref. 10).

With the growth of electronic distribution of journals and alternatives to traditional journals, use levels and patterns of such media may be expected to change. Rogers notes that over half of the faculty and graduate student respondents to her survey use electronic journals and that acceptance of these alternative media is growing (Ref. 9). When asked whether or not the university library should replace its print journal subscriptions with electronic subscriptions, nearly two-thirds of the faculty and students agreed that it is "very important" or "important" to do so, the top advantage for both groups being the availability and ease of use. Brown (2001) surveyed physicists and astronomers who use LANL's arXiv.org service and observed that the majority (67%) of respondents use preprints or e-prints for the same reason many scientists use print journal articles (i.e., research support, current awareness and fact-finding) (Ref. 11). Chemist respondents to Stewart's (1996) survey indicated that the Chemistry Online Research Experiment (CORE) was very important for creating print copies (80%), for browsing to determine the value of an article (72.7%), and for supporting their ongoing education (65.8%) (Ref.12). The SuperJournal Project (1999) determined that the greatest advantages of electronic journals are easy access, convenience, search capabilities, direct access, and better-than-photocopy printouts; the greatest disadvantages are slow access, breadth or depth of journal coverage, reading on screen, poor graphics or presentation, and access problems (Ref. 13).

Quality of electronic journals is of major importance in light of the alleged growing use of and enthusiasm for such media. Speier et al. (1999) asked respondents to rate the quality of peer-reviewed electronic journals versus paper, from those of substantially lesser quality (1) to those of substantially greater quality (7) (Ref. 14). About 61% rated electronic journal quality in the three lowest ratings (average rating of 2.9, excluding non-responses). Budd and Connaway (1997) also asked about the quality of electronic and print journals (Ref. 15). Although most respondents (77.1%) said they could not judge, the majority of remaining respondents rated electronic journals inferior to most print journals. Some felt that electronic journals were improving, but 85% said they could not judge.

Apparently, awareness of electronic journals may yet be an issue. When Speier et al. asked respondents in ARL institutions to rate their awareness of this alternative media, most respondents placed themselves on the middle to lower end of the awareness scale (Ref. 14). These results are partially reflected in use of electronic journals by these respondents: over forty percent claim they rarely use electronic journals while another third of them say they never do. Lenares also reports that 54% of academics in her 1999 survey "did not know of respected e-journals in my field," down from 61% in the previous year (Ref. 16).

4. STUDY METHODS

The 1984 benchmark survey involved a random sample of scientists and other professionals located at ORNL, Rocky Flats and Rockwell. A total of 200 questionnaires were distributed, and 137 (68.5%) were received. To achieve this level of response, the questionnaires were distributed in the winter of 1983/84 by the organizations' libraries and King Research with mail and telephone follow-up of non-respondents. In the summer of 2000, a random sample of 300 scientists and other professionals was chosen from personnel lists at ORNL, and questionnaires were distributed by the ORNL library. In this survey, we received a total of 76 (25.3%) completed responses. Unfortunately, current rules at ORNL do not allow us to do individual follow-ups to the survey; therefore, a mailed reminder was sent to all on the original list. (Anticipated layoffs were announced the week our questionnaire was distributed, and poor morale probably adversely affected our response rates.) In both the 1984 and 2000 surveys, the completed questionnaires were returned by respondents in a self-addressed envelope directly to the survey researcher in order to ensure confidentiality. Many questions were common to the two surveys, but the 2000 questionnaire contained a greater number of questions about electronic options for journals.

Respondents to the 2000 survey tended to be more highly educated than those in the 1984 survey and their age older (measured by the year since they received their last degree). Nearly two-thirds of the 2000 respondents had a doctorate (Ph.D., M.D., or equivalent), and about one-fourth held a masters degree as their highest degree. The average time since receiving their last degree was about 12 years. The scientific fields that best characterized the respondents' work were engineering, physics, and chemistry; other fields represented included environmental science, mathematics and statistics, life science, computer science and social science (See Table 1). The predominant sciences at ORNL are those found by others to be most likely to use electronic journals.

