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How Bibliometric Indicators Should Be Used to Assess Excellence in Science and Technology

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Abstract

In order to identify the best standards for the assessment of world-wide scientific performances at the level of both individuals and institutions, we have carried out a comparative analysis of the relative scientific and technological level of individual scientists and individual scientific institutions for given fields and disciplines, using the prominent bibliometric indicators (patents, citations, publications SCI, impact factor). Individual scientists competing for science and technology career progression and grant awards should be ranked by the number and the total impact factor of their publications as first authors falling into 10 out of 10 deciles. This study, contrary to some gloomy opinions, appears capable to effectively and objectively assess institutions, individual university professors and researchers proving to be quite significant and should be used to provide computer-assisted evaluation criteria for either maintaining or upgrading the given position, maintaining or closing public institutions, and filtering grant applications.

Introduction

Bibliometric indicators when properly weighted appear to be effective parameters to monitor degree of excellence in science and technology establishing reliable objective standards [1-4]. Their utilization [5-9] appears capable to automatize the assessment of both the public and private Institutions and of their individual researchers proving to be quite significant in providing computer-assisted evaluation criteria with the properly referenced international databank. If our goal is to select the very best for science and technology in academia and industry rather emblematic appears the emerging list of most cited Journals worldwide (Figure 1), where the number one by far is the "CA: A Cancer Journal for Clinicians" published by the American Cancer Society with Impact Factor 137 provided by the ISI Journal Citation Reports© Ranking in 2015. CA: A Cancer Journal for Clinicians is a peer-reviewed journal providing cancer care professionals with up-to-date information on all aspects of cancer diagnosis, treatment, and prevention, including primary care physicians, medical, surgical, and radiation oncologists; nurses; other health care and public health professionals; and students in various health care fields.

Critics of bibliometric indicators should reflect on these data since the future of every country depends to a large extent on its ability to carry out advanced research in science and technology at the highest level. This must be done by improving stringent meritocracy and maximal visibility in the decision-making process, which should determine career progression and grant allocation. The Impact Factor and H-index of submitting authors are constantly monitored and

Mark	Rank	Abbreviated Journal Title (linked to journal information)	ISSN	Total Cites	Impact Factor	5-Year Impact Factor	Immediacy Index	Articles	Cited Half-life	Eigenfactor® Score	Article Influence® Score
	1	CA-CANCER J CLIN	0007-9235	20488	131.723	142.204	50.292	24	4.1	0.06261	40.137
	2	NEW ENGL J MED	0028-4793	283525	59.558	56.170	20.012	342	8.3	0.68563	25.797
	3	NAT REV DRUG DISCOV	1474-1776	25460	47.120	43.016	8.475	40	6.8	0.06294	16.363
	4	LANCET	0140-6736	195553	44.002	46.119	13.210	309	9.0	0.40817	19.156
	5	NAT BIOTECHNOL	1087-0156	48650	43.113	41.388	8.947	114	7.2	0.15771	20.953
	6	NAT REV IMMUNOL	1474-1733	31545	39.416	39.328	5.517	58	6.9	0.08760	17.581
	7	NAT MATER	1476-1122	72306	38.891	45.772	8.565	170	6.3	0.20799	19.181
	8	NAT REV MOL CELL BIO	1471-0072	36784	38.602	40.923	4.915	59	7.4	0.09969	20.316
	9	NATURE	0028-0836	627846	38.138	41.458	9.518	897	>10.0	1.44762	22.261
	10	ANNU REV ASTRON ASTR	0066-4146	9000	37.846	31.586	2.875	16	>10.0	0.02021	19.063
	11	JAMA-J AM MED ASSOC	0098-7484	129909	37.684	33.569	9.497	197	>10.0	0.27518	16.023
	12	CHEM REV	0009-2665	148154	37.369	51.560	8.870	261	8.1	0.24548	15.263
	13	NAT REV GENET	1471-0056	30286	35.898	41.215	6.431	51	6.3	0.10725	20.891
	14	ANNU REV IMMUNOL	0732-0582	17023	35.543	40.445	5.154	26	9.3	0.03670	20.366
	15	NAT NANOTECHNOL	1748-3387	40881	35.267	40.632	7.914	152	4.7	0.16769	17.356
	16	SCIENCE	0036-8075	568210	34.661	34.921	8.961	828	>10.0	1.15726	18.048
	17	NAT REV CANCER	1474-175X	41846	34.244	42.340	4.927	55	7.8	0.08819	17.383
	18	CHEM SOC REV	0306-0012	99930	34.090	36.630	9.592	360	4.2	0.27041	9.849
	19	REV MOD PHYS	0034-6861	41133	33.177	46.681	6.474	38	>10.0	0.09735	27.008
	20	LIVING REV RELATIV	1433-8351	2038	32.000	26.333	1.667	3	5.6	0.00737	11.595

