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How to Write a Good Scientific Paper: Significance

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SPIE

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This is the eighth in a series of editorials covering all aspects of good science writing.

A paper must meet four criteria before it is publishable in a scientific journal.

- The content of the paper must match the scope of the journal
- The quality of the paper (method and execution of the research, as well as the writing) must be sufficiently high
- It must present novel results (with the exception of review papers and the like)
- The results must be significant enough to be worth reading about (and thus worth publishing).

After a quick review of the first three items, I'd like to spend some time talking about the last item, paper significance.

1 Scope

The easiest way for your manuscript to be rejected is to submit it to the wrong journal. A perfectly good manuscript will be rejected if the topic of the manuscript does not match the scope of the journal. For reference, here is the *JM*^{3} scope:

> The *Journal of Micro/Nanolithography, MEMS, and MOEMS (JM*^{3}*)* publishes peer-reviewed papers on the science, development, and practice of lithographic, fabrication, packaging, and integration technologies necessary to address the needs of the electronics, microelectromechanical systems, micro-optoelectromechanical systems, and photonics industries. The wide range of such devices also includes biomedical microdevices, microfluidics, sensors and actuators, adaptive optics, and digital micromirrors. The scope is broad to facilitate synergy and interest between the communities served by the journal.
>
> Topical areas covered include:
>
> **Lithography**: tools, materials, and processes associated with the patterning of structures that have submicrometer and nanometer-scale features. Included are imaging and non-imaging approaches using optics, electron and other particle beams, nanoimprint, molecular self-assembly, and their hybrids. Applications include semiconductor fabrication, but also patterning for other micro/nanodevices.
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> **Microelectromechanical systems (MEMS)**: the design, fabrication, operation, reliability, and testing of microdevices which contain both electrical and mechanical elements.
>
> **Micro-optoelectromechanical systems (MOEMS)**: the design, fabrication, operation, reliability, and testing of microdevices that contain electrical, mechanical, and optical elements (that is, the merging of micro-optics and MEMS).
>
> **Microfabrication**: technologies to shape three-dimensional structures leading to the fabrication of active and passive electronics, photonics, MEMS, MOEMS, micro/nano-optics, and other micro/nanodevices.
>
> **Metrology**: metrology and process control for the above devices and their fabrication processes.

2 Quality

There are two aspects of quality relevant to journal publications: the quality of the work being reported, and the quality of the reporting (that is, the written manuscript). The quality of the work is essentially a judgment of the science involved, including the care taken in planning and executing experiments, as well as in analyzing the resulting data and fitting these results into the larger framework of the scientific field. Fully defining what is meant by the quality of the science is a rather large undertaking, and I will defer such a discussion to another day.

The quality of the written presentation of the work has been the subject of various past editorials.[1–7] Here, I'll only add that the quality of the presentation can and should be judged separately from the quality of the work itself. The reason for this is simple: it is often much easier to fix a faulty presentation than to fix faulty science. Still, if the initial quality of the writing is not sufficiently high it may be nearly impossible to judge the quality of the work itself, and we are sometimes forced to reject a paper due to poor writing without any real judgment of the science involved.

3 Novelty

With the exception of review papers and tutorials, a manuscript must contain something new to be worthy of publication in a scientific journal. The explicit mission of the science journal is to add to the body of knowledge in the field. Thus, a journal paper must add something new to that body of knowledge (new theory, new methods, new data, or new analysis). As a consequence, an effective literature search and comprehensive citations are a requirement in order to establish what about the submitted work is novel.[2]

Of course, not everything in the paper must be new. Often publications are akin to progress reports, the achievement of a milestone in a longer-term research project. In such a case it is appropriate that some parts of the paper review prior published work from the same effort. This reality sets up an expected tension between a desire to publish the latest results, even if incomplete, and a desire to ensure that there is sufficient new information in this latest paper to make reading it worthwhile in light of past publications and acknowledged need for future work.

A good rule of thumb is that at least 50% of the results being presented must be new. If you find that more than half of the results you present have been published before, chances are you haven't done enough new work to warrant a new paper. Of course, fully explaining what is new is required.

4 Significance

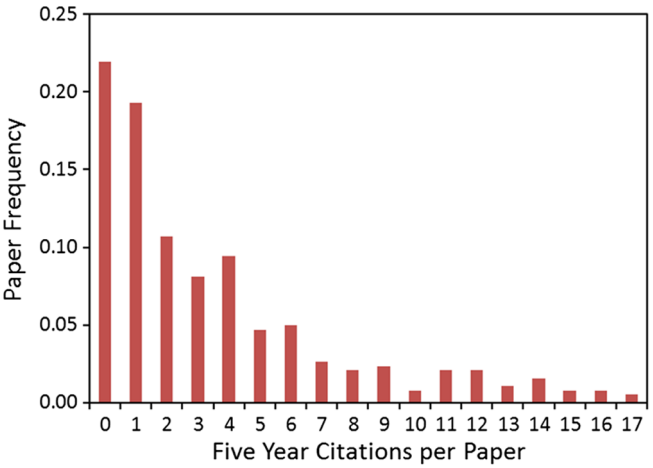
The final publication requirement is perhaps the most nebulous: the work must be sufficiently significant. Significance should be judged based on the viewpoint of the readers: how many people will read the paper and put the conveyed knowledge to use.

