2. évfolyam • 8. szám • 1992. augusztus

I M P A K T

TÉNYEK A TUDOMÁNYOS ALAPKUTATÁSRÓL

Szilárd: Csak a tényeket írom le – nem azért, hogy bárki is elolvassa,csakis a Jóisten számára.
Betbe: Nem gondolod, hogy a Jóisten ismeri a tényeket?
Szilárd: Lehet, hogy ismeri, de a tényeknek nem *ezt* a változatát.

[*Leo Szilard, His version of the Facts. S.R. Weart & Gertrud Weiss Szilard* (Eds), MIT Press, Cambridge, MA, 1978, p.149.]

A tartalomból:

ISSN 1215-3702

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A rektori konferencia figyelmébe: A tudománymetriai elemzés lehetőségei az egyetemi stratégiai döntéshozatalban

A tudományos kutatás legfőbb intézményei világszerte az egyetemek. Amint azt az *Impakt*ban korábban közölt adatok tanúsították [2. évf. 6. szám, 1992. június], 1980-1989 között a magyar természettudományi publikációknak is több, mint a felét a felsőoktatási intézmények produkálták. Ugyanitt azonban az is látható volt, hogy pl. az idézettségi mutatószámokat tekintve korántsem ilyen egyértelműen kedvező a kép. A kutatási tevékenység értékelése és az értékelés eredményeinek figyelembe vétele a stratégiai döntéshozatalban bonyolult és kényes feladat, amire mindazonáltal egyre több gondot fordítanak a világ számottevő egyetemein, valamint a felsőoktatást felügyelő intézményekben.

Az alábbiakban egy rövid válogatást szeretnénk bemutatni azokból a publikációkból, amelyek az egyetemi kutatás eredményességének javítására szolgáló módszerekről számolnak be, különös figyelmet szentelve a tudománymetriai, bibliometriai módszerekre. A téma teljes irodalma, természetesen, az itt megemlítetteknél lényegesen terjedelmesebb.

A felsorolt cikkek xeroxmásolatai, ill. egy részletesebb bibliográfia megrendelhetők az *Impakt* szerkesztőségének címén.

1. **Nederhof, A.J., Noyons, E.C.M.**: Assessment of the International Standing of University Departments Research. A Comparison of Bibliometric Methods, *Scientometrics*, 24 (3): 393-404 (1992)

   Several bibliometric methods of assessing the research performance of departments are examined: international comparison of departments, comparison with foreign departments of good standing, and comparison with a bibliometric word average. In the study, two Dutch experimental psychology departments were compared with one good U.S. and one outstanding U.K. department. The better of the Dutch departments performed below both foreign departments. However, using the method involving Journal Citation Scores, this Dutch department scored above world average recently, while the other department consistently scored below world average. The best picture is obtained when both methods are combined, which shows that the better Dutch department is ranking in the sub-top of the world, while the other department performs below average.

2. **Bowers, J.K.**: Issues in Developing a Faculty Evaluation System, *Journal of Personnel Evaluation in Education*, 3:31-38 (1989)

   Determining job responsibilities for faculty across disciplines, many authorities agree that three areas of involvement characterize a wide variety of faculty positions: instructions, scholarship and services. A relevant evaluation system must allow for individual faculty member differences in the time and effort allocated to these three activities.

3. **Johnston, R.J.**: Do You Use the Telephone Too Much? A Review of Performance Indicators and Appraisal in British Universities, *Journal of Geography in Higher Education*, 13 (1): 31-44 (1989)

   The resource allocation procedure for distributing money among and within British universities has changed substantially in recent years, and with it the preferred management style. Performance indicators have been proposed as important statistics to be used in management of resource allocation. The validity and value of such indicators is discussed in the context of the recent changes and their role within a proper system of appraisal identified.