Figure 1: Emerging list of most cited Journals worldwide.

at the end of each year could and should be used in any new future objective criteria emerging worldwide strictly on the merit and far from the interest and lobbying power of leading Publishing Groups. Career progressions and Research Grant allocations should be based strictly and objectively on the merit worldwide as unfortunately not done everywhere too often. Evaluation is typically carried out worldwide on total H-index of each author regardless the number of coauthors and of his position in each of the quoted papers, which most times is highly misleading and arbitrary. An objective science assessment will instead enhance technology acquisition and creative scientific thinker's promotion worldwide to better focus on the real world achievements and priorities, which is the object of this communication. In order to explore the possibility that the assignment of both chairs and contracts could be automated taking it away from bureaucrats and deals, we carried out a comparative analysis of the relative scientific and technological level of candidates competing nationally using indicators such as the number of publications and citations in highest standard international journals for the corresponding disciplines and sectors, integrated by the number of patents and inventions. This study, contrary to some gloomy opinions, suggests that at least for what concerns hard science, performances can be measured impartially. Bibliometric indicators, only when properly selected (deciles and author position using strictly Science Citation Index) as here suggested, appear capable to monitor degree of excellence in scholastic rating and to establish reliable objective standards for the needed provision of computer-assisted selection criteria pulling properly in the same class (deciles 10 out of 10), where decile is each of ten equal groups into which a population can be divided according to the distribution of values of a particular variable (as the impact factor in this manuscript).

Method

Large amount of literature data exists on bibliometric or scientometric indicators, which provide the methodological background for the applied indicators. Our search through the scientific and technical literature has been carried out using the SCISEARCH database of the Institute of Scientific Information (ISI) of Philadelphia, which we accessed via on-line connection to the DIALOG information services [4, 5]. The database is a well-known multidisciplinary and multinational index to the journal literature of science and technology. According to ISI, SCISEARCH indexes the contents of 90% of the world's most significant scientific and technical literature. It also offers citation indexing, which is essential to our approach. The journals indexed may vary each year on the basis of strict criteria, including citation analysis. As stated by ISI, 3,322 source issues and 620,000 authored source items are included. Citation data concerning journals are also considered, and are collected in the Journal Citation Reports (JCR), which are published annually. In using these data, we have focused on full-length articles, considering these to be the most indicative signs of scientific performance. We have excluded conference proceedings, chapters in books and other contributions to the scientific literature [6-9]. It is well known that the selection of a journal for inclusion in the SCISEARCH database follows strict criteria - namely, the significance and impact of articles, reference from subject specialists, citation frequency, and recommendation from subscribers, historical data, editorial policy, geopolitical considerations, and punctuality. The number of publications as First-author in the first decile (Table 1) is, therefore, a sign of scientific and technological performance with international standard and appears to be an important indicator along with the impact factor of the journal where each First-author article

is published. As far as the number of citations is concerned we acknowledge and correct for the several limitations of this indicator [7-9]. We have thereby successfully tested this new bibliometric tool to assess the excellence in selected scientific disciplines, using data from the Science Citation Index (SCI) published by Thomson Scientific and Google Scholar. For the number of scientists contributing as co-authors to a specific article, we select papers only as first and last authors. In summary: 1_Number of Publications in Top-ranked Journals (Impact Factor above 4.2); 2_Science Citation Index and Google Scholar, where performance indicators are based on Science Citation Index that was created by the Institute for Science Information (ISI) and Google Scholar produced by Google; 3_H-Index and Number of Patents.

