12 Mathematics in Current Science and in Scientific Evaluation

Irma Ayes Rivera

Curiosity killed the cat, says a Latin American proverb, arguing that by going where it is not called, the cat died. However, from my father, I have learned that without curiosity, the great discoveries could not have happened, or they would have taken a little longer. It is not only this fact that my father gave to my sisters and me, but also, to build a critical mind and understand from his professional area (the teaching of medicine) to work with a humanistic approach. Now, while I'm doing my PhD, a lot of what I learned at home has more relevance. Some of these discussions are summarized by the mathematician Eduardo Sáenz de Cabezón in his presentation regarding what is Mathematics useful for? [1]. He explains how mathematics not only helps us in logical thinking—an indispensable element in science development—but also contribute to being in the world in a more human and full manner. While, during childhood, Sáenz explained, mathematics stimulates our curiosity, during higher education, it enables us to understand the logic and interpretation of data and results, allowing us to be more critical, both as a researcher and as a citizen. In this sense, within his "kit of skeptics", Carl Sagan suggested some tools to rationally argue and recognize some fallacies or errors [2]. Two of these (without letting aside the other seven), are the quantification and the use of Occam's Razor; the first refers to the need to be able to measure, in the case that there are quantitative data to the explanation we give or is given to us, while the second within the scientific method states that, in equal conditions, the simplest explanation is usually the most likely. These two recommendations have in common the use of mathematics in the evaluation of scientific arguments, and the probability term used in Occam's principle implies the inherent uncertainty that exists when analyzing the data in a statistical way.

Nowadays, science relies on statistics for both its development and for research evaluation. We just need to look at what the introduction of the *p-value* in the 1920s by Ronald Fisher and the hypothesis theory of Jerzy Neyman and Egon Pearson has allowed us [3]. Indeed, many studies conclude their findings according to the evaluation of *p-values* less than 0.05, this is, we accept that one result in 20 will be a false positive (Type I error), if the null and alternative hypothesis were appropriately defined. However, even though it is based on tests and numerical data, it is also subject to the sample, its interpretation and even hacking. Therefore, how can we evaluate the results of research and researchers? It is true that mistakes and failed attempts are a constant in science and are intellectual incentives, but when it is necessary to evaluate a set of researches, how can they be objectively comparable? One of the possible solutions is through its replicability, which is often not possible to do because of lack of resources, unavailable data or for the confidence we have in the peer-review system of scientific journals. In fact, as researchers "There is no cost to getting things wrong, the cost is not getting them published" (Brian Nosek in [4]). This situation is due to the high competitiveness that currently prevails in science and to the evaluation and award processes of universities and research institutions, based on the quantity of publications and the impact factor of the journals. This leads to future hiring, labor promotions and financing of future research, which is not bad per se, because it allows us to have elements for measuring the performance of the research and its developers. However, in my opinion, this has dehumanized science and its purpose, creating a progressive number of annual publications without generating, in many cases, a true contribution to science itself and although, in some cases, the contribution may be significant, by showing other contexts of the current problems, ultimately the use of these results depends on the will of the decision makers. Examples of this are the two most read articles in the Environmental Research Letters (with an impact factor of 6.192 in 2018): *Quantifying the consensus on anthropogenic global warming in the scientific literature* and *The climate mitigation gap: education and government recommendations miss the most effective individual actions*, with 1,003,096 and 412,158 downloads each one in mid-July 2019 [5]. The 1st article is very clear in its title, while the 2nd, calls to see beyond the global agreements in relation to global warming and what is being neglected, the mitigation measurements from the community.

Finally, it is necessary to emphasize that although mathematics, especially statistics, has allowed significant advances to be made in many areas of science, they have a limit in our logical understanding of the processes in nature, not only when formulating abstract models of our reality, but also in the evaluation of research. In the current world, which leads us to compete in many facets of our lives, unless the paradigm of why we do science does not change, it is very difficult to recommend the best way to evaluate and reward our work.

References

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