Citation Analysis:
A Comparison of Google Scholar, Scopus, and Web of Science

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ABSTRACT

When faculty members are evaluated, they are judged in part by the impact and quality of their scholarly publications. While all academic institutions look to publication counts and venues as well as the subjective opinions of peers, many hiring, tenure, and promotion committees also rely on citation analysis to obtain a more objective assessment of an author's work. Consequently, faculty members try to identify as many citations to their published works as possible to provide a comprehensive assessment of their publication impact on the scholarly and professional communities. The Institute for Scientific Information's (ISI) citation databases, which are widely used as a starting point if not the only source for locating citations, have several limitations that may leave gaps in the coverage of citations to an author's work. This paper presents a case study comparing citations found in *Scopus* and *Google Scholar* with those found in *Web of Science* (the portal used to search the three ISI citation databases) for items published by two Library and Information Science full-time faculty members. In addition, the paper presents a brief overview of a prototype system called *CiteSearch*, which analyzes combined data from multiple citation databases to produce citation-based quality evaluation measures.

INTRODUCTION

Citation analysis, along with peer judgment and assessments of publication counts and venues, is one of the most widely used methods in evaluating the research performance of scholars (Lewison, 2001; Thomas & Watkins, 1998). Researchers and administrators at many academic institutions worldwide make use of citation data for hiring, promotion, and tenure decisions, among others (Wallin, 2005). Citation counts provide researchers and administrators with a reliable and efficient indicator for assessing the research performance of authors, projects, programs, institutions, and countries and the relative impact and quality of their work (Cronin, 1984; van Raan, 2005). The use of citation counts for evaluating research is based on the assumption that citations are a way of giving credit to and recognizing the value, quality, and significance of an author's work (Borgman & Furner, 2002; van Raan, 1996).

Many scholars have argued for and some against the use of citations for assessing research quality (Borgman & Furner, 2002). While the proponents have reported the validity of citation counts in research assessments as well as the positive correlation between these counts and peer reviews and assessments of publication venues (Aksnes & Taxt, 2004; Glänzel, 1996; Holmes & Oppenheim, 2001; Kostoff, 1996; Martin, 1996; Schloegl & Stock, 2004; So, 1998; van Raan, 2000), critics claim that citation counting has serious problems or limitations that impact its validity (MacRoberts & MacRoberts, 1989, 1996; Seglen, 1998).

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Important limitations reported in the literature focus on, among other things, the problems associated with the data sources used, especially *Web of Science*—the standard and most widely used tool for generating citation data for research assessment purposes.[1] Critics note that *Web of Science*: (1) cover mainly English-language journal articles published in the United States, United Kingdom, and Canada; (2) are limited to citations from journals and papers indexed in the ISI database; (3) provide different coverage between research fields; (4) do not count citations from books and other non-ISI sources; and (5) have citing errors (e.g., homonyms, synonyms, and inconsistency in the use of initials and in the spelling of non-English names) (Lewison, 2001; Reed, 1995; Seglen, 1998). For a detailed summary of potentials and pitfalls of citation analysis for research assessment, see Wallin (2005).

Research Questions and Significance

With advances in information technology and improvement in online access to tens of millions of records through databases and services that provide citation information, *Web of Science* may no longer remain the only practical method or tool to be used for locating citations to authors and published works, thus warranting several research questions:

- What differences do databases that provide citation information make in citation counts for authors?
- How do citations in these sources compare to those located through ISI databases in terms of, for example, document source, document type, and refereed status?
- What is the value of the unique citations found in these sources?
- Do these sources represent alternatives to *Web of Science* or do they complement it?
- What problems and limitations do these sources have and how to alleviate these problems and limitations?

Answering these questions is important to academic librarians, scholars, and administrators and anyone trying to decide whether an article, author, or journal citation search should be limited to *Web of Science* or extended beyond it. The answers to these questions are also important for those seeking to use appropriate databases to generate more complete citation counts and accurate citation rankings and assessments of research impact than those based exclusively on *Web of Science*. More complete citation counts can help support or identify more precisely any discrepancies between research productivity, peer evaluation, and citation data. More complete citation counts can also help generate more accurate h-index scores of scholars and journals, among others (Hirsch, 2005). Scholars trying to locate citations to a specific article for pure research purposes (as opposed to citations counts, research evaluation, and otherwise) will find answers to the aforementioned questions very useful too, especially in cases where bibliographic searches fail to identify relevant materials. Vendors and producers of full-text databases, such as Cambridge Scientific Abstracts, EBSCO, Online Computer Library Center (OCLC), ProQuest, Wilson Company, and others will also benefit from answering these questions by applying its findings to develop and illustrate additional features and uses of their products.

