JOURNAL OF CHEMICAL EDUCATION

Article

pubs.acs.org/jchemeduc

Examining the Impact of Chemistry Education Research Articles from 2007 through 2013 by Citation Counts

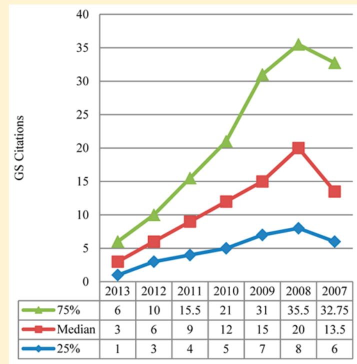
Li Ye,[†] Scott E. Lewis,*,[†,‡] Jeffrey R. Raker,[†,‡] and Razanne Oueini[†]

[†]Department of Chemistry, University of South Florida, Tampa, Florida 33620, United States

[‡]Center for the Improvement of Teaching and Research in Undergraduate STEM Education, University of South Florida, Tampa, Florida 33620, United States

Supporting Information

ABSTRACT: Evaluating the impact of Chemistry Education Research articles has historically centered on the impact factor of the publishing journal. With the advent of electronic journal indices, it is possible to determine the impact of individual research articles by the number of citations it has received. However, in a relatively new discipline, such as Chemistry Education Research, it is necessary to provide context for the citation counts, particularly because Chemistry Education Research faculty are likely evaluated by chemistry faculty in more established subdisciplines. This study seeks to provide context by reviewing the citation counts for a sample of 749 Chemistry Education Research articles published in chemistry education or science education journals from 2007 through 2013. The number of citations was found to follow a non-normal distribution and, thus, results are presented using quartiles to describe the range of citations. The results are delineated by metric of citations (Web of Science and Google Scholar), year published, and in terms of established authors.



KEYWORDS: *Chemical Education Research, Graduate Education/Research, Communication/Writing, Administrative Issues, Professional Development*

FEATURE: Chemical Education Research

INTRODUCTION

Evaluating the impact of research articles is of interest to researchers, as it provides an important perspective in terms of understanding a discipline. It is of particular interest to research active faculty undergoing evaluation of their research productivity for tenure or promotion or for describing the impact of dissemination efforts to funding sources. Chemistry Education Research (CER) is a relatively new field.[1] As part of the effort to characterize the developing field, a series of articles has been generated in service to understanding the nature of the field. These articles have sought to provide expectations for conducting and communicating CER.[2,3] Other articles have sought to establish a baseline for productivity by examining the publication rates of faculty engaged in the field.[4,5] Focusing on the role of journals, Towns and Kraft surveyed those engaged in CER to identify top-tier and middle-tier journals in CER and applicable journals in STEM education to provide a more detailed picture of journal quality beyond impact factor measures.[6] Combined, these articles serve to provide context for those engaged in CER to better understand their productivity and impact. Additionally, they provide background for those who evaluate CER researchers, a vital resource for those who are not engaged in CER. To date, however, there has been no investigation of the citations of CER articles; such a study can provide a baseline to aid in understanding the impact of research in chemistry education.

Bibliometrics and Citation Analysis

Bibliometrics, or scientometrics, is the study of measures of scientific literature. There is a considerable variety of metrics used with each metric targeting a different intended measure, as reviewed by Pendlebury.[7] A brief summary of the metrics is presented here; readers who are interested in learning more are encouraged to consult the source article. Most of the metrics rely on some measure of impact, often described by the number of citations received. Pendlebury distinguished impact from the quality of work, indicating that quality is best evaluated through expert peer-review such as the processes for deciding publication and funding. The role of determining impact then is to aid in the determination of quality, particularly in evaluating the growing number of research artifacts produced and to serve as a guard against bias in evaluating research.

Among the most common measures of impact is the journal impact factor, defined as the average number of article citations for a journal over an established time period. This metric is designed specifically for evaluating journals and provides a metric that is independent of the number of articles published and time frame that the journal has been published. As a metric of a journal, impact factor should not be used to describe the impact of a particular author or paper published in the journal because articles within a journal have considerable variety.

