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Citation of Retracted Articles in Engineering: A Study of the Web of Science Database

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The objective of this study is to compare the quantity of citations that retracted and nonretracted articles received in engineering based on articles indexed in the Web of Science database and published between 1945 and 2015. For data analysis, the Statistical Package for the Social Sciences was used along with the Kolmogorov–Smirnov, Mann–Whitney, Tukey–Kramer tests and descriptive statistics. The data set included 238 retracted and 236 nonretracted articles, with the retracted articles cited 2,348 times and nonretracted articles cited 2,957 times. The results highlight that retraction does not end citation, thus threatening scientific credibility.

KEYWORDS: citation, self-citation, retraction, nonretraction

The development of a scientific text is a complex and arduous process. First, good writing requires the author's honesty, followed by clear, concise text and precision in the information portrayed (Roig, 2006). Along with the authors, all those involved in the process of disseminating knowledge, including researchers, reviewers, and/or editors, must be ethical (Rodrigues, Crespo, & Miranda, 2006). Authenticity and accuracy are key elements in ethical scientific production (Carlson & Ross, 2010).

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Color versions of one or more of the figures in the article can be found online at www.tandfonline.com/hebh.

Scientific misconduct exists within the sciences, and one of the "justifications" for its existence is the pressure that researchers are put under to publish in academia. As a consequence, there has been an increase in the quantity of publications, which can be a defining factor in who is able to survive in the current scientific atmosphere. Often, the quantity of publications is prioritized over quality (Lins, 2014), leading researchers to employ "tricks" to achieve the number of expected publications, thus increasing dishonesty in scientific production (Righetti, 2010).

Although the pressure to publish can instigate unscrupulous and corrupt practices among scientists and institutions (Carafoli, 2015; Moustafa, 2015), the academic community has an obligation to report publications that present falsified data. The principal avenues for disseminating scientific work are abstracts, reviews, essays, articles, research projects, research reports, monographs, dissertations, and theses (Köche, 1997, p. 138). Furthermore, Lins (2014) argued that scientific work does not end with publication. After the work is disseminated, it is further scrutinized by the scientific community, as it is the specialists in the field who are more effective at identifying errors or scientific misconduct than many journal reviewers.

When an error or scientific misconduct is identified, a retraction must be published relating to the fraudulent article (Sox & Rennie, 2006). Retractions can be the consequence of honest errors or scientific misconduct (Cosentino & Veríssimo, 2016). Scientific misconduct occurs when there are cases of fabrication of data, redundant publication, plagiarism, and unethical research (Atwater, Mumford, Schriesheim, & Yammarino, 2014; Casadevall & Fang, 2012; Van Noorden, 2011; Wager, Barbour, Yentis, & Kleinert, 2010) that significantly deviate from the conduct deemed acceptable by the scientific community in the proposal, management, or reporting of research.

The act of publishing a retraction is seen as damaging not only to the authors' academic careers (Van Noorden, 2011; Yadav, Rawal, & Baxi, 2016; Zhang & Grieneisen, 2013) but also to the journal, considering that it has a direct impact on its reputation and credibility (Williams & Wager, 2013). This negative impact leads to resistance against publishing retractions, often resulting in the publication of simple and discrete advisories that do not clearly explain the reason for retraction (Almeida, Catelani, Fontes-Pereira, & Gave, 2016a; Bosch, Hernández, Pericas, Doti, & Marušić, 2012; Van Noorden, 2011). Retractions are expected to coherently justify the factors that led to the retraction and those responsible (da Silva & Dobránszki, 2017). However, the published retraction notice is not always evident to other researchers. According to Bar-Ilan and Halevi (2017) and da Silva and Bornemann-Cimenti (2017), scientific publication databases are not always updated, thus perpetuating the use of retracted articles, as seen through their continued citation without proper acknowledgment of the retraction.

Citations represent a continuation of the life span of a scientific article, demonstrating that the work is being used and appreciated. When used correctly, a citation serves as a tool to support a declaration, method, or hypothesis. Therefore, a retracted article has an impact on the researcher and his or her research institution, because it ends the life span of the article and results in a waste of resources (da Silva & Bornemann-Cimenti, 2017). However, Budd, Sievert, Schultz, and Scoville (1999); Van Noorden (2011); and Davis (2012) have argued that a retraction does not represent the end of the article's life, as they often continue to be cited for many years, even for decades after retraction. According to Bar-Ilan and Halevi (2017), the

retraction of an article due to misconduct helps to clean up the scientific literature, but it does not stop citation, thus representing a real challenge for scientific integrity.

For Unger and Couzin (2006) and Campanario (2000), there are two main types of citations for a retracted article: the citations that the article received before the retraction and the citations that it received after publication of the retraction. According to Campanario (2000) and Redman, Yarandi, and Merz (2008), in both cases scientific integrity is jeopardized, particularly when the retractions are not cited in the reference lists, suggesting that the retracted article is legitimate. When the motive for retraction is manipulation or fraud, its continued citation proliferates false results. It is important to emphasize that articles that are well cited before retraction are more likely to continue receiving citations after retraction.

The continued citation of retracted works demonstrates the problematic system of retraction publication, which is inadequate, is insufficient (Lins, 2014), and significantly affects science (da Silva & Bornemann-Cimenti, 2017). For example, if the methodology of a study is not used correctly, it will produce compromised results that are unreliable. In fact, if there are problems with one part of the data, the entire article is in doubt, making it inappropriate for citation (da Silva & Bornemann-Cimenti, 2017).

According to da Silva and Bornemann-Cimenti (2017), the use of retracted articles puts studies that are based on the retracted publications at risk. One of the main reasons for using these articles is that other researchers in the field are unaware of the retraction. For Cosentino and Veríssimo (2016), researchers must search for all authors who are cited throughout their article to verify if any of their references have been retracted.

