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What do chemists cite? A five-year analysis of references cited in American Chemical Society journal articles

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A five-year analysis of references cited in American Chemical Society journal articles.

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Running Head: What do chemists cite?

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Abstract

This study analyzes references cited by articles published in ten American Chemical Society journals between 2011 and 2015. The median age of references was 6 years. On average, 44% of the references were five years old or younger, and only 11% were more than 20 years old. There appears to be a modest increase in references to older sources, possibly due to the increased availability of older articles online. References tended to be concentrated on a small core of journals. Overall, 20% of the journals cited accounted for 80% of the references. However, there was considerable variation among sub-disciplines.

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Introduction

The use of citation analysis to inform library collection development has a long and venerable history. However, it has become less common in the last few decades, largely due to the availability of online journals, either individually or as part of subscribed databases. While this removes much of the pressure related to space and the physical processing of print journals, citation analysis can still play an important role in collection development. Analyzing the references cited by recent articles can illuminate disciplinary trends in the sources and subjects that published authors consider important, affording opportunities to improve library collections and promote awareness of them. Providing seamless discovery of and access to older literature is particularly important in the field of chemistry, which builds on previous discoveries and methodologies and requires considerable diligence in reviewing the literature.

The majority of recent citation analyses have been based on local user groups, typically faculty publications or student dissertations. These are valuable in terms of measuring "in house" demand, but an analysis of references cited in a discipline's peer-reviewed journals offers a broader perspective. The current study analyzes references cited by 600 articles randomly sampled from ten journals published by the American Chemical Society (ACS) from 2011 through 2015. The reference data were derived from the Elsevier subscription database Scopus. The majority of citation analyses are based on data derived from Web of Science, an extremely expensive database that few small to mid-sized libraries can afford. The current study provides a less expensive option for citation analysis.

The main questions that we consider are: how often are different type of sources cited (original journal articles, reviews, conference proceedings, books, websites etc.); what are the age characteristics of references cited (in particular, how frequently are older references cited); how diverse are the references cited; what are the most frequently cited journals, and how do these correlate with journal impact factors. We also examine local usage of the ACS Legacy Archives as an indication of interest in older chemistry articles at our institution.

The many function of citations

An important function of citations is to "distribute credits and recognition to those whose earlier work has contributed to the development of ideas in different fields" (Cronin and Taylor 1984, p. 2). Their extensive review of the role and significance of citations in scientific communication builds on the work of earlier authors (e.g. Kaplan 1965; Merton 1965; Gilbert 1977) in exploring the complex social factors such as prestige, persuasion, social networks and coping with property rights that play a role in scientists' citation decisions (see Hargens 2000 and Nicolaisen 2007 for more recent analyses). A discussion of the sociology of citing behavior is beyond the scope of this paper, but we acknowledge the importance of this approach, as evidenced by the recent identification of 'citation cartels' - authors who disproportionately cite one another (Iztok and Matjaž 2016). Bornmann and Daniel (2008) provide a comprehensive review and analysis of citation studies from the early 1960's to 2005. Hoffmann *et al*. (2016) offer a recent discussion of citation ethics with a wealth of references and examples of citation errors in the field of chemistry.

Much of the literature related to citation analysis focuses on how often and how persistently journals, authors or individual articles are cited by others. Gross and Gross (1927) are credited as the first to use citation counts to evaluate the importance of scientific work, although the goal of their analysis of references in the 1926 volume of the *Journal of the American Society* was to inform library subscription decisions. Citation analysis has increasingly been used to evaluate individual scholarship and inform promotion and tenure decisions, assess academic institutions or departments, rank scientific journals, and inform grant awards and other funding decisions (Collini, 2012). An entire industry has burgeoned around journal rankings, impact factors and citation counts since Eugene Garfield developed the Science Citation Index, subsequently incorporated into Thomson-Reuter's Web of Science and recently acquired by Clarivate Analytics (Garfield 1964; 2016). Current citation analysis tools include Web of Science's Journal Citation Rankings, Scimago Journal and Country Rank journal rankings and individual h-index, the Source Normalized Impact per Paper (SNIP), and Elsevier's CiteScore. We acknowledge the complexities and controversies surrounding citation-based rankings and impact factors (e.g. Li *et al*. 2010; Garfield 2006; Collini 2012; Nightingale and Marshall 2012; Patience *et al*. 2017), but our study focuses on the references cited by sample documents – in this case, recent chemistry articles. We follow the distinction of Smith (1981) between citations as "the acknowledgment that one document receives from another" and references as "the acknowledgment that one document gives to another" (Ortega 2008, p. 213).

Article obsolescence

In his seminal and often-cited article, renowned physicist and information scientist Derek de Solla Price (1965) observes that most papers cease to be cited and become "obsolete" in about ten years, although a small number of articles endure to become classics. Price estimated that about 35% of articles are uncited each year, and about 10% are never cited. Cawkell (1976) estimates that about 85% of articles are never cited or are cited only once, although Stern's (1978) study of uncitedness in the medical literature suggests that this is an over-estimate. In their study of classic papers in physics and chemistry, Oppenheim and Renn (1978) note articles more than 15 years old are hardly ever cited. More recent studies report similar findings. For example, Kaplan, Steinberg and Doucette 2006 observe that materials more than 20 years old account for less than 9% of references cited in the top 10 medical titles and the top 10 general science titles listed by the 2002 Journal Citation Reports. De Groote (2008) reports a figure of around 7%, noting that while the number of articles cited by faculty at a large urban campus with a college of medicine increased between 1996 and 2007, about 30% of the citations were made within three years of publication. Larivière, Archambault and Gingras (2008) describe the typical life cycle of a scientific article as "short and intense", with a rapid increase in citations after publication followed by a peak and then a "slow but steady fall into oblivion" (p. 288). However, like Price (1965) and Oppenheim and Renn (1978), they note that some articles endure to become classics.

A variety of metrics and mathematical models of obsolescence have been developed (see Sjøberg 2010 for a useful summary), along with much critical discussion (e.g. Gapen and Milner 1981; Line

1993). Two somewhat controversial measures are the Cited Half-Life (the median age of articles citing a given sample of articles) and the Citing Half-Life -- the median age of articles cited by a given sample of articles (Sjøberg 2010, p. 64). Burton and Kebler (1960) are typically credited with applying the "half-life" of radioactive substances to the rate of obsolescence in the scientific literature, but Szava-Kovats (2002) trace the analogy to Charles Francis Gosnell's 1943 dissertation (Gosnell 1943). Burton and Kebler do not claim to have introduced the term, and themselves note that it may be inappropriate because "in scientific literature the half-life in a subject area may change as the nature of the subject area changes" (p. 22). In an extensive and critical review of the literature on obsolescence, Line and Sanderson (1974) distinguish between diachronous studies that analyze citations to a document or body of literature and synchronous studies, which analyze of references cited by a document of body of literature. They conclude that the median age of reference cited rather than the "half-life" is the appropriate measure for synchronous studies such as ours (see also Line 1993; Diodato and Smith 1993, and Ortega 2008). Another common measure of reference age in synchronous studies is the Price Index (named in honor of de Solla Price) - the percentage of references five years old or younger in a journal publication year (Larivière, Archambault and Gingras 2008).

