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Who Is Directing The Evolution Of Science?

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Abstract: Clarivate Analytics™, the company responsible for managing Web of Science, publishes once a year a list with the scholars that have written papers that rank in the top one percent by citations for field and publication year. Using this list, this paper analyses the profile of the scholars who contributed the most to the evolution of science in the decade ending at 2017 and the methods they used to become top scholars. The study concludes that science is being driven by male scholars affiliated to institutions located in highly developed countries where the official language is English. Scholars who work and publish as large groups and self-cite potentially bias the science agenda and gain possible inappropriate standing. This work concludes that to avoid bias, research budgets need to be more equitably distributed among scholars with multiple profiles, especially including women from Latin America and Africa, and search engine algorithms need to be adjusted to include scholar's characteristics, such as gender and place of affiliation, and to avoid skewing created by multiple authorship.
Keywords: Clarivate Analytics Ranks; Profile of Top Scholars; Science Evolution; Trends of Science

Article Highlights:
1. The evolution of science is skewed towards the perceptions of the most cited scholars.
2. The evolution of science is also skewed towards the perceptions of male scholars affiliated to institutions located in highly developed countries.
3. Bias of science should be made explicit.

Main Text

Culture plays a key role on deciding the topics and research questions of any research; therefore science, even when developed under strict rigor, is always biased (Sinay, 2008 and Sinay et all, in press). For this reason, it is important to know in which direction science is skewing, so that mechanisms can be put on place to correct its course of evolution. Previous research has indicated that science has been mostly developed by male scholars (Berg, 2017; Penner, 2015; Pain, 2011; Vernos, 2013; Unknown, 2018b; Nielsen et al., 2017; Unknown, 2018a; Zatz, 2018; Ovseiko et al. 2016; Heidari et al., 2016; Commission, 2012; Shen, 2013) whose first language is English (Kaplan, 2001, Drubin and Kellogg, 2017). This research investigates publishing trends during the decade that ended in 2017 as reflected in the database published by Clarivate Analytics™ (Analytics, 2018a), the company responsible for managing the Web of Science.

The specific objective of this research is to analyze the profile of the scholars who contributed the most to the evolution of science during the decade ending in 2017 and the methods they used to become top scholars. Focus is on gender, on the official language and on the level of human development of the country of primary affiliation of the top scholars. Other personal characteristics, such as religion and race, are likely to be similarly important, but the information is not currently available.

Methods

To achieve the objectives of this research, the Clarivate Analytics™' list for 2017 most cited scholars was used. The 2017 Clarivate Analytics™ database categorizes published scientific contributions into 21 areas of knowledge[1], listing the authors that have written the year's highly cited papers and their primary affiliation. "Highly Cited Papers are defined as those that rank in the top one percent by citations for the area of knowledge and publication year in the Web of Science" (Publons, 2017).

The list published by Clarivate Analytics™ was used because, Web of Science is one of the most used search engines (Mongeon and Paul-Hus, 2016) and its database covers "over 100 years of comprehensive coverage and more than one billion cited reference connections" (Analytics, 2018b), which includes "multidisciplinary information from over 18,000 high impact journals, over 180,000 conference proceedings, and over 80,000 books from around the world" (Analytics, 2018b). Therefore, because the database is populated and dominated by existing, although expanding, high impact publications and well-established, and reputable book publishers, an inherent bias is explicit and self-compounding. Consequently, the chosen database serves the academic status quo.

According to the summary of the statistical analysis of the 2017 rank, 130,000 papers from 900 institutions were considered (Analytics, 2017a). The database from Clarivate Analytics™ reports three columns that are of interest to this research: (1) name of scholar, (2) area of knowledge, and (3) country of primary affiliation. This information was used with: (1) Google Images to identify the scholars' gender; (2) Wikipedia to identify the main language spoken in the country of affiliation; (3) UNESCO's Human Development Index for establishing the level of development of each country; and (4) Google Scholar to discover the number of scientific works published by each top scholar. The list of scholars is presented on the database on alphabetical order.

Analysis for this research focused on five random samples per area of knowledge: Sample 1- 1st scholar of the list, Sample 2- the first ten scholars and Sample 3 - the complete database.

Table ***1*** presents a synthesis of the analyses. For analyzing the profile of Sample 1, the sample size was twenty instead of twenty-one, because one of the scholars (Dr Abecasis) was the first (alphabetically speaking) in two different areas. Also, for analyzing the profile of Sample 3, the sample size was 2,089 instead of 2,100, because the original database only ranked the top 93 and 96 scholars in the fields of economics and business & mathematics, respectively. Due to the difficulty of accessing these data, the gender analysis was restricted to Sample 2. The number of scientific works published by scholar was done only for Sample 1, and had a sample size of 15 scholars, as five scholars do not have a public profile on Google Scholar; hence, data were not retrievable.