Field	Proportion
Engineering	39%
Physics	24%
Chemistry	13%
Other	24%

Table 1
Distribution of Respondents
By Scientific Field: ORNL 2000

5. INFORMATION SEEKING AND READING PATTERNS: 1984 TO 2000

In this section we compare amount of reading, source of articles read, how the articles were identified, time spent obtaining and reading articles, and other factors affected by the introduction of electronic journals. In all of our surveys we have defined reading as "going beyond the table of contents, title, and abstract to the body of the article." To be current, we stated in the 2000 survey that "articles include those found in journal issues, author Web sites, or separate copies such as preprints, reprints, and other electronic or paper copies." It was noted that estimates of amount of "readings" could include multiple readings of one article. In fact, about 17 percent of the 2000 readings involved articles that had been read prior to the most recent reading. This occurred more often with paper-based articles (22%) than with electronic/ digital articles (4%).

In 1984 we estimated that the energy scientists had an average of 99 journal article readings per year, and in 2000 the average was 113 article readings—an indication that the amount of reading of articles may be increasing. This phenomenon is consistent with over 13,500 survey responses from scientists observed from 1977 to 1998 (Ref. 1). What have changed over time are the sources used to obtain the articles, both in proportion and amount of reading obtained (see Table 2).

	1984		2000	
Source	**Proportion**	**Amount of Reading**	**Proportion**	**Amount of Reading**
Personal Subscription	37%	37	29%	33
Library Subscription	53%	52	48%	54
Shared Dept/ Unit Collection	2%	2	3%	3
Separate Copy	8%	8	20%	23

Table 2
Proportion And Average Amount Of Readings Per Person From Various Sources Of Articles: ORNL 1984 And 2000

The most striking differences in sources from 1984 to 2000 were the increase in the proportion and amount of readings from separate copies and the decrease in personal subscriptions. One consequence of this change in behavior was that scientists appear to be reading from a larger number of journals. The 2000 energy survey showed that respondents read at least one article per year from approximately 23 journals. While we do not have comparable data from the 1984 survey, other surveys of scientists indicate that the number of journals from which a scientist read articles in a year rose from 13 in the late 1970s to 18 in the 1994 to 1998 time period (Ref. 1). Some of the changes observed in range of journal titles and amount of readings from separates were due to an increase in readings of articles identified by online searches (7.5% of readings in 1984 to 13.3% in 2000) or recommended by other persons, such as colleagues (8.6% and 24.0%, respectively). Observations from OhioLINK confirm that users read from a wider variety of titles when the literature is made available electronically (Ref. 17).

Another difference observed from 1984 to 2000 was the proportion of readings from electronic journals and digital databases. There were no readings from these media in 1984, but in 2000 about 35 percent of the readings were from them. Over one-half of these readings involved browsing electronic subscriptions provided by the ORNL libraries (16% of readings), free author Web sites (2.7% of readings), or personal electronic subscriptions (1.3% of readings). Nearly all of the browsed electronic journals were published in 2000, but one respondent reported a publication date of 1999. Another five percent of the readings were from electronic library subscriptions but were identified from citations in other publications or from online searches; five percent were from personal electronic subscriptions involving articles identified from citations in other publications or mentioned by other persons; and four percent were from Web sites with articles mentioned by other persons. These readings were nearly all year 2000 publications, but one reading from a personal electronic subscription was from a 1990 publication.

The proportion of readings found by browsing did not change much over time. In 1984 about 41 percent of readings were found by browsing personal or library current collections, and 6.5 percent were found by browsing copies routed by the library (i.e., 48% total browsing). In 2000, a total of about 45 percent of readings were found by browsing personal print subscriptions, library print subscriptions, department collections, and electronic or digital copies as mentioned above (see Table 3).

Source	Proportion Found By Browsing
Personal Subscriptions	20%
Electronic/ Digital Copies	20%
Library Print Subscriptions	4%
Department Collections	1%

Table 3
Proportion Of Readings Found By Browsing From Four Sources: ORNL 2000

In 1984 about 13 percent of readings were identified in printed indexes, but use of printed indexes dropped to zero in the 2000 survey. Readings identified by citations in other publications dropped from 24 percent in 1984 to about 12 percent in 2000. The distribution of the age of articles read sheds some light on reading patterns as shown in Table 4.