Published: April 16, 2015

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305

Critics of the metric note that it varies greatly from field to field based on the number of researchers in the field, number of references commonly used in articles in the field, and speed of publications. The metric also provides a single average value to represent a very skewed distribution, because it is common for a small fraction of articles to receive a substantial number of a journal's citations.[7,8] Another common metric, the *h*-index, describes author impact as the number of articles, *h*, that have at least *h* citations. This index is meant to consider both author productivity and impact of articles through citation counts. Like journal impact factor, the *h*-index varies considerably across fields. Unlike journal impact factor, the *h*-index does not have a time component and, as a result, is biased toward researchers with longer careers.[8]

As this work seeks to understand the impact of CER articles, Pendlebury described several guidelines for citation analysis that are applicable to analyzing the impact of individual articles. The central tenet of citation analysis is to only compare articles to like articles, which is aided by clearly defining the set of articles to be considered including the field, year of publication, and article type. It is also recommended to use relative measures to aid in understanding impact, such as citations per paper compared with citations per paper in the field over the same period of time. It is the purpose of this study to provide a baseline of citations per paper in the field to aid in such comparisons.

Identifying CER Articles

CER articles were identified from the following seven journals: *Journal of Chemical Education* (JCE), *Chemistry Education Research and Practice* (CERP), *Journal of Research in Science Teaching* (JRST), *Science Education* (SE), *International Journal of Science Education* (IJSE), *Research in Science Education* (RSE), and *Biochemistry and Molecular Biology Education* (BAMBED). These journals represent the chemistry education and science education journals that publish chemistry-specific education research with impact factors indexed by Web of Science.[6] To create the initial database, a search was performed in Web of Science for the three chemistry education journals: JCE, CERP, and BAMBED for the years 2007 through 2013. This time frame was chosen because it matches the common time frame used in multiyear evaluations of faculty productivity. An additional search was done for the four science education journals: JRST, IJSE, SE, and RSE using a topic search for the word "chemistry" or "chemical" with the same time frame. This procedure identified 4,342 articles. The initial database was screened using the following procedures.

In JCE, chemistry education research articles were identified by two forms: articles published with the *byline* "Chemical Education Research" from 2007 through issue 4 of 2011 and articles published with the *keyword* "Chemical Education Research" from issue 5 of 2011 through 2013. In CERP, all articles were included except for editorials and introductions to special issues. In BAMBED, all articles with the "articles" tag were included. In the four science education journals, articles were screened by review of the title and abstracts to determine if chemistry was clearly tangential to the article or if the article represented a book review. Two researchers reviewed the titles and abstracts of 261 science education articles independently and discrepancies were discussed until a consensus was reached, resulting in 196 articles from science education journals retained. The intention was to create a database that took a broad, inclusive picture of CER; for example, articles in biological chemistry, nanotechnology, or chemistry-specific teacher training were retained. Additionally, articles that reviewed prior research literature or introduced new methodologies or theories to the field were also included as these efforts contribute to the field's advancement. The resulting database includes 749 articles (see Supporting Information).

Sources of Citation Data

Web of Science (WoS) is a database maintained by Thomson Reuters that has compiled journal impact factors annually since 1906. The goal of Thomson Reuters is "providing comprehensive coverage of the world's most important and influential journals...."[9] The WoS database includes over 17,000 international and regional journals in the natural and social sciences, arts, and humanities. Thomson Reuters editors evaluate journals for inclusion in the database by considering a combination of a journal's publishing standards, editorial content, diversity of authorship, citation data, quality of peer-review process, and frequency of funding acknowledgments.[9] Within the WoS database, there are 8,717 journals classified as Science in the expanded Science index, of which 38 journals are listed as Education, Scientific Disciplines. In the Social Science Index, 226 journals are listed as Education and Educational Research.[10]

Google Scholar (GS) offers an alternative metric for citations. Launched by Google in 2004, GS is an open access database of scholarly documents. There has been increased interest in using GS as a research tool for assessing the impact of research output.[11−13] Compared to WoS, GS covers a broader range of scholarly materials including book chapters, monographs, book reviews, theses, proceedings of conference articles, and non-English language literature.[12,14] However, a disadvantage of GS is that, unlike WoS, inclusion of publications is not subject to quality control. Citation counts obtained from GS may exaggerate impact because of lack of review and moderation.[15] The two databases, WoS and GS, differ significantly from each other with respect to degree of coverage, type of publications included, and quality of data. Therefore, evaluating both data sources separately gives the opportunity to describe the impact of CER from two distinct metrics.