Although there are many databases and services that could be used to answer the abovementioned research questions, the current study focuses on comparing *Scopus* and

[1]*Web of Science* is the portal used to search the three ISI (Institute for Scientific Information) citation databases: *Arts & Humanities Citation Index*, *Science Citation Index*, and *Social Sciences Citation Index*.

Google Scholar with *Web of Science*.[2] *Scopus* and *Google Scholar* were chosen because of their similarity to *Web of Science* in that they were created primarily for citation searching while at the same time can be used for bibliographic searching as well, among other things. *Scopus* and *Google Scholar* were also chosen because they represent major competitors to *Web of Science* in the field of citation analysis and bibliometrics. Currently, there are no general, comprehensive databases or services that represent a major challenge to *Web of Science* as the citation analysis tool than *Scopus* and *Google Scholar*.

METHOD

Search Tools

This study compares *Scopus* and *Google Scholar* with *Web of Science* for locating citations to individual papers and authors. As mentioned earlier, *Web of Science*, which comprises the three ISI citation databases, has been the standard tool for a significant portion of all citation studies worldwide. Its website provides substantial factual information about the database, including the number of records and lists of journals indexed[3]. It also offers powerful features for browsing, searching, sorting and saving functions, as well as exporting to citation management software. Coverage in *Web of Science* goes back to 1945 for *Science Citation Index*, 1956 for *Social Sciences Citation Index*, and 1975 for *Arts & Humanities Citation Index*. As of January 2006, there were over 35 million records in the database from approximately 8,700 scholarly journals (including open access ones) and a number of refereed conference proceedings. Subjects covered in Web of Science include all disciplines one can think of or find in the curricula of universities in arts, humanities, sciences, and social sciences. For more details on Web of Science, see Goodman and Deis (2005) and Jacso (2005a).

Similar to ISI, Elsevier, the producer of *Scopus*, provides substantial factual information about the database, including the number of records and lists of journals indexed (http://www.info.scopus.com/). It also offers powerful features for browsing, searching, sorting, and saving functions, as well as exporting to citation management software. Coverage in *Scopus* goes back to 1966 (1996 for citations). In 2005, there were over 27 million records in the database from 14,200 titles broken down as follows: 12,850 academic journals including coverage of 535 Open Access journals, 750 conference proceedings, and 600 trade publications. Subject areas covered in Scopus include: Chemistry, Physics, Mathematics, and Engineering (4,500 titles), Life and Health Sciences (5,900 titles—100% Medline coverage), Social Sciences, Psychology, and Economics (2,700 titles), Biological, Agricultural, and Environmental Sciences (2,500 titles), and General Sciences (50 titles). For more details on Scopus, see Goodman and Deis (2005) and Jacso (2005a).

In contrast to ISI and Elsevier, Google does not offer a publisher list, journal list, or any information about the time-span or the refereed status of records in *Google Scholar*. This and other studies, however, have found that *Google Scholar* covers print and electronic journals, conference proceedings, books, theses, dissertations, preprints, abstracts, and technical reports available from major academic publishers, distributors, aggregators, professional societies, government agencies, and preprint/reprint repositories at universities, as well as those available

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[2]Other databases and services that could have been examined include: *Academic Search Premier* (EBSCO), *The Association of Computing Machinery Digital Library* (ACM), *Chemical Abstracts SciFinder* and *SciFinder Scholar*, *CiteSeer*, HighWire Press (Stanford University), *IEEE Computer Society Digital Library*, *InfoTrac* (Gale), *JSTOR*, *Library Literature and Information Science Full Text* (WilsonWeb), *Project Euclid*, *Project Muse*, *PsycINFO*, *ScienceDirect* (Elsevier), SpringerLink (Springer), and *Wiley InterScience*.

[3]http://scientific.thomson.com/support/products/wos7/

across the web (Bauer & Bakkalbasi, 2005; Gardner & Eng, 2005; Jacso, 2005b; Wleklinski, 2005). Examples of these sources include: The American Physical Society, Annual Reviews, arXiv.org, Association for Computing Machinery (ACM), Blackwell, Cambridge Scientific Abstracts (CSA), HighWire Press, Ingenta, Institute of Electrical and Electronics Engineers (IEEE), Macmillan, Meta Press, NASA Astrophysics Data System (ADS), National Institute of Health (NIH), National Oceanic and Atmospheric Administration (NOAA), Nature Publishing Group, Project MUSE, PubMed, RePEc (Research Papers in Economics), Sage, Springer, Taylor & Francis, University of Chicago Press, and Wiley, among others. Although *Google Scholar* does not cover material from all major publishers (e.g., American Chemical Society and Elsevier), it contains citations to articles from ACS and Elsevier when documents from other sources cite these articles.