Retraction sheds a negative light on the article, and such articles should be used only in cases where the erroneous section of the article is clarified in the retraction and all issues clearly pointed out. In this case, both the original article and the retraction should be referenced (da Silva & Bornemann-Cimenti, 2017).

Bar-Ilan and Halevi (2017) found that authors cite retracted work for several reasons: The full article is freely available, the work attracts the attention of society, the retraction notices are insufficient, the manipulation of data and/or images does not affect the validity of the conclusions, or the retraction is due to self-plagiarism or duplicate publication. Hence, citing retracted articles can propagate false premises for future research, which can have a serious impact on the advancement of science.

The publication and dissemination of a manuscript that includes misconduct has significant consequences for the progress of science (Murphy, Bulman, Shariati, Hausmann, & ISN Publications Committee, 2014), negatively affecting the scientific process and its credibility, as well as severely undermining confidence in science (Lewis, Duchac, & Beets, 2011). This violation affects individuals who participate in research, society, researchers, the research process, research institutions, and research promotion agencies (Lins, 2014). In addition, it can have an impact on those who use the results in decision making, thus wasting time and resources (Claxton, 2005).

For Bergada (2012), both researchers and society must be involved in discussions of scientific misconduct, as its consequences can affect not only the academic system but society as a whole. Erroneous or fraudulent data about a medicine, pesticides, or the climate have direct impacts on society, for example, by influencing the implementation of health and social policies, which are often difficult to revert. According to Russo (2014), there is a need for

society to become more scientifically responsible, building an awareness that scientific inquiries have consequences that can affect all aspects of social life.

The scientific community requires transparent and responsible practices that encourage scientists to improve the way scientific results are reported and published. With such advancements, science should be made accessible for all of society and practices of misconduct discouraged (Cosentino & Veríssimo, 2016).

Because there are still no clear tools or mechanisms to combat misconduct, identifying the profile and propagation of a retraction provides a better understanding of the situation. According to Archambault, Vignola-Gagné, Côté, Larivière, and Gingrasb (2006) and Wang, Frang, and Sun (2016), the Web of Science is the most important database in the world, covering a wide range of disciplines and enabling comparisons across scientific areas. For this purpose, the Web of Science database was selected for the current study.

In the literature, several authors have analyzed retractions: Sox and Rennie (2006), Wager and Williams (2011), Almeida et al. (2016a), Steen (2011), and Steen, Casadevall, and Fang (2013) focused on the area of medicine; Foo (2011) and Fang, Steen, and Casadevall (2012) assessed retractions in biomedicine and the life sciences; and Madlock-Brown and Eichmann (2015) focused on biomedicine. Grieneisen and Zhang (2012); Resnik and Dinse (2013); Almeida, Rocha, Catelani, Fontes-Pereira, and Vasconcelos (2016b); and Rubbo, Helmann, Bilynkievycz Dos Santos, and Pilatti (2017) did not focus solely on one area of research but analyzed the profile of databases. Meanwhile, Neale, Dailey, and Abrams (2010); Madlock-Brown and Eichmann (2015); Bornemann-Cimenti, Szilagyi, and Sandner-Kiesling (2016); da Silva and Bornemann-Cimenti (2017); Bar-Ilan and Halevi (2017); and Budd et al. (1999) studied the citation of retracted articles. Although these studies deal with retractions, to date there have been no analysis that compares the citation of retracted articles with nonretracted articles. In this context, the general objective of the present study was to compare the number of citations that retracted and nonretracted articles received in engineering, based on articles indexed in the Web of Science database and published between 1945 and 2015. To achieve this objective, our study seeks to respond to the following questions: How many citations and self-citations did retracted and nonretracted articles receive? After how many years do nonretracted articles become obsolete? How many retracted articles continue to be referenced after retraction?

METHODOLOGY

The study consists of two groups: the research group and the control group. The research group was constructed considering scientific retractions included in the Web of Science database and published between 1945 and 2015. We searched for documents that included in the title the following words: “retracted” OR “retraction” OR “withdrawal” OR “redress.” We then searched for documents listed as “correction.” Subsequently, categories were selected to define articles in the field of engineering. As such, all categories that include the word *engineering* were selected: mechanical engineering, biomedical engineering, chemical engineering, metallurgical engineering, cell tissue engineering, electrical engineering, multidisciplinary engineering, civil engineering, manufacturing engineering, petroleum engineering, industrial engineering, ocean engineering, and geological engineering. The control group consisted of

a randomly selected set of articles from the same number, volume, and journal as the articles included in the research group.

In both the control and research group, in terms of number of citations, each article was searched through the Web of Science database, using the title found in the retraction. Thus, the number of citations found for the title of the article indicated the number of citations the article received and who cited the article, which was used to verify self-citations.

Furthermore, for the research group we identified if authors referenced the retraction in the reference list of the article. To do this, the publications that cited the retracted articles were downloaded and their reference list checked. For the control group, the obsolescence based on the year in which the article was cited, obtained through the information published about the article.

Article selection was conducted in April and May 2016. The collection of data from the control group and information regarding citations and self-citations occurred from March 26, 2018, to April 4, 2018.

For the comparison of citations and self-citations among groups of retracted and non-retracted articles, the Statistical Package for the Social Sciences was used to perform descriptive statistical analysis, along with the Kolmogorov–Smirnov normality test and Mann–Whitney nonparametric test. According to Fávero, Belfiore, Silva, and Chan (2009), "the Kolmogorov-Smirnov test is an adhesion test that compares the frequency distribution of a set of observed sample values with the expected or theoretical distribution" (p. 112). For Field (2009),

> if the test is non-significant ($p > 0.05$), it tells us that the distribution of the sample is not significantly different from a normal distribution (i.e., it is probably normal). If, however, the test is significant ($p < 0.05$), then the distribution in question is significantly different from a normal distribution (i.e., it is non-normal). (p. 144)

The data set studied herein had a non-normal distribution, and as such, nonparametric tests were used.