There were about 28,000 peer-reviewed journals in 2012, and they now publish about 2 million articles a year (with these numbers growing by about 3%–3.5% each year).[8] This represents a doubling of the number of scientific papers every 20 years or so, a rate that has been relatively constant for over 300 years.[9,10] If you are like me, your inbox overflows with invitations to publish in new journals you have never heard of. An uncomfortable reality is that a fair number of the papers published in these journals are rarely if ever read by anybody. Publishing a paper that has little or no impact on our scientific community does not serve the interest of science, and yet many of these "peer-reviewed" journals will pretty much publish anything (for a fee), gratifying the ego and the "publish or perish" needs of the researcher. Thus, the more reputable journals (and of course, I count *JM*^{3} among their number) are anxious to ensure that the papers they publish are significant, adding signal rather than noise to our communal collection of knowledge.

Journals generally use two useful though imperfect measures of significance when retrospectively evaluating published articles. Number of downloads is becoming the dominant measure of readership for a paper, though this measures interest in the topic and quality of the title, abstract, and keywords rather than the significance of the work as a whole. The number of citations that a paper garners is, over the long run, a measure of its significance, but only to one segment of the readership: those who go on to publish other papers. A paper that significantly influences the practice of scientists and engineers, especially as it relates to commercial application, may not find its importance reflected in its citation numbers. Still, the combination of downloads and citations over a long period of time is a reasonable measure of the significance of a paper.

While it is hard to retrospectively judge the significance of a published paper, it is much harder for editors and reviewers to prospectively judge the significance of a submitted manuscript. Generally editors and reviewers take a two-step approach to making such an evaluation: How important is the problem being addressed by the work, and how big of an advance over the prior literature does this work represent? For example, even a small advance in a topic that hundreds or thousands of readers care about can be considered significant. Alternately, a big improvement in a technology that few care about may not be as significant. As one can imagine, these judgments are not easy to make. The experience and efforts of the associate editors and reviewers of *JM*^{3} are absolutely essential to our success in ensuring the significance of our publications.

How well have we done at picking significant papers for *JM*^{3}? Within five years of publication, the average number of citations for a *JM*^{3} paper is 4.4. The distribution of five-year citations is highly skewed (about an exponential), with a maximum of 42 citations, and with 10% of papers having twelve or more citations (as of the end of 2013). But about 22% of *JM*^{3} papers did not get cited over that first five years. While this number is certainly higher than I would like, it is not out of line with the more engineering-related disciplines. According to the Web of Science, 18% of the approximately 38,000 articles published in 2008 in journals related to electrical engineering have not been cited. The citation rate is also a function of how broad-based or narrow the scope of the journal is, with broad-based publications (think *Nature* or *Science*) having both higher readership and citation rates.

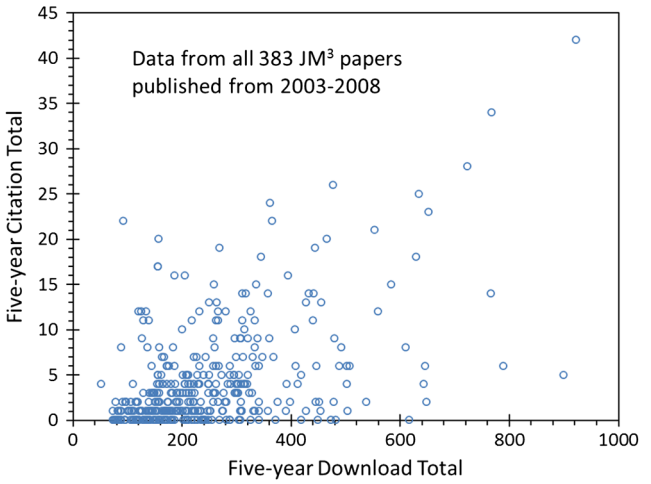


Since many of the papers published in *JM*^{3} appeal to semiconductor and MEMS/MOEMS manufacturing, readership is also an important measure of a paper's success, independent of citations. Today, most reading is done after downloading an article (libraries being the primary destination of the printed *JM*^{3} journals), and download rates have steadily increased each year. Up through the end of 2013 the average *JM*^{3} article has been downloaded over 300 times (with an average of about 55 downloads a year). The median number of downloads per paper per year is about 35, indicating a highly skewed distribution. From 2009–2012 the top papers received about 700 downloads in a year, but since then the feedback loop of promoting the top downloads on the *JM*^{3} digital library homepage has resulted in papers with up to 7,000 downloads in a year. Obviously, some *JM*^{3} papers are very well read. For papers published in 2008, the five-year total of downloads averaged 253 per paper (median of 231), and the paper with the least number of downloads received 87 over that five-year period (second-least downloaded had 107).

Another interesting metric is citations in patents. A quick search on the US Patent Office website found over 750 US patents that cite to *JM*^{3} papers—quite a significant number.

5 Conclusions

The combined view, looking at both citations and downloads, indicates that *JM*^{3} is publishing papers that are having a significant impact on our community. Even the least-read papers are downloaded on the order of 100 times over a period of five years, and most are downloaded many hundreds of times.



Citation rates are solid, in line with what one should expect for a narrow field with both academic and commercial interest. As the accompanying figure indicates, only a small number of *JM*^{3} papers have both low download rates and no citations.

At the high end, it is interesting to note that only four of the top-ten most cited articles (using the five-year citation total) are also in the top ten of the most downloaded articles. Clearly, citations and downloads are different measures of impact.

Of course, *JM*^{3} is always trying to improve the quality and significance of the papers we publish, an effort that involves all of us. If you have any suggestions, please let me know.

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Editor-in-Chief

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