

Do not throw equations out with the theory bathwater

In a recent PNAS paper (1), Fawcett and Higginson analyze citation data for biological journals and conclude that overall citation rate is reduced by including equations in papers. As a serial offender in this regard, I found the paper interesting, if troubling. Here I show that an alternative analysis reveals a more complex picture and suggest an alternative explanation for the pattern.

The most complete analysis presented (1) predicts citation count from the explanatory variables of main text equation density, appendix equation density, journal, and number of pages, with interaction terms between the page number and equation density measures. This approach assumes that any equation density effect is the same across all journals. This seems unlikely, as *The American Naturalist* generally has a more theoretical content than *Proceedings of the Royal Society of London B*. To test this, I used exactly the same analysis approach as described by Fawcett and Higginson (1) but also included interaction terms between journal, the equation density measures, and pages. This more complete model has substantially better support than the simpler model (Akaike Information Criteria lower by 7.7) with odds ratios of 2.1 for main text equation density for *The American Naturalist* compared with 0.7 across all journals in the simpler analysis. So there is evidence that, for some journals, citations actually increase with equation density.

Equations are a concise and unambiguous way of expressing ideas and theory and are usually already accompanied by explanatory text. Where more effort could be made is in graphically illustrating theories rather than describing by equation and text alone. However, there are two possible mechanisms that could be operating. The first, implicit in the work of Fawcett and Higginson (1), is that overly technical presentation of theory reduces comprehension by biologists as a whole. The second is that biologists as a whole have less interest in theoretical than empirical studies. The latter may be a rational approach; most proposed theories are likely to be wrong, so only those with empirical support will gain traction and associated citations. Importantly, without an independent way of separating theoretical content and equation density, it is not possible to distinguish between these two explanations from citation analysis.

In conclusion, there is very limited evidence that future citations can be directly manipulated by inserting or removing equations in papers. However, I would join with the sentiment in the work of Fawcett and Higginson (1) that we should seek ways to make theory more accessible and find ways to better mathematically educate biologists.

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1. Fawcett TW, Higginson AD (2012) Heavy use of equations impedes communication among biologists. *Proc Natl Acad Sci USA* 109:11735–11739.

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