(folytatás a következő oldalon)

4. **Rushton, J.P., Meltzer, S.**: Research Productivity, University Revenue, and Scholarly Impact (Citations) of 169 British, Canadian and US Universities (1977), *Scientometrics*, 3(4):275-303 (1989)

The universities were evaluated in terms of their productivity across disciplines. The 1977 *Arts & Humanities Citation Index, Social Science Citation Index* and *Science Citation Index* were used as the basis for counting the total number of publications from each universities. The most productive university was Harvard University. Fifteen of the most productive 100 universities were from the United Kingdom, while eleven were from Canada. Additional data were collected including: the revenue of the university, the year the university was founded, the number of subscriptions to current periodicals, the number of bound volumes in the library, the aptitude scores and number of both graduate and undergraduate students, the total number of faculty members, and the number of publications of, reputational rating, and citation to, the faculty members in the psychology departments. A powerful general factor was found to permeate the more than 30 disparate measures, i.e., those universities that were high on one measure were high on others.

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5. **Batshaw, M.L., Plotnick, L.P., Petty, B.G., Woolf, P.K., Mellits, E.D.**: Academic Promotion at a Medical School. Experience at Johns Hopkins University School of Medicine, *New England Journal of Medicine*, 318:741-747 (March 24, 1988)

Over a five-year period, 93 percent of candidates for the rank of associate professor and 79 percent of candidates for the rank of professor were promoted in Johns Hopkins University School of Medicine. There were no significant differences between clinical and research faculty members in terms of the probability that they would be promoted or their age at promotion to either associate professor or professor. Despite these findings, the responses to a questionnaire indicated that the former faculty members perceived clinician-teachers as likely than researchers to be promoted. Those who where promoted had had about twice as many articles published in peer-reviewed journals as those who were not promoted.

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6. **Carpenter, M.P., Gibb, F., Harris, M., Irvine, J., Martin, B.K., Narin, F.**: Bibliometric Profiles for British Academic Institutions: An Experiment to Develop Research Output Indicators, *Scientometrics*, 14 (3-4):213-233 (1988)

In this paper, the results are reported of an explanatory study commissioned by the Advisory Board for the Research Councils to produce bibliometric research profiles for academic and related institutions within the U.K. The approach adopted is based on the methodology developed by the CHI Research whereby publications from a given institution are weighted according to the influence of the journal in which they appear. Although certain technical institutions were encountered with the approach, the study nonetheless yielded potentially useful information on the comparative research output of British universities and polytechnics.

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7. **Johnes, G.**: Ranking University Departments: Problems and Opportunities, September 1988 (A manuscript)

The author encounters some potential difficulties which arise in ranking university departments: the distinction between quantity, impact, importance and quality is a crucial question in this respect. He criticizes the bibliometric approach, and the evaluation of departments using peer review as well, and proposes an evaluation based on inputs and outputs for judging the efficency of the department in question.

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8. **Johnes, G.**: Research Performance Indications in the University Sector, *Higher Education Quarterly*, 42 (1): 54-71 (Winter 1988)

Bibliometric tools of analysis are becoming increasingly common as means of measuring research output of university departments. This paper provides a critical review of these techniques. It is concluded that such methods may profitably be used to enhance our understanding of the optimal research environment within each subject area.

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9. **Wallmark, J.T., McQueen, D.H., Sedig, K.G.**: Measurement of Output from University Research: A Case Study, *Transactions on Engineering Management*, 35 (3):175-180 (1988)

A case study to test the feasibility of measuring output from university research has been performed at Chalmers University of Technology based on five factors: graduate degrees awarded, scientific publications, citations, patents, and spin-off companies. These outputs have been subjectively combined into a merite figure and compared to inputs in the form of department budgets and other outputs such as the teaching load. Regression analyses with the budget allocated with a peer review have been made. Cost estimates for the measurement method are presented. The method has also been compared to a peer review method.

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10. **Muffo, J.A., Susan V. Mead, A.E. Bayer**: Using Faculty Publication Rates for Comparing "Peer" Institutions, *Research in Higher Education*, 27 (2): 163-175 (1987)

This paper reports the results of a study of faculty publication productivity at five major research universities. Data on publication rates were gathered for two years from the Corporate Indexes published by the Institute for Scientific Information, while numbers of faculty by academic discipline were computed using standard reports generated annually by the participating universities. The primary conclusion drawn from the study is that institutional publication rates can be estimated from references in the Corporate Indexes and provide one measure of relative university research productivity.