Line (1993) predicted that articles would become obsolete more quickly with the increasing pace of scientific discovery and publication (i.e. the median age of references cited would decrease over time and the Price Index would increase). A longitudinal study of the scientific literature published since 1990 found that the opposite trend: the age of articles cited has risen steadily since the 1970's Larivière, Archambault and Gingras 2008). Several recent studies also report that the age of articles cited has increased over time, (e.g. Barnett and Fink 2007; Milojevic 2012; Verstak *et al*. 2014; Šubelj and Fiala 2017), possibly due to the availability of online journals, databases and search tools that provide easy access to archival content. Davis (2014) also credits the development of the Digital Object Identifier (DOI) that facilitates links to full text. However, the expansion of open access journals, repositories such as arXiv and institutional e-repositories that provide free access to preprints may exert a contrary tendency to cite more recent literature by providing access to recent content for readers without paid subscriptions (Kennan and Wilson 2006). As Garfield (2005) notes, reading or downloading articles does not guarantee future citation, but it is (one hopes) a precondition, and there may well be a positive correlation between usage and citation.

Citation Analyses and collection development

A great many citation analysis studies have been conducted from a library perspective since the seminal work of Gross and Gross (1927). Like print book circulation and journal usage studies, early citation analyses were often prompted by constraints on library shelving space as well as budgets. Space became less of a concern with increased availability of online journals, although the recent trend of converting stacks of old periodicals into student-friendly research spaces has prompted renewed interest in print usage statistics (Rose-Wiles and Irwin 2016). Still, the premise that more frequently cited publications are more important to have in a library collection than rarely-cited publications applies to online as well as print materials. Escalating journal prices and stagnant library budgets have forced libraries to pay close attention to indicators of value, including usage statistics, impact factors and citation analyses, to inform collection management. This is particularly true for journals in the sciences, including chemistry, which are typically the most costly library subscriptions (Rose-Wiles, 2011; Liu and Gee, 2017).

Citation analysis studies undertaken from a library perspective often focus on references cited in articles published by associated faculty or graduate student dissertation at the parent institutions. Kushkowski, Parsons and Wiese (2003) list 26 studies of this type published between 1981 and 2001. Hoffmann and Doucette (2012) reference 34 similar studies published between 2005 and 2010. Differences in methodology and reporting make it difficult to compare studies, but it clear that there are both changes over time and disciplinary differences. Kushkowski, Parsons and Wiese (2003) report a mean age of 12 years (median eight years) in their study of 629 theses and dissertations submitted between 1973 and 1992. Arts and humanities dissertations had the highest mean citation age (18.1 years) while engineering had the lowest (12.3 years). Brazzeal and Fowler (2005) calculate a median reference age of 7 years for forestry theses submitted between 1999 and 2003. Vallmitjana and Sabaté (2008) report a mean age of 14 years for 46 chemistry dissertations submitted between 1995 and 2003, while Kayongo and Helm's (2012) give a mean reference age of 10.8 years for 68 science dissertations from 2005 through 2007. More recent analyses of anthropology and sociology dissertations (Rosenberg 2015) and music dissertations (Arao, de Costa Santos and da Silveira Guedes 2015) report median reference ages of 14-15 years,

Other authors have explored citation patterns in leading journals in various subject areas. For example, Yang (2005) reports a Price Index ranging from 22.18% to 38.59% for eleven journals in tropical medicine. Yang, Pan and Chen (2006) give similar results for five andrology journals, where the Price Index ranged from 25.36 to 38.5%. Of particular interest for our study are previous analyses of citations in chemistry journals. The extensive work of Ortega (2008) reviews and summarizes findings from over 20 studies on the age of references cited conducted prior to 2007, including nine that included chemistry and/or biochemistry journals. Differences in methodology and measures reported make it difficult to determine trends over time, and a great deal of variation is apparent both within and across the reported results (Ortega 2008, Table 2, p. 218-19), but there is a clear tendency to primarily cite recent literature. Ortega's own study of articles published by chemists associated with the University of Oklahoma between 1975 and 2005 found that the age of references cited "tended to be similar across the study years", with median ages ranging from 5.0-7.5 years (p. 223).

Methodology

We selected ten journals published by the American Chemical Society (ACS) that cover diverse areas of chemistry (Table 1). We sampled journals from the same publisher for consistency of reference style, and chose ACS as one of the most extensive and reputable publishers in chemistry. We sampled one article from one issue per month for five years (2011-2015), yielding a total of 600 sample articles (60 per journal sampled). For the six bi-weekly journals, we randomly sampled an article from the first issue each month in one year and from the second issue in the subsequent year. For the two weekly journals, we sampled the first issue for 2011, the second issue for 2012, the third issue for 2013, the fourth issue for 2014, and the fifth issue for 2015 (if there was no fifth issue we chose the first issue). We sampled only "articles", excluding editorials, brief communications, letters, reviews, perspective, corrections etc. The one exception was *Chemical Reviews,* in which all articles were reviews.

We used the free web service "Random.org", which we gratefully acknowledge, to generate a random number for each sample article. The online version of each ACS journal issue provides a table of contents with the option to "select all" items; we then de-selected any items that did not meet our criteria for articles. Clicking on "download" yields the selected citations as a numbered list, making it easy to select the article corresponding to the randomly generated number. Once a sample article was identified we copied the title into the Scopus search box (set to "title" search) to retrieve the record and associated references. Occasionally it was necessary to remove chemical symbols, dashes or parentheses before the record was successfully returned. Scrolling down the record past the abstract to the link "View in search results format" allows the article's references to be exported to Excel by selecting "all" and "csv export". (It is possible to export the references from the 'CSV export' option above the reference list, but this format does not include the field "document type" and is limited to the first 70 references.) We downloaded the references for each of the 12 sample articles for each year and then combined them for analysis in Excel (2016 Version). We noticed that Scopus incorrectly recorded some books and book chapters as well as patents and dissertations as "articles", so we manually inspected and corrected the document type designations prior to analysis. We estimated the error rate at about 1%. The errors were generally easy to identify (e.g. a blank title field for books with the book title appearing in the "source title" field; blank volume and issue fields), but the manual adjustments may have caused some slight under-estimate of the book/book chapter and "other" categories.