Table 1. Items Used in the Study

	Mostafa	**Nisonger**
	Document Type	
Journal articles	11	28
Conference papers	22	6
Reports	0	15
Bibliographies	0	5
e-Journal articles	3	0
Review Articles	1	3
Books	1	2
Chapters in Books	0	3
Other	2	0
Total	**40**	**62**
	Refereed Status	
Refereed	16	28
Not Refereed	18	27
Not Applicable	6	7
Total	**40**	**62**
	Publication Year	
Pre-1986	0	8
1986-1990	0	8
1991-1995	2	16
1996-1997	10	7
1998-1999	2	8
2000-2001	7	9
2002-2003	16	3
2004-2005	3	3
Total	**47**	**62**

Units of Analysis

To compare citations found in Scopus and *Google Scholar* with those found in *Web of Science*, and determine differences between them in terms of citation counts as well as the source of the citations, their type (e.g., journal article, conference paper), and refereed status, we used the publication lists of two colleagues from the School of Library and Information Science at Indiana University, namely Javed Mostafa and Thomas E. Nisonger. We selected Mostafa and Nisonger because they both are highly published and cited authors and work on considerably different Library and Information Science (LIS) research areas: Mostafa in the areas of intelligent interfaces for information retrieval and filtering, knowledge discovery, user modeling, and personalized delivery of information, and Nisonger in the areas of collection management and evaluation, bibliometrics, and serials. As shown below, this wide variety of research areas provided a valuable framework to make comparisons between Scopus, *Google Scholar*, and *Web of Science*. Table 1 shows detailed information about the items used in this study.

Data Collection Method

Google Scholar can be searched for citations to an individual item or author in two different ways:

- *Author* search: this retrieves items published by the author in question and ranks these items by citation counts. The searcher will need to click on the "Cited by . . ." link to view the documents that cite each item. In cases where an author name is very common, additional keywords (e.g., journal name or keywords in title) may be necessary to use to increase precision. Also may be needed is searching under variations of the author name to account for all name changes and/or citing styles, such as last-name, first-name last-name, and first-name middle-initial last-name. All these variations of the author name can be ORed in the same search statement with each phrase placed between quotation marks. In cases where an accurate author search is not possible, a title search is recommended (albeit more tedious), especially when an author has published tens or hundreds of papers.
- *Title search*: this uses the title of each item (e.g., journal article, book, book chapter, or conference paper) published by the author in question. The result will be a list of all the documents that cite the item. In cases where the title is too short or ambiguous to refer to only the item in question, the searcher has to use additional information as keywords ANDed with the title search string to narrow the result set to the most relevant records. These additional keywords could include the author's last name, journal name, book or conference title, publisher name, or a combination of these keywords.

A major disadvantage of *Google Scholar* is that its records are retrieved in a way that is very impractical for use with large sets, requiring a very tedious process of manually cleaning, organizing, and classifying the information into meaningful and useable formats. Unlike Scopus and *Web of Science*, *Google Scholar* does not allow re-sorting of the retrieved set in any way (such as by date, author name, or data source); retrieved sets are usually rank ordered by number of citations.[4] The result sets show short entries, displaying the title of the cited article and the name of the author(s); entries which include the link [Cited by . . .] indicate the number of times the article has been cited. Clicking on the link will take users to the list of citing articles. Other disadvantages of Google Scholar include duplicate citations—e.g., a citation published in two different forms, such as preprint and journal article, will be counted as two citations). In many cases, the item for which citations are sought for is retrieved and considered a citation.