Past Work on Article Citations

Examining article citations in discipline-based education research is a new area of study with past work focusing on citations of articles in science education. Van Aalst created a database that focused on articles from the first author of each chapter in the *Handbook of Research on Science Education*.[14] The database was compiled of up to five of the most influential articles from each author. Influence was determined by a GS search of each author, where Google places the articles that have a greater web presence toward the top of the search. The resulting database had 132 articles. Citations for the articles were pulled from GS with the articles averaging 14 citations. However, the researcher only considered the first 100 citations for each article, so this average does not include the full impact of very highly cited articles. Cited documents were indexed in terms of whether they came from a WoS journal and the numbers of such documents were used as a measure for WoS citations. A correlation between the number of WoS citations and the number of GS citations of approximately 0.75 was reported. A linear relationship was found between year published and the number of GS citations, with an intercept of −4.4 and a slope of 3.9 GS citations per year, suggesting a

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305

growth of approximately four citations per year with no citations in the first year.

Greenseid and Larwenz examined the impact of products that resulted from evaluations of four STEM education programs.[16] One product type was defined as publication, which was comprised of journal articles, books, book chapters, monographs, dissertations, or newsletters. Citations for each product were determined by seeking unique citations across WoS, GS, and Google. Regression analysis suggested the average citation count for the products that were categorized as publications was 0.95. It was not possible to delineate the citations for only journal articles from the broader category of publications, which may mean that average citations of journal articles was substantially different.

These two studies were the only ones found that quantified the citations attributed to a series of articles in Science Education. Neither study attempted to quantify citations for articles in a discipline-specific education research field such as CER, which may be substantially different as it has a narrower audience than Science Education. Both studies focused on an exclusive grouping of articles and did not seek to describe the much larger number of researchers publishing in educational research. Van Aalst sought articles from prominent authors in the field, and Greenseid and Lawrenz were particularly interested in the impact of project evaluation. To date, no studies were identified that attempted to provide citation data for a larger, inclusive set of articles published in science education or CER. Such a study is important in order to provide information for researchers describing the impact of their work and for administrators who are evaluating the impact of articles in CER as well as to provide a baseline to identify articles with an unusually high impact in CER.

Research Objectives

The following research questions guided this study:

1. How many times are CER articles cited by metric of citation (WoS or GS) and year of publication?
2. To what extent do the number of citations differ when considering established authors in CER?

■ METHODS

For each of the 749 articles in the database, the number of citations was downloaded from WoS on March 2, 2015. Citations of articles from GS were obtained manually by searching for each article on the GS Web site on the same date. Self-citations were retained in the database under the assumption that self-citations largely represent legitimate instances of authors building upon their past work and, thus, correctly describe impact.[17]

As CER is a relatively new field that is rapidly expanding, there is the potential that the impact of work from established CER authors is notably different from researchers who are new to the field or researchers established outside CER who publish infrequently in CER. For example, established CER authors would likely be more visible in disseminating their work in CER venues. To investigate this possibility, a subset of articles in the database were identified as those created by established CER authors. Established CER authors were defined as those authors who had published four or more CER articles (using the criteria for creating the database) between 2007 and 2013. This operationalization was chosen as it could be consistently applied to the database and indicates a publication rate of at least one paper every other year. Although this operationalization may exclude some authors who are considerably established, the subset identified 71 authors and is thought to provide a representative sample of established authors in the field. From the original database, 318 CER articles (42.5%) were from established authors.

A screening for outliers among the first database of 749 CER research articles was performed. Articles that have citations more than three standard deviations above the mean were labeled as outliers. In the GS metric, there were 18 articles with greater than 78 citations, and these were considered outlier articles. With the WoS metric, 6 additional articles had citation counts greater than 29 and were considered outliers. These 24 outliers were removed and the remaining 725 articles were used for analysis. Similarly, a screening for outliers was conducted on the established author database identifying ten of the 318 articles as outliers. These 10 outliers were removed, and the analysis was conducted on the remaining 308 articles. The articles identified as outliers are noted in Supporting Information. Statistical analyses in this study were performed by SPSS Statistics 22.