We used Excel's pivot table function to summarize results for each journal year by reference publication year, document type and source title. We copied and saved the results as "values" for further analysis. For each journal we calculated the average number of references per sample article ("citation density", Garfield, 2005), the proportional distribution of document types: articles (reports of original research, typically although not exclusively in peer-reviewed journals), review articles, conference proceedings, books or book chapters and "other". The category "other" included brief communications, dissertations, letters to the editor, notes, patents, personal communications, short surveys, software or software manuals and websites.

We sorted the references for each journal and year by descending reference publication year, calculated reference ages by subtracting the reference publication year from the journal's publication year, and calculated percentages and cumulative percentages of references by age for each journal and year sampled. We calculated seven frequently-used measures of reference age: the Price Index (percent of references $\leq$ 5 years old), % of articles $\leq$10 years old, $\leq$15 years old and >20 years old, median reference half-life, median reference age, and the number of years prior to the sample article publication year that included 90% of the references. We calculated the median half-life and median age of references cited following the procedure of Ortega 2008 (Appendix A).

We used Excel's pivot table function to derive a lists of journals cited in our sample articles across the five years for each of our ten ACS journals. Not all journal titles were standardized, (e.g. *American Journal of Chemistry* also appeared as *Am. J. Chem.* or *The American Journal of Chemistry*) so we manually inspected and corrected the lists prior to further analysis. The process was straightforward for familiar titles and abbreviations, but at least 50 of the more than 2,000 journals listed required additional checking. Fortunately Google typically returns complete journal titles in response to searches of abbreviations, acronyms or foreign languages, but it required several inspections and revisions of the final title list to standardize the variant titles. We excluded about 15 titles that were unable to verify (the majority were cited only once). We maintained separate title designations such as "A, B and C" when these clearly referred to "split" publications such as *Journal of Physical Chemistry*, which was counted separately as *Journal of Physical Chemistry*, *Journal of Physical Chemistry A, B* and *C,* and *Journal of Physical Chemistry Letters.*

We sorted the list of journals cited by descending reference frequency for each of the ten ACS journals. For each journal we calculated six measures of reference diversity: the overall number of journals cited, the number of journals that accounted for 50% of the references, the cumulative percentage of references accounted for by the top 30 journals referenced, and the percentage of journals that accounted for 80% of references, the number of journals included in the top 20%, and the percentage of references to that journal ("self-citations"), Finally we compiled a list of the top journals referenced by all of the 600 sample articles for comparison with their most recently-reported impact factors and Scimago Journal Ranking (SJR) values, and with our institution's library subscriptions.

Results

Our analysis included over 53,000 references from the 600 articles samples (Table 1). The average number of references per article was 52, excluding the outlier *Chemical Reviews* with an average of 418 references. The average number of references per article was positively correlated with journal impact factor ($r = 0.965$, $p < 0.001$, $df = 9$) and SJR ($r = 0.933$, $p < 0.001$). There were no significant correlations between journal age (2015 minus first year published) and either impact factor or SJR.

The majority of references cited in our sample were original articles, which comprised an average of 83% of sources cited (Table 2). About 11 % of the references were classed as "reviews" in Scopus, bringing the total proportion of articles to almost 94%. *ACS Chemical Biology* and the *Journal of Medicinal Chemistry* cited the highest proportion of reviews. Despite the much larger number of references cited by articles in *Chemical Reviews,* the proportion of review articles was slightly below average. The *Journal of Physical Chemistry Part C* had the lowest proportion of review articles. The proportions of conference papers and books or book chapters cited were consistently low, each less than 2.5% on average. The exception was the *Journal of Organic Chemistry,* where 9% of the sample references were conference papers and 4% were books. ACS Nano was the least likely to cite books or book chapters. The *Journal of Medicinal Chemistry* and *Analytic Chemistry* shared the highest proportion of "other" sources, largely due to a tendency to cite patents, websites and software or technical manuals.

Table 3 summarizes various indicators of the age of references cited by the 600 sample articles, averaged across the five years sampled for each of the ten journals (the individual values for each of the five years 2011-2015 are provided in Appendix B). There was considerable variation across journals but there was a consistent trend to primarily reference recent literature. The average median reference age was 6 years (range 3.6 – 7.9 years), with an average Price Index (references $\leq$ 5 years old) of 44% (range 38-59%). On average, only 11% of references were more than 20 years old, and on average 23 years encompassed 90% of references. The *Journal of Organic Chemistry* consistently had the oldest indicators of reference age, followed by *Inorganic Chemistry*. The most recent journal, *ACS Nano*, had the most recent reference indicators. *Chemical Reviews* had close to average values for all indicators of reference age. There were no significant correlations between any of the measures of reference age and journal impact factor, SJR or age of the sample journal.

Five years is a short period of time to detect trends, but most journals showed a decrease in the Price Index and an increase in the percentage of references more than 20 years old, the median reference age and the age of 90% of the references (Table 4), suggesting a modest tendency to cite older references. There were some exceptions -- for example the *Journal of Physical Chemistry C* and the *Journal of Organic Chemistry* showed modest increases rather than decreases in the Price Index. However, no journal showed a decrease in the age of references cited across all four measures. Across the ten journals there was an average increase of 6% in the Price Index, a 3.3% increase in the percentage of references more than 20 years old, and an increase of 4.6 years in the age of 90% of references (Table 4).

Based on the combined sample of articles and reviews, we identified 2,560 source journals, including split and superseded titles. The average number of journals cited by each journal was 582, or 453 excluding the outlier *Chemical Reviews*, which cited 1,738 journals (Table 5). The *Journal of*

Organic Chemistry cited the fewest journals, followed by the *Journal of Inorganic Chemistry*. These two journals also had the least diversity, with nine and eleven journals respectively accounting for 50% of their references, and over 70% of all references to their top 30 journals cited. *Chemical Reviews* was the most diverse. On average about 20% of the journals cited (n = 114) accounted for 80% of the references cited (Table 5). The 80% mark for *Chemical Reviews* was only 13%, but because of the overall high number of journals cited, this represented 229 journals. *Analytical Chemistry* had the highest percentage of journals accounting for 80% of references at almost 34% as well as a high number of 196 journals, with a similar pattern of 31% (183 journals) for the *Journal of Medicinal Chemistry*. *Macromolecules* had the highest self-citation rates, while *ACS Chemical Biology* and *Chemical Reviews* had the lowest. The only measure of diversity that was significantly correlated with journal impact factors was the number of journals cited (impact factor: $r = 0.950$, $p < 0.001$, $df = 9$). SJR showed a similar correlation with the number of journals cited ($r = 0.904$, $p < 0.001$).