In order to facilitate data collection, we developed a Web-based citation search and analysis system (*CiteSearch*[5]) that facilitates the citation-based assessment of information by

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[4]*Google Scholar* uses Google's crawler to index the content of research materials and adds citation counts to raise or lower individual articles in the rankings of a result set.
[5] The *CiteSearch* system is being developed by the Virtual Collection Builder (VCoB) project, which is one of the research project undertaken by the Web Information Discovery Integrated Tool (WIDIT) Laboratory

extracting and analyzing citation metadata from multiple citation databases. The development of CiteSearch system is a work-in-progress, so what follows is a general description and brief overview of the overall system design, only part of which were implemented for the pilot study. Given a publication title, for example, the *CiteSearch* system will automatically search multiple Web-based citation databases and analyze the search results to produce bibliographical metadata of all citations and compute various citation-based quality evaluation measures such as CiteRank, which is a citation propagation measure similar to PageRank, and weighted CiteRank, which is CiteRank weighted by source, author, or time of citations. The initial citation metadata will then be aggregated and analyzed to produce meta-level citation measures for authors, publications, and schools. In addition to CiteRank, the meta-level citation analysis will compute the H-Index, an index developed by Hirsch to quantify an individual's scientific research output, as well as the Mentor-Index, an index that measures the mentoring impact by the research impact or performance of students produced. Figure 1 displays the overview of the *CiteSearch* system architecture.

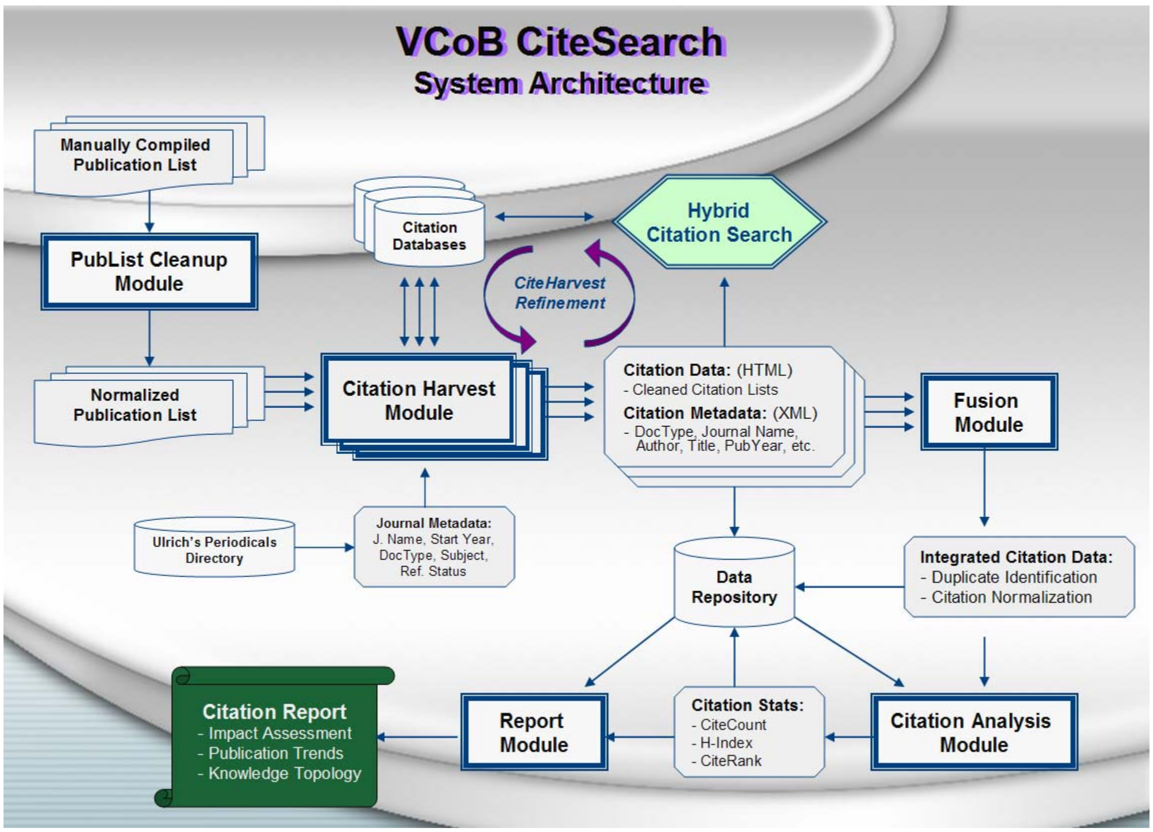

Figure 1. CiteSearch Prototype System Archtecture

CiteSearch allowed us to automatically: (1) conduct both author and title searches at the same time; (2) retrieve and merge results from both types of searches; (3) remove duplicate records; and (4) export results directly into a spreadsheet while parsing data into identifiable fields (e.g., author, title, journal name, and year of publication). Although all searches were done automatically, the results for each search were examined twice by a research assistant and

(http://elvis.slis.indiana.edu/) at Indiana University School of Library and Information Science. The aim of the VCoB project is to develop an adaptive, interactive agent for building and maintaining a virtual collection of Web documents.

twice again by one of the authors (Meho) to guarantee high precision and recall. Comparisons between all four sets were made and all errors with the data and the retrieval system were corrected. To generate accurate Web of Science and Scopus citation data, we conducted searches for each item published by the two faculty members. We also conducted cited author searches to enhance recall.