■ RESULTS AND DISCUSSION

Descriptive Statistics

Descriptive statistics of citations of CER articles in GS and WoS are presented in Table 1 and histograms showing the frequency of citation counts are presented in Figure 1. A substantial portion of CER articles have been cited less than three times, specifically 137 articles by the GS metric (18.9%) and 277 articles by the WoS metric (38.2%). A partial explanation for this trend is the year of publication, as discussed below. Owing to the positive skew (see Figure 1), the data follow a non-normal distribution, which was supported by the results of the Kolmogorov−Smirnov test (K−S) and Shapiro−Wilk (S−W) tests.

Table 1. Descriptive Statistics of Citations of CER Articles in GS and WoS from 2007−2013[a]

Metric	GS	WoS
Mean	13.48	5.56
Std. Dev.	14.06	5.70
75th percentile	19.0	8.0
Median	8.0	4.0
25th percentile	4.0	1.0
K−S (p-value)	0.17 (<0.001)	0.19 (<0.001)
S−W (p-value)	0.82 (<0.001)	0.84 (<0.001)

[a]Outliers were removed.

The mean citation of CER articles in GS is over twice that of WoS, corresponding to a broader and lower threshold for inclusion of sources included in GS. To determine the extent of the difference in the two metrics, a linear regression was performed relating citations in WoS to citations in GS for the database. The linear regression equation obtained was

$$GS = 2.163 \times WoS + 1.462 \qquad R^2 = 0.768$$

This equation suggests that on average the number for GS citations is just over twice the number of WoS citations. The correlation between WoS and GS is 0.877, indicating that the relationship between citations of CER articles in GS and WoS is positive, strong, and exceeds the value observed in prior research.[14] However, even though the citation numbers in GS

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305

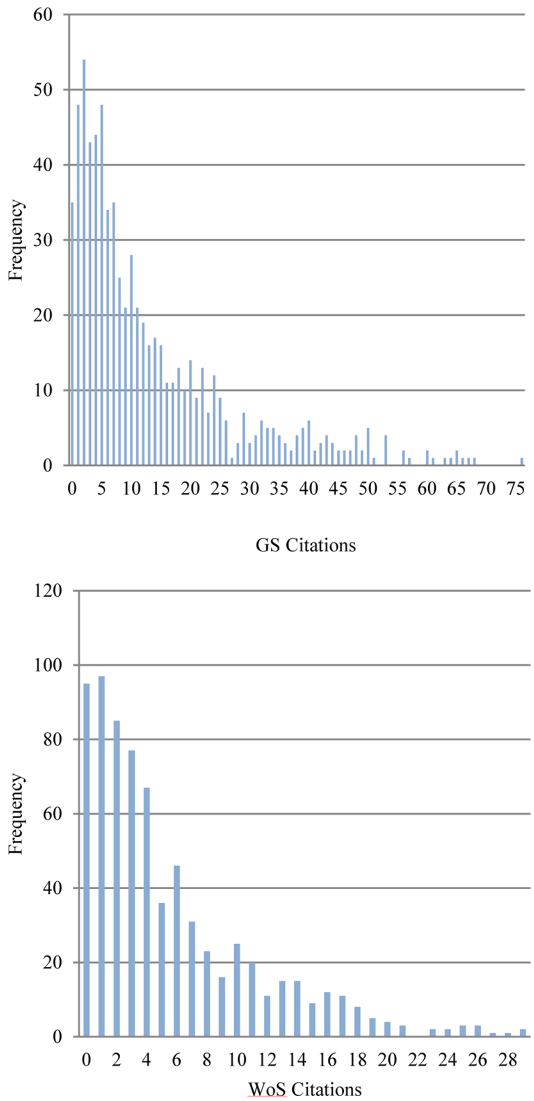


Figure 1. Frequency of GS and WoS citations of CER articles from 2007−2013.

and WoS were highly associated, there are articles that sufficiently departed from the trend, indicating that the two metrics are not redundant. For example, Schwartz et al.'s work on relating high school content to college level success, Bunce et al.'s work on students' classroom attention span, and Abdo and Taber's work on mental models of the particulate nature of matter each have much higher GS citation than expected by WoS citation.[18−20] Given the differing nature of the citation metrics, it is likely that these articles generated a stronger presence among online sources of scholarly material than typical CER papers. The high correlation suggests that such departures are rare; departures emphasize the weakness, though, of relying on any single metric of impact.

