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RESEARCH

Does Female-authored Research have More Educational Impact than Male-authored Research? Evidence from Mendeley

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Female academics are more likely to be in teaching-related roles in some countries, including the USA. As a side effect of this, female-authored journal articles may tend to be more useful for students. This study assesses this hypothesis by investigating whether female first-authored research has more uptake in education than male first-authored research. Based on an analysis of Mendeley readers of articles from 2014 in five countries and 100 narrow Scopus subject categories, the results show that female-authored articles attract more student readers than male-authored articles in Spain, Turkey, the UK and USA but not India. They also attract fewer professorial readers in Spain, the UK and the USA, but not India and Turkey, and tend to be less popular with senior academics. Because the results are based on analysis of differences within narrow fields they cannot be accounted for by females working in more education-related disciplines. The apparent additional educational impact for female-authored research could be due to selecting more accessible micro-specialisms, however, such as health-related instruments within the instrumentation narrow field. Whatever the cause, the results suggest that citation-based research evaluations may undervalue the wider impact of female researchers.

Keywords: Mendeley; Gender; Altmetrics; Scientometrics; Educational impact; Readership

Introduction

The underrepresentation of women in quantitative and other areas of science internationally is a concern because of historical sexism in science and the potential loss of talent to society. The causes of this are not well understood but in the USA may include life choices rather than bias (Ceci & Williams 2011), a preference for other subjects (Su & Rounds 2015; Tellhed, Bäckström & Björklund 2017) and female-alienating cultures in some fields (Cheryan et al. 2017). A factor that may be related to both life choices and subject choices is that females tend to be in more teaching-oriented roles within academia (Ceci & Williams 2011). This raises the possibility that female-authored research is, on average, more useful within an educational context, for example if females tend to work in professional subject areas with many students (e.g., education, nursing). Thus, the main goal of this paper is to assess whether female-authored research tends to have more educational impact than male-authored research.

The issue of gendered audiences for academic research has rarely been analysed before. Research into gender differentials has focused on participation rates, productivity and citation advantages. Females are underrepresented in academia overall (Larivière et al. 2013). There are dramatic gender differences in participation rates within subjects, with females dominating health care, elementary education and the domestic sphere (HEED) topics (Tellhed, Bäckström & Björklund 2017) but males dominating science, technology, engineering and maths (STEM) in the USA (Su & Rounds 2015). In terms of productivity, male researchers produce more papers each in the USA, but the differential shrinks and possibly disappears when the tendency for females to be in more teaching and service-based roles is accounted for (Ceci & Williams 2011). Male-authored research has also been claimed to be more cited overall, perhaps because of a gender bias in citing (Larivière & Sugimoto 2017). Conversely, female first-authored research has been shown to be slightly more cited in Spain, the UK, and the USA, using a field-normalising method that reduces the influence of individual highly cited articles (Thelwall 2018b). In terms of audiences, female-authored research is more downloaded (Elsevier 2017) and more read (at least according to Mendeley data: Thelwall 2018b) in many, but not all, countries, suggesting that female-authored research might tend to have a wider audience, although the nature of the additional audience is unknown.

Information about which people read research is scarce. It is difficult to systematically track the readers of even a single journal article due to the multiple ways in which it can be accessed, many of which leave no useful trace. Some studies have attempted to infer reader types mathematically or have investigated the information-seeking behaviour

of groups of people that sometimes access research. A survey found that younger researchers read more (Tenopir et al. 2009), presumably because they have more time or more need to learn a field. There is indirect evidence that in some fields students form a substantial proportion of article readers (Bollen & Sompel 2008). Professionals in some fields may also read academic research (Dawes & Sampson 2003; Hertzum & Pejtersen 2000), although it is not clear whether non-academics form a substantial fraction of article readers in any subject. Indirect information about article downloaders inferred from their internet location can give some insights (Duin, King & Van Den Besselaar 2012) but is not definitive. Researchers are more likely to read articles authored by people in their own country (Thelwall & Maflahi 2015), presumably due to a combination of familiarity through proximity, co-authorship (e.g., Wallace, Larivière & Gingras 2012), or nation-specific shared topics (e.g., in law, economics, history, archaeology, botany, zoology, politics, health care policy).