To verify significant differences in the means between citations and self-citations for the retracted and nonretracted articles, the nonparametric Mann–Whitney test was performed. According to Fávero et al. (2009, p. 176), this test is applied when the assumption of normality is not met. We assumed that if $p < .05$, there was difference between groups, and if $p > .05$, there was no difference between groups.

RESULTS

Research group

A total of 264 documents were identified, with two documents (in the years 1997 and 2001) classified as nonretractions and two other documents (in the year 2015) identified as duplicates. Thus, 260 retractions were obtained. In the study period from 1945 to 2015, 3,352,852 articles were published; therefore, retractions represent 0.008% of all articles published. Table 1 shows the number of retractions per year.

We can see that between the years of 1945 and 2002, no scientific retraction is reported in the Web of Science. We assume that attitudes related to misconduct have always been present in

TABLE 1
Number of Retractions per Year

Year	*Retractions*
1945–2001	0
2002	1
2003–2005	0
2006	2
2007	2
2008	16
2009	33
2010	21
2011	20
2012	21
2013	33
2014	78
2015	33
Total	260

academia; therefore, from this result we can infer that scientific publications prior to 2002 were not subjected to such scrutiny, or if they were, there was no interest in reporting the failure. We also found that in the years 2003 to 2005 there were no retractions, and until 2007 the incidence was low. Retractions gaining representativity beginning only in 2008. The year 2014 has the largest representation of retractions with 78, followed by 2009, 2013, and 2015, each with 33 retractions.

However, of the 260 retractions, 22[1] documents were disregarded (21 in 2009 and one in 2012), as they were not available as open access. A total of 238 documents were considered for analysis, corresponding to more than 91% of all identified retractions.

Of the 238 published retractions, 11 were referenced once, 2 retractions were referenced twice, 1 retraction was referenced four times, and 224 retractions were not cited in any scientific work.

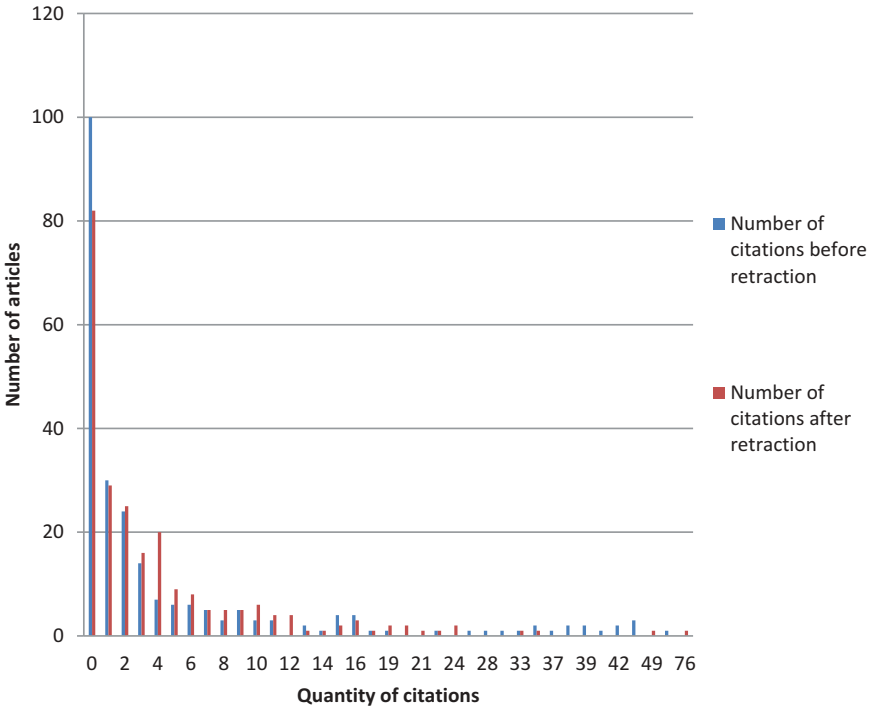
Graph 1 shows the number of citations before and after retraction.

Before retraction, 42.02% (100) of the articles received no citations. In contrast, six articles were cited more than 40 times. The most cited article had 55 citations. After retraction, 34.45% (82) of the articles were not cited, and the two most cited articles received 49 and 76 citations. The total number of citations that the retracted articles received were 2,348, of which 1,291 occurred before retraction and 1,057 after retraction.

Graph 2 demonstrates the number of self-citations before and after retraction.

Before retraction, 65.97% (157) of the articles were not self-cited, showing that a minority (34.03%; 81) of the articles were self-cited. The highest concentration was one self-citation for 28 articles, with six articles being self-cited 20 times or more. Regarding self-citation after retraction, 90.76% (216) of the articles were not self-cited. The highest concentration was 11 articles with one self-citation. The greatest number of self-citations was reached for two

[1] In addition, 20 of the retractions in 2009 were issued by the journal *Tissue Engineering and Regenerative Medicine* (JCR 1.088).



GRAPH 1. Number of citations.