Citations of CER Articles by Year

The number of CER articles published by year and by journal are listed in Table 2. From 2007 through 2011, the total number of articles published were relatively constant. There was then an increase in the number of articles published annually since 2012.

As citations are likely dependent on the length of time an article has been published, the articles were delineated by their year of publication. For each year of publication, quartiles of the citation values were determined; such a delineation can offer a description of what would constitute high, medium, and low values for number of citations. The resulting quartiles are graphed in Figure 2. The general trend, as expected, is that citations increase relative to the amount of time the article has been published. The 2013 articles were in print between 14 and 26 months by the date of the data pull. For the articles published in 2013, the median values are 3 GS citations and 1 WoS citation, indicating that a substantial number of articles are not cited in the first year of publication. Examining trends across years, the relationship is consistent, except 2008 has higher citations than year 2007. The relationship across years appears to be approximately 3 GS citations per year for the median and 5 GS citations per year for the top quartile. By comparison, Van Aalst performed a regression and found 3.9 GS citations per year for his analysis of papers from prominent authors.[14] For WoS citations, it is approximately just over 1 WoS citation per year for the median and just over 2 WoS citations per year for the top quartile. Analysis of citations by year relies on an assumption that the articles in the database are of consistent quality and interest from year to year. In support of this assumption is the number of articles incorporated into this study, where it is unlikely that a collection of greater than 80 articles in any given year is substantially different from another collection of greater than 80 articles from a different year. However, the assumption is tenuous given the possibility that there are factors that could impact a large group of articles, such as a change in journal editorship or acceptance rates. Ultimately, to provide more conclusive evidence about the timeline for citations, the number of citations for the articles in this database will need to be periodically revisited to track and analyze growth in number of citations for each article. This is a goal for future work in understanding article impact. The current results still serve Chemistry Education Researchers by providing context for comparison that controls for the year published.

Table 2. Numbers of CER Articles Published by Year and by Journal

Journal	2007	2008	2009	2010	2011	2012	2013	Total (%)
BAMBED	37	20	14	18	15	17	16	137 (18.9%)
CERP	27	36	29	33	47	50	49	271 (37.4%)
IJSE	8	16	13	11	12	13	11	84 (11.6%)
JCE	16	8	12	16	15	32	38	137 (18.9%)
JRST	3	4	3	6	5	2	7	30 (4.1%)
RSE	1	10	5	4	5	4	16	45 (6.2%)
SE	4	2	3	3	2	4	3	21 (2.9%)
Total	96	96	79	91	101	122	140	725