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11. **Moed, H.F., Burger, W.J.M., Frankfort, J.G., van Raan, A.F.J.**: The Use of Bibliometric Data for the Measurement of University Research Performance, *Research Policy*, 14:131-149 (1985)

In this study bibliometric indicators were calculated for all research groups in the Faculty of Medicine and the Faculty of Mathematics and Natural Sciences at the University of Leiden. When used properly, bibliometric indicators can provide a "monitoring device" for university research-management and science policy.

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12. **Narin, F.**: Measuring the Research Productivity of Higher Education Institutions Using Bibliometric Techniques, Workshop on Science and Technology Measures in the Higher Education Sector, Organization for Economic Cooperation and Development, Paris, France, June 10-13, 1985

The paper reviews the basic ideas of bibliometrics, the systems for classifying papers by field, subfield and by research level, and the evidence for the validity of the use of bibliometric indicators as measures of research productivity. Two alternative methods for measuring the quality of a collection of university papers have been discussed: direct citation counting versus journal influence, and shows that for relatively large sets of papers these are, in fact, quite equivalent. Some of evidence is discussed that there are neither economies nor diseconomies of scale in biomedical paper productivity — that is, for U.S. universities and medical schools, the number of papers produced per dollar of research support is the same for both large and small schools.

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13. **Schubert András, Zsindely Sándor, Braun Tibor**: Egyetemi tanárok és a tudományos kutatás színvonala, *Tudományos és Műszaki Tájékoztatás*, 32 (5):201-210 (1985)

Általánosan elterjedt – de eddig még konkrét mérési adatok alapján kevéssé igazolt – nézet szerint az egyetemi tanárok a tudományos kutatásban kiemelkedő színvonalat képviselnek. A tanulmány tudománymetriai mutatószámok segítségével több ország és szakterület professzorainak munkásságát hasonlítja össze az átlagos országos kutatói színvonallal. A mérési adatok igazolták, hogy publikációs produktivitásuk és idézettségük átlagosnál nagyobb értékei alapján a professzorok átlagos kutatási tevékenysége valóban elit jellegű.

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14. **Beck Mihály, Gáspár Vilmos**: A KLTE természettudományi karán végzett kutatómunka tudománymetriai értékelése. *In*. Braun Tibor, Bujdosó Ernő (szerk.): A tudományos kutatás minősége, MTA Könyvtára, Budapest 1984, 11-24. old.

A szerzők a KLTE természettudományi karán dolgozó 314 diplomás munkatárs publikációs tevékenységét vizsgálták. Megállapították, hogy az egy szerzőre eső teljes impakt ("hatás") összegének 90 %-a a cikkek 40 %-át kitevő idegen nyelvű és az SCI-ban szereplő közleményektől származik. Felhívják a figyelmet az idegen nyelven közlő, rangos folyóiratokban történő közlés fontosságára, de a magyar nyelvű szakfolyóiratokban való publikálást ettől függetlenül, továbbra is szorgalmazni kell.

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15. **Garfield, E.**: How to Use Citation Analysis for Faculty Evaluations and when is it Relevant, *Current Contents*, No. 44 (31 Oct., 1983) 5-13, No. 45 (Nov. 2., 1983) 5

(Magyarul: Az egyetemi kutatási tevékenység értékelése, *In*: Braun Tibor, Bujdosó Ernő (szerk.): A tudományos kutatás minősége, MTA Könyvtára, Budapest 1984, 177-197. old.

A szerző ismerteti az amerikai egyetemeken szokásos kutatási tevékenység értékelésére szolgáló kritériumokat és javasolja azok kibővítését idézési adatokkal. Ezzel kapcsolatban leírja az idézettségi kapcsolatok alakulását, az idézetek számának időbeli változását, az impakt fogalmát és a cikkek eloszlását a kapott idézetek száma szerint.