Table 1: Analyses undertaken

Analysis	Sample size	Number of scientific works published	Gender	Country of affiliation	Language spoken at the country of affiliation	Level of development of each country
Sample 1	20	✓				
Sample 2	210		✓			
Sample 3	5575			✓	✓	✓

It is important to also note that Google Scholar retrieves up to 3,000 works per scholar. This was not a limitation for studying the strategies used by the top scholars, as they published less than 3,000 works, but it affected the analysis presented at

Table **3**, which gives examples of scholars who published thousands of papers.

Results

The disparities regarding gender, language and level of development were obvious for the samples considered. Eighty-seven of the scholars are male, 68 per cent are affiliated to countries where the main language is English, and 92 per cent to countries ranked as having a very high development level.

USA led with about half of the scholars, UK followed with about ten percent, then China with seven per cent. The contribution of Germany remained at about five percent, while Spain and Saudi Arabia contributed with about 2.5 percent of the scholars. China only contributed seven percent of the scholars for the two largest samples.

[1] Agricultural Sciences, Biology & Biochemistry, Chemistry, Clinical Medicine, Computer Science, Economics & Business, Engineering, Environment/Ecology, Geosciences, Immunology, Materials Science, Mathematics, Microbiology, Molecular Biology & Genetics, Neuroscience & Behavior, Pharmacology & Toxicology, Physics, Plant & Animal Science, Psychiatry/Psychology, Social Sciences, general, Space Science.

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Scholars of sixty-one countries are part of the database. That is, 115 countries are not represented in the samples analyzed[2]. Of the 5,575 scholars[3], only nineteen are from Latin-America and fourteen from the Sub-Saharan Africa (thirteen of these are from South Africa). Apart from Australia and New Zealand, only one scholar from Oceania (from Indonesia) made the list. Eighty-three percent of the scholars are from North America and Europe (

Table ***2***).

Table 2: Synthesis of results

Sample	Gender (%)		Countries where the main language is English (%)	Number of countries represented	Main contributors (countries) (%)						Scholars per level of development of each country [4] (%)			
	F	M		Count	USA	UK	Spain	Saudi Arabia	China	Germany	1	2	3	4
Sample 2[5]	13	87	71	28/210	50	10	3	3	0	6	100	0[6]	0	0
Sample 3	***	***	68	61/5575	53	11	2	2	7	6	92	8	0[7]	0[8]

The author who published the least number of scholarly works (137 articles) is the only female scholar in Sample 1. Her first publication was in 1987; therefore, she publishes an average of 4.5 papers per year. She is the first author of nine of her twenty most cited works.

Of Sample 1, the male scholar with the highest number of published works (1,176 articles) was cited 140,205 times. His first publication was in 1981. Therefore, he publishes an average of 30 scholarly works per year. Among his twenty most cited works, he is the first author of only three.

Scholars of Sample 1 published an average of 508 papers each. If we consider a working life span of 30-years, then each would publish about 17 articles per year.

The only scholar of Sample 1 that appears in two areas published 617 scholarly works. He is the eighth author of his most cited work (cited 16,777 times). His next seven most cited works were written by consortiums and no names are listed as authors. These articles were cited 29,124 times. Among his twenty most cited works, he is the first author of only one. His first publication was in 1999. Therefore, he publishes an average of 30 articles per year.

Other scholars, which are not on the database, have been found to publish up to 3,000 works.

Table 3: Examples of scholars who have published more than one thousand scholarly works.

Number of publications	Number of citations	Scholar	Link to scholars' profiles
3,000	358,716	Solomon H Snyder	https://scholar.google.com/citations?hl=en&user=gm9yzgEAAAAJ
3,000	334,396	Braunwald E.	https://scholar.google.com/citations?hl=en&user=yQoYhjwAAAAJ.
2,982	273,580	Robert Langer	https://scholar.google.com/citations?hl=en&user=5HX--AYAAAAJ
2,420	267,022	JoAnn E.	https://scholar.google.com/citations?hl=en&user=QK07bYEAAAAJ.

[2] Considering the 175 states that are recognized by UNESCO
[3] Top 1% most cited
[4] 1 states for Very High Human Development, 2 for High Human Development, 3 for Medium Human Development and 4 for Low Human Development.
[5] Scholars per country: 50% (105) United States; 10% (21) United Kingdom; 6% (13) Germany; 5% (10) France; 4% (9) Netherlands; 3% (7) Spain and (6) Saudi Arabia; <3% Switzerland (5), Canada (4); Australia and China (3); Ireland, Japan, Luxembourg, New Zealand, Denmark and Sweden (2); Algeria, Austria, Belgium, Finland, Italy, Lebanon, Malaysia, Portugal, Taiwan, Thailand and Turkey (1)
[6] Two countries – China and Thailand -, and five scholars
[7] Five countries – India, Indonesia, Pakistan, Egypt & South Africa - and 26 scholars
[8] One country - Uganda, one scholar

		Manson.	
2,313	235,750	Gordon Guyatt	https://scholar.google.com/citations?hl=en&user=VKGc654AAAAJ
2,172	291,952	Graham Colditz	https://scholar.google.com.au/citations?user=M5_mEHQAAAAJ&hl=en.
1,963	308,262	Michael Graetzel	https://scholar.google.com/citations?hl=en&user=B0h47WAAAAAJ
1,814	200,750	Richard A. Flavell	https://scholar.google.com/citations?hl=en&user=IPbxgZkAAAAJ
1,598	326,983	Shizuo Akira	https://scholar.google.com/citations?hl=en&user=0TG2laoAAAAJ.
1,567	333,912	Ronald C Kessler	https://scholar.google.com/citations?hl=en&user=EicYvbwAAAAJ.