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305

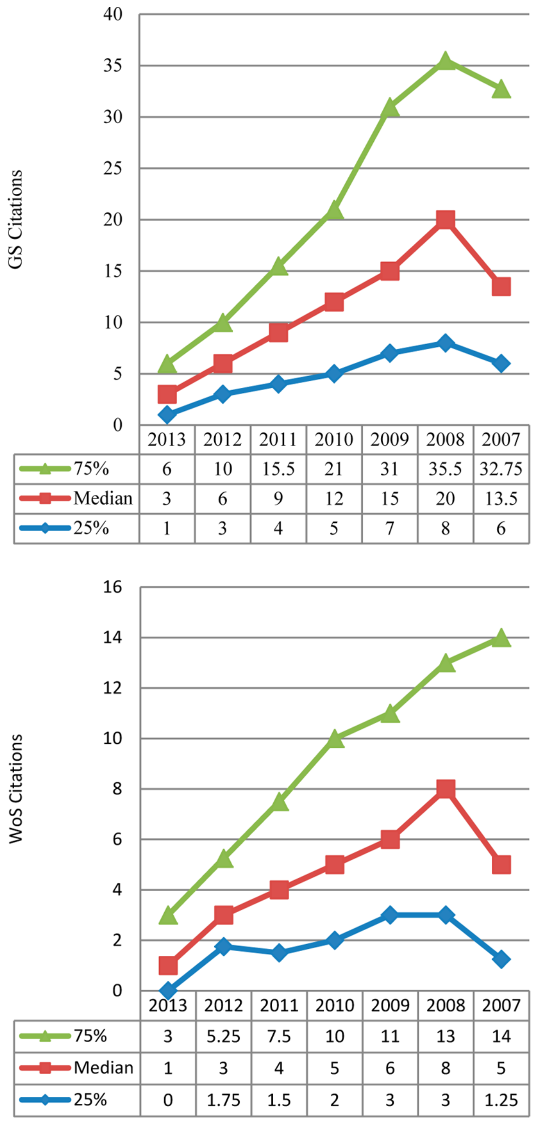


Figure 2. Quartiles of GS citations and WoS citations by year.

Citations of CER Articles from Established Authors by Year

Descriptive statistics of citations from established authors are presented in Table 3. (An established author is defined as an author that published four or more chemistry education research articles in our database.) The mean, median, and 75th percentile for GS is 4 to 5 citations higher for articles by established authors than for all authors (see Table 1). For WoS, the difference is 2 to 3 citations higher for the established authors than for all authors.

Table 3. Descriptive Statistics of Citations of CER Articles from Established Authors[a]

Metric	GS	WoS
Mean	17.80	7.73
Std. Dev.	16.72	7.01
75^{th} percentile	24.00	11.00
Median	13.00	6.00
25^{th} percentile	5.00	3.00

[a]Outliers were removed.

The number of CER articles published by established authors by year and journal are listed in Table 4. The general trend matches the growth in publications in recent years observed in the full set of articles. Under this metric of established authors, the proportional representation of BAMBED articles is considerably decreased compared to Table 2, with CERP and JCE increasing in overall percentage of articles by journal.

Similar to above, the quartiles of citations were calculated for each year with the results presented in Figure 3. Comparing Figure 3 with Figure 2, the established authors have consistently higher GS citation values than all authors. The difference becomes more pronounced among articles with earlier publication dates. In particular, articles from 2007 to 2009 have at least 6 more GS citations than all authors for each quartile, with four of the differences observed greater than 10 GS citations. The established author subset is also consistently higher on the WoS citations; but these differences are not as pronounced. The increase in citation differences for the articles with earlier publication dates remains present, but only 2008 articles have substantially more WoS citations than all authors on each quartile. Given the differences observed, it is recommended that values from Figure 3 should be used in determining a context for citations among papers from established authors, particularly when GS citation values are used.

Limitations and Future Work

A review of the limitations to this study are necessary to promote the appropriate use of the results. First, results presented provide context specifically for the articles listed. CER articles that appear in other journals, including *The Chemical Educator*, *Journal of College Science Teaching*, *Journal of Science Teacher Education*, or outside the time frame listed may have substantially different citation rates. For this reason, the results cannot be generalized to all CER articles published.

Second, inferences are made regarding the growth in citations over time; these inferences assume that article quality and size of audience, on average, is consistent across the years. This assumption may be problematic owing to systemic changes that impact article quality over time. Future work will chart the citations of the articles in these databases at periodic intervals to address the growth in citations over time without relying on this assumption.

Finally, it is important to note that the use of article citations as a sole measure of the impact of research is problematic. Any single measure used to determine important outcomes, such as tenure and promotion, includes a high likelihood that the measure will be targeted for manipulation. In particular, the GS metric can be easily manipulated by a single individual employing little effort.[21] The WoS metric can also be influenced, for example by self-citation, particularly because fewer than five citations would typically represent a shift from an article with the median number of citations to the 75th percentile in Figure 2. Citations should be considered as a single piece of information on the impact of research that should be triangulated with additional measures, especially when using these metrics as the basis for decisions with substantial outcomes.

