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Women in STEM in Higher Education: A Citation Analysis of the Current Literature

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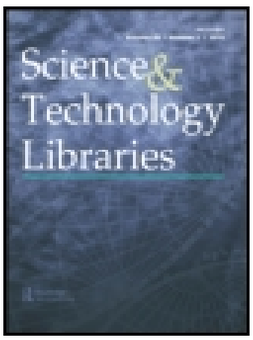

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Women in STEM in Higher Education: A Citation Analysis of the Current Literature

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ABSTRACT

Increased efforts to diversify science, technology, engineering, and math (STEM) education in the United States have increased the number of studies regarding the experiences of women in STEM programs in higher education. Using citation analysis and data visualization, this study aims to determine the major publishers and journals in this area. We reviewed 647 articles published between 2007 and 2018. Citations were concentrated on a small core set of journals and then scattered over other publications. Overall, just 3% percent of the publications accounted for 25% percent of the citations. The ramifications for STEM librarians and collection development are discussed.

KEYWORDS

Citation analysis; collection development; science; technology; engineering; mathematics; data visualization

Introduction

In 1965, Rossi (1965) noted the lack of women in academic science positions and fifty years later, the question sadly remains the same "Why so few?" The participation of more women in science, technology, engineering and math (STEM) is linked to economic growth, gender equity, and women's contributions in these fields (Sarseke 2018). The intersectionality of the research regarding women in STEM has attracted a wide range of researchers from different disciplines. In recent years, the increased public attention paid to STEM education in the United States (U.S.) has had a tremendous impact on the professional literature generated on this topic. Specifically, the recruitment and retention of women in STEM programs by U.S. universities has produced hundreds of studies ranging from the stereotypes and biases women students face in the classroom to the workplace climate of women faculty and staff. This paper provides an overview of how and where researchers are currently discussing the status of women in STEM in higher education within the literature. The purpose of this study is to understand the scope of publishers promoting this research and the research questions posed in this study are as follows:

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(1) Which journals lead in publishing literature regarding women in STEM in higher education?
(2) Which publishers are most often involved with these journals?

Libraries must consider how to strategically connect collection development activities with current and anticipated academic programs (Pickett et al. 2011), including nationwide efforts focusing on STEM degrees (National Center for Education Statistics 2017). One of the key activities of academic librarians is requesting journals that support the research being conducted by faculty and students, thereby also supporting the retention efforts on university and college campuses (O'Toole 2017). This article alerts librarians to opportunities for collection development outside traditional STEM journal titles by providing an understanding of where and how research on this topic is being published.

Background

Roemer and Borchardt (2015, 28) define bibliometrics as " … a set of quantitative methods used to measure, track, and analyze scholarly literature." Bibliometrics focuses on four levels of analysis: individual scholarly output, the venues that produce scholarly output, author output over time, and group/institutional output over time (Roemer and Borchardt 2015). These four distinct levels of analysis can inform a variety of collection development aspects in academic libraries (Hoffmann and Doucette 2012) and evaluate issues and research fronts within the body of literature of specific disciplines (Delwiche 2018). Historically, citation analysis has been used to rank journals for collection development purposes (Black 2012; Bradford 1934; Garfield 1972; Gerhard, Kushkowski, and Dobson 1998). Independent citation analyses can identify new journals for collections, ideal publications for manuscript submissions, or evaluate collection usefulness (Black 2013; Feyereisen and Spoiden 2009; Kohn and Gordon 2014; Smith 2003; Vaaler 2018). As Mering (2017) notes:

> Libraries must identify the most influential journals in the fields taught at their colleges and universities. They must track which journals are essential when making collection decisions. For recruitment, accreditation, funding, and other administrative purposes, universities must quantify the value of their faculty's research and the journals in which they publish.

Deviating from the standard use of citation analysis for journal rankings, Mohler (2005) used citation analysis to assess effectiveness of library instruction given to first-year engineering students by reviewing student bibliographies. Librarians are increasingly using data visualization to explore citation

networks through visual maps and nodes as well as other decision-making projects (Eaton 2017; MacDonald and Dressler 2018; Murphy 2013)

Ellegaard and Wallin (2015) conducted a meta-study on bibliometrics and found that, while the majority of the literature is published by the information and library science field, a growing number of subject-based citation studies have been published in the applied, health, physical, and life sciences. Bibliometrics have been used to measure journal impact factors for tenure and promotion purposes (Mering 2017; Morrisey 2002), understanding motivations for faculty citation behavior (Bornmann and Hans-Dieter 2008) and citations used in successful National Science Foundation and National Institutes of Health grants (Monroe-Gulick, Currie, and Weller 2014). Researchers have also used citation analysis in a variety of other academic settings, particularly in the STEM fields. Recently, they have explored the co-citation networks (Jiang, Ritchie, and Benckendorff 2017), gender disparity in scientific publishing (Frietsch et al. 2009; Ghiasi, Larivière, and Sugimoto 2015; Larivière et al. 2013), types of sources used by researchers (Choinski 2007; Goodchild and Zhao 2017; Kelly 2015; Rose-Wiles and Marzabadi 2018; Stephens et al. 2013), co-author networks (Lewis and Alpi 2017; Zhang 2018), and works cited in graduate student dissertations and theses (Brazzeal and Fowler 2005; Brush 2015; Fransen 2012; Kaczor 2014; Kuruppu and Moore 2008; Sinn 2005; Smith 2003; Williams and Fletcher 2006).