The social reference sharing site Mendeley (Gunn, 2014) has the potential to reveal some information about article readership on a large scale. Mendeley users usually add academic publications to their libraries when they have read or intend to read them (Mohammadi, Thelwall & Kousha 2016). Counting the number of people that have added an article to their Mendeley library therefore gives an altmetric readership impact indicator. Although only about 12–20% of researchers use Mendeley (Van Noorden 2014), Mendeley readership counts tend to be higher than citation counts in almost all fields, except for articles that are decades old (Thelwall & Sud 2016), making it a useful source of impact evidence. High correlations between Mendeley reader counts and citation counts in almost all narrow fields (n = 325) suggest that readership data is a type of scholarly impact indicator (Thelwall 2017). It is particularly useful as a source of early impact evidence (Kudlow et al. 2017). Mendeley asks users to register some information about themselves, such as their occupation, country and subject area. It reports this information alongside reader counts so that the types of people that have read an article can be detected (Haustein & Larivière 2014; Mohammadi et al. 2015; Pooladian & Borrego 2017). These readership categories are currently (June 2018) no longer displayed in the Mendeley.com website but can be accessed via the Mendeley API (Applications Programming Interface), such as via the free software Webometric Analyst. Reader demographics in Mendeley are known to vary between journals, giving evidence that they attract different types of audience (Thelwall 2018a).

Although the goal of this paper is to look for evidence of gender differentials in educational impact, the research question is widened to take advantage of the additional reader types available in Mendeley. This paper is a follow-up (with the same data) to a previous study using field normalised logged readership counts that found female-authored research to have more Mendeley readers than male-authored research in Spain, Turkey, the UK and the USA, but not India for Scopus articles in 2014 (Thelwall 2018b).

- **RQ:** Are there differences in the types of people that read articles in narrow fields based on the gender of the first author?

Methods

The overall research design was to compare the average number of Mendeley readers of articles in narrow fields by first-author gender in five different countries. Mendeley was chosen as the only major source of reader type information. Whilst download data gives the total number of electronic accesses of an article, it does not reveal who has downloaded it. The following list summarises the methods, which are described in detail below. Each step was calculated separately for each country.

- Collect a list of articles published in Scopus in 2014 with an author from the given country.
- Filter out articles where the first author was not from the given country.
- Collect Mendeley reader data for each article for the number of readers of several occupational types.
- Detect the gender of the first author using their first name, and discard articles with an unknown first author gender.
- Calculate the geometric mean number of readers for each gender, narrow field and occupational type.
- Estimate the extent to which one gender has more readers than the other for each narrow field and occupational type.
- Repeat the above step for the largest 100 narrow fields (those with the most gendered authors for the country).

Five countries were chosen as major producers of science. The USA and UK are similar in culture and therefore make an interesting comparison. India, Spain and Turkey have different cultures with potentially alternative gender perspectives. Malaysia would have been a useful addition for its unusual gender profile (Othman & Latih 2006), but Malaysian given names are often reported second, with the first name sometimes being the father's first name (e.g., Professor Abdullah Abrizah), making the detection of Malaysian names through gender unreliable. Narrow fields (narrow subject categories in Scopus) were investigated rather than academia overall because some female-dominated areas have relatively large numbers of undergraduates (e.g., nursing) and ignoring fields would therefore bias the results due to gender differences in field specialisms. Moreover, the education broad field has a high proportion of female contributors and may include many articles that are relevant within education, potentially biasing the results of a single overall assessment in the same way. The year 2014 was selected to give at least three years for articles to accrue substantial numbers of readers.

The Mendeley records were downloaded for the Scopus articles from all 308 Scopus narrow subject categories (Scopus 2018: for a list, see the AJSC tab of the Source title list spreadsheet, excluding the codes for all broad categories except the first) in May–June 2018 with the Mendeley API in Webometric Analyst combining both DOI searches and metadata searches, following best practice (Zahedi, Haustein & Bowman 2014). The Scopus narrow subject categories are journal-based using all 311 All Science Journal Classification (ASJC) codes. For example, 3506 Periodontics applies to journals covering this dentistry speciality. Overlapping codes (those ending in 00 except for 1000 multidisciplinary were not collected; e.g., 1100 *Agricultural and Biological Sciences (all)* overlaps with the other 11— codes in the *Agricultural and Biological Sciences* broad area).