■ CONCLUSIONS AND IMPLICATIONS

This study explored the number of citations for CER articles published from 2007 to 2013. The results serve to provide a high, medium, and low context for the authors of any of the 749

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305

Table 4. Numbers of CER Articles Published from Established Authors by Year and by Journal

Journal	2007	2008	2009	2010	2011	2012	2013	Total (%)
BAMBED	2	0	0	0	1	5	1	9 (2.9%)
CERP	16	18	11	21	24	23	23	136 (44.2%)
IJSE	4	9	9	7	5	8	2	44 (14.3%)
JCE	10	5	6	4	7	18	29	79 (25.6%)
JRST	0	2	2	4	2	1	4	15 (4.9%)
RSE	0	5	3	1	1	1	6	17 (5.5%)
SE	1	1	2	2	1	1	0	8 (2.6%)
Total	33	40	33	39	41	57	65	308

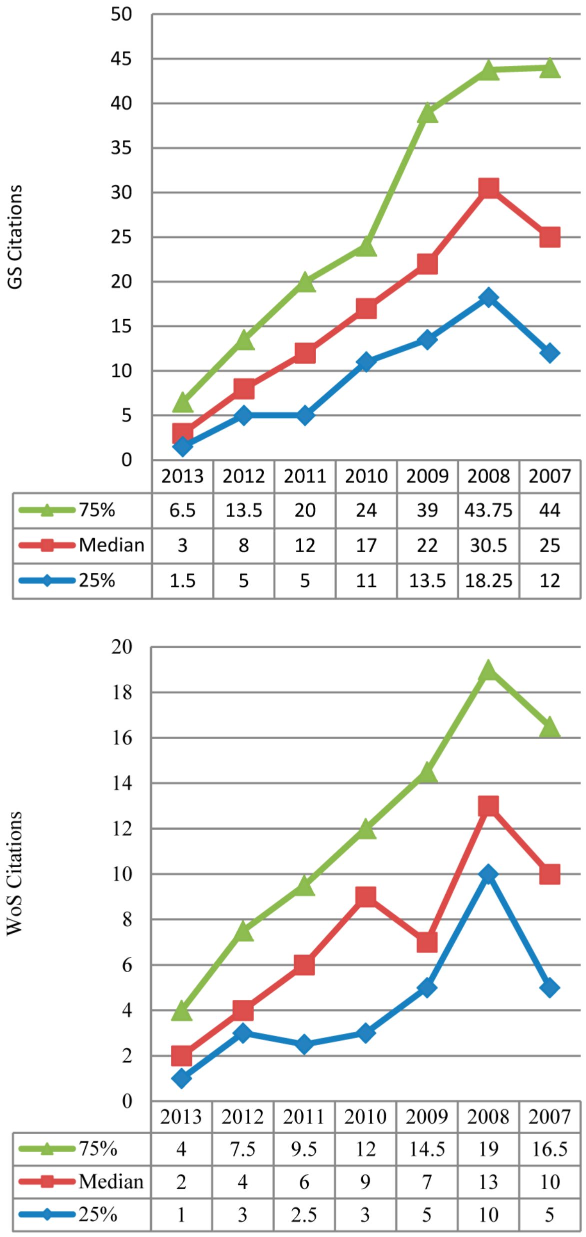


Figure 3. Quartiles of GS citations and WoS citations of established authors by year.

articles in the database using either the GS or WoS metric. This information can provide information to researchers in the field to place their work in context and to serve those who evaluate CER researchers. Citation rates by established authors were found to be higher than the full set of CER articles, suggesting that established authors could make a stronger case for an appropriate context of citation values by using the subset provided.

■ ASSOCIATED CONTENT

Ⓢ Supporting Information

To increase the utility of the results, the databases used in this study are available as Supporting Information. This includes (1) the database of the original 749 articles identified and (2) the database of the 318 articles by established authors that is a subset of the original database. These databases provide the citation number for each article on the day the citations were pulled for this study (March 2, 2015) and also provide a means to create journal specific citation rates if desired. This material is available via the Internet at http://pubs.acs.org.

■ AUTHOR INFORMATION

Corresponding Author

*E-mail: slewis@usf.edu.

Notes

The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS

The authors wish to acknowledge the help of Benjamin Van Norman, who aided in creating the database used for this study.

■ REFERENCES

(1) National Research Council. *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*; Singer, S. R., Nielsen, N. R., Schweingruber, H. A., Ed.; Committee on the Status, Contributions, and Future Directions of Discipline-Based Education Research: Washington, DC, 2012.

(2) Eybe, H.; Schmidt, H. Quality criteria and exemplary papers in chemistry education research. *Int. J. Sci. Educ.* **2001**, *23*, 209–225.