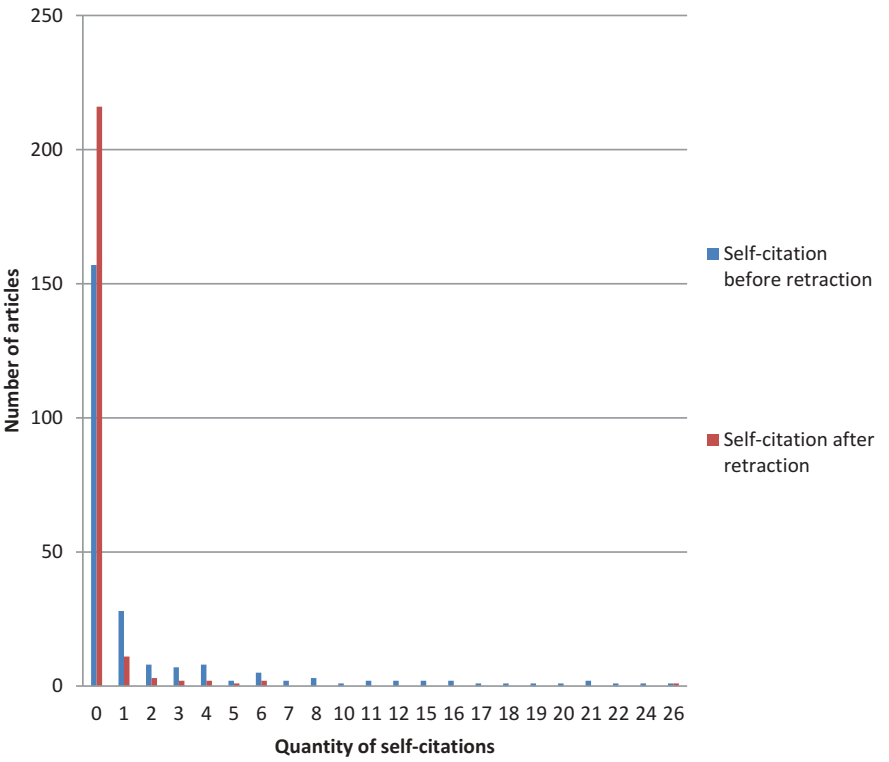
articles, both of which were self-cited 26 times, one before retraction and the other after retraction. The total number of self-citations that the retracted articles received was 555, with 481 before and 74 after retraction.

Control group

The control group consisted of randomly selected articles from the same number, volume, and journal as the articles in the research group. However, of the 238 retractions, two retractions had been removed, which prevented verification of the number and volume of the publication. Therefore, because a corresponding nonretracted article could not be identified, 236 nonretracted articles were analyzed.

Citation of nonretracted articles

In assessing the number of citations of nonretracted articles, we found that 8.05% (19) of the articles did not receive any citation. The greatest concentrations of articles were as follows: 23 articles with four citations, 20 articles with one citation, 18 articles with two citations, 17 articles with six citations, 12 articles with eight citations, 11 articles each with three and five citations, and

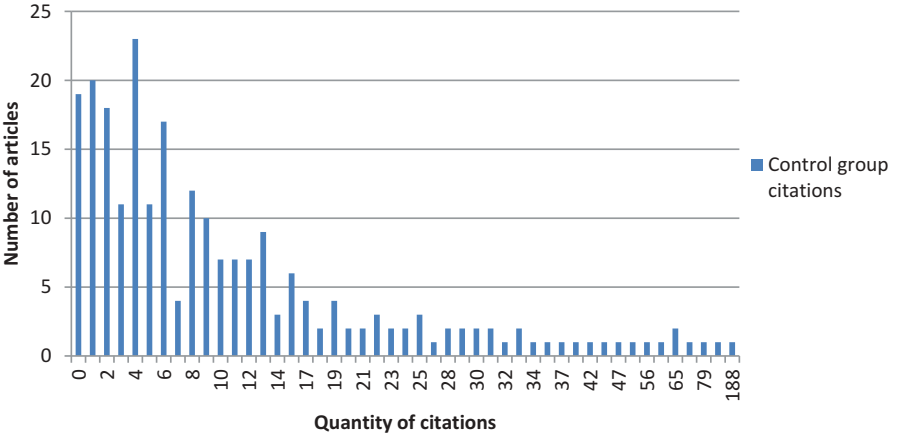


GRAPH 2. Number of self-citations.

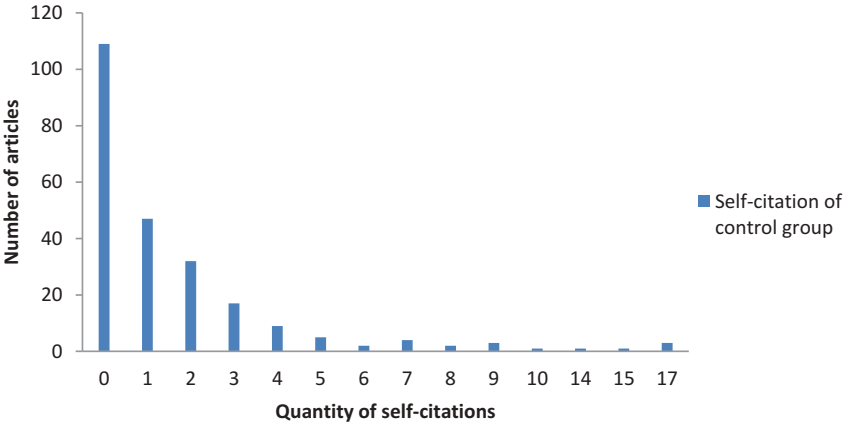
10 articles with nine citations. Two articles received the most citations: one with 188 and the other with 156. The remainder received fewer than 80 citations per article. The total number of citations that the nonretracted articles received was 2,957. Graph 3 represents the number of citations that nonretracted articles obtained.

Graph 4 shows the quantity of self-citations that nonretracted articles received.

We found no incidences of self-citation for 46.19% (109) of articles in the control group. The greatest concentrations of articles were as follows: 47 articles with one self-citation, 32 articles with two self-citations, 17 articles with three self-citations, and nine articles with four self-citations. Although the majority of articles had low numbers of self-citations, we found articles that exceeded 10 self-citations as follows: one article with 14, one article with 15, and three with 17 self-citations. The total number of self-citations that nonretracted articles received was 396.