Results

In the Disciplines of Nanotechnology-Biophysics-Biochemistry-Biotechnology (covering the full range of NanoWorld Journal) taken as reference in this study only 379 International Journals are present in the SCISEARCH database with Impact Factor Computed for each Decile within the Upper and Lower Range Indicated in Table 1. For the first decile chosen to identify the fraction of international journals with highest impact factor in excess of 4.2 to be defined as equally excellent in the given scientific and technological sector, regardless the level of impact factor achieved associating artificially a large number of authors frequently in excess of 20 in highly popular and well diffuse journal similarly proliferating in all parts of society to include part of the community extraneous to science and technology, as nurses, undergraduate students, bureaucrats, managers, patients and businessman. Bureaucrats handling grant should keep this in mind. In Table 2 is summarized the objective Ranking using all prominent bibliometric indicators (patents, H-index, Articles in Science Citation Index) of worldwide leading scientists and technologists members of the Editorial Board of the NanoWorld Journal including a Nobel Prize winner and Clinicians, where in terms of number of publications (SCI only) with Maximum Number decili (10 over 10 for impact factor)

Table 1: In the Disciplines of Biophysics-Biochemistry-Nanobiotechnology and Biotechnology only 379 International Journals are present in the SCISEARCH database with Impact Factor Computed for each Decile within the Upper and Lower Range Indicated Below. Decile is each of ten equal groups into which a population can be divided according to the distribution of values of a particular variable (as the impact factor in this table).

Impact Factor	Number	Deciles
>4.2	I	10
>3.3 e <4.2	II	9
>2.4 e <3.3	III	8
>1.9 e <2.4	IV	7
>1.5 e <1.9	V	6
>1.1 e <1.5	VI	5
>0.86 e <1.1	VII	4
>0.70 e <0.86	VIII	3
>0.35 e <0.70	IX	2
>0.0 e <0.35	X	1

Table 2: Objective Ranking of Individual leading scientists and technologists (as test are taken Editorial Board members of the NanoWorld Journal 2015).

	Number Best Articles (10 over 10 decile)	H-Index (Citations)	Articles	Patents	Impact Factor (Best Articles)		
					As First author	As Last author	As Middle author
EBM1	**101**	49 (9432)	645	40	**315 (35)**	**355 (62)**	**18 (4)**
EBM2	**74**	99 (54472)	386	43	**289 (10)**	**997 (64)**	**0 (0)**
EBM3	**82**	91 (30592)	753	4	**217 (12)**	**652 (62)**	**91 (8)**
EBM4	**32**	64 (14214)	407	0	**153 (16)**	**187 (12)**	**19 (4)**
EBM5	**25**	32 (3528)	199	6	**119 (19)**	**43 (5)**	**5 (1)**
EBM6	**18**	21 (1171)	114	3	**60 (10)**	**30 (4)**	**17 (4)**
EBM7	**27**	51 (10270)	315	1	**57 (8)**	**172 (19)**	**0 (0)**
EBM8	**10**	45 (8597)	340	10	**42 (3)**	**29 (6)**	**5 (1)**
EBM9	**23**	32 (3812)	169	2	**22 (5)**	**98 (7)**	**10 (1)**
EBM10	**7**	19 (4372)	60	2	**9 (1)**	**34 (5)**	**0 (0)**
EBM11	**1**	9 (302)	85	1	**7 (1)**	**0 (0)**	**0 (0)**
EBM12	**3**	10 (314)	25	7	**5 (1)**	**18 (2)**	**0 (0)**
EBM13	**2**	21 (1367)	97	12	**0 (0)**	**12 (2)**	**0 (0)**
EBM14	**2**	18 (1105)	120	34	**0 (0)**	**10 (2)**	**0 (0)**
EBM15	**0**	9 (322)	47	0	**0 (0)**	**0 (0)**	**0 (0)**
EBM16	**0**	0 (0)	3	3	**0 (0)**	**0 (0)**	**0 (0)**

Table 3: Objective Ranking of best scientists in the Biophysics Division at Temple University Health Science Center in USA between 1972 and 1984 (In USA) and in the Biophysics Institute, the Biophysical STM Department, the Interuniversity Nanobiotechnology Center at Genova University between 1985 and 2015 (In Europe) all Chaired by Professor Claudio Ando Nicolini.