All data collected were entered into an Excel file where items were coded by document type (e.g., journal articles, review articles, and conference papers) and refereed status of both the cited and citing item(s), as well as where the item was cited (in which book, article, chapter, and so on) and what source was used to identify the citation. The refereed status of the citations found through Google Scholar exclusively was determined through *Ulrich's International Periodicals Directory* as well as relying on the knowledge domain of the authors.

Limitations

Although the number and type of records used in this study are larger and more diverse than those used in similar published studies (e.g., Bauer & Bakkalbasi, 2005; Jacso, 2005a), the primary limitation of the study is still the small size of the sample examined. Despite these limitations, the study contributes significantly to research, especially because it is the first to show empirically how the use of multiple sources provides a more comprehensive picture of an author's research impact. The study also generates several important questions for future research (see below). *CiteSearch*, the search system developed and used here, should also be very valuable to researchers interested in citation analysis and bibliometric studies.

RESULTS AND DISCUSSION

In this section, two topics are discussed: a comparative analysis of all three databases and an analysis of the value and quality of citations found through Google Scholar. For the first topic, only two sets of citations from Google Scholar are used in the analysis here: (1) citations that overlapped with Scopus and/or Web of Science; and (2) citations found in refereed journal articles. This decision was made to make accurate and fair comparisons between the three databases. As mentioned earlier, both Scopus and Web of Science index primarily refereed journals articles whereas Google Scholar indexes several refereed and non-refereed types of documents in addition to journal articles. For the second topic, all citations found through Google Scholar are analyzed to discern their overall value and quality. Before discussing the results, it should be emphasized that the content of all three databases are updated very frequently; therefore, the numbers reported here will change by the time of publication of this paper.

As far as citation counts are concerned, results show that coverage in the three databases is highly dependent on the subject matter of the faculty member. For example, in Mostafa's case (whose research focus is in the areas of intelligent interfaces for information retrieval and filtering, knowledge discovery, user modeling, and personalized delivery of information), all three databases retrieve relatively the same number of citations, whereas in Nisonger's case (whose research is in the areas of collection management and evaluation, bibliometrics, and serials), all three databases retrieve significantly different results. In Nisonger's case, Web of Science retrieves almost twice as much citations as both Scopus and Google Scholar.

Table 2. Citation Counts by Source

Source(s)	**Mostafa**	**Nisonger**
Web of Science	122	173
Scopus	120	98
Google Scholar	119	83
Total (unique)	**170**	**215**

Table 2 also shows that when all three databases are used to locate citations to an author's work, the number of citations increases significantly in comparison to using only one database. More detail on this is presented in Table 3 which indicates the difference it makes when broadening the citation sources beyond *Web of Science*. As in straight counts, the impact of multi-sourcing of citations is highly dependent on the research area(s) of an author. In the cases of our two samples, the use of Web of Science and Scopus together increases Mostafa's citations by 31.1% and that of Nisonger by 8.7%; the combination of Web of Science and Google Scholar increases their citations by 25.4% and 19.7%, respectively. The use of all three databases together increases the number of citations in scholarly journals by 39.3% in Mostafa's case and 24.3% in Nisonger's case.

If we assume that Mostafa is a representative of the Information Science field and Nisonger of Library Science, then one could conclude that: (1) Scopus is much more useful for Information Science than it is for Library Science in identifying citations not found in Web of Science; (2) Web of Science is indispensable for both Information Science and Library Science; and (3) Google Scholar is useful for both fields in locating citations not found in Web of Science.

Table 3. Impact of Multi-Sourcing of Citations on Web of Science Results

Source(s)	**Mostafa**		**Nisonger**	
	citations	**%** difference	citations	**%** difference
Web of Science (WoS)	122		173	
WoS + Scopus	160	**+31.1**	188	**+8.7**
Wos + Google Scholar	153	**+25.4**	207	**+19.7**
Scopus + Google Scholar	156	**+27.9**	140	**-20.6**
Wos + Google Scholar + Scopus	170	**+39.3**	215	**+24.3**

Table 4 further confirms these conclusions in that it shows an inverse relationship between unique and overlapped citations found in any two databases. Table 5 too confirms the conclusions made in that it shows a significantly higher percentage of unique items in Web of Science for Nisonger than for Mostafa and vice versa for Scopus.