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16. **Rushton, J.P., Murray, H.G., Paunonen, S.V.**: Personality, Research Creativity, and Teaching Effectiveness in University Professors, *Scientometrics*, 5(2):93-116 (1983)

Two separate studies were undertaken of the personality characteristics associated with research creativity and teaching effectiveness in university psychology professors. In the first study, 52 professors at the University of Western Ontario were evaluated on 29 trait dimensions using four assessment techniques: faculty peer ratings, student ratings, self ratings, and objective questionnary. A composite criterion of research creativity was generated from publication and citation counts. A composite for teachning effectiveness was created from 5 years of archival data based on formal student evaluations. A second study, using a self report survey sent to 400 professors in graduate psychology departments at 9 Canadian universities, revealed substantial replications of the findings of study 1. Limiting ourselves to those personality traits that reliably loaded on Research and Teaching factors in both studies, we may describe the creative researcher as ambitious, enduring, seeking definiteness, dominant, showing leadership, aggressive, independent, non-meek, and non-supportive. The effective teacher is best described as liberal, sociable, showing leadership, extraverted, non-anxious, objective, supporting, non-authoritarian, non-defensive, intelligent, and aesthetically sensitive.

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17. **Jauch, L.R., Glueck, W.F.**: Evaluation of University Professors' Research Performance, *Management Science*, 22(1):66-75 (1975)

A sample of 86 "hard" science professors pursuing funded research in 23 departments were evaluated at the University of Missouri. The effectiveness *can* be measured by a simple count of the number of publications in respectable journals. But because the researchers and their department chairmen do not believe simple counts to be effective, this should be supplemented by weighting the publications with a journal quality index.

Együttműködési kapcsolatok nyolc ország természettudományi alapkutatásában (1981-1986)

Az *Impakt* korábbi számaiban már mutattunk be adatokat a hazai természettudományi alapkutatás nemzetközi társszerzőségi kapcsolatrendszeréről [1], és hangsúlyoztuk a nemzetközi kutatási együttműködés jelentőségét [2].

A most bemutatásra kerülő ábrák egy finn szerzőnek a közelmúltban megjelent publikációja [3] alapján adnak számot nyolc ország társszerzőségi prioritásairól a természettudományok egészét tekintve az 1981-1986 években.

Az együttműködési prioritás rangsorolására használt mutatószám értelmezése az idézett cikk alapján a következő:

Observed/expected = $(C_{x,y} \times T)/(C_x \times Cy)$;

$C_{x,y}$ = number of collaborations (co-authorships) between countries x and y;

C_x = total number of collaborations country x has with other countries in the matrix of 30 countries;

Cy = total number of collaborations country y has with other countries in the matrix of 30 countries;

T = total number of collaborations in the matrix of 30 countries.

When the index value exceeds one, there are more collaborations between the pair of countries than expected, given their size and tendency to collaborate internationally.

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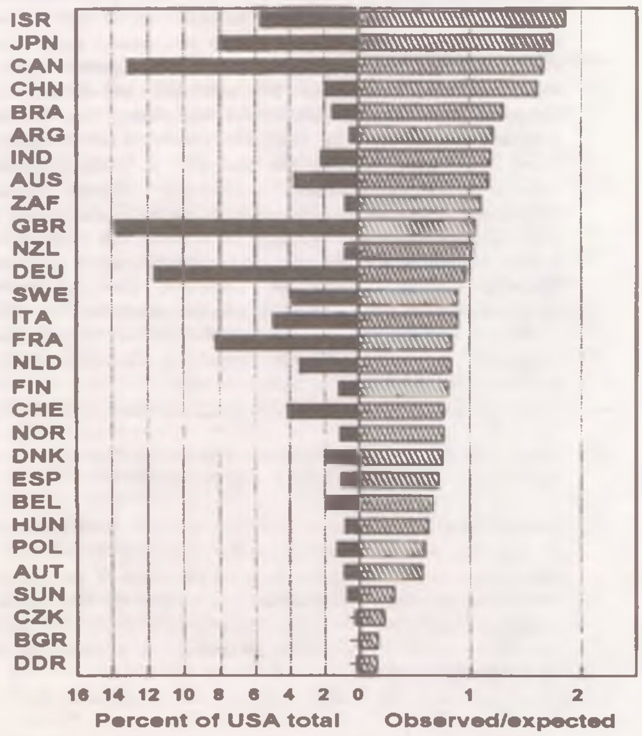
[1] A hazai természettudományi alapkutatás nemzetközi társszerzőségi kapcsolatrendszere, *Impakt*, 2(2) 1-2 (1992)
[2] Hányadán állunk? *Impakt*, 2(4) 4-8 (1992)
[3] Luukonen, T.: *Science, Tecbnology, & Human Values*, 17(1) 101-126 (1992)