The authorship gender of a paper was calculated based on the first author, who is probably the main contributor in all broad fields (Larivière et al. 2016), although there is partial alphabetical ordering in some quantitative areas (Levitt & Thelwall 2013). The gender of each first author was identified from their first name using Gender-API.com for their country. An author was assigned a gender if their first name matched at least 50 Gender-API.com records, with at least 90% being of the same gender. For the USA, first names in the top 1000 of the 1991 census that were at least 90% of one gender were also used. People with rare names, initials, or ambiguous gender names were ignored. The result was two sets of articles for each country and field: one with first authors likely to be male and one with first authors likely to be female. This method detected gender for about half of the authors in each country. Records for authors with an unknown gender were discarded.

For each narrow field, year and gender, the geometric mean number of readers per article of each reader category was calculated. Geometric means (Thelwall & Fairclough 2015; Zitt 2012) were used rather than arithmetic means due to the skewed nature of Mendeley data (Thelwall & Wilson 2016).

Two comparisons were made of male-authored and female-authored articles. First, for each field, country and reader type (e.g., undergraduate), the male geometric mean Mendeley reader count was subtracted from the female geometric mean Mendeley reader count and expressed as a percentage of the geometric mean number of readers for the field, country and type. This estimates the percentage reader count gender bias for each reader type. Second, the average number of readers of female-authored articles was expressed as a percentage of readers of all articles for each reader type. This gives the gender bias within each reader type.

The above calculations are unreliable for small numbers and vary by field. To report a consistent set of results for each country, the median was calculated over the largest 100 fields in each case. Field size was judged to be the minimum of the number of male- and female-authored articles. To check whether the choice of 100 might affect the results, a second calculation was conducted for all fields where this minimum was at least 50. As a second cross-check, a third calculation used the number of fields with a gender majority rather than the median of the gender differences across fields. A list of the fields used is here: https://doi.org/10.6084/m9.figshare.7069820.

Results

Articles written by females are likely to attract more readers that are students of any kind or researchers in all countries except, for some categories, India (bars are on the right of the centre for student categories in **Figure 1**). This is not due to females publishing more in education-related fields because the statistics compare only within narrow fields. Thus, the result applies to research published in the same narrow field. In contrast, higher level academics (professor, associate professor) are more likely to read male-authored articles (bars are mostly on the left of the centre for senior academic categories in **Figure 1**).

The results do not change much if the set of fields is changed to include all fields with at least 50 male-authored and at least 50 female-authored articles (Appendix, **Figure 2**). The results also do not change if the number of *fields* with a higher average reader count for female first-authored papers is counted (not shown). The results are therefore robust rather than artefacts of the calculation procedure or set of fields.

Discussion

This study is limited by using Scopus narrow subject category definitions, which are based on journal classifications that are manually assigned within Elsevier and contain errors (Wang & Waltman 2016) as well as multidisciplinary journals that do not fit well into any category. Only a minority of Mendeley users are academics (Van Noorden 2014), and there may be gender differences in uptake of this service. The results may also change over time and underestimate the influence of minority cultures within each country, for which the name-based gender detection may be less effective. There may also be biasing second-order class effects caused by differing levels of uniqueness between genders and class (e.g., if richer people choose rarer baby names then, as adults, they will be underrepresented in the results). Some of an article's Mendeley readers may also be its authors. Given the increasing proportion of female academics (Holman, Stuart-Fox & Hauser 2018), these would tend to generate more additional younger readers for female-authored articles. A direct limitation is that some undergraduate readers may have become more senior without updating their Mendeley profiles. Similarly, senior academics may have added some of the articles analysed here (from 2014) when they were more junior. The Mendeley occupational categories do not reflect common practice in all countries and can overlap (e.g., PhD student and doctoral student) and so differences between similar categories may be misleading. Finally, the study only includes five countries and there may be substantially different gender roles in academia elsewhere, and it ignores important non-article scholarly outputs, such as monographs, artworks and performances.