Across our entire sample of references there were 32 journals that were referenced more than 300 times. The 32nd ranked journal had 370 references and the 33rd had 286, creating a natural breakpoint to identify "highly cited journals". These 32 journals from ten publishers accounted for 47% of the references in our sample (Table 6). Impact factor and SJR were positively correlated across the 32 journals ($r = 0.984$, $df = 31$, $p < 0.001$), but there was no significant correlation between the percentage of references to a journal and its impact factor ($r = 0.0.54$) or SJR ($r = 0.092$). We cross-checked the "highly cited journals" list against our library subscriptions and identified four that were not currently subscribed.

Discussion

Source types

As expected in a science discipline, the vast majority of references cited in our study were articles. As Flaxbart (2001) remarks, in chemistry "the cutting edge and archival research are both found almost exclusively within the realm of peer reviewed journals" (p. 8). The range of 75-87% for original articles is similar to the 77-90% reported by Ortega (2008). The mean number of references cited (excluding *Chemical Reviews*) ranged from 39 to 64 compared with Ortega's range of 16.5 to 38.7, confirming her observation that the number of references cited by chemists is increasing over time. We did not find a disproportionate reliance on review articles, although we did note a relatively high proportion of review articles in biological and medicinal chemistry that warrants future investigation.

Like Ortega (2008), we found that non-journal sources, including books, conference proceedings, and websites, were not frequently cited. The use of "other sources" as references in Ortega's study ranged from 9% to 23% across sample years; in our study these ranged from 3% to 16%. This is consistent with Ortega's observation that the percentage of references to sources other than articles is decreasing over time. Numerous library-based studies have demonstrated a decline in the circulation of print books, although see Rose-Wiles and Irwin (2016) on the need to examine in-house use as well as circulation data). References to books still seem to be decreasing despite the expansion of eBooks, which are often indexed and available for download (frequently at the chapter level) through publisher sites and discovery services as well as traditional library catalogs.

A detailed analysis of book citations is beyond the scope of this study, but an examination of the 104 books cited by our sample articles in *Journal of the American Chemical Society* indicated that almost 50% were published prior to 2002 and only 10% were published after 2010, a very different pattern from references to articles. Most notably, about one third of the books referenced had previously been cited more than 1,000 times in the Scopus database. The most frequently cited book, *Electrochemical Methods: Fundamentals and Applications* (published in 1980) had been cited over 40,000 times. This indicates that although books in general are rarely cited, some become classics that are repeatedly cited in the same way as classic articles (Price, 1965; Oppenheimer and Renn, 1878; Larivière, Archambault and Gingras, 2008) Future studies might usefully focus on books that are frequently cited by chemists to ensure that they are maintained in or added to library collections.

Age of References

We were especially interested in whether the age of references cited by chemists has increased over time, as suggested by our five year sample. Comparing our results with earlier studies shows mixed results. Fussler's (1949) study of references in *Journal of the American Chemical Society* articles published in 1899, 1919, 1939 and 1946 showed an uneven pattern in median age, with eight years reported for both 1899 and 1946, compared with the six years in our study. Overall, one had to go back 50 years to encompass 90% of the references cited in Fussler's study, compared with 18 years in this study. Burton and Kebler's (1960) review of citation studies in engineering and others sciences, including chemistry, found an average "half-life" of 8.1 years (slightly older than the average of seven years in our sample), and 77% of references ≤ 20 years compared with 89% in our sample. Walcott's (1994) study of local molecular biology and biochemistry dissertations reported a Price Index of 50% (higher than our average of 44%) with 90% of references ≤ 15 years compared with 81% in our sample.

Moed, van Leeuwen and Reedijk (1998) break down the "half-life" of references in chemistry journals between 1981 and 1995 by subject area, which is particularly informative. They report a median half-life of 4.6 years for biochemistry and molecular biology compared with 7.2 years for *ACS Chemical Biology* in our sample; 5.7 years for general chemistry, the same as our result for *JACS*; 7.2 years for physical chemistry vs. 7.4 years for *Journal of Physical Chemistry C*; 6.4 years for organic chemistry vs. 8.9 years for *Journal of Organic Chemistry*, 6.5 years for analytical chemistry vs. 7.1 years for *Analytical Chemistry*; and 7.4 years for inorganic and nuclear chemistry vs. 7.9 years for *Inorganic Chemistry*. A study of references in JACS articles published in 2000 (Liu, 2003) allows a direct comparison between the Price Index (49.3% vs. 44% in our study) and references ≤ 15 years old (78.4% versus 86% in our study). These comparisons suggest a modest increase in the tendency to cite older sources in the past few decades, as noted by Larivière, Archambault and Gingras (2008). However, the median age of references in our sample was six years, consistent with Ortega's (2008) observation that "generally, median ages have remained around six years" (p. 223), suggesting that the change is slow and probably quite variable across sub-disciplines in chemistry.

Clearly one must view comparisons among studies very cautiously due to variations in sample composition, study durations, sampling methods and statistics reported. In addition, our study was based on results reported in Scopus while the majority of earlier studies used *Web of Science*. However, the comparisons with earlier studies as well as the current study suggest that although references to older sources has indeed declined substantially since the early studies, the trend seems to be gradually although unevenly reversing. We particularly note the increased "half-life" of references in chemical and organic chemistry suggested by comparison with Moed, van Leeuwen and Reedijk's (1998) study. It is suggestive that the increase accompanies the expansion of online journals, but there are likely a variety of factors involved. Our study found very few references to institutional or open access repositories, and only one reference was identified as coming from ArXiv. Preprints could not be readily identified, but the few references with no date in our sample (<1%) were typically commercial websites and not articles. Overall, despite modest increases over time, there is still a marked pattern of referencing the recent literature with few references to older publications.

