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Electronic journals and changes in scholarly article seeking and reading patterns

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Abstract

Purpose – By tracking the information-seeking and reading patterns of science, technology, medical and social science faculty members from 1977 to the present, this paper seeks to examine how faculty members locate, obtain, read, and use scholarly articles and how this has changed with the widespread availability of electronic journals and journal alternatives.

Design/methodology/approach – Data were gathered using questionnaire surveys of university faculty and other researchers periodically since 1977. Many questions used the critical incident of the last article reading to allow analysis of the characteristics of readings in addition to characteristics of readers.

Findings – The paper finds that the average number of readings per year per science faculty member continues to increase, while the average time spent per reading is decreasing. Electronic articles now account for the majority of readings, though most readings are still printed on paper for final reading. Scientists report reading a higher proportion of older articles from a wider range of journal titles and more articles from library e-collections. Articles are read for many purposes and readings are valuable to those purposes.

Originality/value – The paper draws on data collected in a consistent way over 30 years. It provides a unique look at how electronic journals and other developments have influenced changes in reading behavior over three decades. The use of critical incidence provides evidence of the value of reading in addition to reading patterns.

Keywords User studies, Scientists, Electronic journals, Libraries, Information retrieval, Reading

Paper type Research paper

Introduction

Over the last three decades, extensive research has examined how faculty, students, and other researchers use scholarly journals in their work. Many studies have focused on the ways faculty members access scholarly information, with a recent focus on how

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Nation-wide surveys in 1977 and 1984 were sponsored by the National Science Foundation. Surveys in the USA in 2005 were sponsored by the Institute of Museum and Library Services. Over the years, many collaborators, too numerous to mention individually, have worked on the gathering and analysis of these data. The authors wish to thank William Birch, Regina Mays and Luiyan Yang, University of Tennessee, and Songphan Choemprayong, University of North Carolina for their assistance.

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they have transitioned from print journals to electronic journals when locating and using scholarly information (see studies summarized in King and Tenopir, 2001; Tenopir, 2003a; Friedlander and Bessette, 2003; Tenopir and King, 2000, 2004; Rowlands, 2007; and Vakkari, 2008). Although academics continue to use print articles, their use of electronic journal articles has increased substantially over time, particularly as university libraries continue to transition their collections to electronic journals available on the scholar's desktop and elsewhere. Moreover, while faculty exhibit a variety of information-seeking patterns (e.g. browsing, searching, seeking recommendations from colleagues) by which to identify and use scholarly information, online searching has increased as a strategy to identify needed journal articles. Electronic publishing has influenced, and in some ways altered, information seeking and reading patterns in many ways.

The authors have conducted surveys of university faculty and other researchers periodically since 1977. This paper tracks reading patterns of science, social science, technology, and medical university faculty over time with data gathered in these surveys[1]. From this point science, technology, social science, and medical research are referred to as simply "science" for the sake of brevity. Trends from the surveys of scientists through 1998 were summarized thoroughly in Tenopir and King (1997, 2000), with specific subsets of information reported for all science fields in 1977 (King *et al.*, 1981), non-faculty scientists from 1983-1995 (Griffiths and King, 1993), engineers compared with scientists over the years (Tenopir and King, 2004), astronomers in 2003 (Tenopir *et al.*, 2005; Boyce *et al.*, 2004), and pediatricians in 2005 (Tenopir *et al.*, 2007). This paper compares earlier results to results from surveys conducted in the US from 2000-2005, to examine how reading patterns have changed as widespread availability of electronic journals became commonplace. Understanding changes in behavior over time and the scholarly publishing environment at each stage helps provide insights into possible future patterns of scholarly article reading and how the library and publishing environment can contribute to those changes.

Background

Previous research by the authors has focused on information seeking and reading patterns of scientists in both university and non-university settings. For example, a survey of faculty at three US universities found that electronic journal use is high among faculty members, and particularly among science faculty (King *et al.*, 2003). Surveys conducted on behalf of the American Academy of Pediatrics (AAP) looked at the overall amount of reading of pediatric journals (King *et al.*, 2006) and reading patterns of pediatricians (Tenopir *et al.*, 2007). Pediatricians rely on scholarly articles for many reasons and continue to read heavily from personal print subscriptions for current awareness in addition to electronic journal articles for research and clinical purposes. On the other hand, readings by astronomers, studied in conjunction with the American Astronomical Society (AAS), are almost 80 per cent from electronic articles, most often from library-provided e-journals and second, from e-articles in sources such as e-print services (Tenopir *et al.*, 2005). AAS and NASA working together have demonstrated particularly advanced journal-related processes that portend advances by other publishers in the future.

Compilations of earlier survey data of university and non-university scientists (Tenopir and King, 2000, 2002; Tenopir, 2003a, b) found that reading patterns such as amount of reading, source of reading, and time spent reading changed moderately from 1977 to the mid-1990s, with changes accelerating as electronic journals and electronic alternatives to journals became more widespread. On a smaller scale, an analysis by Belefant-Miller and King (2001) of data collected by Donald W. King during 1993-1994 from university and non-university scientists reports that reading patterns among scientists and non-scientists were similar in many ways, although scientists read more articles on average and are more likely to have personal subscriptions.

Many studies have focused on aspects of the transition of scholarly publishing from print to electronic sources and changes in formal scholarly communication (see, for example, King *et al.*, 2003; King and Tenopir, 2001; Kling and Callahan, 2003; Healy *et al.*, 2002; Friedlander, 2002; Lawal, 2002; Borgman, 2007). Faculty members continue to read from both print and electronic journals, although access to e-journals has become especially important (Maughan, 1999). Most faculty want non-core journal titles in an electronic format, with core titles in both print and electronic formats (Dillon and Hahn, 2002). Many studies have demonstrated that faculty in the sciences tend to read more in electronic journals or from e-prints than do humanists or those in the social sciences (Brown, 1999, 2003; Cochenour and Moothart, 2003; Dillon and Hahn, 2002; and Tenner and Yang, 1999), although Vakkari has shown that when normalizing for availability, humanities faculty are no less inclined to use electronic journals (Vakkari, 2006).

A comparison of readings by researchers in three evolutionary phases from the 1990s to early 2000s show that widespread electronic publishing was beginning to change reading patterns, including reading more and relying more on electronic sources (Tenopir *et al.*, 2003). Although the last “evolutionary” stage in this comparison was comprised solely of astronomers and astrophysicists who are on the high end of reading, this community already had mature e-journals and e-article systems, so was thought to provide insights into future patterns of reading behavior as the publishing environment switches almost totally to electronic systems and distribution.

Other studies of astrophysicists show an increase in the amount of reading and range of journals from which an article is read, while, at the same time, a narrowing in what is cited (Kurtz *et al.*, 2000, 2005; Henneken *et al.*, 2008). The number of journal titles and concomitant number of articles published continues to increase each year, thus putting pressure on faculty to read more articles just to tackle the same proportion of the literature in their discipline and increasing multidisciplinary research (Morris, 2007; Mabe, 2003; Mabe and Amin, 2001; Tenopir and King, 2009).

Although he looked at citation patterns rather than reading patterns, Evans (2008), like Kurtz *et al.* (2000, 2005) and Henneken *et al.* (2008), found that the availability of electronic journal articles has resulted in authors citing fewer older articles and a narrower diversity of sources. In contrast, our reading patterns suggest that scientists read a higher percentage of older articles and from a wider range of sources. Of course, they read for many purposes, not just research and writing. We did not look at citation patterns.

Context

The studies reported in this paper focus on the information seeking that leads to scholarly article reading. They begin with the last article read, therefore following the successful identification of a relevant article to read. It can be seen as one step in various scholarly communication or information-seeking models and narrowly focuses on this one step, by examining article reading in depth.

Research on scholarly communication for many years has shown that scientists read from many sources to do their work, including conference papers, reports, and books, in addition to preprints and final versions of journal articles. From Garvey and colleagues seminal works in the 1960s and 1970s (Garvey and Griffith, 1963, 1964, 1971; Garvey *et al.*, 1970; Garvey, 1979) to Meadows' in depth look in the 1980s and 1990s (Meadows, 1998), to Borgman's modern look at scholarship in the digital age (2007), information and communication have been shown to be an essential part of science. Scholarly communication "serves a number of distinct functions in validating the products of research, reaching present and future audiences, and establishing and maintaining the scholarly record" (Borgman, 2007, pp. 65-6). Scholarly articles play an important role in the overall communication cycle, both for readers and authors, but journals and articles are by no means the only dissemination channel, but rather a formal channel often following informal communication with colleagues and at professional meetings or through technical reports and published proceedings.