GRAPH 3. Citation of nonretracted articles.

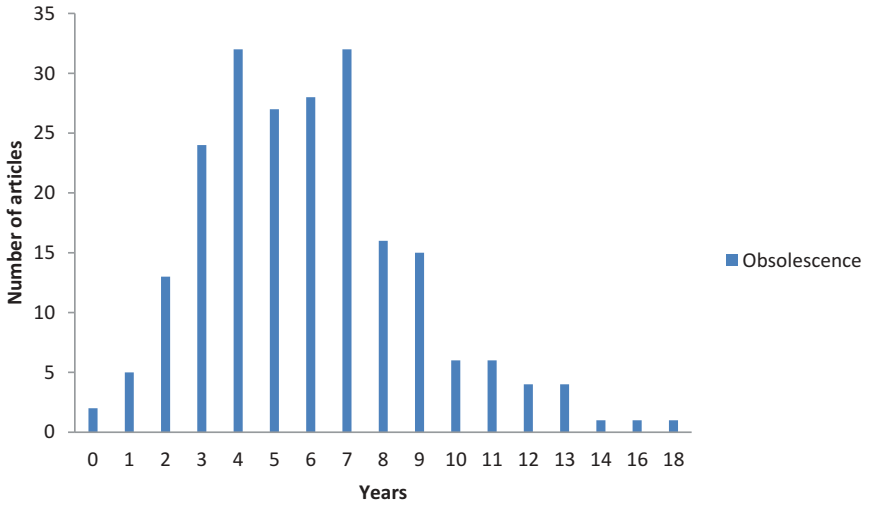


GRAPH 4. Number of self-citations of nonretracted articles.

Obsolescence

To determine obsolescence, we considered only 217 articles, as 19 articles did not receive citations. Graph 5 shows the variation in postpublication years of article citations.

The greatest concentration was found at 4 and 7 years, each with 14.75% (32) articles. For two articles, we found that the interval did not reach 1 year, whereas one article reached 18 years of permanence in the literature. On average, the life span of articles in this field is 5 years.



GRAPH 5. Obsolescence.

Comparing citations and self-citations between retracted and nonretraced articles

To analyze the citations and self-citations of the articles, we considered 238 retractions and 236 nonretractions. The difference is because two retractions were removed, and therefore information about the publication volume and number were unavailable. These two articles represent 0.8% of the 238 retractions and therefore do not compromise the data analysis.

Using descriptive statistics, we can see the difference between retracted and nonretracted articles, as shown in Table 2.

Based on the number of citations, it is clear that nonretracted articles received a greater quantity, with an average of 12.53, whereas retracted articles received an average of 9.87 citations. The greatest number of citations was 188 for a nonretracted article from the journal

TABLE 2
Descriptive Statistics Related to the Number of Citations and Self-Citations

	No. of Citations		*No. of Self-Citations*	
Procedure	*Retracted*	*Nonretracted*	*Retracted*	*Nonretracted*
Average	9.87	12.53	2.33	1.68
Mdn	4.00	6.00	0.00	1.00
Variance	190.530	397.305	25.784	8.338
SD	13.803	19.933	5.078	2.888
Minimum	0	0	0	0
Maximum	91	188	28	17
Amplitude	91	188	28	17

International Journal of Human–Computer Studies, and for retracted articles it was 91 from the journal *Annals of Biomedical Engineering*.

The average for self-citations was greater for retracted articles, with the article with the greatest quantity of 28 self-citations published in the journal *Computer Methods in Applied Mechanics and Engineering*. The average number of self-citations for nonretracted articles was lower, with three articles reaching the highest number of self-citations (17) from the journals *Chinese Journal of Chemical Engineering, Control Engineering Practice*, and *Journal of Vibration and Control*.

Figure 1 shows the number of citations for retracted and nonretracted articles using histograms and box-plots.

Both histograms have a data curve distribution that is elongated to the right, indicating a low frequency of higher values, or a positive asymmetry of data distribution. We note that in both cases there is a large number of articles with no citations. Meanwhile, the box-plots demonstrate the presence of outliers.

Figure 2 presents histograms and box-plots for the number of self-citations for retracted and nonretracted articles.

The histograms demonstrate that there is a strong concentration of no self-citations. Both diagrams show positive asymmetry, forming a distribution curve elongated to the right. The box-plots present a significant presence of outliers, particularly for retracted articles.

Subsequently, the Kolmogorov–Smirnov test of normality was conducted to identify the type of distribution (parametric or nonparametric). For the variables number of citations and self-citations, the level of significance was .0001, suggesting a non-normal distribution of data.

Because of this non-normal distribution, we chose to use a Mann–Whitney *U* test to verify the difference in the number of citations and self-citations between retracted and nonretracted articles. As such, we tested the following hypotheses:

Considering the number of citations:

- Hypothesis 0: The average number of citations of retracted articles is equal to the average number of citations of nonretracted articles.
- Hypothesis 1: The average number of citations of retracted articles is different to the average number of citations of nonretracted articles.

Considering the number of self-citations:

- Hypothesis 0: The average number of self-citations of retracted articles is equal to the average number of self-citations of nonretracted articles.
- Hypothesis 1: The average number of self-citations of retracted articles is different to the average number of self-citations of nonretracted articles.

Table 3 shows the result from the Mann–Whitney *U* test.

Considering the number of citations of retracted and nonretracted articles and $p \leq .05$, we found a significant statistical difference between the averages, thus rejecting Hypothesis 0 ($p = .003$). This difference was also identified in the descriptive statistics, in which the retracted articles had a lower average number of citations (9.87) than nonretracted articles (12.53).