<u>Highly cited journals and collection development</u>

Our study revealed some tendency for articles published in ACS journals to reference articles published in the same journal, and a marked trend for references to be concentrated on a relatively small subset set of journals. More than 47% of the references in our sample came from 32 journals. The well-known 80/20 "Pareto Rule" holds that approximately 80% of the use of books and serials in libraries is accounted for by about 20% of the collection (Trueswell 1969; Nisonger's (2008) review provides an excellent discussion of the history and application of Pareto's rule to usage and citation studies.) The 80/20 pattern seems generally applicable to chemistry journals. In our sample, an average of 20.2% of journals cited accounted for 80% of all journals cited, although the statistic across the ten sample journals ranged from 12% to nearly 34%. A very important caveat is that although 20% seems a low value, it represents over 100 journals that should be considered valuable or “core” across the various fields of chemistry. Specialized journals may also have particular value in their own fields, despite having a lower number of overall citations and being relegated to the “long tail” of reference distributions (Nisonger 2008). For example, the journals in analytical and medicinal chemistry had close to 200 journals accounting for 80% of references, almost double the average value. As Flaxbart (2001) observes, chemistry “is not a homogenous discipline. The same kind of differences that separate broad disciplines also separate – to a somewhat lesser extent – subfields within the discipline” (p.23).

Our comparison of the top 32 highly cited chemistry journals with our library subscriptions proved useful in identifying several gaps in the library’s current journal collection. We plan to extend the comparison to the most commonly referenced journals for each of the sub-disciplines represented in our sample, and conduct an analysis of references in faculty publications and student dissertations.

The trend for the chemistry articles in our sample to predominantly cite a relatively small core of journals is consistent with the findings of previous studies (e.g. Gooden 2001; Tonta and Al 2006; Nisonger 2008). Several factors likely combine to account for this pattern. The first is the proliferation of journals in chemistry and related fields. Scimago currently lists 863 journals under the subject “chemistry” and 705 under “chemical engineering”. The vast number of associated articles unfortunately reflects the “publish or perish” mentality of many academic institutions as well as prolific research activity, flooding the literature with rarely cited and possibly marginal publications. Many publishers and vendors bundle low-quality (or at least rarely cited) journals into their packages or databases along with core titles so the articles they contain are included in search results. In the face of such over-abundance of published information, one realistic coping strategy is to focus primarily on familiar and trusted publications or search a single publisher’s site rather than use a database or aggregated subject search. In a small but deep survey of six chemistry faculty, Flaxburg (2001) reported that senior faculty still tend to rely on scanning specific journal table of contents, a practice retained from the days of print journals (Brown, 1999).

The above practice relates to the second factor tending to concentrate chemistry references on core journals. Many chemists, especially seasoned researchers, are conservative in terms of the journals that they regularly read and publish in, and are typically suspicious of open access journals. This is unfortunate in view of the legitimate attempts of the open access movement to liberate information from paid subscriptions, but the rise of predatory journals that taint the open access movement and confuse it with “vanity publishing” (e.g. Ferris and Winker 2017) make such caution understandable. Junior faculty concerned with achieving promotion and tenure may also tend to favor traditional, high impact journals, especially when they have been enculturated and will be evaluated by senior, more conservative colleagues. However, the reverse side of this argument is that junior faculty desperate to publish may be tempted by the promise of easy (or no) peer-review and rapid turnaround in less reputable journals, or they may wish to publish in open-access journals on principle but lack the often exorbitant funds demanded for open access options in leading journals. Nisonger (2008) notes that more research is needed on the impact of open-access journals on usage patterns. More research is also needed on the impact of open-access journals and e-repositories on citation practices.

An additional consideration is that our sample included only well established and reputable journals, most with relatively high impact factors. It may well be that chemists who successfully publish in these journals, which are highly selective and competitive, may themselves tend to predominantly read and reference similar publications, including those from the same publisher. A citation analysis of less prominent journals may throw light on this aspect of citation practices.

The lack of significant correlations between SJR or impact factor and the number of references to a journal is somewhat surprising since the number of citations a journal receives is a measure included in those metrics. Tonta and Al (2006) made found a similar lack of correlation in their study of dissertations in library science. Venturing into the quagmire of impact factors and their relevance is beyond the scope this study, but this contradiction warrants further investigation. We did find significant positive correlations between journal impact factor (and SJR) and both the average number of references per article and the overall number of journals that were cited. This suggests that articles in higher ranked journals tend to have more references and cite a greater number of sources, and/or that these measures contribute to journal rankings. However, neither the age nor the diversity of sources cited appear to be related to a journal's impact factor.

Usage and "turnaway" statistics

It has become common practice for vendors and publishers to furnish librarians with "denial" or "turnaway" data. A turnaway is recorded when a user clicks on the record for an article to which their library does not have full text access. An analysis of ScienceDirect data at our institution revealed that we had current subscriptions to 70% of the 1,222 journal for which turnaways were recorded, and a further 18% were "complimentary or open access". Almost all of the turnaways for the subscribed journals were for articles more than five years old (prior to our current subscription to the Freedom Collection), and 31% were for articles fifteen or more years old. There were virtually no interlibrary loan requests for the journals in which the articles appeared, so the link between turnaways and true demand is unclear. However, the high number of turnaways for older content suggests some level of interest among library users. Publishers, including Elsevier and ACS, frequently use turnaway data in order to promote their journal archives or "back-files", a practice previously noted by Ortega (2008, p. 211).

At the end of 2015, our institution's library purchased the ACS "Legacy Archive", which extends access to the journals available through ACS Web editions package to which we subscribe from 1995 back to the each journal's inception. This provided us with an opportunity to examine usage of older articles (as determined by full-text downloads) and compare it with previously reported turnaways. We found significant positive correlation at the journal level between turnaways for 2011-2015 and full-text downloads for 2016 and 2017 ($r = 0.931$, $p < 0.001$, $df = 26$), suggesting that turnaways can be a valid indicator of future use. We also found that 18% of all full-text downloads in 2016-17 came from the Legacy Archives. This is considerably higher than the 11% of references more than 20 years old found in our sample of ACS journal references. The oldest article downloaded was from 1894, and the highest number of downloads (n = 114) were for articles published in 1962. While usage may be only a very general predictor of future citation (Garfield, 2005), again it indicates an interest in older articles. Since there were very few interlibrary loan requests for ACS journal articles in the two years prior to our acquiring the Legacy Archive, immediate online availability is clearly important to our users. A broader and more detailed study of turnaways, usage and interlibrary loan requests at our institution is currently underway.