The following question was asked to place a context on journal information seeking and reading patterns:

> What sources did you use for the last substantive piece of information you used for work? (Select all that apply).

Results are shown in Figure 1. Clearly, journal articles dominate as a source of information used by science faculty for work. It is significant that web sites are used for about one third of the time, although the type of web site information is not established.

An important aspect of journal information seeking and reading is that readers sometimes know about the information reported or discussed in an article prior to reading it for the first time. In fact, readers said that they knew about the information in about half of the articles they last read (51.4 per cent). The readers first found out about the information from the sources shown in Figure 2.

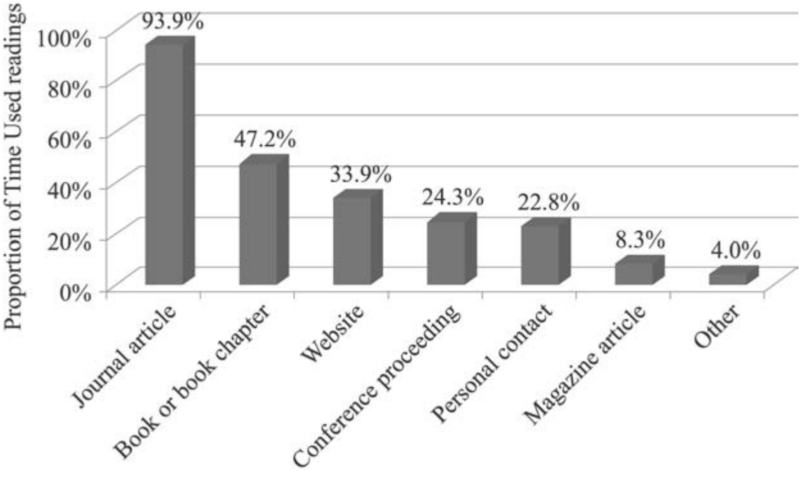


Figure 1.
Sources used by US science faculty for their last substantive piece of information for work ($n = 869$)

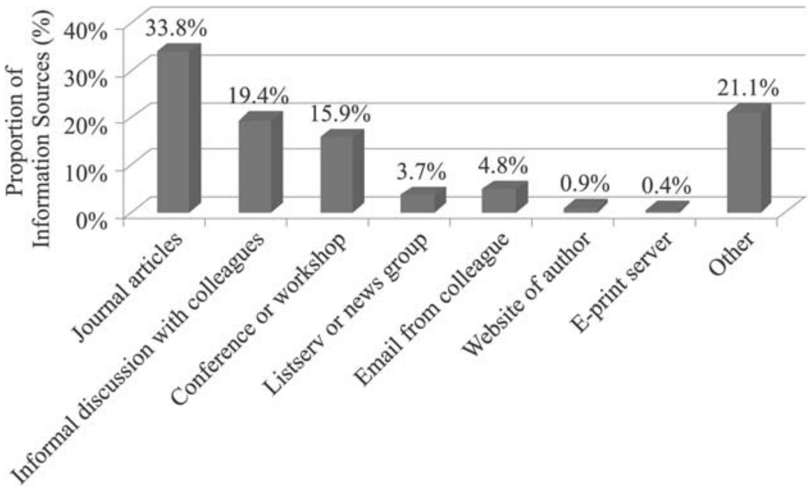


Figure 2.
How US science faculty became aware of information, prior to reading about it in articles ($n = 904$)

Again, journal articles are found to be an important source of information. However, it is demonstrated that information is communicated through many channels with articles only being a single channel in this information flow, although an important one. Garvey and Griffith (1963), Crawford *et al.* (1996), and Tenopir and King (2000) describe the flow of research information from discovery through oral and written reporting over time, with journal articles being somewhat down the communication chain in time.

Many models for information-seeking patterns have been used to achieve a conceptual understanding of reading patterns (see Tenopir and King, 2004, for a summation of communication models). Typically they begin with an information need and go through information seeking, relevance judging, finding, reading, and using, with iteration at any stage (Kuhlthau, 1993; Ellis and Haugan, 1997; Dervin, 1983, 1992).

The longitudinal studies reported in this paper focus on one instance within any stage of these models – that is the reading of an article thought to be relevant enough to spend time reading it. It examines information seeking patterns leading to reading and explores how this reading contributes to the outcome of the intended broad purpose (research, teaching, current awareness, etc.). Furthermore, it seeks to predict the outcome and value of specific readings within the broader context of an information seeking and use event. The instance of reading is a microcosm of the thought processes that go into the broader models of information seeking and use.

Methods

Starting in 1977, surveys were sent from time-to-time to groups of scientists from nine fields designated by NSF in the 1970s: physical sciences, mathematics, computer sciences, environmental sciences, engineering, life sciences (including medical research), psychology, social sciences, and other sciences. These surveys involved scientists in university and non-university settings, mostly in the USA (surveys from 1977-1998 were compared in Tenopir and King, 2000). This paper includes findings only from university science faculty members and compares the responses over time.

Surveys in 1977 ($n = 2{,}350$) and 1984 ($n = 865$) were NSF-sponsored national surveys of scientists in the US. The response rates for these surveys were over 60 per cent. From 1993 through 2003, a total of 397 science faculty members in three US universities responded to printed questionnaires. In October-November 2005, a total of 935 science faculty members in five US universities responded to questionnaires administered online. Response rates for the 1993-2005 surveys varied from a low of about 30 per cent in one university to nearly 50 per cent in several US universities. Surveys of specific populations (for example, astronomers or pediatricians) are not included in this comparison, instead only the early national surveys and later comprehensive surveys at universities are included here. In total, over 3,700 science faculty respondents are included in the results over nearly 30 years[2].

The survey questions have remained consistent over time, with both "reader-related" (demographic) and "reading-related" questions asked. Reader-related or demographic questions include such things as faculty status/rank, year of last degree, age, gender, subject discipline, and number of personal subscriptions.

One general recollection question begins the questions that focus on reading-related questions. Scholarly article reading and use is measured first by asking respondents how many scholarly articles they had read in the past month (30 days). In the older surveys, scholarly articles did not need to be defined, as there were few choices for format. Scholarly articles in the recent surveys were defined to include "those found in journal issues, author web sites, or separate copies such as preprints, reprints and other electronic or paper copies". In all surveys at all time periods, reading was defined as "going beyond the table of contents, title, and abstract to the body of the article".

In all surveys most questions were reading-related, focusing on the specific article read most recently. The incident of last reading is a variation on the critical incident technique, first developed by Flanagan (1954) and applied in many different contexts, including libraries and readings (Bradford, 2006; Andrews, 1991; Fisher and Oulton, 1999; Shirey, 1991).

Instead of focusing on a specific information need or important "critical" incident, respondents were asked to focus on the last scholarly article reading (Griffiths and King, 1991). The last article reading is assumed to be random in time and allowing discovery of detailed patterns of reading and use. The details about a specific reading are more likely to be recalled accurately by the respondent and are, therefore, found to be more valid than general recollection questions. The last article reading is a second stage random sample of readings, where the first stage is a sample of readers. Specific questions about the last incident of reading establish conclusions about readings rather than about readers. This distinction is important, as every faculty reader is likely to read for many reasons and read from many different sources at various times.

Questions about the last article reading include time spent on the reading, how the reading was located and obtained, age and format of the reading, purpose of reading, and importance and value of reading to the purpose. In a sense, every reading is unique from among all the possible combinations of information seeking and reading patterns. By examining many readings one can establish such combinations as how older articles are identified, the format of these articles, from what source they are obtained, for what purpose they are read, and the consequences of reading. By focusing on readings, one can make conclusions about all types of readings by faculties in the universities surveyed. The universities are assumed to be typical of universities in the USA.

Value of information has two aspects, as described by Machlup (1979) and demonstrated with journal readings by Tenopir and King (2007). Purchase value is what one is willing to pay for the information that is found in journals. Payment includes either directly with money or in the time of the reader. Use value, in contrast, is the favorable consequences derived from reading and using the information. Questions helped estimate total investment in time spent reading (purchase value), as well as questions that establish the consequences of reading (use value).

Several versions of the questionnaire are available at web.utk.edu/~tenopir/research All questionnaires are similar, in fact are nearly identical, with variations mostly to accommodate differences in specific names of systems at individual libraries or departmental names at individual universities. For purposes of analysis these variations are translated into, for example, "electronic" source if respondents indicated they located the last article read from their specific library automated system or to "science" as a subject discipline if the respondents came from a science field such as chemistry or biology. Their subject discipline was coded "social sciences" if the respondent came from a traditional social sciences field such as sociology or political science or from the fields of education, law, or business. Sometimes respondents did not report their academic discipline, in which case the reported title of the journal from which the last article was read (or topic of the article) is used as an indicator of their discipline.