Egyesült Államok



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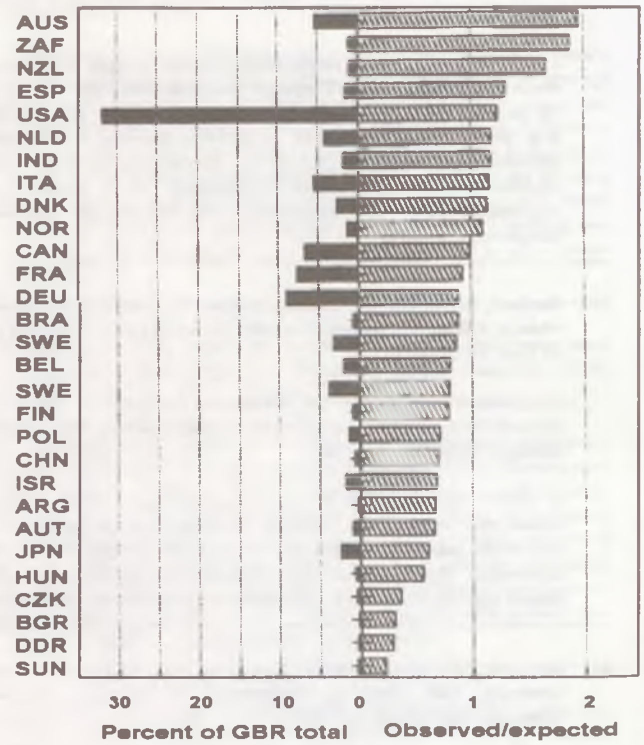

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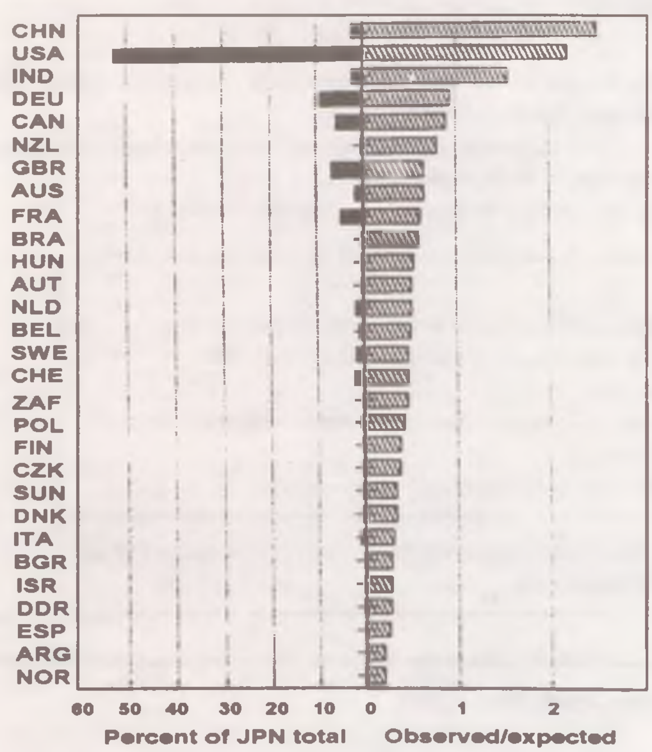

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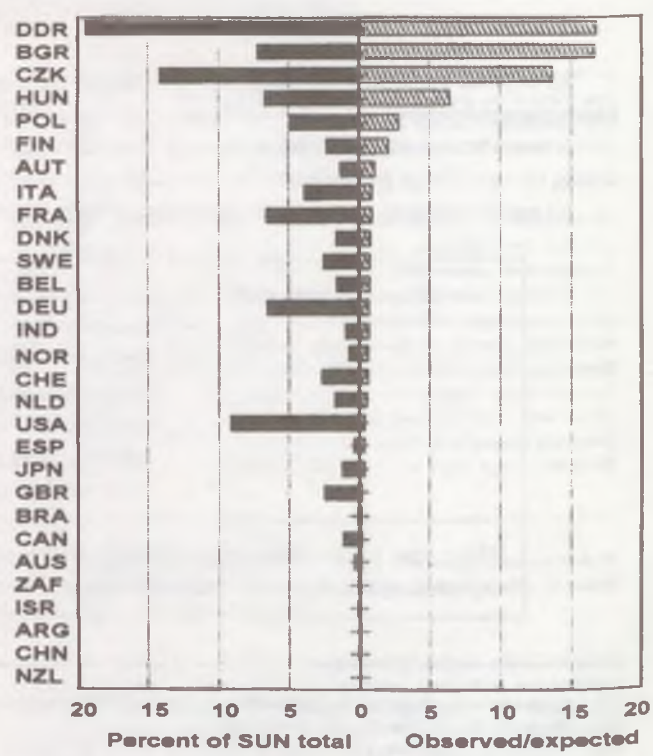