(3) Towns, M. H. New Guidelines for Chemistry Education Research Manuscripts and Future Directions of the Field. *J. Chem. Educ.* **2013**, *90*, 1107–1108.

(4) Pienta, N. J. Measuring Productivity in College-Level Chemistry Education Scholarship. *J. Chem. Educ.* **2004**, *81*, 579–583.

(5) Craig, A. F.; Koch, D. L.; Buffington, A.; Grove, N. Narrowing the Gap? Revising Publication Rates in Chemistry Education. *J. Chem. Educ.* **2012**, *89*, 1606–1608.

(6) Towns, M. H.; Kraft, A. The 2010 Rankings of Chemical Education and Science Education Journals by Faculty Engaged in Chemistry Education Research. *J. Chem. Educ.* **2012**, *89*, 16–20.

(7) Pendlebury, D. A. The use and misuse of journal metrics and other citation indicators. *Arch. Immunol. Ther. Exp.* **2009**, *57*, 1–11.

(8) Öchsner, A. Statistical Evaluation of Bibliographic Data: Evaluation of Journals, Scientists, and Institutions. In *Introduction to Scientific Publishing*; Springer: New York, 2013.

(9) Testa, J. *The Thomson Reuters Journal Selection Process*. http://wokinfo.com/essays/journal-selection-process (accessed March 26, 2015).

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299–1305

(10) *Thomson Reuters Master Journal List*. http://ip-science.thomsonreuters.com/mjl/ (accessed September 16, 2014).
(11) Kousha, K.; Thelwall, M. Google Scholar citations and Google Web/URL citations: A multi-discipline exploratory analysis. *J. Am. Soc. Inf. Sci. Technol.* **2007**, *58*, 1055−1065.
(12) Meho, L. I.; Yang, K. Impact of data sources on citation counts and rankings of LIS faculty: Web of Science versus Scopus versus Google Scholar. *J. Am. Soc. Inf. Sci. Technol.* **2007**, *58*, 2105−2125.
(13) Smith, A. G. Benchmarking Google Scholar with the New Zealand PBRF research assessment exercise. *Scientometrics* **2008**, *74*, 309−316.
(14) Van Aalst, J. Using Google Scholar to Estimate the Impact of Journal Articles in Education. *Educ. Res.* **2010**, *39*, 387−400.
(15) Diem, A.; Wolter, S. C. The Use of Bibliometrics to Measure Research Performance in Education Sciences. *Res. Higher Educ.* **2013**, *54*, 86−114.
(16) Greenseid, L. O.; Lawrenz, F. Using Citation Analysis Methods to Assess the Influence of Science, Technology, Engineering, and Mathematics Education Evaluations. *Am. J. Eval.* **2011**, *32*, 392−407.
(17) Glanzel, W. Seven myths in bibliometrics: about facts and fiction in quantitative science studies. *Collnet J. Scientometrics Inf. Manage.* **2008**, *2*, 9−17 DOI: 10.1080/09737766.2008.10700836.
(18) Abdo, K.; Taber, K. S. Learners' Mental Models of the Particulate Nature of Matter: A study of 16-year-old Swedish science students. *Int. J. Sci. Educ.* **2009**, *31*, 757−786.
(19) Bunce, D. M.; Flens, E. A.; Neiles, K. Y. How Long Can Students Pay Attention in Class? A Study of Student Decline Using Clickers. *J. Chem. Educ.* **2010**, *87*, 1438−1443.
(20) Schwartz, M. S.; Sadler, P. M.; Sonnert, G.; Tai, R. H. Depth versus Breadth: How Content Coverage in High School Science Courses Relates to Later Success in College Science Coursework. *Sci. Educ.* **2009**, *93*, 798−826.
(21) Lopez-Cozar, E. D.; Robinson, G. N.; Torres Salinas, D. Manipulating Google Scholar Citations and Google Scholar Metrics: Simple, Easy and Tempting. 2012, *arXiv:1212.0638*. arXiv.org e-Print archive. http://arxiv.org/abs/1212.0638 (accessed March 26, 2015).

DOI: 10.1021/ed5007635
J. Chem. Educ. 2015, 92, 1299−1305