Every survey since 1977 has examined statistical aspects of survey responses including dealing with item non-responses by imputing valid substitute values. Sample sizes are given to assess statistical validity (see Griffiths and King, 1991). "Outliers" were identified by those observations which are three standard deviations above the mean and eliminated from estimates when appropriate.

Analysis of reading

Analysis over time has revealed that several patterns of information seeking and reading have changed, most likely due to the availability of electronic journals and the increase in the number of articles published. From 1977 through 2005, results show that university faculty on average read more in not much more time; have increased the variety of methods used to identify needed articles; rely more on library provided articles; read for many purposes, finding journal articles valuable for those purposes; and, because they make choices based on what helps them get their work done, will readily adapt to new technologies that are convenient to their information seeking, reading, and work patterns. Some of these large-scale changes lead to more subtle alterations in reading patterns over time.

Amount of reading

Since 1977, and dramatically since the mid-1990s, academics across all fields of science have been reading more. This increase in the number of article readings is due to many factors, including increases in the number of journals and articles, and the increased accessibility to articles provided by electronic publishing and distribution. Faculty members report reading many more articles per month now than in the past and the trend is accelerating greatly. For the sake of convenience, annual average reading is calculated by multiplying the average monthly reported reading times 12 to get a rough estimate of average yearly number of readings (see Figure 3); monthly results directly from the surveys can be easily seen by dividing by 12[3].

Although the amount of reading has greatly increased, the exact amount of reading has always varied considerably by field of science or discipline. For example, Tenopir and King (2001) reported that medical faculty consistently over time have relied on journal articles more than any other group and read on average nearly twice as many articles per year as do social science scholars. In 2005 the average number of annual article readings by medical faculty was an estimated 414, compared to 331 for sciences, and 233 for social sciences (Tenopir *et al.*, 2009)[4].

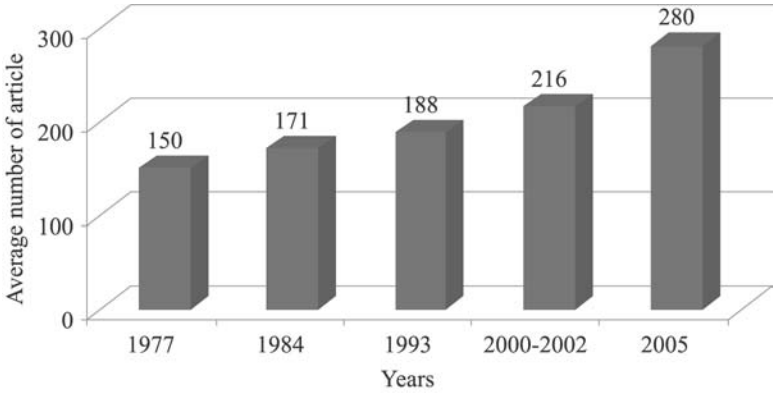
Note that readings may also include re-readings of the same article, so the number of readings does not equal the number of articles read per year. From 1977 through the mid-1990s only about 60 per cent of readings are reported to be first time readings, so that the 188 readings reported in 1993 represents only 110 unique articles per scientist per year (Tenopir and King, 2000). In 2005 the proportion of first-time readings was up to 73 per cent, so the 280 readings per academic per year represent 204 unique articles.

Time spent reading

At the same time that the average number of article readings per person is increasing, the average time spent per reading is declining. In the 2004-2005 surveys, faculty reported spending an average of 31 minutes per reading, down from 48 minutes in 1977 (Figure 4).

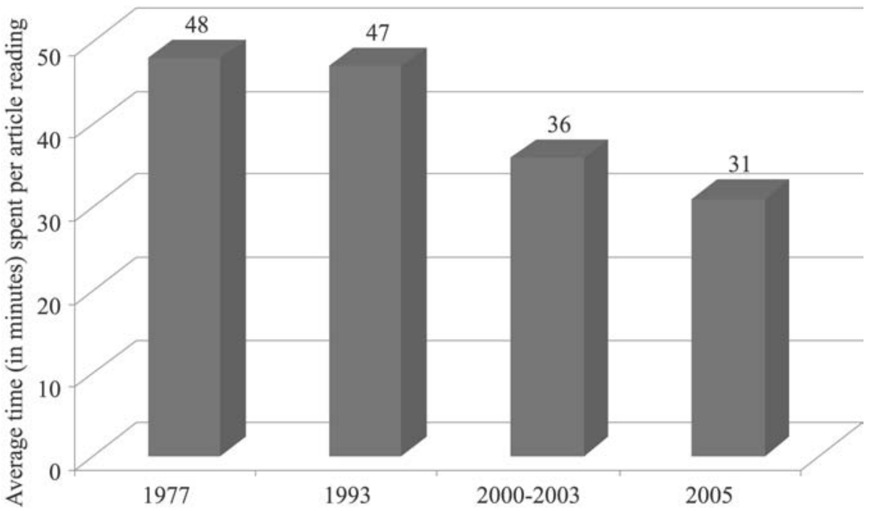
Multiplying the average time spent per reading by the number of article readings, however, shows that the total commitment to reading by US science faculty continues to go up from approximately 120 hours annually in 1977 to 144 hours annually in 2005. Faculty members continue to show they value scholarly articles by spending more total time on reading, even though they spend less time per reading on average. With the increase in number of readings, it is natural that the average time spent per reading must decline, as people's time is a scarce resource that is used cautiously. The amount of time available for reading scientific articles is likely reaching a maximum capacity.

Faculty clearly spend less time per reading, but that does not mean they are reading each article with less care. A question in the surveys asked with what care an article is



Note: 95 % confidence interval for 2005: 25.848, between 254 and 306

Figure 3.
Average number of article readings per year per university science faculty member (n = 932)



Note: 95 % confidence interval for 2005: 1.911, between 29 and 33

Figure 4.
Average time (in minutes) spent per article reading by science faculty member ($n = 898$)

read, ranging from "just to get the idea" to "with great care". In the five US universities in 2005, a total of 94 per cent of readings were either read "with great care" (43 per cent) or "with attention to the main points" (51 per cent). The attention paid to each reading remains relatively high even when the time available per reading is less. The depth of reading has clearly remained about the same over the years (Figure 5).

Time spent per reading has varied consistently over time by subject discipline of the reader. Tenopir and King (2000) reported that physical and life scientists spend over twice as many hours per month reading journal articles (although engineers spend much more time reading other types of literature). In the 2005 surveys, medical faculty reported spending on average only 25 minutes per reading, while engineering faculty

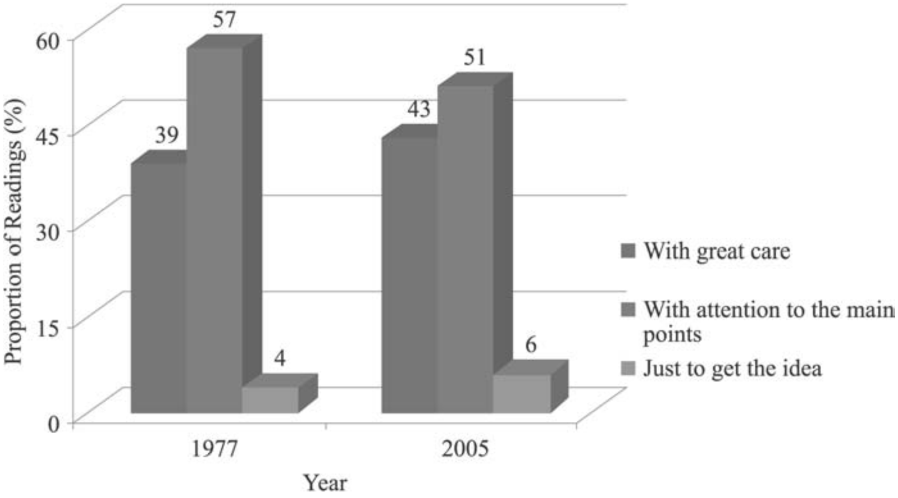


Figure 5.
Depth of reading by US science faculty in 1977 and 2005($n = 905$)

members reported spending 43 minutes per reading on average (Tenopir *et al.*, 2009). The differences in amount of time spent per reading by subject discipline are likely related to the differences in the purposes and use of readings by each subject discipline as discussed later.