References to older literature

While there are some indications that the trend to cite primarily recent literature is slowly reversing, our study indicates that chemists primarily reference recent sources. References more than 20 years old only comprise about 11% (on average) of references, and almost one third of references are ten years old or less. Several authors have lamented a failure to adequately cite the older literature (e.g. Sjøberg 2010; Johnson 2014; Augustine 2016). Veteran catalysis researcher Robert Augustine suggests that current researchers rely too much on the "readily available current literature" and need to recognize the importance of earlier work in understanding current results (Augustine 2016, p. 2394). The editors of the *Journal of Physical Chemistry Letters* discuss the importance of selecting and citing scientific references correctly, noting that important and relevant papers are sometimes absent from published papers (Kamat and Schatz 2014). In their delightful essay on citation ethics, Hoffmann *et al*. (2016) bemoan the decreased attention paid to good citation practices, noting that over time they have seen "less and less guidance for the budding scientific writer" (p. 10967). Librarians as well as chemistry faculty bear a responsibility to make students aware of the need to review the older literature, where and how to access it, and to reference it where appropriate.

Institutions with accredited undergraduate chemistry programs in the United States typically have access to SciFinder®, which provides comprehensive and historically deep search results. However, inexperienced searchers may find the number of results returned overwhelming and should be provided with careful instruction on how to use SciFinder® effectively. Students should also be familiarized with techniques such as citation chasing (tracking down the references cited by a particular article or author) and cited reference searching (finding articles that cite a particular work) to understand the impact of particular articles and the broader context of their research. This can be done quite easily in Web of Science, Scopus or even Google Scholar, an option for libraries whose budgets do not permit the former costly subscription services.

Given chemistry's reliance on well-established and relatively highly-ranked journals, librarians must ensure that faculty and students have access to the leading chemistry journals through direct subscriptions (to the extent that budgets permit) and/or an efficient interlibrary loan or document delivery system. Equally important, librarians have a particular responsibility to ensure that faculty and students are aware of all the relevant resources that the library offers, and how to use them effectively. Usage statistics can be a useful metric in assessing resources, but there is an underlying (and perhaps unrealized) assumption that users are aware of all the resources that are available. In addition to providing instruction in the availability and usage of the most popular sources, chemistry students and faculty should be made aware of lesser-known publications and how to assess them, so that the field does not become increasingly narrow.

Conclusion and future studies

Our study confirms a strong tendency for chemists to reference articles rather than books or other forms of publication. It also confirms a tendency to predominantly reference recent publications, although there are some indications that this trend is gradually reversing, perhaps in response to the increased online availability of older articles. Our examination of downloads from the ACS Legacy archive suggests that usage (an indicator, but not necessarily an accurate predictor, of future citation) increases when articles are immediately available online. As in previous studies, we found that chemists, at least those who publish in ACS journals, predominantly reference a relatively small number of well-established journals. This may be a practical response to large and growing number of journals in the field and/or conservatism on the part of established chemists. The 80/20 Pareto rule (20% of journals account for

80% of references) appears to be consistent with citation practices in chemistry, despite a move from print to primarily online journals.

We suggest that chemists, at least those who publish in ACS journals, retain the habit of predominantly referencing subset of core journals that they developed in the days of print-only journals. This is both informative and challenging for science librarians. In terms of collection development, it highlights the need to ensure that the core journals are readily available, and that less-cited journals may be considered for cancellation – with the important caveat that different specialities may have their own corpus of core journals. In terms of library instruction, it suggests a need for librarians to inform faculty and students (tomorrow's chemists) of the need to search for important and relevant articles regardless of their age or the journal in which they are published. This requires both familiarizing users with all the resources the library offers and how to use them effectively, and providing training on how to judge the relevance, accuracy and importance of articles, regardless of where they are published. As one colleague observed, there may be a disparity between librarians' focus on subject searching across a wide range of journals and disciplinary practices of searching only specific journals or collections.

Our study is limited in terms of journals analyzed and years covered. It would be useful for future studies to analyze results from a wider range of journals and years, and for institutions that have access to both Web of Science and Scopus to compare results. New surveys and interviews involving faculty and graduate students in regard to their habits and training in conducting literature reviews and their citation practices could also inform both collection development and library instruction. Future studies might also consider exploring heavily referenced "classic" books in chemistry to inform collection development (especially weeding projects) and the impact of open-access journals and e-repositories on citation practices.

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Table 1: American Chemical Society Journals Sampled (n = 10) for years 2011-2015.

Journal Title	Start year	Issues per year	Impact factor	SJR	Average articles per issue	Articles sampled	Average references per article sampled	max references	Standard error	Total references analyzed
ACS Chemical Biology	2006	12	4.995	2.567	15	60	43	71	1.46	2,586
ACS Nano	2007	12	13.942	6.916	102	60	49	125	2.60	2,947
Analytical Chemistry	1923	24	6.32	2.255	52	60	39	84	1.71	2,341
Chemical Reviews[1]	1924	24	47.928	19.282	14	60	418	2075	42.75	25,159
Inorganic Chemistry	1962	24	4.857	1.774	54	60	63	190	4.201	3,751
Journal of Medicinal Chemistry	1959	24	6.259	1.976	25	60	46	80	1.976	2,730
Journal of Organic Chemistry	1936	24	4.849	2.995	36	60	57	135	3.23	3,451
Journal of Physical Chemistry C [2]	2007	52	4.536	1.948	65	60	49	102	2.38	2,928
Journal of the American Chemical Society	1879	52	13.858	7.368	30	60	65	211	3.42	3,931
Macromolecules	1968	24	5.835	2.557	39	60	55	124	3.05	3,319
Total						600				53,143

[1] Published monthly through 2013, then bi-weekly

[2] Began in 1986 and subsequently split into sections A-C

Table 2 : Type of sources cited by 600 articles sampled from ten ACS journals, 2011-2015

Journal Title	Total references analyzed	% articles	% reviews	% conference papers	% book or book chapter	% other
ACS Chemical Biology	2,594	75.9%	19.1%	1.0%	1.4%	2.6%
ACS Nano	2,948	86.1%	10.5%	1.2%	1.1%	1.1%
Analytical Chemistry	2,343	81.6%	12.5%	2.1%	1.8%	4.3%
Chemical Reviews	25,195	84.5%	10.4%	1.8%	1.6%	0.2%
Inorganic Chemistry	3,751	83.7%	9.4%	1.4%	2.5%	3.4%
Journal of Medicinal Chemistry	2,730	75.4%	17.3%	1.4%	1.5%	4.3%
Journal of Organic Chemistry	3,440	83.6%	8.3%	9.0%	4.1%	3.1%
Journal of Physical Chemistry C	2,928	88.6%	5.1%	1.6%	3.4%	1.4%
Journal of the American Chemical Society	3,881	82.6%	10.5%	1.2%	3.0%	2.7%
Macromolecules	3,318	85.1%	8.0%	1.9%	3.2%	1.9%
average	5,313	82.7%	11.1%	2.3%	2.4%	2.5%