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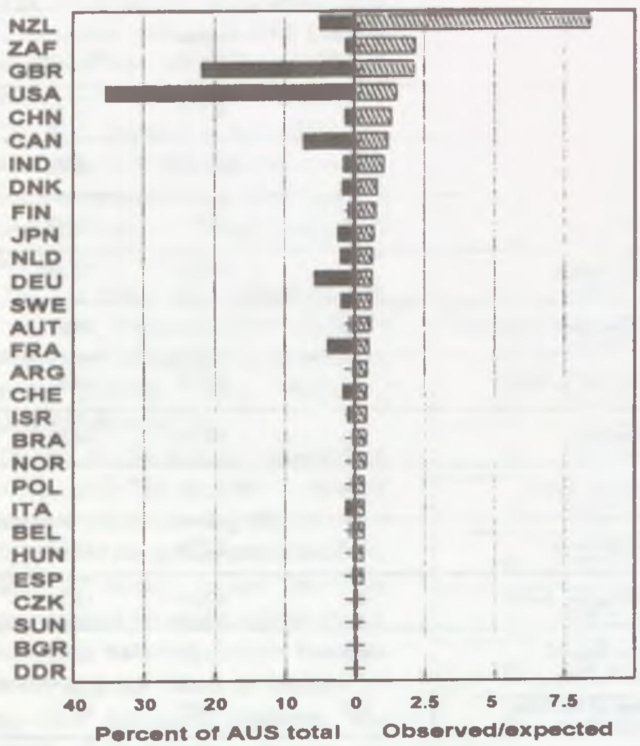

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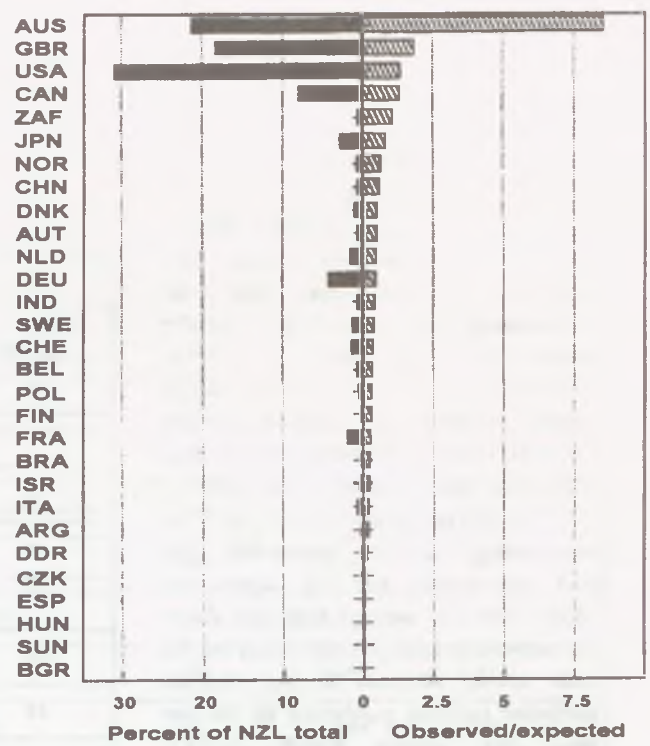