Information seeking and locating scholarly articles

Faculty members use many ways to become aware of and locate articles, but the relative importance of those means has changed since the 1970s. For example, they browse through the tables of contents in print or electronic journals, typically for current awareness; they search for information in online search engines, e-journal systems, aggregated full-text databases, and indices to identify new topics or for research and writing. Following citation links in print and electronic journals is also employed, as are recommendations from a colleague or some other person (Table I).

The proportion of reading by the US science faculty from browsing decreased in recent years[5], replaced by other means of learning about articles that are read. In 2005, over half of browsing (58.4 per cent of browsed readings) continued to be from print subscriptions (i.e. 47.6 per cent from personal subscriptions, 8.2 per cent from library subscriptions, and 2.6 per cent from department subscriptions). Browsing from electronic sources (41.6 per cent of browsed readings) comes largely from library or department subscriptions of electronic sources (30.0 per cent), as well as, personal subscriptions (5.6 per cent), free web journals (4.5 per cent), and other sources (1.5 per cent).

Searching in 1977 was primarily from A&I publications, Tables-of-Contents and other alerting tools, and by other means. Less than 1 per cent of readings were from automated searches. Most searching in 2005 was from electronic sources (92.6 per cent of readings from searching), although some searching continues from A&I print publications (1.9 per cent of readings from searching). Most online searching by science faculty is electronic from A&I services such as Academic Search Premier, PsychINFO, etc. (63.2 per cent of readings from online searching), as well as web search engines, including Google, Yahoo, Alta Vista, etc. (14.2 per cent), an online journal collection such as Highwire, JSTOR, etc. (20.1 per cent), or other electronic source (2.5 per cent).

When an article is found through browsing subscriptions, the article can then be read immediately or later. However, when articles are identified by other means such as searching, it may be necessary to locate the article and obtain it from a source such as a library collection. This has partially led to substantial increases in readings from library-provided sources (discussed later).

Table I.
How US science faculty learned about articles they last read: proportion of reading (%) by year of survey

	Survey year(s)				
Method of learning about read articles	1977 (*n* = 2,350)	1987 (*n* = 865)	1993 (*n* = 70)	2000-03 (*n* = 397)	2005 (*n* = 884)
Browsing	58.5	54.1	56.6	48.7	33.9
Automated searching	0.7	1.1	9.4	23.7	23.1
Other searches (e.g. A&I)	10.4	10.0	11.4	3.1	4.9
Citations	6.7	13.1	7.5	11.5	14.9
Persons (e.g. colleagues, authors, etc.)	17.7	15.3	11.3	13.0	18.5
Other	6.0	5.4	3.8	–	4.7
Total	100.0	100.0	100.0	100.0	100.0

In addition to the time spent reading, academics devote time to finding information. In 2005 US faculty were asked how much time they spent seeking the last article they read, when browsing or searching. In many cases they located more than one reading for each act of browsing, searching, etc. This varies with the method used to seek and become aware of articles (see Table II).

The average time spent browsing varies by the format of the source browsed, where an average of 26 minutes is spent browsing print journals and 40 minutes browsing electronic journals.

Of course, articles from journals or other sources are not the only important source of scholarly information. As mentioned earlier, Garvey and Griffith (1963, 1964, 1971) showed the range of information sources that are used in the scientific process to disseminate findings, including formal and informal sources such as dissertations, conferences, patents, correspondence, articles, and books. From the readers' point of view, this range of sources for potentially relevant information has increased over time with new methods of scholarly communication (Borgman, 2007). Tenopir and King (2004) reported that engineers spend time reading many different types of scientific outputs, including (in descending order): scholarly journal articles, other (including e-mail), internal reports, books, trade journals, external reports, and patents.

Sources of articles read

The average number of personal subscriptions reported in surveys of scientists in non-university settings has decreased steadily over time, from six in 1977 to under three personal subscriptions on average per scientist by 2003. For the US university science faculty, the average number of personal subscriptions has remained about the same: 4.2 subscriptions per scientist in 1977 and 4.1 in 2005. There are some exceptions to this average: medical faculty members continue to hold an average of five to six personal subscriptions, including many supplied by medical or pharmaceutical supply companies. For other faculty, subscriptions are dominated by those from scholarly societies to which they belong.

The proportion of readings that come from personal subscriptions has steadily declined, at a much steeper rate than the decline in number of personal subscriptions. Readings from library collections in particular have made up for the decline in reading from personal subscriptions, followed by readings from other sources such as web sites and separate articles from colleagues. The changes in proportion of article readings from personal subscriptions, library provided sources, and other sources are shown in Table III.

Library-provided articles include those obtained from library collections or school or department collections (often supported from the main library) and from interlibrary loan or document delivery. "Other sources" include article copies obtained from a colleague, author, etc. preprints or reprints, an author or other web site. In 1977, "other

Method of seeking articles	Average time per session (minutes)	Average time spent becoming aware per reading (minutes)
Browsing	31.7	5.2
Searching	37.9	5.3

Table II.
Average time spent by US science faculty browsing or searching and average time spent per article read ($n = 732$)

sources" were largely reprints, preprints and photocopies provided by authors or publishers.

It is abundantly clear that library-provided articles are replacing personal subscriptions as a source for read articles. The picture is even clearer when comparing the number of readings in 1977 and 2005 (Figure 6).

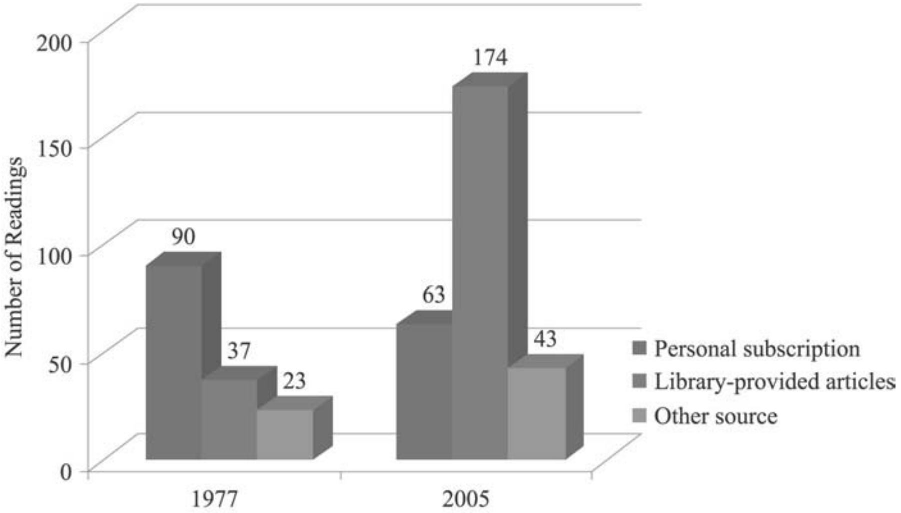
The number of readings increased by an estimated 130 readings per scientist from 1977 to 2005. The "other sources" increased by about 20 readings which might be attributable to Open Access initiative indicated by 11 readings from preprint; 19 copies provided by authors, colleagues, etc.; four from an author web site and two from other web sites.

Reading from personal subscriptions decreased about 27 readings per faculty scientist. Some of the decrease represents a drop in personal subscriptions from 4.21 in 1977 to 4.10 in 2005, but most is attributable to less reading per subscription (i.e. about 21 readings per subscription in 1977 to 15 in 2005).

Most remarkable is that readings from library-provided articles increased by 137 readings, which is comparable to the net increase in readings overall (130 readings). As mentioned earlier, much of this increase may be due to articles identified by means that

Table III.
Sources used by US science faculty to obtain article they last read. Proportion of readings (%) by years of survey

	Survey year				
Source of read article	1977 ($n = 2{,}350$)	1984 ($n = 865$)	1993 ($n = 70$)	2000-03 ($n = 397$)	2005 ($n = 924$)
Personal subscriptions	60.0	53.0	35.5	38.6	22.6
Library-provided articles	24.8	30.1	53.8	43.6	62.0
Other	15.2	16.9	10.7	17.8	15.4
Total	100.0	100.0	100.0	100.0	100.0



Note: Number of readings in 1977 and 2005

Figure 6.
Sources used by US science faculty to obtain article they last read. Number of readings in 1977 and 2005

require locating the articles and then obtaining them mostly through libraries. Automated searching increased from an average of one reading in 1977 to 65 in 2005 with 49 of these articles obtained from libraries. Articles identified from citations increased from 10 to 42 with 34 of these articles located in libraries. With articles mentioned by other persons, the number went from 27 to 52 in 2005, of which 25 were obtained in libraries. Thus, libraries appear to be the primary choice when articles are identified by the means above. Finally, electronic library collections have expanded dramatically due to aggregators and bundled-title offerings from publishers.