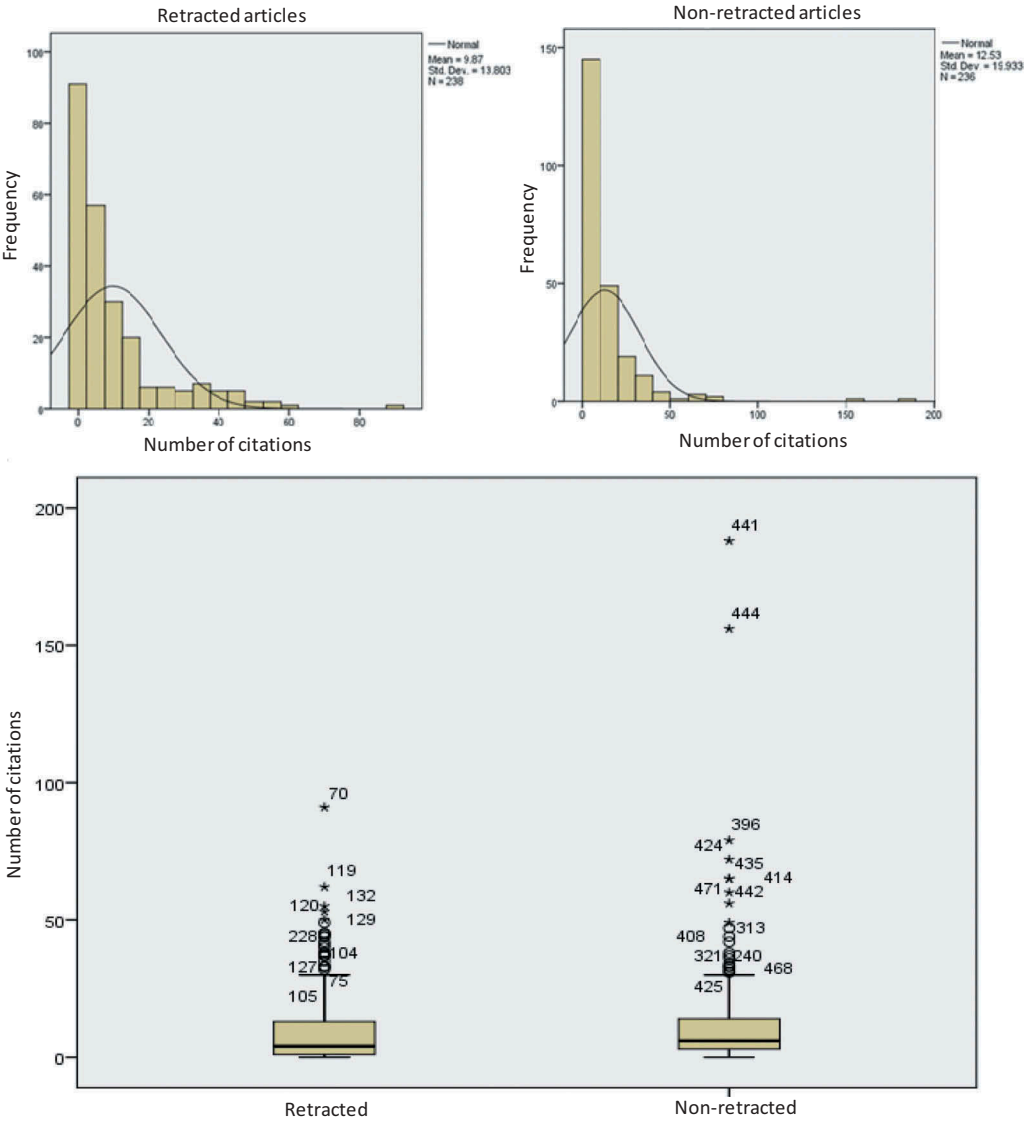


FIGURE 1 Histograms and box-plots of the number of citations for retracted and nonretracted articles.

In terms of self-citation, we also found a significant statistical difference between the average number of retracted and nonretracted articles (p = .049). The average was 1.68 for nonretracted articles and 2.33 for retracted articles.