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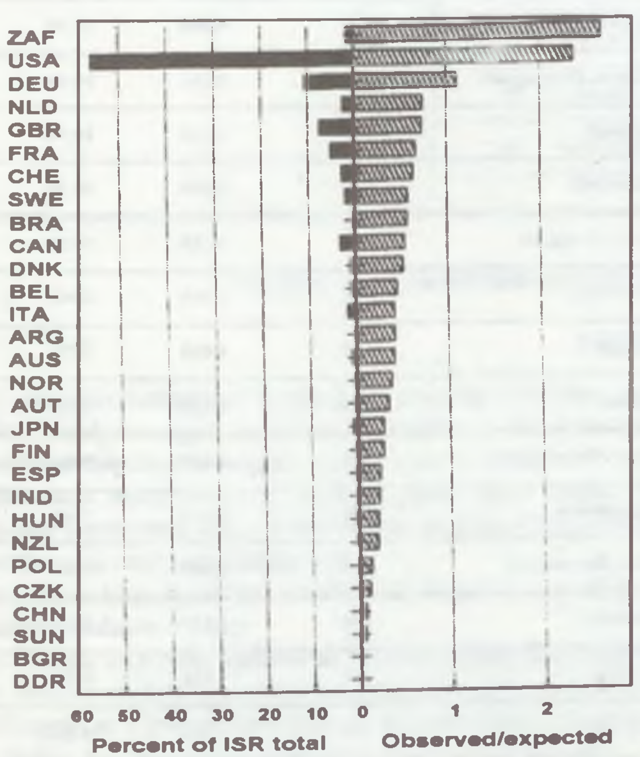

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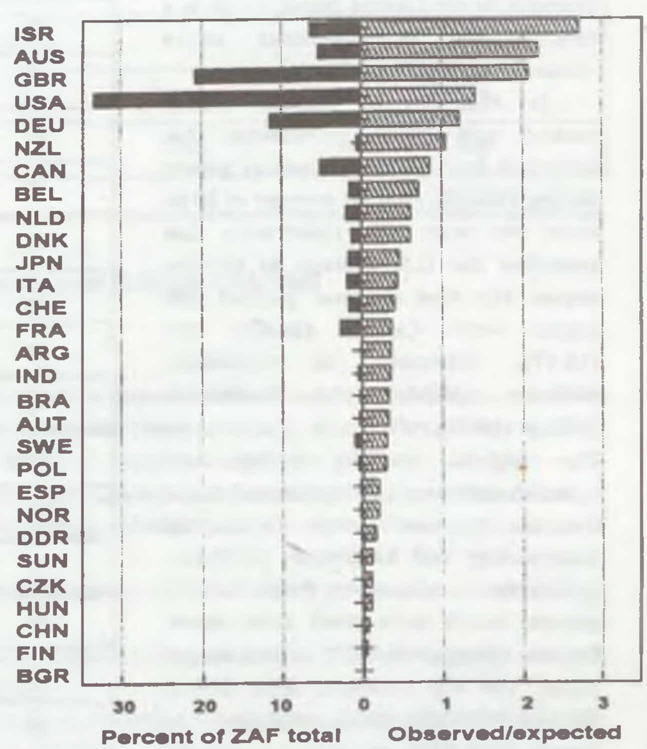

Immunology: The Top 50 U.S. Universities Ranked By Citation Impact, 1986-90

(Among Those Publishing > 100 Papers)

The 50 U.S. universities listed here ranked highest in terms of average citations per paper (citation impact) for articles appearing in immunology journals during 1986-90.

In all, *Science Watch* scanned a total of 40,276 papers, of which 18,888, or 46.8%, were by U.S. authors. The journals surveyed are the 36 immunology titles indexed by ISI for the immunology subsection of *Current Contents/Life Sciences*. (Immunology papers published in multidisciplinary journals, such as *Science*, *Nature*, and *PNAS*, were not included in this study.)

The average citations per paper for immunology articles worldwide was 6.62; the average for U.S. papers was 10.29. The U.S. average falls just above the university ranked nineteenth in the table above, whereas in the clinical-medicine ranking published in the last issue (see *Science Watch*, 2[10]:7, November/December 1991), the U.S. average fell just above the university ranked forty-third. This seems to indicate that, for immunological research in the United States, there is a concentration of excellence in a relatively small group of universities.

In this survey, *Science Watch* ranked only those universities that fielded at least 100 immunology papers during 1986-90 – or an average of 20 or more per year. U.S. universities that exceeded the U.S. average in citation impact but that did not publish 100 papers were: Caltech (24.09); MIT (16.57); University of California, Berkeley (15.50); and Dartmouth College (12.18).