In 1977, university scientists averaged reading at least one article from about 13 journals. In 2005 at least one article was read from 33 sources[6]. This increase in number of sources used to obtain articles to read is due in part to availability of more journal titles in library collections, but also because there are more access points available to obtain separate copies of articles such as author web sites and preprint databases (i.e. about 43 readings in 2005 compared with 23 in 1977). Some of these specific sources are used infrequently, thus expanding the number of sources used at least once. From the reading perspective this points to a broadening of science, at the same time that citation patterns point to a narrowing of science (Evans, 2008).

Over half of readings in 2005 are from electronic sources (59.5 per cent vs. 40.5 per cent from print sources). However, as shown in Figure 7, personal subscriptions continue to be frequently read from print issues. On the other hand, most library-provided articles and other sources are read from electronic versions. School or department collections also tend to be read in electronic format (i.e. 30 per cent in print vs 70 per cent in electronic format).

Most print reading is from print journal issues (78.6 per cent of readings from print format) with the rest from photocopies (20.7 per cent) and facsimile copies (0.7 per cent). Over two-thirds of reading from electronic versions (69.5 per cent) involves immediately downloading and printed on paper, but some reading takes place online on a computer screen (21.6 per cent) or from previously downloaded/saved

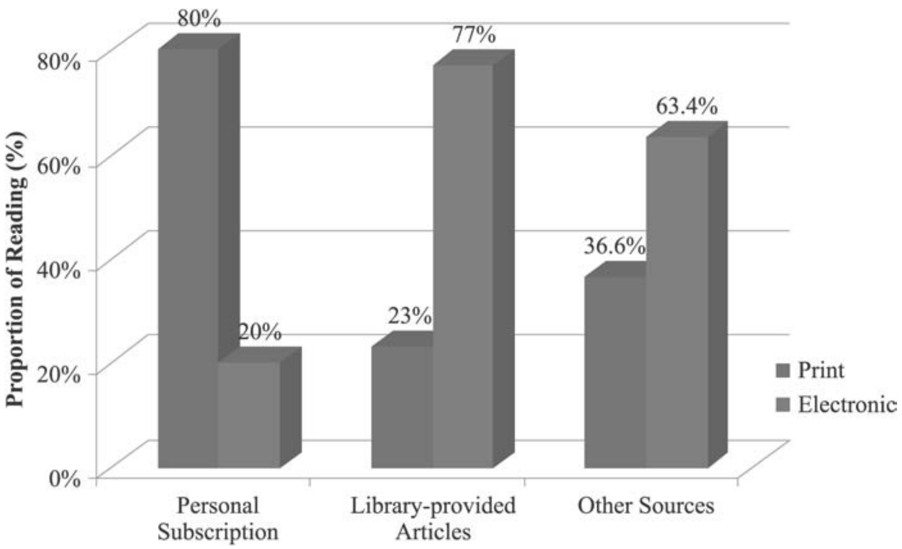


Figure 7.
Format of articles read by US science faculty by format of sources ($n = 923$)

articles that are later read on a computer screen (8.9 per cent). This has not changed much since Schauder (1994) reported that three quarters of respondents to his survey said they preferred to print out electronic articles on paper for reading. Others observed this preference even earlier (Cakir *et al.*, 1980; Dillon *et al.*, 1989; Dillon, 1991).

The amount of time spent reading an article is about the same regardless of whether the format is print (32 minutes) or electronic (33 minutes). However, the time spent reading on the computer screen is 24 minutes versus reading from a download print copy (36 minutes).

Online access to articles has meant that articles can be obtained and read in the convenience of one's office, lab or home. In fact, nearly two-thirds of readings (64.7 per cent) are in the office or lab of which 63.9 per cent of these readings are electronic versions. Most of the rest are read at home (25.7 per cent of which 54.8 per cent are electronic) or while traveling (4.1 per cent of which 54.1 per cent are electronic). Very little reading of science articles is done in the library (2.9 per cent of which 76.9 per cent are in print) and other locations account for the remainder of readings (0.9 per cent). The fact that scientists have access to articles online saves them about seven hours per year.

In 2005 science faculty were asked where they would go if they had not found the article they were seeking from their first choice of source. Just 18 per cent said they would not bother getting the article, but most indicated a wide range of second-choices, displayed in descending order in Table IV. Although it is only speculative, on average scientists estimated they would need to spend nearly 30 minutes locating the item if their first choice was not available and an estimated $7.60 on communication, purchasing, etc.

Purpose of reading

Indicators of the usefulness and value of information gained from reading are purpose of reading and ways in which the information affects these purposes. Scientists were asked:

> For what principal purpose did you use, or do you plan to use, the information obtained from the article you last read? (Choose only the one best answer.)

Table IV.
Thinking back to the source of the article, where would you obtain the information if that source was not available? ($n = 893$)

When actual source was the library, where would you go if you had not found it?	When actual source was personal subscription, where would you go if you had not found it?	When actual source was other, where would you go if you had not found it?
Another library	From library	From library
ILL	Online	From journals/articles
From another journal	Database search	Online
Author of the article	From another journal	ILL
Check online	IIL	Friend or colleagues
Friend or colleague	Ohio link	Author of the article
Personal subscriptions	Author of the article	Database
Database	Colleagues or friends	OhioLink
OhioLink, OCLC	Not sure of source	School subscription
Not sure how	Books	Not sure how

Scientists read for many purposes, including research, teaching, current awareness and other purposes (Figure 8). Every faculty member reads for different reasons at different times.

Nearly all the readers (99.5 per cent) thought the reading of the article had some effect on the principal purpose, mostly in positive ways (Figure 9).

Scientists were then asked how important the information in the article is in achieving the principal purpose (Figure 10). Almost all readings have value to faculty members in achieving the purpose of the reading, regardless of what that purpose may be. These indicators show that the information obtained from reading scholarly articles continues to be important to scientific work (Tenopir, 2002).

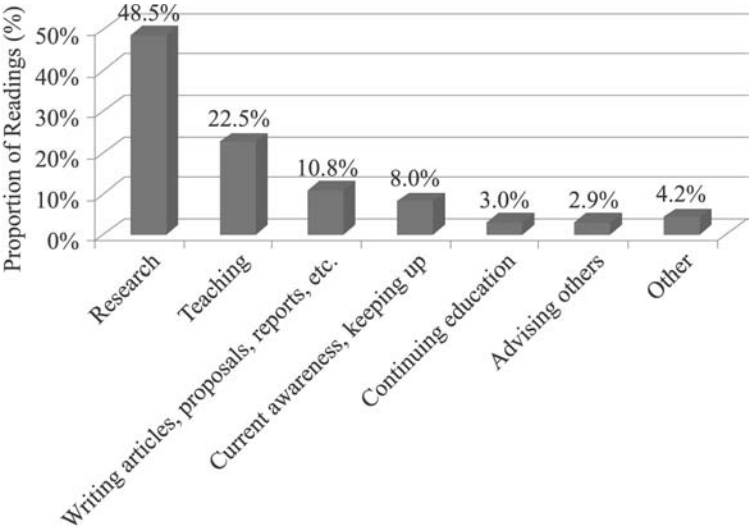


Figure 8.
Principal purpose for reading by US science faculty ($n = 888$)

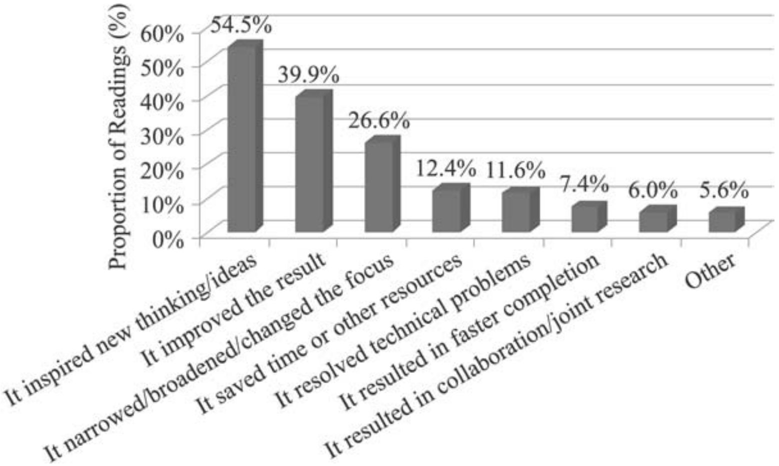


Figure 9.
Ways in which the last reading affected the principal purpose of reading ($n = 880$)