Yu, Chang, and Yu (2016) conducted a bibliometric study on the literature characteristics of STEM education globally and found the U.S. published 54% of the literature from 1992–2013. Aytac and Slutsky (2017) also found that the U.S. was the leading producer of STEM librarianship research articles published from 2011–2015. However, there are large amounts of research being produced regarding women in STEM in higher education so there is a need for analysis in this area (Blackburn 2017). Yet the authors found no articles regarding citation analysis for the topic of women in STEM, broadly or as related to higher education.

Methodology

For this study, all of the articles collected and analyzed were available through major database systems (including Google Scholar, Web of Knowledge, Scopus, ScienceDirect, ProQuest and EBSCO) and came from peer-reviewed, scholarly journals and conference proceedings published from 2007–2018. This period was sufficient to provide reliable data to present trends. Books, dissertations, and theses were excluded from this analysis as well as non-research pieces such as book reviews and editorials.

Citations were imported into a Zotero library and then exported into a Microsoft Excel spreadsheet, using a customized output style. Once in

Excel, the results were de-duped and off-topic articles were identified through manual review of the authors, title, date, and journal fields. Many off-topic articles were incidental retrievals due to the occurrence of the word *stem* as related to *stem cell* or *plant stem*. As the citation information was entered into the database, titles were standardized by referring to Ulrichs Global Serials Directory. The results were sorted alphabetically by the titles of the journals in which the articles appeared. The total number of journals was determined, as well as the number of articles published by each source journal as well as publishing house. The journal list was sorted with the journal publishing the most articles listed at the top, followed by the journal that published the second most, continuing down the list.

After collecting the bibliographic information in Zotero, we could proceed with visualizing the information. Using the R statistical language and the *tidyverse* library, we proceeded with data clean up that removed extraneous characters and null values. A second transformation of the data took our semicolon-delimited lists of authors and separated authors into their own rows while maintaining the appropriate bibliographic metadata. With the resulting tidy data (Wickham 2014), this study utilized the bibliometric and co-citation method to depict literature characteristics of STEM education, including distribution of journals, publication countries, subject area, most cited references and so on. The analytical data is from querying the database of Social Science Citation Index (SSCI) of ISI Web of knowledge. Data, collected in the database, could be easily analyzed to figure out the popularity of publications and impact of articles through citation indexes. This study provided the distribution of core, relevant, and marginal journal, and describe the academic trend in STEM education. The code and resulting data can be found on GitHub.

We generated three subsets of data for analysis. First, we separated out conference proceedings from journals so we could analyze the data without skewing the results towards proceedings. That left us with two sets of data: one for proceedings, and one for journal publications.

Findings

The 647 citations occurred in 295 unique journal titles and ten conference proceedings. Overall, just 3% percent of the publications accounted for 25% percent of the citations. The majority of the articles were concentrated over the top ten publications (22%) and the rest were distributed within 286 journals (74%) and nine conference proceedings (4%). *American Society of Engineering Education (ASEE) Annual Conference and Exposition, Conference Proceedings* had the most publications (n = 34) overall, followed by the *Journal of Women and Minorities in Science and Engineering* (n = 21,) and S*ex Roles* (n = 21).

Journals

Journal of Women and Minorities in Science and Engineering (n = 21,), S*ex Roles* (n = 21) and *Social Sciences* (n = 16) were the top journals, accounting for 25% of the overall journal articles. Seven of the ten titles fell within social science disciplines, including the subcategories of psychology and education. Only three of the top ten journals publishing articles on topics regarding women in STEM in higher education fell within the science disciplines, as defined by Ulrichs Global Serials Directory Subject Classifications. Table A1 displays the top ten journals that publish articles on women in STEM in higher education and the ranking of publisher by number of articles.

Conference proceedings

Table A2 displays the ten conference proceedings that publish articles on women in STEM in higher education and the ranking by number of articles. The *ASEE Annual Conference and Exposition, Conference Proceedings* (n = 34) had the most publications, trailed by the *2007 37th Annual Frontiers in Education Conference* (n = 2). There was a steep decline in proceeding articles outside of the *ASEE Annual Conference and Exposition, Conference Proceedings*.

Publishers

One hundred and eleven publishers represented over 305 publications within the sample. Sage Publications, Inc. was the most prolific publisher of articles in this area, with 77 journal articles published of which *Psychology of Women Quarterly, Personality and Social Psychology Bulletin*, and *Journal of Career Assessment* comprised the top three journals. Overall, Sage Publications (11.9%), Springer/Nature (11.75%), and Elsevier (9.89%) were the top publishers of articles. Table A3 shows the top ten publishers that publish articles on women in STEM in higher education and the ranking of publisher by number of articles.