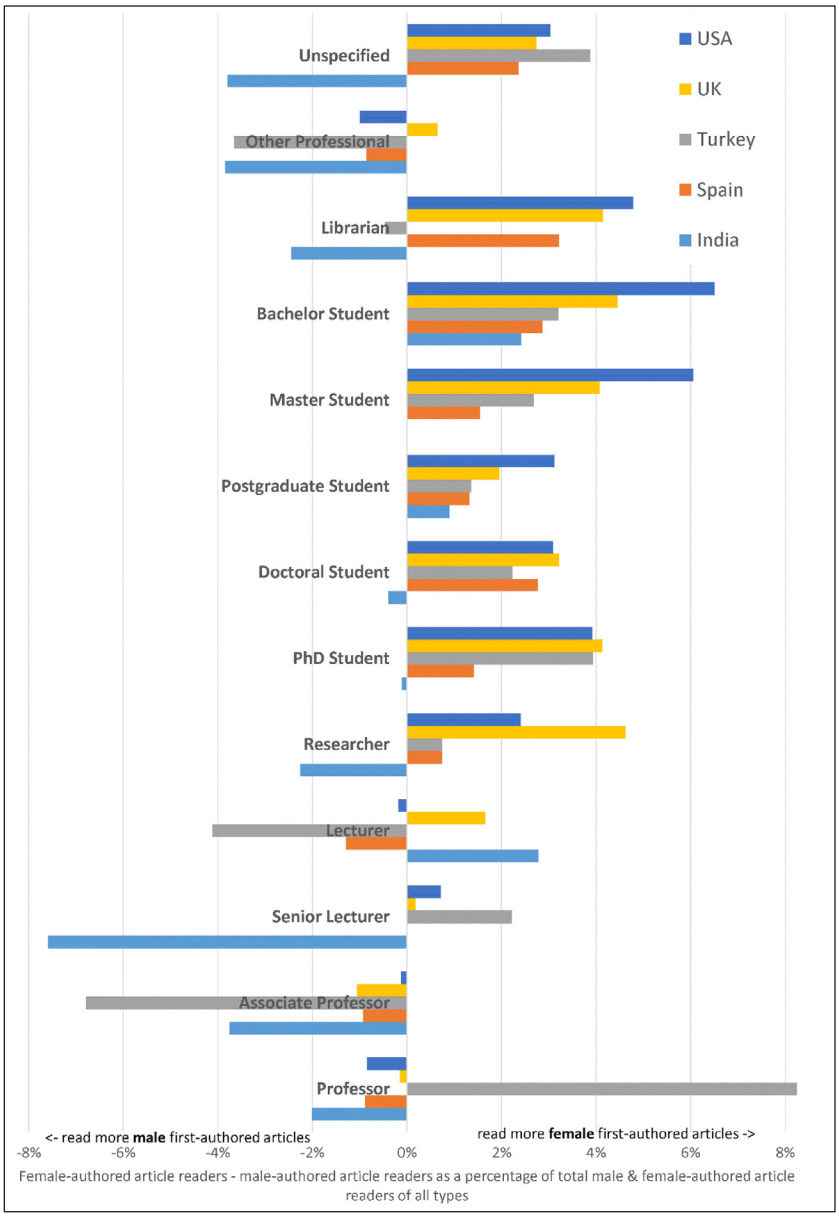

Figure 1: The median of the geometric mean number of Mendeley readers for female-authored articles subtract the geometric mean Mendeley readers for male-authored articles for the 100 narrow fields in each country with the largest minimum number of readers of each gender. Figures are expressed as a percentage of the average number of readers per article in each category. The categories are those selected by users when joining Mendeley or when they subsequently update their self-description. A list of the fields used is here: https://doi.org/10.6084/m9.figshare.7069820.

The Indian results stand out in that for many reader types, it is the only country with an overall male bias, and for all reader types except two (lecturer, associate professor) it is the country that reads the lowest proportion of female first-authored articles (**Figure 1**). This deepens the results of a previous study with citation counts and overall reader counts for the same Mendeley data as the current paper (Thelwall 2018b) by showing that this relative male reading bias is prevalent at all levels of academia in India. A possible explanation is that a minority of academics do not value the work of females in India (Gupta 2015, 2016). Alternatively, gender differences in research topics may persist within narrow fields and because there are relatively many male researchers in India (Godbole & Ramaswamy 2008) male-oriented research topics attract more attention in India.

Narrow fields (i.e., narrow subject categories in Scopus) in the USA with a high gender bias in undergraduate readers were investigated to identify potential causes of the differences found. The USA was chosen for this additional investigation because it had published the most articles.

- Algebra and Number Theory (471 male-authored, 91 female-authored; 74% undergraduate readers per article for female-authored articles and 55% overall). This category had only 50 undergraduate readers in total and many journals had none (e.g., the 21 articles in *Algebra and Number Theory*). This gender imbalance was caused by a single **gender classification error** (a male Sandy authoring an article with 7 undergraduate readers).