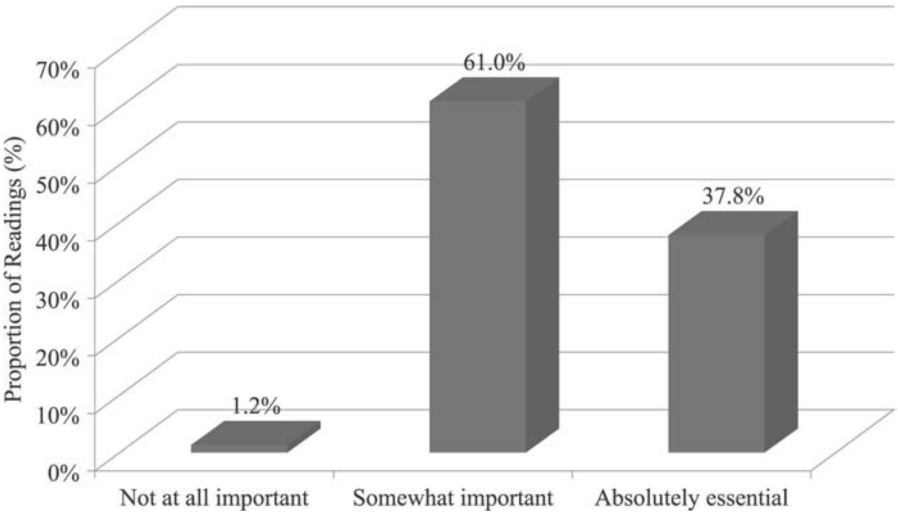


Figure 10.
Rating by science faculty of how important the last reading was in achieving the principal purpose of reading ($n = 882$)

Reading for research purposes may be increasing and consistently rates highly among purposes for reading. For example, the 2005 surveys found that on average nearly half (48.5 per cent) of readings are for the principal purpose of research. In surveys conducted from 2000-2003, 30 per cent of readings were for the principal purpose of research. Sometimes readings are made for more than one purpose, as shown in Tenopir *et al.* (2003), in which research was by far the most often indicated purpose for reading among university scientists (and non-university scientists as well). When allowed to choose more than one purpose per reading, 75 per cent of university-based readings in the mid-1990s were for research purposes at least in part and 41 per cent were used for teaching at least in part (Tenopir and King, 2000). Engineering faculty in surveys from 2000-2003 reported that the primary purpose of nearly 83 per cent of readings was for either primary or background research. Despite the difference in the measurements of the purposes of reading and differences by subject discipline, research consistently surfaces as the primary objective of scientists. Readings for research are more likely to come from the library than readings for other purposes and are more likely to be from electronic sources (Tenopir *et al.*, 2009).

Articles are read for many purposes, but readers tend to vary their information seeking patterns depending on whether the information is read for research, teaching or current awareness (and continuing education). For example, the way in which readers became aware of articles they read varies substantially by these three purposes of reading (Table V).

Some browsing is done for research purposes (29.9 per cent), but most articles read for this purpose are identified by other means. Teaching requires keeping current for classes and this is reflected in proportion of reading found by browsing (43.7 per cent). As might be expected, browsing accounts for about 61.4 per cent of reading done for current awareness or continued education.

Source of information used to obtain articles also varies by the purposes for which information is read (Table VI).

Libraries are the most common source used by readers and this particularly holds true for research and teaching[7]. The library is a particularly important source for research (65 per cent of reading). This is because articles generally found from searching, citations and other persons are older articles which, when identified, need to be located and then obtained (for which libraries are well-suited).

The format of the article read for these three purposes reflects the means used to become aware of them (Table VII). Most browsing is from personal subscriptions read in print format and this is clearly reflected in the proportion of reading from print versions for all three purposes.

Age of article readings

From 1977 through the mid-1990s readings of articles from the first year following publication remained relatively consistent at about two-thirds of total readings, with older articles constituting approximately one-third of all readings. Starting in the late 1990s, readings of older articles began to increase slightly (Tenopir *et al.*, 2003). In the 2005 surveys, the reading of older materials increased somewhat; readings within the first year of publication and older readings are more nearly equally split (see Figure 11)[8].

World-wide members of the American Astronomical Society (AAS) in 2002 were observed to have 63.8 per cent of readings from articles published within the past 12

	How readers became aware of articles (%)				
Purpose of reading	Browsing	Searching	Citations	Persons	Total
Research	29.9	31.6	19.8	18.8	100
Teaching	43.7	25.8	10.5	20.0	100
Current awareness	61.4	12.5	3.4	22.7	100
All	37.8	27.5	15.1	19.6	100

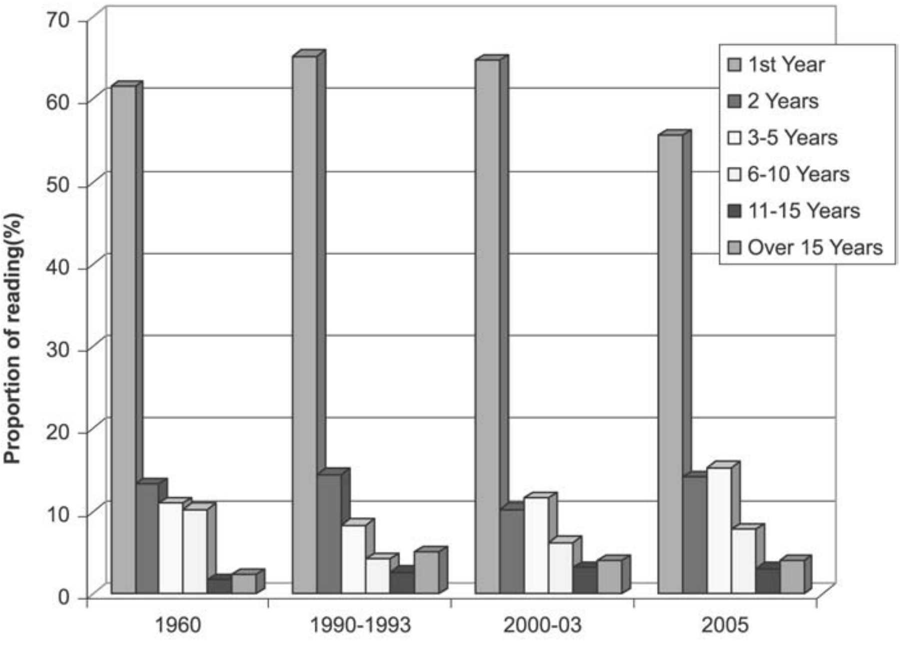
Table V.
How US science faculty learn about articles read for research, teaching and current awareness ($n = 683$)

	Source of last read article (%)			
Purpose of reading	Personal subscription	Library-provided	Other	Total
Research	16.0	65.0	19.0	100
Teaching	32.5	48.0	19.5	100
Current Awareness	37.8	35.7	26.5	100
All	23.5	56.4	20.2	100.0

Table VI.
Sources of articles read by US science faculty for research, teaching and current awareness ($n = 729$)

	Format of last read article (%)		
Purpose of reading	Print	Electronic	Total
Research	31.3	68.7	100
Teaching	46.2	53.8	100
Current awareness	59.8	40.2	100
All	39.2	60.8	100

Table VII.
Format of articles read by US science faculty for research, teaching, and current awareness purposes ($n = 727$)



Notes: 1960, Survey conducted by Case Institute of Technology; 1990-1993, n = 862 includes both university and non-university scientists; 2000-03, n = 327; 2005, n = 920. Proportion of reading (%) by age of articles

Figure 11. Age of articles read by US scientists by year(s) of observation. Proportion of reading (%) by age of articles

months and 4.5 per cent over 15 years old, again indicating a similar pattern (Tenopir *et al.*, 2005).

Readings of older articles are different from more current readings in several respects, including method of finding out about the reading, source of the reading, and format of reading. Age of articles has a bearing on how they are identified and where they are obtained as shown in Tables VIII and IX.

