

A note on comparison of scientific impact expressed by number of citations in different fields of science

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Abstract: Citation distributions for 1992, 1994, 1996, 1997, 1999, and 2001, which were published in the 2004 report of the National Science Foundation, USA, are analyzed. It is shown that the ratio of the total number of citations of any two broad fields of science remains close to constant over the analyzed years. Basing on this observation, normalization of total numbers of citations with respect to the number of citations in mathematics is suggested as a tool for comparing scientific impact expressed by the number of citations in different fields of science.

1 Introduction

Number of citations is usually considered as one of important indicators of the scientific impact of a scientist in his/her particular field. This criterion can be easily used in each particular field, when two mathematicians (or two physicists, or two chemists, or two medical researchers, or two engineers, etc.) are compared. This comparison is used by ISI (the Institute for Scientific Information) for compiling various lists, like ISIHighlyCited.Com [2], arranged by scientific field.

The more difficult problem arises when we have to compare two scientists working in *different* fields, for example, a mathematician and a chemist. The difficulty is underlined by the fact that even the most prolific author of citation analysis, Dr. E. Garfield, used only absolute figures for compiling lists of scientists with the highest impact – see, for example, the list in [6], where we cannot see any mathematician, engineer, or a specialist in social sciences.

It is obvious that we cannot compare absolute numbers of citations – it is well known that in absolute figures there is much less citations in mathematics than in chemistry, but a mathematician with a relatively low total number of citations can have higher impact in mathematics than a chemist with a larger number of citations in chemistry. The question, therefore, is: *is it possible to compare two scientists working in different fields of science on the basis of their citation numbers?* Surprisingly, the author of this article could not find any answer to this seemingly natural question in the available literature.

The answer suggested in this article is: *yes, it is possible, with the help of a certain normalization of their respective numbers of citations.* The suggested approach is described below.

2 The Data

In the recent publication of the National Science Foundation the distribution of scientific citations across wide fields of science in 1992, 1994, 1996, 1997, 1999, and

2001 was published (see [1], Chapter 5, Table 5-27 on page 5-50). The sources for the data appearing in that table were the Science Citation Index (SCI) and the Social Sciences Citation Index (SSCI).

3 The Law of the Constant Ratio

The data in the NSF table for the distribution of scientific citations led me to the observation that *the ratio of the number of citations in any two fields of science remains close to constant*.

For example, for clinical medicine and physics we have the ratio close to 4:

$$(1992) 475793 / 137922 = 3.44972521$$

$$(1994) 516665 / 141653 = 3.64739893$$

$$(1996) 554332 / 138417 = 4.0047971$$

$$(1997) 574859 / 131958 = 4.35637854$$

$$(1999) 584330 / 125968 = 4.63871777$$

$$(2001) 589762 / 120593 = 4.89051603$$

Similarly, for engineering and mathematics we obtain the ratio close to 5:

$$(1992) 32680 / 6858 = 4.76523768$$

$$(1994) 35189 / 6631 = 5.30674106$$

$$(1996) 33664 / 6961 = 4.83608677$$

$$(1997) 32958 / 6418 = 5.13524462$$

$$(1999) 34001 / 7520 = 4.52140957$$

$$(2001) 36809 / 7794 = 4.72273544$$

The same observation holds for any pair of fields of science in the Table 5-27 of the NSF 2004 report.

It is worth noting that the similar law of a constant ratio in citation analysis is known for the number of publications and the number of citations processed by ISI – it gives the so-called Garfield's constant [5].

4 Normalization

Basing on the observed law of the constant ratio, we can normalize all scientific fields by computing the ratio of the number of citations in each field to the number of citations in mathematics (the smallest number of citations among all fields). The results are shown in Table 1 in the columns titled "*ratio to maths*"; numbers are rounded to integers. In such a form the law of the constant ratio is even more obvious.

The average ratio of citation number to the number of citations in mathematics is given in a dedicated column in Table 1.

5 Comparing different fields of science

Using the suggested normalization of the citation data provided by SCI (Science Citation Index), we could – to some extent – compare the relative scientific impact of scientists working in different fields of science.

Example 1.

Q: Who has more impact in his field: a physicist with 70 citations or an engineer with 20 citations?

A: In normalized units, the physicist's impact is $70:19=3.68$, while the engineer's impact is $20:5=4$. Therefore, the engineer has slightly higher impact in his field than the physicist in his one (although it is not clear at all from their total numbers of citations).

Example 2.

Q: Which citation numbers can be considered as equivalent for mathematics, chemistry, physics, and clinical medicine?

A: According to Table 1, one citation in mathematics roughly corresponds to 15 citations in chemistry, 19 citations in physics, and 78 citations in clinical medicine. In other words, 250 citations in mathematics can be considered as equivalent to 3750 citations in chemistry, 4750 citations in physics, and 19500 citations in clinical medicine.

6 Conclusion

In conclusion, the following could be mentioned.

It seems that the *law of the constant ratio*, described in this brief note, gives reasonable results and can be used in average for comparing the scientific impact of scientists with low or average scientific impact from the viewpoint of citations of their works. In case of large numbers of citations it will probably need some correction.

It may seem that by considering only total numbers of citations in various fields of science we do not take into account the fact that the numbers of scientists working in those fields also differs significantly, as well as the total number of publications in those fields. However, the reality is the opposite: the smaller number of citations, for example, in mathematics comparing to biomedicine, simply reflects that the number of articles in mathematics is also smaller than the number of articles in biomedicine, and that there is less people publishing in mathematics than in biomedicine. Therefore, the differences in the number of people and in the number of publications in different fields are taken into account implicitly through the total number of citations produced by those people in those publications.

The approach suggested in this article can bring mathematicians, engineers, and other "less visible" scientists to the multidisciplinary lists of high-impact scientists, correcting therefore the approach used in [6] and other similar lists.

Finally, the formal analysis of citation data cannot be considered as a one and only one basis for evaluation of the scientific impact [3]-[4]. However, the approach described in this article allows at least rough comparison of the scientific impact of scientists working in different fields.

References

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Table 1. Comparison of the numbers of citations in different fields of science. Based on the data from *Science and Engineering Indicators 2004. National Science Foundation, May 04, 2004.*

Field	Average ratio of citation number to the number of citations in mathematics	1992		1994		1996		1997		1999		2001	
		number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths
Clinical medicine	78	475793	69	516665	78	554332	80	574859	90	584330	78	589762	76
Biomedical research	78	460148	67	518304	78	562361	81	572122	89	594596	79	568328	73
Biology	8	52535	8	57825	9	58649	8	58130	9	56981	8	57899	7
Chemistry	15	88010	13	96827	15	105960	15	105762	16	110927	15	109703	14
Physics	19	137922	20	141653	21	138417	20	131958	21	125968	17	120593	15
Earth/space sciences	9	55086	5	58818	9	71230	10	73507	11	83053	11	82614	11
Engineering/technology	5	32680	5	35189	5	33664	5	32958	5	34001	5	36809	5
Mathematics	1	6858	1	6631	1	6961	1	6418	1	7520	1	7794	1
Social/behavioral sciences	13	80282	12	84353	13	93032	13	93187	15	99481	13	104793	13