Faculty Members	Excellent Articles (10 over 10 decili)	Impact Factor As First Author
FK	**2**	**37.92**
EP	**3**	**20.84**
SP	**2**	**13.42**
RB	**1**	**7.42**
LV	**1**	**4.88**
Post Doctors		
EP	**3**	**23.35**
MR	**3**	**15.33**
SV	**22**	**12.86**
EV	**2**	**12.86**
FP	**2**	**10.86**
AM	**2**	**10.40**
DA	**2**	**10.03**
DT	**1**	**9.84**
NR	**2**	**9.47**
SR	**2**	**8.51**
DH	**1**	**7.44**
MG	**1**	**6.38**
MJ	**1**	**6.38**
ES	**1**	**5.46**
GR	**1**	**4,69**
PS	**1**	**4,52**
SD	**1**	**4.52**
RA	**1**	**4,57**
TA	**1**	**4.57**
OG	**1**	**4.46**
SC	**1**	**4.46**
SZ	**1**	**4.31**
PhD Candidates		
AB	**3**	**16.77**
PF	**2**	**15.06**
EP	**2**	**13.87**
MS	**1**	**6.41**
ES	**1**	**6.41**
MA	**1**	**6.41**
VT	**1**	**5.00**
PB	**1**	**4.85**
LM	**1**	**4.69**
FA	**1**	**4.46**
VB	**1**	**4.45**
SA	**1**	**4.31**
NB	**1**	**4.2**
MB	**1**	**4.2**
LB	**1**	**4.2**

the best author appears to have 35 as first author for a total IF of 315, 62 as last author for a total IF of 349 and 4 as middle name for a total IF of 18 in the period 2014-2015 or at given publication date if out press. This objective science assessment will enhance technology transfer and creative scientific thinkers worldwide to better focus on innovative technology and on the real world priority. The objective ranking of the Editorial Board (kept anonymous) of NanoWorld Journal in 2015 is shown in Table 2. In Table 2 over the total of 102 publications with Max Number decili (10 over 10) the number of those published as first name corresponds to the absolute excellence identified in my proposal as the best criteria to better characterize individual scientists performance in the early part of their carrier.

In Table 3 is shown the objective Ranking of best scientists in the Biophysics Division at Temple University Health Science Center in Philadelphia (USA) between 1972 and 1984 (In USA) and Biophysics Institute, Department and Nanobiotechnology Center and Labs in Genova University (Italy) between 1985 and 2015 (In Europe) all Chaired by Professor Claudio Nicolini. While in Genova University during 1989-2012 38 PhDs in Biophysical Sciences and Technologies over 80 admitted and in joint Genova and Marburg Universities Programme 24 PhDs in Nanobiotechnology over 24 admitted. In Table 3 the summary for 1989-2013 38 best PhDs in Genova over 80 admitted and the 12 PhDs NBT in Genova over 24 admitted NBT 12 in Genova and 12 in Marburg jointly recognized by German and Italian Universities. Extending the search to 9 deciles the Impact Factor range for excellence shifted to the lower values indicated in Table 1 increasing the number of best scientists in the three classes *to MA, GV, BP, GP, GP, FA* for *PhD Candidates*; *TV, DD SN, RR, SV, TA, SB, DT, DH* for *Post Doctors; RJ* for *Faculty*. Table 3 gives also the objective ranking of best scientists in Biophysics Division at Temple University Health Science Center in USA between 1972 and 1984 (**In USA**) and in the Biophysics Institute and Department, Interuniversity Nanobiotechnology Center and Labs in Genova University between 1985 and 2015 (*In Europe*) all Chaired by Professor Claudio Nicolini.

In Table 4 the first (number I) of the 10 deciles of the Nanobiotechnology- Biophysics-Biochemistry-Biotechnology disciplines of the SCISEARCH database, namely in a) the following 19 Excellent International Journals are present with Claudio Nicolini as first author for a total of 35 full length papers, and b) the following 22 Excellent International Journals are present with Claudio Nicolini as last author for a total of 62 full length papers.

Table 4: In the first (number I) of 10 deciles of the Biophysics-Biochemistry-Nanobiotechnology- Biotechnology disciplines of the SCISEARCH database. **A)** the following 19 Excellent International Journals are present with Claudio Nicolini as first author for a total of 35 full length papers. **B)** the following 22 Excellent International Journals are present with Claudio Nicolini as last author for a total of 62 full length paper.