Articles published in 2005 (prior to October/November when the survey was done) were largely identified through browsing (52.6 per cent), but as the articles became older readers were more frequently made aware of them by other means. Articles published prior to 1996 were mostly identified through citations (46.9 per cent) and searching (32.8 per cent). Most articles found by browsing were recently published articles (74.5 per cent of readings found by browsing), diminishing to 0.7 per cent of

Table VIII. How US science faculty in 2005 became aware of articles by age of article read ($n = 835$)

	How readers became aware of articles (%)				
Year published	Browsing	Searching	Citation	Another person	Total
2005	52.6	20.4	7.8	19.2	100
2004	24.6	37.3	16.9	21.2	100
2001-03	21.3	39.4	19.4	20.0	100
1996-2000	15.5	39.4	25.4	19.7	100
Prior to 1996	3.1	32.8	46.9	17.2	100

these readings prior to 1996. Age patterns of other means of identifying articles are as follows: browsed readings decreased from 35.5 per cent for 2005 articles to 8.7 per cent of those published prior to 1996; citations from 25.0 per cent for 2005 articles to 22.7 per cent; and persons from 49.7 per cent for 2005 articles to 6.7 per cent.

Articles published in 2005 were most often provided by libraries (46.7 per cent of readings of these articles), but libraries become increasingly prominent as a source as age increases while reading from personal subscriptions diminish. The proportion of reading from other sources (i.e. copies from authors, colleagues, etc., free web journals, preprint copies, etc.) remains about the same regardless of age. If the articles are found by browsing, most come from personal subscriptions regardless of the age of the articles (e.g. 76.0 per cent of articles published in 2005 to 63.8 per cent of those published prior to 2004). This evidence reinforces the continued importance of print personal subscriptions, particularly for browsing (Table IX).

An important issue is how much impact retrospective conversion to electronic format has had on information seeking (Table X).

While reading of print and electronic versions are roughly equal for articles published in 2005, over the next nine years (1996 to 2004) electronic versions are much more often read. Prior to 1996 reading tends to revert somewhat to print, probably reflecting lower availability of electronic databases beyond that time. As shown earlier, access to electronic versions of articles has an important effect on readers' time since older articles are often obtained from library collections through remote access to the collection which saves them time.

Although date of readings remains highly skewed towards newer articles, the increase in the proportion of readings after the first year of publication may have many reasons, including the increased availability of backfiles coupled with the increased amount of reading from library e-collections; embargoes on open access availability of articles so that readings from the open web or other open access systems will not be able to access full texts of articles within the first year of publication; and the

	Source of last read article (%)			
Year published	Personal subscription	Library-provided	Other	Total
2005	33.3	46.7	20.0	100
2004	13.4	68.5	18.1	100
2001-2003	13.3	64.5	22.3	100
1996-2000	6.8	73.0	20.3	100
Prior to 1996	8.5	69.0	22.5	100

Table IX.
Source of articles by the age of article read by US science faculty in 2005 ($n = 913$)

	Format of last read article (%)		
Year published	Print	Electronic	Total
2005	46.3	53.7	100
2004	29.1	70.9	100
2001-2003	33.3	66.7	100
1996-2000	31.5	68.5	100
Prior to 1996	49.3	50.7	100

Table X.
Format of articles read by US science faculty in 2005 by the age of articles ($n = 911$)

prevalence of relevance ranking search engines which display older articles intermixed with new articles. Previous norms for search systems were to display “last in, first out”, putting newer articles at the top of display lists. Relevance ranking does not favor newer articles and, in fact, when the numbers of citations an article receives is part of the relevance ranking algorithm as it is with Google Scholar, it favors older articles that have had more chance to be cited.

There is also a relationship between age of the article and purpose of reading (Table XI). From 1977 through 1998, 74 per cent of articles read for research purposes were within the first year of publication. Conversely, only about one-half of articles read for teaching purposes were less than one year old; however, this proportion declines over time, i.e. 30 per cent of articles read for teaching were more than one year old and 20 per cent of articles were five years old or older (Tenopir and King, 2000).

In 2005 the age of articles read for teaching remains the same as previous years, but those read for research have become much older. The age of articles read for current awareness is about what one would expect.

Time spent reading as an indicator of value of content

Machlup (1979) describes value of information in two ways as:

1. *Purchase or exchange value* or what one is willing to pay for information found in journals in one’s time and/or money.
2. *Use value* or the favorable consequences derived from reading and using the information.

Purchase value is presented here as the time readers spend reading articles. They would not devote this time if the information did not have some value to them. It also reflects the price paid for subscriptions. Use value can be characterized in many ways. An indicator of the value of articles is the number of times they are cited, which is one way the information is used. Purposes of reading and the importance of information to these purposes are other indicators of use value. A more in-depth discussion of value is given by Tenopir and King (2007).

Value of articles obtained from sources of scholarly journals is presented by the time readers spend in identifying, obtaining and reading articles. Faculty readers average nearly 144 hours per reading in information seeking and reading, and, since there is very little difference in the time spent reading print versions compared with electronic (31.7 minutes for print vs. 33.4 for electronic) one could conclude that there is little difference in the value readers are willing to pay in their time for print and electronic versions. The time spent for library-provided articles, however, is somewhat higher than that spent on personal subscriptions (35.0 minutes spent reading

Table XI.
Age of articles read by US science faculty in 2005 for research, teaching and current awareness

	Purpose of reading (%)		
Year published	Research ($n = 427$)	Teaching ($n = 196$)	Current awareness ($n = 70$)
2005	48.5	48.0	90.0
2004	16.4	10.2	4.3
2001-2003	18.3	21.4	4.3
1996-2000	7.0	13.3	-
Prior to 1996	9.8	7.1	1.4

library-provided articles and 25.9 minutes for personal subscriptions). About 33 minutes are spent reading from other sources.

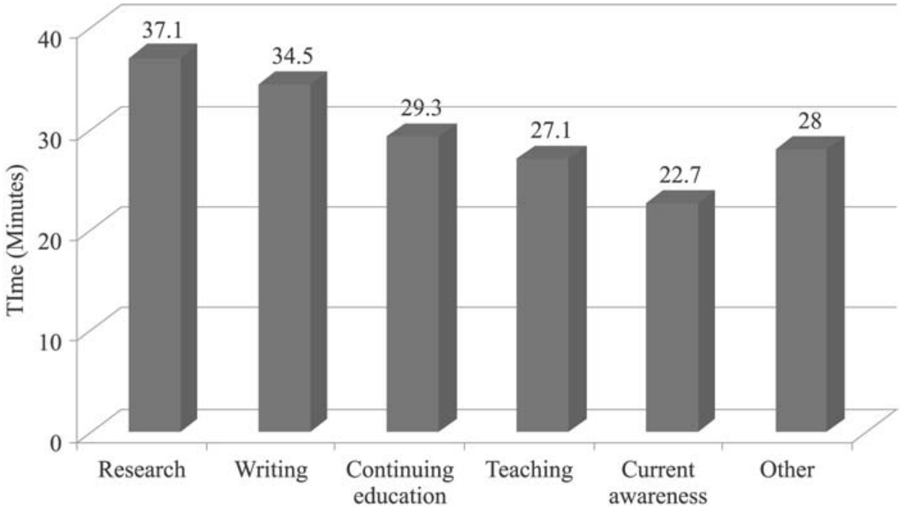
Most articles found by searching are obtained from library-provided means (i.e. 75.6 per cent of articles identified through searches). This is because articles identified in this way often need to be located and then obtained and the most logical source is library-provided. Furthermore, more time is spent reading older articles as shown in Table XII.

The time spent reading also varies somewhat for various purposes (Figure 12). More time is spent reading for conducting research and writing than other purposes, which suggests that this information is more valuable to the readers. Not surprisingly, the least time is spent reading for current awareness.

Faculty members were asked whether they had received any awards or special recognition in the past two years for their research or other profession-related contributions. About one-third of the faculty indicated they had received such recognition. Those recognized average 25 readings of scholarly articles in the past month compared with 19 readings by other faculty. The annual time spent reading is

Table XII. Time spent reading articles (minutes) obtained from personal subscriptions or libraries by the age of the articles read in 2005 ($n = 889$)

		Source of last read article (%)	
Year published	All sources	Personal subscription	Library-provided
2005	30.3	26.8	32.1
2004	32.4	33.1	33.1
2001-2003	34.3	23.0	37.5
Prior to 2001	39.4	32.0	41.5



Note: 95% confidence intervals: Research: 2.997, between 34 and 40; Writing: 7.029, between 27 and 42; Continuing education: 10.359, between 19 and 40; Teaching: 3.067, between 24 and 30; Current awareness: 4.141, between 19 and 27; Other: 5.968, between 22 and 34

Figure 12. Average time spent reading for various purposes by US science faculty in 2005 ($n = 884$)

166 hours for the award winners and 133 hours for others. These results provide evidence that achievers tend to read more and spend more time reading articles, which are indicators of value to them. This, of course, does not mean that if you just read more you will receive awards.