There was a 210.90% increase in the numbers of articles published between 2007 and 2018. Specifically, there was a 190.91% increase among the top ten journals. Conference proceedings also had a 77.27% increase in papers between 2007 and 2018.

Limitations of the study and further research opportunities

One of the study's limitations is the use of convenience sampling of the journals and including the *International Journal of STEM Education* whose

content focuses exclusively on the study of teaching and learning in science, technology, engineering and math, although the demographics are not limited to higher education. Additionally, the sample is restricted to research articles whereas a future study may employ a larger sample, including non-research articles such as reviews, editorials, web/bibliographies, and opinions. In addition, while the *ASEE Annual Conference and Exposition, Conference Proceedings* is published annually, this and other publications are technically conference proceedings.

Discussion

Only three of the top ten journals covering topics involving women in STEM were published within traditional science, technology, engineering, and math journals as defined by Ulrichs Global Serials Directory Subject Classifications. This supports the findings of Yu, Chang, and Yu (2016) who found 13% of journal articles on STEM education were published within only four journal titles. However, a majority of these studies expand the theoretical knowledge base of disciplines such as psychology, gender and sexuality studies, education, and sociology. Due to the interdisciplinary nature of the topic, roughly 70% of the top ten publications were published outside traditional STEM journals. These findings suggest there may be ramifications for the scientific and engineering communities when the broader discussions on the recruitment and retention of women in STEM are taking place outside the typical communication channels for that discipline. These studies could have limited impact if they are not included the resources that STEM researchers routinely turn to for literature reviews and timely information. The audience that needs this information the most may not even be aware of the studies because they are generally not reading publications outside of their specialties due to the difficulty of keeping up on their own research areas (Niu et al. 2010; Pain 2016; Tenopir et al. 2009a, 2009b; Tenopir, Mays, and Wu 2011). It is important that researchers be informed about what has been published about women in STEM to avoid the duplication of research work and identify gaps. Additionally, it is helpful for researchers knowing which journals are highly involved in research on women in STEM and which may be looking for submissions to fill this gap for readers.

Collection development has always been a core function for subject specialists (Day and Novak 2019) and STEM librarians need to select and support access to materials on subjects of interests to the communities they serve. Bracke, Hérubel, and Ward (2010, 257) note librarians must be responsible for building "useful, coherent collections that fulfil both current user needs and anticipate the needs of future generations." Based on the findings of this study, it is recommended that librarians broaden the

traditional scope of science, technology, engineering, and math journals to include the top publications listed within this study as well as other publications that focus on STEM careers and higher education. Subject liaison librarians serving the STEM disciplines may want to collaborate with Social Sciences or Education liaison librarians to ensure there are no gaps in the coverage between these areas. Journals in the areas of psychology, sociology, gender and sexuality studies, business, and career development may add value to the STEM periodical collections at institutions of all sizes and research scope.

Data availability

The data that support the findings of this study are openly available in GitHub at 10.5281/zenodo.3228477.

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Appendix

Table A1. Journals publishing articles on women in STEM in higher education.

	Journal	Number of articles
1	Journal of Women and Minorities in Science and Engineering	21
2	Sex Roles	21
3	Social Sciences	16
4	Frontiers in Psychology	14
5	Journal of Science Education and Technology	13
6	Psychology of Women Quarterly	13
7	Research in Higher Education	13
8	Journal of Vocational Behavior	10
9	PLoS ONE	10
10	Journal of Diversity in Higher Education	8

Table A2. Conference proceedings publishing articles on women in STEM in higher education.

	Conference	Number of articles
1	American Society of Engineering Education (ASEE) Annual Conference and Exposition, Conference Proceedings	34
2	2007 37th Annual Frontiers In Education Conference	2
3	2014 Institute of Electrical and Electronics Engineers (IEEE) Frontiers in Education Conference (FIE) Proceedings	1
4	7th Institute of Electrical and Electronics Engineers (IEEE) Gulf Cooperation Council (GCC) Conference and Exhibition	1
5	Association for Computing Machinery (ACM) Conference on Innovation and Technology in Computer Science Education	1
6	Association for Computing Machinery (ACM) International Conference on Measurement and Modeling of Computer Systems	1
7	American Institute of Physics (AIP) Conference Proceedings	1
8	Proceedings – 2016 International Conference on Computational Science and Computational Intelligence	1
9	Proceedings of the 7th Institute of Electrical and Electronics Engineers (IEEE) Integrated STEM Education Conference	1

Table A3. Top publishers of articles on women in STEM in higher education.

	Publisher	Number of articles
1	Sage Publications	77
2	Springer/Nature	76
3	Elsevier	64
4	Taylor & Francis – Routledge	51
5	American Society of Engineering Education	35
6	John Wiley & Sons	27
7	American Psychological Association	25
8	Begell House	21
9	Frontiers	20
10	MDPI – AG	17