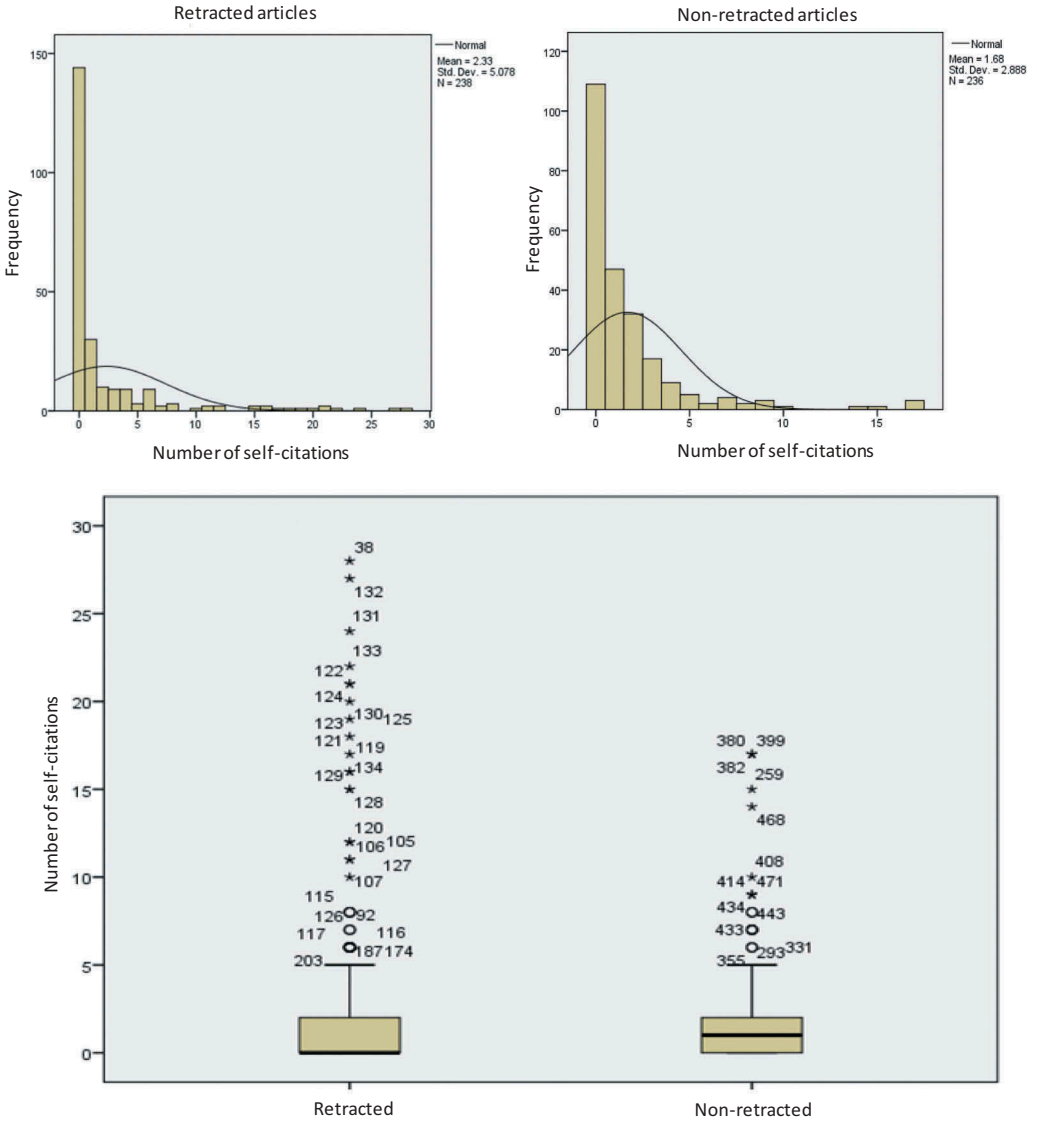


FIGURE 2 Histograms and box-plots of the number of self-citations for retracted and nonretraced articles.

DISCUSSION

This study compares the quantity of citations that retracted and nonretracted articles received. We can see that in the field of engineering, the rate of retracted articles is 0.008%, which is higher than that found by Almeida et al. (2016b), who studied retractions included in the SciElo

TABLE 3
Mann–Whitney Test

Procedure	*No. of Citations*	*No. of Self-Citations*
Mann–Whitney *U*	23.636.500	25.394.500
Wilcoxon W	52.077.500	53.835.500
Z	−2.991	−1.965
Asymp. Sig. (two-tailed)	0.003	0.049

and LILACS databases and found a retraction rate of 0.005%. Lu, Jin, Uzzi, and Jones (2013) found a retraction rate for articles in biology and medicine of 0.014%, in multidisciplinary studies of 0.014%, in other sciences of 0.006%, in social sciences of 0.002%, and for arts and humanities of 0.001%. Despite these low levels, the field of engineering shows greater representativity than other areas, thus demonstrating the need for further analysis.

With regards to citations, we can see that 58% (138) of retracted articles were cited before retraction, whereas 66% (156) of articles were cited after retraction, and only 6% (14) of the actual published retractions were cited.

Considering the control group, we found that the majority of articles (92%; 217) were cited, with two articles being cited 188 times. For da Silva and Bornemann-Cimenti (2017), this demonstrates that the work is being appreciated by those using the articles, resulting in a continuation of the article's life span. For Garfield (1982), citations represent a recognition that the studies are related.

In comparing the retracted and nonretracted articles, we found that the difference in the average number of citations is 9.87 for retracted articles and 12.53 for retracted articles. Both groups included articles that received no citations. However, the greatest quantity of citations for retracted articles was 91 and nonretracted was 188, representing more than twice the number of citations than for retracted articles.

The results are consistent with the findings of Bergh, Perry, and Hanke (2006), who inferred that articles with more methodological rigor possess more structured results, are seen as more reliable, and consequently are more frequently cited. Similarly, Antonakis, Bastardoz, Liu, and Schriesheim (2014) examined 776 articles published in the high-impact journal *The Leadership Quarterly* from 1990 to 2012. They estimated that 79.73% of articles included methodological problems, and these articles received only 12.31% of the number of citations that an article without methodological problems received. In other words, articles with issues or threats to the validity of the study are cited significantly less often.

However, our results show a surprisingly high number of articles that are cited after retraction, for a total of 65.55% (156). For Redman et al. (2008), authors are not recognizing these articles as retractions, because the rate of citation of retracted articles is high, both before and after retraction. The authors found that prior to retraction, the articles had been cited 3942 times and after retraction they were cited 4,501 times. This problem is also emphasized in the study by Bornemann-Cimenti et al. (2016), who demonstrate that 5 years after retraction Scott R. Reuben's work received 274 citations. According to Davis (2012), this problem continues because the articles remain available to authors due to decentralized access through online search engines.

Fang et al. (2012) identified that the 20 most cited articles after retraction in their studied sample did not include articles retracted due to plagiarism and duplicate publication. In addition, they emphasize that although the retracted articles are identified, scientists do not stop citing these articles, especially those retracted due to errors. Researchers support continued access to these articles as long as the retraction provides detailed information about the reasons for retraction.

It should be noted that retracted articles can continue to be cited. According to da Silva and Bornemann-Cimenti (2017), the use of retracted articles can continue if the problematic section of the article is explicitly detailed in the retraction. However, it is necessary to cite both the original article and the retraction. For Neale et al. (2010), very few authors cite the retraction in their reference lists.