Table 3: Measures of age of references cited by 600 articles sampled from ten ACS journals, 2011-2015

Journal	Price Index (References ≤ 5yrs old)	Refs. ≤ 10 years	Refs. ≤ 15 years	Refs. > 20 years	Median half-life	Median Reference Age	Age of 90% of references (years)
ACS Chemical Biology	42%	71%	86%	7%	7.2	6.2	18
ACS Nano	59%	82%	90%	6%	4.6	3.6	16
Analytical Chemistry	46%	69%	81%	12%	7.1	6.1	24
Chemical Reviews	41%	66%	80%	12%	7.8	6.8	23
Inorganic Chemistry	38%	61%	74%	16%	7.9	6.9	28
Journal of Medicinal Chemistry	44%	69%	83%	8%	5.9	4.9	19
Journal of Organic Chemistry	37%	59%	72%	18%	8.9	7.9	31
Journal of Physical Chemistry C	43%	64%	77%	14%	7.4	6.4	27
Journal of the American Chem Society	52%	75%	86%	7%	5.7	4.7	18
Macromolecules	41%	64%	78%	13%	7.6	6.6	24
Average	44%	68%	81%	11%	7.0	6.0	22.9

Table 4: Change in key reference age indicators across 60 articles sampled from ten ACS journals from 2011 to 2015

Journal	Price Index lower = older	% References > 20 yrs old higher = older	Median reference age higher = older	Age of 90% of references higher = older
ACS Chemical Biology	-4.9%	-1.9%	0.3	-2.0
ACS Nano	-5.6%	0.3%	-0.1	1.0
Analytical Chemistry	-14.0%	2.0%	2.1	3.0
Chemical Reviews	-8.0%	4.0%	2.0	4.0
Inorganic Chemistry	-9.2%	3.5%	1.1	4.0
Journal of Medicinal Chemistry	-8.0%	1.0%	2.9	2.0
Journal of Organic Chemistry	1.3%	0.6%	1.2	0.0
Journal of Physical Chemistry C	4.3%	9.5%	0.0	17.0
Journal of the American Chemical Society	-12.5%	6.0%	2.0	8.0
Macromolecules	-3.1%	7.8%	1.8	9.0
2011 Average	46.9%	9.5%	5.5	20.5
2015 Average	40.9%	12.8%	6.8	25.1
Average	**-6.0%**	**3.3%**	**1.3**	**4.6**

Table 5: Number and diversity of journals cited by 600 articles sampled from ten ACS journals, 2011-15

Journal Title	Journals cited 2011-15	journals accounting for 50% of references	% of references from top 30 journals cited	% Journals accounting for 80% refs	# journals in top 20%	% references from source journal
ACS Chemical Biology	507	30	50.4%	27.2%	138	1.3%
ACS Nano	442	14	66.2%	17.2%	76	5.6%
Analytical Chemistry	580	38	45.6%	33.8%	196	12.4%
Chemical Reviews	1738	43	42.9%	13.2%	229	1.5%
Inorganic Chemistry	390	11	70.5%	14.4%	56	12.1%
Journal of Medicinal Chemistry	585	40	45.4%	31.3%	183	9.4%
Journal of Organic Chemistry	321	9	75.5%	12.1%	39	12.3%
Journal of Physical Chemistry C	406	29	58.4%	21.4%	87	6.5%
Journal of the American Chemical Society	475	15	64.0%	14.9%	71	16.3%
Macromolecules	378	13	66.8%	16.9%	64	19.0%
average	582	24	58.6%	20.2%	114	9.6%
total unique journals	2,560					

Table 6: Journals most frequently cited by sample references from ten ACS journals

Journal title	Publisher	refs	% of refs	Impact Factor	SJR
Journal of the American Chemical Society	ACS	4014	7.99%	13.858	7.370
Angewandte Chemie - International Edition	Wiley	1671	3.32%	11.994	5.800
Chemical Communications	RSC	1114	2.22%	6.319	2.506
Journal of Organic Chemistry	ACS	1013	2.02%	4.849	1.976
Inorganic Chemistry	ACS	998	1.99%	4.857	1.774
Chemical Reviews	ACS	836	1.66%	47.928	19.282
Science	Science	822	1.64%	34.661	13.535
Proceedings of the National Academy of Sciences	Nat Acad Sci	771	1.53%	9.661	6.321
Macromolecules	ACS	699	1.39%	5.835	2.557
Analytical Chemistry	ACS	698	1.39%	6.21	2.255
Journal of Physical Chemistry B	ACS	670	1.33%	3.177	1.348
Organic Letters	ACS	654	1.30%	6.479	2.964
Journal of Chemical Physics	AIP	639	1.3%	2.965	1.073
Nature weekly	Springer	630	1.25%	40.137	18.134
Tetrahedron Letters	Elsevier	624	1.24%	2.379	0.754
Journal of Biological Chemistry	Biochem.	594	1.18%	4.125	2.755
Langmuir	ACS	567	1.13%	3.833	1.559
Chemistry - A European Journal	Wiley	566	1.13%	5.317	2.247
Nano Letters	ACS	544	1.08%	12.712	7.983
Physical Review B	Am Phys. Soc.	536	1.07%	3.836	1.939
Journal of Medicinal Chemistry	ACS	514	1.02%	6.259	2.529
Journal of Physical Chemistry C	ACS	453	0.90%	4.536	1.948
Dalton Transactions	ACS	447	0.89%	4.029	1.243
Chemical Society Reviews	RSC	435	0.87%	38.618	14.944
Physical Review Letters	Am Phys. Soc.	427	0.85%	8.462	3.560
Tetrahedron	Elsevier	421	0.84%	2.645	0.907
Physical Chemistry Chemical Physics	RSC	400	0.80%	4.123	1.678
Advanced Materials	Wiley	399	0.79%	19.741	8.364
Accounts of Chemical Research	ACS	394	0.78%	20.268	10.782
Organometallics	ACS	386	0.77%	3.862	1.713
ACS Nano	ACS	374	0.74%	13.942	6.916
Chemistry of Materials	ACS	370	0.74%	9.466	4.114
Total		23,680	47.1%		

Appendix A: Method for calculating Median Age of References Cited

JCR explains journal and aggregate citing half-life at http://admin.isiknowledge. com/JCR/help/h_ctghl.htm.

The formula can be found in Thomson ISI. 2003. "*Journal Citation Reports* on the Web 2.0 Training Guide." Institute for Scientific Information, Inc®, page 10.