Number of publications and of citations as per Google Scholar on October 17, 2018. Note that Google Scholar retrieves maximum of 3,000 works.

Discussion

As the literature indicates and analysis of the Clarivate Analytics™ database confirms, science continues to be written mostly by men affiliated with institutions located in English speaking countries that are classified as having very high human development (e.g. North America and Europe). While this skewing can be attributed to demographic, political, economic and linguistic constraints, the analyses raise concerns for how the databases and reflected performance are used beyond the primary purpose of making disciplined study accessible.

Within academia, there is a trend for publication quantity to become more important than its quality, at the cost of teaching effectiveness and the contribution to social service. There is a danger that scholars from more developed countries are in an output race that has lost its goal. It is a race that is unwinnable by scholars affiliated with less developed countries, where teaching time significantly exceeds time allocated for research.

In this context, it is important to note that Isaac Newton wrote eight papers (Wikipedia, 2018b) and Einstein twenty (Wikipedia, 2018a), and they have made history. In contrast, today it is common to find scholars who have (co)authored thousands of papers (e.g.

Table **3**). This high level of output is inconceivable for scholars of less developed countries, and calls into questioning the amount of time allocated to innovative thought, experimenting or undertaking fieldwork.

The magnitude of research outputs (mainly measured by the number of publications) improves a universities' position on global ranking systems, which perpetuates the 'publish or perish' pressure on academic activity. Scholars with high number of publication outputs are setting the expected standard for academics, and those that do not follow this path are considered unproductive and may find that they do not qualify for preferred academic jobs or for promotion.

While this may be the case, a scholar that has written, say, three thousand papers, has produced (over a career of 40-years) 75 scholarly works per year. This does not seem possible, unless they work in large groups, whose members equitably contribute to article production.

In the description of the methods used to develop the database used in this study, Clarivate Analytics™ advises that papers with more than 500 authors were not considered in their analysis, but identified that some papers have as many as 3,000 authors (Analytics, 2017b). It does not seem plausible that 3,000 people, or even 500, could contribute in a meaningful way to a manuscript. However, if a mere 50 collaborators produce one paper per year and self-cite, they would each be one of the most productive authors and quickly generate 2,500 citations. In the game of academic outputs and citations, the system can be exploited and influential on areas of study within a research field.

Of concern also are the journals selected for the counting system, which by default excludes most journals published in languages other than English. Yet, not all knowledge is applicable worldwide. Some has particular relevance for the place from where data were collected. It may have immense value for informing policy and merit publication in the local language, and prove to be useful in addressing related issues elsewhere. These studies, despite their merit, may not be captured in global search engines because they are not in English.

If scientists were to adopt the Weberian ideal of "knowledge for the sake of knowledge" (Tuckett, 2018), then limiting the development of science to questions asked by scholars of highly developed countries and limiting answers to their own perspectives should not be a problem. But this does not seem to be what scholars desire (Russell, 2016; Brightman, 1939). Scholars have called the attention to the fact that knowledge is "embedded in political, cultural, [and] valuational dimensions" (Ihde, 2002) that helps to create social reality (Law, 2005). Bauman goes further to assert that:

"Not asking certain questions is pregnant with more dangers than failing to answer the questions already on the official agenda; while asking the wrong kind of questions all too often helps to advert eyes from the truly important issues. The price of silence is paid in the hard currency of human suffering. Asking the right questions makes, after all, all the difference between fate and destination, drifting and travelling" (Bauman, 1998).

Hence, while demographics, gender, political, economic and linguistic barriers explicate the monopoly within scientific debates, they do not mitigate the impact of not including the questions and answers put by a multiple profile of scholars (e.g. female scholars and scholars affiliated to institutions located in less developed countries or in countries where English is not the first language). Coincidently, these are the scholars that often deal with the worst of human misery. Their questions and answers are, therefore, fundamental for improving the human condition.

Conclusion

If science is to adopt an agenda beyond the Weberian ideal and focus on producing knowledge for the sake of improving the human condition, it needs to consider multiple perspectives. For doing so, (1) skewness created by publication databases should be made overt; (2) scholarly works published in languages other than English need to be made more accessible; (3) citation bias needs to be removed by setting reasonable limits to the number of co-authors considered for ranking scholars and (4) greater effort is needed to democratize the distribution of budgets for scientific inquiry.

Materials

Clarivate Analytics™ database is available at: https://hcr.clarivate.com/researchers-list/archived-lists/

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