In comparison with the study by Van Noorden (2011), who analyzed 235 retracted articles, only 8% of the citations of retracted articles included a reference to the retraction. In the study by Neale et al. (2010), who analyzed 102 retracted articles, less than 5% of articles referenced the retraction. These percentages show how far we are from truly representative indicators that reliably and correctly perpetuate and propagate scientific knowledge. According to Redman et al. (2008), when the retraction is not referenced, the article is presented as correct and legitimate, which can conceal errors or fraud that is further propagated in the literature.

With regard to self-citation for nonretracted articles, although they did not have restrictions, 46% (109) of articles were not self-cited, and the variation ranged from one to 17 self-citations per article, with the greatest concentration being one self-citation per article. For retracted articles, the majority of self-citations occurred before retraction, representing 34% (81) of self-cited articles. After retraction, 9% (22) of the articles received self-citation.

Retraction does not prevent authors from self-citing. One of the articles included in this study was self-cited 26 times after retraction, a significant amount that, according to Madlock-Brown and Eichmann (2015), creates the illusion that the work has no ethical problems and that it continues to be valid.

The study by Madlock-Brown and Eichmann (2015) identified that 18% of retracted articles were self-cited after retraction. This result is twice as much as that found in the current study. Meanwhile, Hutson (2006) studied self-citation for nonretracted articles in archeology and sociocultural studies while also analyzing the factors that influence self-citation. The author found that, in the area of archeology, self-citations comprise about 8.4% of the total number of citations of an article, whereas in sociocultural studies about 5.1% of the total citations of an article are self-citations. According to Hutson, more experienced authors include more self-citations than younger authors. This is likely because more experienced and older authors had more time to publish relevant works and consequently refer to previously published studies.

Snyder and Bonzi (1998) argued that the development of knowledge explains the difference between the number of citations and self-citations across areas; research that must be based on previous studies is more likely to cite or self-cite earlier publications. Nevertheless, Bonzi and Snyder (1991) argued that scientific quality measures are based on the quantity of citations, so the practice of self-citation is sometimes seen as questionable.

Another important result of the current study is that the average number of self-citations of retracted articles is greater than nonretracted articles, with averages of 2.33 and 1.68, respectively, as based on the Mann–Whitney test. Furthermore, one retracted article had 28 self-citations in comparison to 17 for a nonretracted article. It is also important to highlight the

startling number of outliers for retracted articles in comparison to nonretracted articles, as seen in the box plot diagram in Figure 2.

In terms of obsolescence of nonretracted articles, we found that the longest period of relevance of an article was 18 years, with the majority remaining in the current literature for 4 and 7 years, each with an incidence of 32 articles. On the other hand, we identified articles that did not even remain 1 year in the current literature. On average, the life span of an article is approximately five years. As no similar studies were found that quantify the density of the studied articles, we compared the data with studies that assessed the obsolescence of the literature used, or the references employed. Along these lines, the analysis by Pao (1989) demonstrates that in the field of chemistry, article obsolescence occurs in less than 8 years after publication, whereas in the area of mathematics, obsolescence occurs at about 20 years. Borba, Hoeltgebaum, and Silveira (2011), in their study presented at the Academy of Management Meeting on the field of entrepreneurship between 1954 and 2005, found that the obsolescence of the cited literature was 11 years. Meanwhile, Freitas (1997), studying the journal *Transinformação* and the area of communication and information sciences, found that the average length of time literature was used was 10 years.

Comparing the aforementioned studies with the field of engineering, the focus of the current study, we can see that the average of the studied area is recent. Borba et al. (2011) established that literature within 5 years of publication are considered current. According to Price (1965), we should consider that in the 2 years after publication, literature has a lower probability of being cited as some time is necessary for the study to be disseminated. Price further argued that studies older than 15 years tend to receive fewer citations, with the exception of classic articles that are cited four or more times a year; the concentration of almost 75% of the referenced literature is from studies published in the last 10 years; and the normal aging of the literature occurs between 15 and 20 years.

The limitations of this study are as follows: The research was restricted to only the Web of Science database; the search was limited to the English language; and the retractions are available open access online and through the journal portal of CAPES, of which less than 10% of the total number of identified articles were not evaluated and therefore does not compromise the reliability of the study. Furthermore, we did not verify if the articles with the greatest number of citations were published in journals with higher impact factors, nor did we assess the impact factor of the journals that cited the group of retracted and nonretracted articles.

CONCLUSION

This applied study sought to compare the quantity of citations that retracted and nonretracted articles received in the field of engineering through articles indexed in the Web of Science and published between 1945 and 2015. We analyzed 238 retracted and 236 nonretracted articles. Regarding self-citation, the retracted articles showed greater representativity than nonretracted articles.

Based on our results, we conclude that the scientific publication system has faults, due to the publication of articles with misconduct and their propagation through continued citation. Even after an article is retracted, we found that it continues to be cited, which can proliferate unethical and plagiarized research. Not only does this situation compromise the science that

builds on existing research, it affects society that financially supports research in the hope of new discoveries and governments that use these studies to develop public policies.

The entire scientific publication system should be revised, in terms of both increasing researcher awareness and improving the process of revising and editing of research. Editors must be increasingly attentive to data and research consistency, conducting thorough reviews and effectively collaborating in the construction of preventative mechanisms and corrections of the system. It must be made clear that the act of retracting an article with ethical issues does not absolve the editor of responsibility, nor is it sufficient to mitigate the damage; when retraction occurs, it is possible that many studies have already used the publication as reference.

Because preventative and corrective methods remain ineffective in combating scientific misconduct and its propagation, both researchers and journals may be jeopardizing scientific credibility.

DISCLOSURE STATEMENT

The authors declare no conflict of interest.

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