Faculty members frequently publish as part of their responsibilities. Science faculty in the five surveyed universities averaged authoring the following publications in the past two years (Figure 13).

Just as in reading, scholarly articles also dominate authorship, again indicating value of scholarly articles to authors as well as to readers. Only 13 per cent of faculty in our surveys did not author any of these publications in the past two years. Most faculty members authored at least one scholarly article (78.5 per cent). The proportion of faculty that authored at least one of the other publications is as follows: chapters in scholarly books, proceedings, etc. (40.7 per cent), non-refereed articles (32.7 per cent) and books (7.3 per cent).

An indicator of faculty output (or productivity) is authorship. An indicator of the value of scholarly journal information is whether amount of reading is related to authorship. Unfortunately, the number of co-authors was not asked in these surveys so the output cannot be weighted (King *et al.*, 2003). However, overall authorship is an indicator of the value of reading, as those who publish more also read more (Figure 14).

Conclusion and implications

With the growth of electronic journals, the continued increase in the number of journals and articles published yearly, and alternative sources of scholarly articles, many information seeking and reading patterns of science faculty are changing. Articles are identified and located through a variety of information-seeking methods, including browsing, online searching, following citation links, and getting recommendations from colleagues, yet the proportion of articles located by searching is increasing. Articles come from many sources, but the proportion of readings from personal subscriptions is decreasing as reading has shifted to access through library-oriented

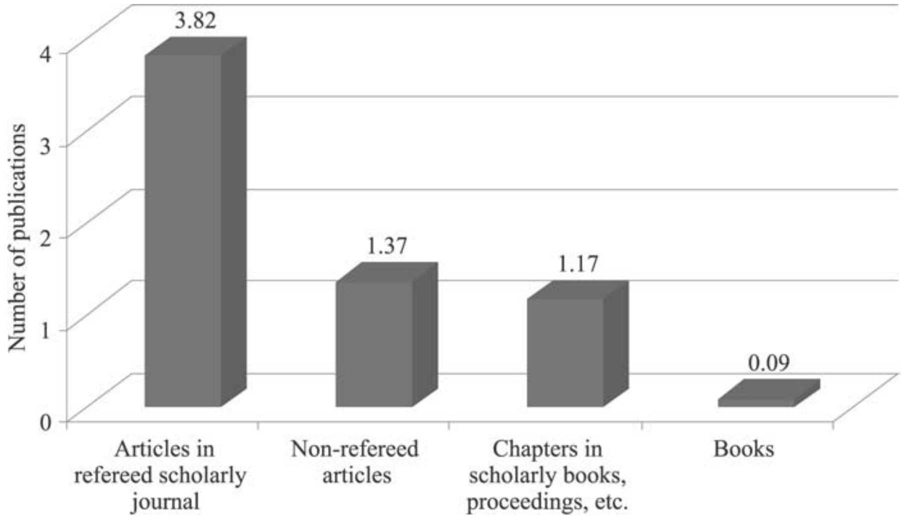


Figure 13.
The number of publications authored by faculty in five US universities in the past two years ($n = 845$)

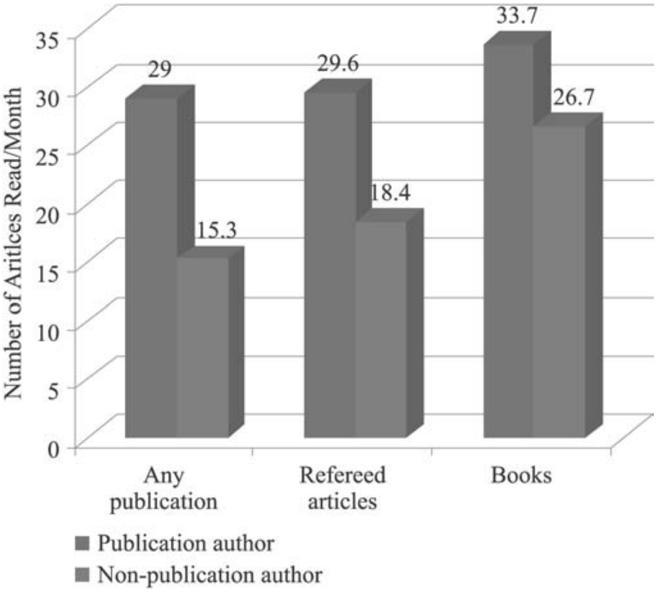


Figure 14.
Average number of articles read in the past month by faculty who authored and did not author any publications, articles and books ($n = 843$)

subscriptions and other library provided articles. Readings from personal subscriptions are much more likely to be from print journals than are readings from library provided articles. Library provided electronic journals are the single most common source for article readings today by science faculty.

The number of readings per faculty member is rising and the proportion of older articles is also increasing as they become available electronically, yet there is less time spent on average per reading due to limitations on time available to read. Since there are more articles published now than in the past, much of this increase in reading is “running in place”. Scholars must read more merely to keep up with the same proportion of the literature. Others have found that the number of citations and range of journals cited has not followed this trend.

The university and scholarly environment have some influence on reading patterns. All of the studies reported here surveyed faculty members who are affiliated with universities that provide them with access to electronic and print journal collections and databases and that have a robust technology infrastructure. The e-journal systems from their libraries and through the Web make it possible for them to access more articles more quickly. There are now many places for academics to access articles and the faculty members in these studies all come from universities with large serials collections, providing them with access to many thousands of journal titles in electronic format through their libraries.

In addition to journal subscriptions in print or electronic format, from the library or personal subscriptions, articles from journals are taken out of their journal context and are now made available as separates. These separate articles are made available in aggregations or e-print servers in some subjects, notably physics, and provide access to pre-prints and later versions of articles submitted by the authors. Institutional repositories or authors’ own web sites have some versions of articles that may or may not ever be published in a journal. Not surprisingly, the growth in both the number of electronic journals and the range of places where articles are made available have influenced the ways in which researchers locate and read journal articles.

Much of the increase in reading that we have observed can be attributed to electronic articles available through their libraries. When backfiles of journal issues became widely available in this decade, the reading of older articles increased. Larger and deeper e-collections are used when they are made available.

Academics and scientists continue to show the value of scholarly articles to them by the total time they spend reading and by the range of purposes of reading. The current trend of more readings in less time per reading can only go so far, however. Because there are only so many hours in the day, information products and services need to help readers identify high quality readings and help them read quickly.

Notes

1. All surveys were distributed about midway through the academic year, usually in October and November. As we know from usage logs, downloads (and probably also readings) are not distributed equally across the calendar year (In the US, October and November and, to a lesser extent, April are typically peak months, with the smallest number of downloads during the summer), so these yearly estimates are likely over-estimates. The relative growth across the years is more important than the exact estimated number each year.
2. Standard errors and 95 per cent confidence intervals: Medical (27.54, 360-468), sciences (26.79, 279-384), social sciences (12.24, 209-257).
3. The results presented here include university faculty respondents from all fields of science, technology, medicine, and social sciences. Our surveys since 2000 have included humanities faculty members, but in the interest of consistent comparison over time, the results here exclude humanities. Whenever we refer to “scientists”, “academics”, or “faculty” in this article it includes respondents in all subject disciplines except humanities.
4. National surveys in 1977 and 1984 reached respondents at many universities in the US. Surveys from 1990 through 2005 were conducted at specific universities in the US including Drexel University, University of Pittsburgh, University of Tennessee, Case Western Reserve University, University of Akron, Ashland University, and Malone College. Similar surveys have also been conducted in Australia (University of New South Wales, University of Queensland), Japan and Finland, but are not included in order to maintain consistency of observing only US scientists over time.
5. While the proportion of readings decreased over the years, that number of readings found by browsing remains about the same: 88 readings in 1977 and 95 in 2005.
6. This calculation is based on the question: “From this same source (e.g. journal, author’s web site, preprint archive), how many articles did you read in the last year (12 months)?” Since articles frequently read from a source has a higher probability of entering the sample, responses are weighted to provide an estimate of articles read per source which is divided into average number of articles read to yield number of sources read at least once.
7. Note that the proportion of reading from other sources for these three purposes exceed the overall proportion because details of the other purposes are not included.
8. The proportion of readings within the first year of publication by faculty at the University of Tennessee were on average greater than those at the four universities in Ohio, perhaps due to the greater number of journal backfiles provided by OhioLink.

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