(A)

Impact Factor	International Journal SCI (Number of times)
44.75	Nature (1)
33.37	Science (2)
15.68	Journal of the National Cancer Institute (1)
15.03	Advanced Drug Delivery Review (1)
13.86	Cancer Treatment Reports (1)
11.96	Trends in Biotechnology (1)
9.60	Proceedings National Academy of Sciences USA (1)
8.09	Cancer Research (1)
7.85	Biochimica et Biophysica Acta Reviews on Cancer (1)
6.38	Journal of Cell Science (2)
6.41	Biosensors & Bioelectronics (4)
5.98	Nanomedicine (4)
5.58	The Journal of Biological Chemistry (1)
5.41	Carcinogenesis (1)
5.01	Biochemical Pharmacology (1)
5.00	Biophysical Journal (1)
4.46	Langmuir (1)
4.41	Expert Review of Proteomics (1)
4.31	Cell Biophysics (8)

(B)

Impact Factor	International Journal SCI (number of times)
33.37	Science (1)
11.96	Trends in Biotechnology (1)
9.60	Proceedings National Academy of Sciences USA (1)
9.48	Acta Crystallographica D (3)
9.11	Nucleic Acid Research (2)
7.85	Biochimica et Biophysica Acta Reviews on Cancer (1)
7.44	Journal Material Chemistry (1)
6.38	Journal of Cell Science (4)
6.41	Biosensors & Bioelectronics (11)
5.74	Computer Application in Bioscience (1)
5.20	Journal Biochemical Biophysical Methods (1)
5.20	Journal Proteome Research (1)
4.94	Macromolecular Rapid Communications (1)
4.85	Electrochemistry Communications (1)
5.00	Biophysical Journal (2)
4.52	Journal Physical Chemistry B (3)
4.46	Langmuir (9)
4.39	Journal Crystal Growth (2)
4.39	Biochemical Journal (1)
4.31	Cell Biophysics (8) & Cell Biophysics Biochemistry (1)
4.24	The International Journal Biochemistry & Cell Biology (1)
4.20	Critical review Eukaryotic Gene Expression (5)

In Table 5 are shown the results emerging from USA Temple University, Genova University in Italy and Fodazioneldwide. EL.B.A. Nicolini NanoWorld Institute worldwide. The objective Ranking of Leading Universities and Institutions is made evident by the Average Impact Factor per Year originating from the Best Articles as first author in 10 over 10 decili.

Conclusions

The data presented appear conclusive in showing the capacity in measuring excellence of this new criterion based on the number and the total impact factor of the very best papers published as first author in the top journals with impact factor included in the very top decile I (Tables 1 and 4). This being true for both individual scientists (Table 3) and institutions (Table 5) in both side of the Ocean, as apparent in these preliminary data taken from web at the Institute Scientific Information and at the Google Scholar and from the correlated earlier published papers [3-5, 7-9].

Table 5: Objective Ranking of Leading Universities and Institutions directed by Nicolini Claudio.

	Total Impact Factor (Best Articles as first author in the first (number I) of 10 deciles	Average Impact Factor per Year (Best Articles as first author in the first (number I) of 10 deciles)
Temple University Biophysics Chair, USA	356	35,6 over 10 years
Genova University Biophysics Chair, IT	309	11,4 over 27 years
Fondazione ELBA Nicolini NanoWorld Institute, IT	473	22,6 over 21 years

80% of Nicolini Claudio Best Publications as first author amounting to 252 (out of 315) IF were obtained in USA over first 10 years and 20% amounting to 64 IF (out of 315) in Italy over last 27 years.

30% of Nicolini Claudio Best Publications a last author amounting to 104 (out of 349) IF were obtained in USA over first 10 years and 70% amounting to 252 (out of 349) IF in Italy over last 27 years.

Over 374 International publications of Fondazione EL.B.A. Nicolini with total Impact Factor of 1030 in the last 21 years the total Impact Factor of Fondazione EL.B.A. Nicolini is 473 for a total of 74 excellent publications in the first (number I) of 10 deciles over the same 21 years.

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