Age of Article	Readings Per Person	
	1984	2000*
1 year	59.4	80.2
2 years	12.9	10.2
3 years	5.9	4.5
4-5 years	11.9	6.8
6-10 years	4.0	4.5
11-15 years	3.0	2.3
over 15 years	4.0	4.5

* Readings adjusted from 8 months to a year.

Table 4
Average Number Of Readings Of Articles Per Person By Age Of Article Read: ORNL 1984 And 2000

The amount of reading of articles over one year old remained similar for the two time periods; however, in 2000 there appeared to be substantially more new articles read (i.e., 80.2 readings per person in 2000 versus 59.4 in 1984). Nearly all the shift to recently published articles was attributable to reading of electronic or digital articles. Of all articles read from electronic or digital media, 85 percent were published in the year 2000 (8 months into the year), while only 56 percent of articles read from print subscriptions or copies were published in 2000. The oldest article read in the 2000 survey was 25 years old.

The fact that the electronic/ digital reading tended to be of more recent articles means that fewer of the articles had been read prior to the most recent reading (4% in 2000 vs. 22% in 1984). In reading from both digital and print journals, a high proportion of the readings involved information that was known by the scientist prior to the first reading of the article (44% electronic reading vs. 58% print). In both instances such articles were often found from citations in other publications or after mention of the article by another person.

Time spent identifying, locating, and obtaining the articles changed since 1984 in a way that might not be expected: the time per reading spent browsing or searching for the article and determining where the article was located approximately doubled, according to the 2000 survey. The reported time spent browsing electronic/ digital articles was estimated to be 13.3 minutes per reading, but the time spent browsing print copies was half of that time (6.5 minutes). The time spent obtaining or accessing the article was about the same in the two surveys (7 and 6 minutes, respectively). When time involving other activities such as locating, displaying, and downloading or printing was added, the time spent totaled 17.7 minutes per electronic/ digital reading. This was compared with 8.2 minutes for browsing print copies (including locating and photocopying the articles). About 38 percent of the electronic/ digital readings were read from the screen. These readings tended to be of shorter duration than the downloaded/ printed readings (i.e., 20 vs. 62 minutes, respectively). Interestingly, the proportion of print articles photocopied was about 50 percent compared with 62 percent of electronic/ digital articles downloaded/ printed out. The time spent photocopying was about three minutes compared with 4.5 minutes spent downloading/ printing. When articles were identified by means other than browsing, the

time spent using the two media was about the same (i.e., 22 minutes per reading electronic/ digital articles and 19 minutes for print articles).

6. USEFULNESS AND VALUE OF JOURNALS

The principal purposes of the information obtained from the articles read were most frequently primary research (34% of readings), background research (24%), and current awareness or continuing education (22%). These proportions of readings tended to be slightly higher for electronic/ digital articles than for print articles. About 16 percent of the readings were for communications-related purposes such as writing, making presentations, or consulting/ advising others. Other purposes, such as administration, accounted for the remaining purposes of reading.

The respondents surveyed in 2000 indicated that they averaged 98 hours per year reading journals (96 hours in 1984). This estimate was based on estimated amounts of reading (99 readings in 1984 and 113 in 2000) and average time spent per reading (58 minutes and 52 minutes, respectively). Because their time is a scarce resource, this amount of time spent was an indicator of the value of information gained from reading journal articles. The amount of time spent reading electronic/ digital articles was nearly identical to that of paper-based articles (i.e., 52.2 minutes per article versus 51.4 minutes). Thus, this indicator of value was also the same for the two media sources. Other indicators of value of information include the observation that respondents whose most recent reading was from an electronic/ digital article tended to be older and publish more articles.

7. READING OF PREPRINTS

In some scientific fields, preprints of journal articles are an important distribution means. Physics, particularly high energy physics, is an example. In a 1977 national survey of scientists, it was estimated that scientists received and read 2.1 million preprints (Ref. 18). In 1981, physicists read about 20,000 separate copies of articles from 19 American Institute of Physics journals; 4,500 of them were preprints. Physical science authors averaged distributing 110 preprints per article (Ref. 19). Several digital preprint services have evolved in recent years including the Los Alamos National Laboratory arXiv.org e-print archive and the DOE PrePRINT Network. We did not specifically include preprint reading in the 1984 survey but rather included it as part of a general category of separate copies of articles. In the 2000 survey we asked respondents about their awareness of these (and other) preprint services, how much reading they did from them, and whether they submitted articles to the services.