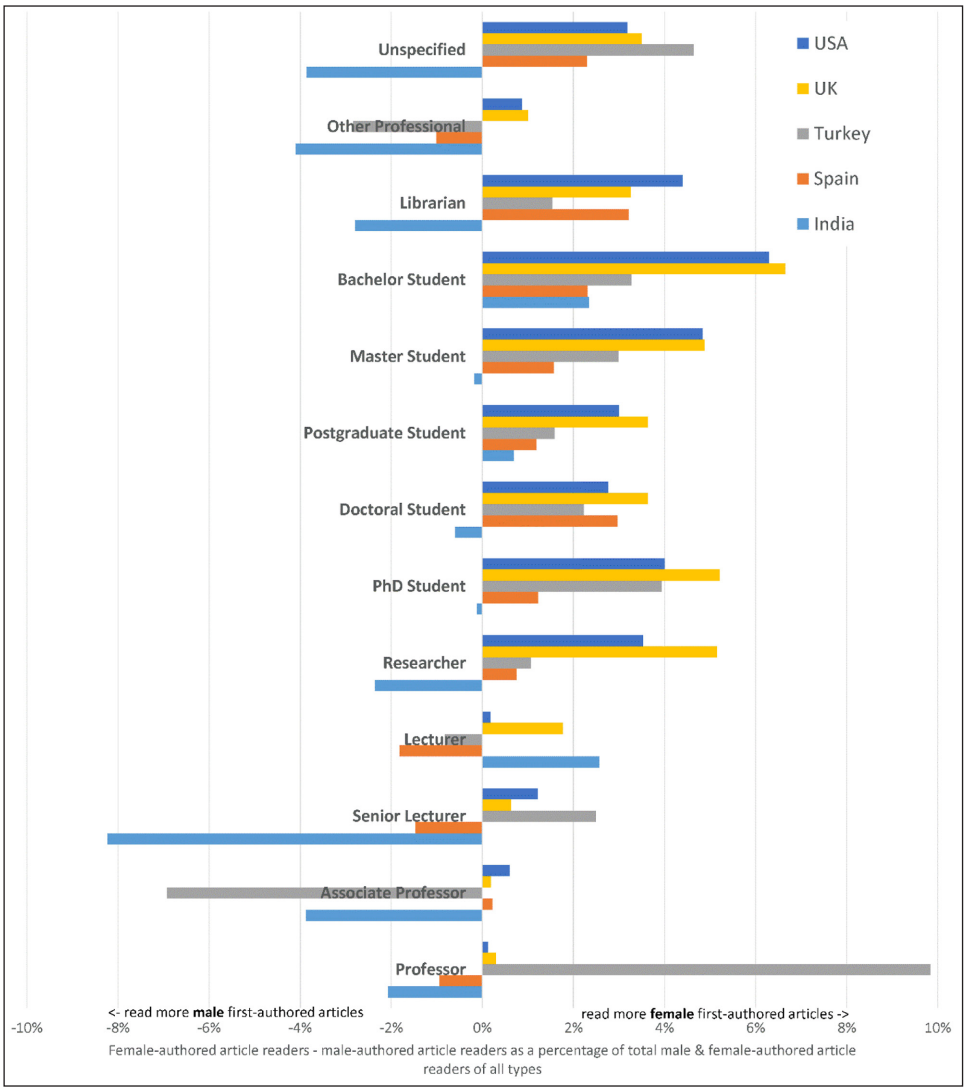

Figure 2: [As for Figure 1 except calculating the median across all fields with at least 50 male-authored and at least 50 female-authored articles in each country.] The median of the geometric mean Mendeley readers for female-authored articles subtract the geometric mean Mendeley readers for male-authored articles for the narrow fields in each country with at least 50 male-authored and at least 50 female-authored articles. Numbers are expressed as a percentage of the average number of readers per article in each category.