Table 4. Citation Overlap Among Databases

Source(s)	Mostafa		Nisonger	
	citations	% overlap	citations	% overlap
Web of Science (WoS) + Scopus	160	**51.3**	188	**44.7**
WoS + Google Scholar	153	**57.5**	207	**23.7**
WoS + Google Scholar + Scopus	170	**36.5**	215	**16.3**
Scopus + Google Scholar	156	**53.2**	140	**70.0**

Table 5. Unique Citations Found in Each Database

	WoS		Scopus		Google Scholar	
	count	%	count	%	count	%
Mostafa (n=170)	14	8.2	17	10.0	10	5.9
Nisonger (n=215)	75	34.9	8	3.7	28	13.0
Total (n=385)	89	23.1	25	6.5	38	9.9

Table 6. Breakdown of Citations Found in Google Scholay by Document Type

	Mostafa (n=247)		Nisonger (n=111)	
	Count	%	Count	%
Journal Articles	87	35.2	82	73.9
Conference Papers	83	33.6	7	6.3
Research reports	31	12.6	8	7.2
Dissertations and Theses	11	4.5	4	3.6
Dead links	6	2.4	1	0.9
Editorial Materials	6	2.4		
Workshops	5	2.0		
No access	4	1.6		
Technical reports	3	1.2		
Websites	3	1.2	1	0.9
Other (chapters, bibliographies)	8	3.2	8	7.2
Total	247	100.0	111	100.0

Value and Quality of Citation Found in Google Scholar

Gardner and Eng (2005) examined the top 100 retrieved records in Google Scholar on the topic of home schooling and found the following breakdown: 40 journal articles (32 of them peer-reviewed), 16 books, 15 magazines, seven dissertations, six ERIC documents, five newspaper articles, three Web sites, two conference papers, and one monograph, newsletter, and government document. In this study, we found relatively similar results (see Table 6).

Of the 247 citations found for Mostafa in Google Scholar, 119 (or 48.2%) were refereed items. As for Nisonger 83 (or 74.8%) of his citations in Google Scholar were in refereed items. This suggests that citations found through Google Scholar are more likely to be in refereed journals in Library Science than is the case in Information Science where almost two thirds of the citations originate from either conference papers or non-refereed materials. The current authors are examining a much larger and representative sample to verify these results.

CONCLUSIONS AND IMPLICATIONS

This study provides direct and meaningful implications for faculty members who need assistance in compiling their own citation records and also for use as a general reference tool (e.g., for locating citations to a particular paper or book). The study informs reference and other information specialists of novel ways of identifying citations to an author, paper, or journal. Until very recently, ISI citation databases were essentially the only practical sources for locating these references and citations. This study showed that other practical methods and sources, such as Scopus and *Google Scholar*, can be used to locate citations not covered by ISI. Significantly, this study showed that:

1. *Web of Science* should not be used alone for locating citations to an author or title.
2. *Scopus* and *Google Scholar* can help identify a considerable number of valuable citations not found in *Web of Science*;
3. *Scopus* and *Google Scholar* can help identify a considerable number of citations in document types not covered by ISI citation databases;
4. *Scopus* and *Google Scholar* may assist in providing a more comprehensive picture of the extent of international and interdisciplinary nature of scholarly communication of and among researchers; and
5. *Google Scholar* has several technical problems that users should be aware of in order to accurately and effectively locate citations.
6. The selection of the database(s) for locating citation is field-dependent.

This study, furthermore, has significant implications on the wider scholarly community as researchers start to adopt the search method used here and *CiteSearch* that was developed as part of the study to identify citation sources in such fields as business, economics, history, law, medicine, political science, psychology, and sociology.

Given the continuous advances in information technology and improvement in online access to tens of millions of records through databases and services that provide citation information, future studies should explore:

- Other sources and searching methods that can and should be used to locate citations not covered by ISI citation databases, Scopus, or *Google Scholar*.

- Differences that these sources could make in citation counts and citation traits for authors, papers, and journals.
- Whether broader sourcing of citations can alter one's relative ranking vis-à-vis others and, if so, how.
- Which sources of citations provide better coverage of certain subject disciplines than others.

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