About 29 percent of the ORNL respondents were aware of the LANL archive service, and about three-fourths of those who are aware had read 7.9 preprints per person from the service in the past 12 months. Roughly one-half of physicists were aware of the LANL services, and nearly all of those aware had read preprints from it in the past year. Other fields particularly acquainted with the service included engineering (31% aware) and chemistry (20% aware). Of all the respondents aware of the service, only 14 percent of them had ever submitted article preprints to arXiv.org, even though those respondents averaged authoring or co-authoring about 8 articles per person in the last two years. About ten percent of the articles published by those aware of arXiv.org were submitted to the LANL service. A similar proportion of respondents (25%) were

aware of the DOE PrePRINT Network, but fewer of them (53%) actually read preprints mentioned by the service. Those who did so averaged reading six preprints per person in the last year. Most of these readers were physicists or engineers. Other services were mentioned and used by a few of the respondents, including such Web sites as Physics of Plasmas, IOP, and Nuclear Fusion; ACM; and High Tc Update.

Altogether, the total electronic preprint reading amounted to about 3.6 percent of all reading. In addition, about 4.5 percent of readings were from preprints sent to respondents for article review or refereeing. Since about one-half of reading from separate copies of articles involved preprints, the increase in amount of reading from those separate copies may be partially attributable to reading from preprints and corresponding preprint services.

8. SUMMARY AND CONCLUSIONS

The past decade has witnessed profound changes in the scholarly journal system. Many traditional paper-based journals have converted solely to digital form or have turned to electronic publishing as an alternative medium. Digital collections of articles are being developed through input of preprints, retrospective conversion of older articles, and input of recently published electronic journal articles. As part of ongoing research into electronic journals, the University of Tennessee School of Information Sciences recently replicated a 1984 survey of energy scientists and other professionals to determine how information seeking and reading patterns might have changed and, more particularly, what effects the new media have had on such changes. While the research focused on a specific segment of scholarly journal readers and at two periods of time, the results shed some light on the effects of the introduction of electronic journals and digital databases.

The evidences of change in this environment from 1984 to 2000 are summarized as follows:

- Journals have remained a useful and valuable channel of communication for the energy community studied.

- The amount of reading of journals by the scientists and other professionals has appeared to increase from 99 readings per person per year in 1984 to 113 in 2000. About one-third of the 2000 readings are from electronic journals or digital databases.

- Evidence suggests that the journal users are reading from a wider range of journal titles. That is, they are estimated to read at least one article from about 23 journals, an amount greater than observed in the past in other surveys.

- While amount of reading of personal and library subscriptions has remained about the same, the number of readings from separate copies of articles (i.e., preprints, reprints, interlibrary loan, etc.) has increased from an estimated eight readings per person to 23, the difference being about the same as the increase in amount of reading.

- Amount of reading of articles published over one year ago to as long ago as 25 years has remained relatively consistent from 1984 to 2000. However, amount of reading of articles

published in the past year has increased from 59 readings per person in 1984 to 80 in 2000—again, an amount comparable to the increase in amount of reading.

- Reading from electronic/ digital media and from separates tends to involve articles that are recently published. Eighty-four percent and 64 percent of readings, respectively, are from articles published in the past eight months. These two factors appear to appreciably influence greater amount of reading and reading from a wider range of journals.

- Other factors contributing to more and broader reading are changes in the means used to identify and locate articles. The proportion of readings of articles identified through online bibliographic searches increased from 7.5 percent to 13.3 percent (with some of this increase reflecting a decline in use of printed indexes). Such searches tend to broaden the scope of reading. Many more articles are identified through another person (e.g., a colleague). It may be that e-mail has encouraged interpersonal notification of important articles.

- The proportion of separates read from preprints appears to be increasing, and the introduction of preprint services has influenced this increase.

In conclusion, information seeking and reading patterns appear to be changing, and the introductions of electronic journals and digital media are important reasons for this change.

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