- Analysis (468 male-authored, 68 female-authored; 73% undergraduates per article for female-authored articles and 56% overall). This pure maths category included a **misclassified journal**, *Explore: The Journal of Science and Healing*, which attracts undergraduates (118 readers) rather than professors (24 readers) and had relatively many female-authored articles for this category (8 out of 20).
- History and Philosophy of Science (531 male-authored, 276 female-authored; 67% undergraduates per article for female-authored articles and 68% overall) included two journals with mostly female-authored articles and relatively high numbers of undergraduate readers per article, the *Journal of Sex Research* (13 male-authored, 28 female-authored articles) and *Social Science and Medicine* (48 male-authored, 85 female-authored articles). In this case the undergraduate preference for female-authored articles echoes the overall preference for female-authored articles (68%) and is due to the **inclusion within the category of higher impact specialist journals with more female authors**.
- Instrumentation (568 male-authored, 113 female-authored; 65% undergraduates per article for female-authored articles and 54% overall) included two journals where the female-authored articles attracted noticeably more undergraduate readers. *IEEE Sensors Journal* included 4 female-authored articles, 75% with at least one undergraduate reader, and 48 male-authored articles, 25% of which had undergraduate readers. The difference was presumably influenced by two of the four female-authored articles having health topics ("Characterization of mammary tumors using noninvasive tactile and hyperspectral sensors" and "Unobtrusive sleep stage identification using a pressure-sensitive bed sheet") in comparison to none of the male-authored articles (e.g., "Calibration of electromagnetic dot sensor – Part 1: B-dot mode"). Similarly, the *International Journal of Mass Spectrometry* included 5 female-authored articles, 80% with undergraduate readers, and 13 male-authored articles, 15% with undergraduate readers. There wasn't a clear theme for the female-authored articles compared to the male-authored articles. Here, part of the female advantage for undergraduates can be assigned to a more **female-authored micro-specialism**

(i.e., smaller than the level of Scopus narrow fields) of health-related sensors with greater educational interest.

- Geometry and Topology (389 male-authored, 55 female-authored; 67% of undergraduates per article for female-authored articles and 54% overall). The main gender difference in this category seemed to be the inclusion of many journals without any female authors (or a tiny percentage) and no undergraduate readers. These included *Advances in Geometry* (4 male-authored articles), *Beitrage zur Algebra und Geometrie* (5M), *European Journal of Combinatorics* (4M), *Geometriae Dedicata* (16M, 1F), *Geometric and Functional Analysis* (14M), *Groups, Geometry, and Dynamics* (15M), *Journal of Homotopy and Related Structures* (5M), *Journal of K-Theory* (4M), *Journal of Spectral Theory* (6M), *Order* (8M), and *Quantum Topology* (7M). Thus, in this area **males seem more likely to author in** (multiple) **specialist areas that are not of interest to (or are mathematically beyond) undergraduates**.

These five categories point to two errors (presumably random and affecting males as much as females overall, therefore not affecting this article's conclusions). Combining the last three causes, it is at least plausible that the greater undergraduate interest in female-authored research is partly due to a greater male tendency to focus on micro-specialisms that are not of interest to them, and a greater female tendency to conduct interdisciplinary research with human-related angles (e.g., health, biological sex: see: Su & Rounds 2015) in other research fields.

The above analysis would not reveal some types of bias that remain theoretical possibilities. For example, females may be more accomplished academic authors that write in a more accessible style. Authors may also recommend their own articles to students as part of their teaching. This would affect females more since they are more likely to be in teaching-intensive roles, at least in the USA.

Conclusions

The results give evidence, for the first time, that female-authored research is more likely to be read by undergraduates, master's students and junior researchers (with a partial exception of India) than male-authored research within the same narrow subject field. The investigation of the USA suggested that the main cause might be females choosing more accessible micro-specialisms, such as health-related instruments rather than other instrumentation. The evidence is not conclusive because of the potential confounding factors mentioned in the research limitations. It adds to prior findings of more citations (Thelwall 2018b), downloads (Elsevier 2017) and total Mendeley readers (Thelwall 2018b) for female first-authored research in many countries.

It seems unlikely that many students or researchers would choose what to read based on first-author gender. Possible causes of any student (and junior researcher) reading gender bias include choice of more human-related research topics (even within narrow fields) and avoiding esoteric topics, a more accessible writing style, and greater female involvement in teaching. More male-authored articles may be read in total by students, however, since more male-authored research is published, unless there is a greater student readership in female-dominated fields, such as nursing. Since junior researchers read more than senior researchers (Tenopir et al. 2009; Bollen & Sompel 2008) and numerically dominate academia, the junior female reading tendency is an important phenomenon.

Although the evidence is weak, the findings raise the possibility that female-authored research has, on average, a greater non-research impact within education. Since it is theoretically possible that there are also gender differences in other types of non-scholarly impact (e.g., perhaps greater male industrial impact), it would not yet be reasonable to claim that female-authored research has more overall impact than male-authored research, but it is now a distinct possibility. Thus, citation-based evaluations of female researchers might undervalue the impact of their work.

Competing Interests

The author has no competing interests to declare.

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