Example from 1975 Citing Journal Articles:

Cited Year	*1975*	*1974*	*1973*	*1972*	*1971*	***1970***	***1969***	*1968*	*Prev Yrs*	*Total*
# Cites from 1975 Citing Articles	13	62	76	64	50	45	35	36	247	628
Cumulative %	2.07	11.94	24.04	34.24	42.20	**49.36**	**54.94**	60.67		

Citing Half-Life Calculation:

The citing half-life calculation finds the number of years from the citing year that account for the halfway point in the age of references. This research study used *JCR*'s method for figuring citing half-life and then adjusted it by one year to find the median age of references.

For 1975 Citing Journal Articles, the citing half-life of 6.1 years is arrived at by:

subtracting from 50% the cumulative % that is just under 50%, so **50.00 – 49.36 = 0.64**;

then subtracting the cumulative % just under 50% from the cumulative % that is just over 50%, so **54.94 – 49.36 = 5.58**;

then dividing the first number by the second and rounding to the nearest tenth, so **0.64/5.58 = 0.1**.

This amount is added to the number of years where the cumulative % falls just under 50%, so **0.1 + 6 (counting back from 1975 to 1970) = 6.1 years**

However, after figuring the citing half-life, one year was subtracted so that the same cited year (in this case, 1975) was not counted as a separate year; therefore in the results, **5.1** years is reported as the median age or as the adjusted half-life.

Source: Ortega, L. (2008). Appendix. Age of references in chemistry articles: a study of local authors' publications from selected years, 1975-2005. *Science and Technology Libraries*, *28*(3), 209-246.

Appendix B: Measures of age of references cited by sample articles by journal and year, 2011-2015

Journal	Year	Price Index (References < 5yrs old)	References < 10 years	References < 15 years	Reference > 20 years	Median half-life	Median Reference Age	Age of 90% of references
ACS Chemical Biology	2011	45%	75%	88%	6%	6.7	5.7	18
ACS Chemical Biology	2012	48%	74%	85%	8%	6.3	5.3	19
ACS Chemical Biology	2013	41%	66%	85%	5%	7.6	6.6	18
ACS Chemical Biology	2014	38%	67%	82%	9%	8.4	7.4	21
ACS Chemical Biology	2015	40%	72%	89%	4%	7.0	6.0	16
ACS Nano	2011	60%	80%	88%	7%	4.7	3.7	17
ACS Nano	2012	60%	80%	88%	8%	4.7	3.7	18
ACS Nano	2013	66%	86%	92%	4%	3.8	2.8	14
ACS Nano	2014	56%	84%	92%	5%	5.2	4.2	14
ACS Nano	2015	54%	78%	88%	7%	4.6	3.6	18
Analytical Chemistry	2011	59%	79%	89%	8%	4.7	3.7	17
Analytical Chemistry	2012	47%	70%	83%	11%	6.6	5.6	22
Analytical Chemistry	2013	51%	73%	84%	8%	5.9	4.9	19
Analytical Chemistry	2014	27%	49%	64%	25%	11.4	10.4	42
Analytical Chemistry	2015	45%	73%	85%	10%	6.8	5.8	20
Chemical Reviews	2011	44%	72%	85%	9%	7.7	6.7	19
Chemical Reviews	2012	38%	62%	76%	15%	8.1	7.1	26
Chemical Reviews	2013	46%	71%	83%	10%	5.6	4.6	20
Chemical Reviews	2014	39%	65%	77%	15%	7.8	6.8	26
Chemical Reviews	2015	36%	62%	78%	13%	9.7	8.7	23
Inorganic Chemistry	2011	42%	63%	78%	14%	7.5	6.5	26
Inorganic Chemistry	2012	41%	61%	75%	15%	7.6	6.6	27
Inorganic Chemistry	2013	37%	58%	70%	18%	8.1	7.1	28
Inorganic Chemistry	2014	41%	63%	76%	15%	7.8	6.8	28
Inorganic Chemistry	2015	33%	57%	72%	18%	8.6	7.6	30

Journal	Year	Price Index (References ≤ 5yrs old)	References ≤ 10 years	References ≤ 15 years	Reference > 20 years	Median half-life	Median Reference Age	Age of 90% of references
Journal of Medicinal Chemistry	2011	46%	73%	88%	7%	5.0	4.0	18
Journal of Medicinal Chemistry	2012	48%	72%	84%	5%	5.5	4.5	16
Journal of Medicinal Chemistry	2013	46%	70%	83%	8%	5.6	4.6	19
Journal of Medicinal Chemistry	2014	42%	67%	80%	12%	5.6	4.6	24
Journal of Medicinal Chemistry	2015	38%	63%	81%	8%	7.9	6.9	20
Journal of Organic Chemistry	2011	39%	65%	79%	14%	7.7	6.7	27
Journal of Organic Chemistry	2012	29%	49%	60%	28%	11.5	10.5	40
Journal of Organic Chemistry	2013	34%	59%	72%	19%	8.9	7.9	30
Journal of Organic Chemistry	2014	40%	61%	75%	15%	7.6	6.6	30
Journal of Organic Chemistry	2015	41%	62%	76%	15%	8.9	7.9	27
Journal of Physical Chemistry C	2011	40%	63%	78%	13%	7.5	6.5	25
Journal of Physical Chemistry C	2012	53%	73%	82%	9%	5.5	4.5	21
Journal of Physical Chemistry C	2013	34%	56%	74%	13%	9.4	8.4	26
Journal of Physical Chemistry C	2014	43%	69%	81%	11%	7.3	6.3	22
Journal of Physical Chemistry C	2015	44%	60%	69%	22%	7.5	6.5	42
Journal of the American Chem Society	2011	60%	80%	92%	3%	4.4	3.4	13
Journal of the American Chem Society	2012	49%	74%	86%	8%	6.2	5.2	18
Journal of the American Chem Society	2013	53%	77%	87%	8%	5.7	4.7	18
Journal of the American Chem Society	2014	52%	74%	85%	8%	5.8	4.8	19
Journal of the American Chem Society	2015	48%	70%	82%	9%	6.4	5.4	21
Macromolecules	2011	34%	55%	77%	13%	8.6	7.6	25
Macromolecules	2012	50%	73%	87%	7%	6.0	5.0	18
Macromolecules	2013	51%	71%	80%	12%	5.8	4.8	24
Macromolecules	2014	41%	68%	81%	10%	7.4	6.4	21
Macromolecules	2015	31%	52%	67%	21%	10.4	9.4	34
average		44%	68%	81%	11%	7.0	6.0	22.9