The highest ranking independent research institute in the United States was the National Jewish Center for Immunology and Respiratory Medicine, in Denver. Its researchers published 158 papers, which were cited 2,801 times, for an average of 17.73 citations per paper. The top industrial firm, DNAX, Inc., of Palo Alto, Calif., published 134 papers cited 4,846 times, for an average of 36.16, which was the highest citation impact score of any university, industrial

Rank	Institution	Papers 1986-90	Citations 1986-91	Citations Per Paper
1	Tufts University	362	6,799	18.78
2	Harvard University	1,119	17,992	16.08
3	Yale University	236	3,742	15.86
4	Univ. of Texas, Dallas	331	4,959	14.98
5	Uniformed Serv. Univ. Health Sci.	193	2,875	14.90
6	Univ. of Calif., San Francisco	353	5,038	14.27
7	Stanford University	431	6,028	13.99
8	Univ. of Colorado, Denver	248	3,337	13.46
9	Rockefeller University	163	2,171	13.32
10	Univ. of Washington, Seattle	461	6,097	13.23
11	Univ. of Massachusetts	108	1,335	12.36
12	Baylor College of Medicine	147	1,803	12.27
13	Johns Hopkins University	401	4,834	12.05
14	Duke University	299	3,482	11.65
15	Univ. N. Carolina, Chapel Hill	187	1,987	10.63
16	Washington University	427	4,500	10.54
17	Univ. of Alabama, Birmingham	302	3,166	10.48
18	Univ. of Maryland	185	1,920	10.38
19	New York University	225	2,308	10 26
20	Univ. of Calif. Los Angeles	475	4,756	10.01
21	Columbia University	149	1,466	9.84
22	Univ. of Chicago	167	1,635	9.79
23	Univ. of Virginia	124	1,194	9.63
24	Yeshiva Univ., Albert Einstein	124	1,179	9.51
25	Univ. of Pennsylvania	321	3,042	9.48
26	Univ. of Texas, San Antonio	169	1,600	9.47
27	Boston University	168	1,577	9.39
28	Emory University	140	1,314	9.39
29	Univ. of Rochester	156	1,458	9.35
30	Indiana University	112	1,038	9.27

(Continued on next page)

firm, or government or private research laboratory.

The top three non-U.S. universities were: the University of Oxford (14.01); University College, University of London (12.49); and McMaster Univertsity (12.21). The Imperial Cancer Research Fund in the United Kingdom was the highest ranking non-U.S. independent research institute; its papers exhibited a citation impact score of 13.69.

The top hospitals worldwide turned out to be Brigham and Women's Hospital (15.87); Massachusetts General Hospital (15.29); and Middlesex Hospital, London (13.69).

Of the 40,276 papers examined in this survey, only 738, or 1.8%, were cited 50 times or more. Among the 25 most-cited papers of the group (cited between 199 and 787 times), Harvard University was represented on seven papers; DNAX on four; the National Cancer Institute on three; and the National Institute of Allergy and Infectious Diseases, the University of Washington, Seattle, the State University of Ghent, and University College of the University of London on two each.

Science Watch (January, 1992) 7.

Rank	Institution	Papers 1986-90	Citations 1986-91	Citations Per Paper
31	Case Western Reserve University	121	1,119	9.25
32	Univ. of Calif., San Diego	192	1,771	9.22
33	Univ. of Minnesota Minneapolis	308	2,827	9.18
34	Univ. of Utah, Salt Lake City	128	1,136	8.88
35	Medical Univ. of S. Carolina	111	943	8.50
36	Univ. of Wisconsin, Madison	277	2,352	8.49
37	Univ. of Texas, Galveston	105	887	8.45
38	Univ. of Pittsburgh	295	2,471	8.38
39	SUNY Stony Brook	104	835	8.03
40	Virginia Commonwealth University	122	970	7.95
41	Cornell University	296	2,333	7.88
42	Univ. of Iowa, Iowa City	193	1,519	7.87
43	Univ. of Texas, Houston	358	2,759	7.71
44	Georgetown University	131	984	7 51
45	Univ. of Michigan, Ann Arbor	247	1,852	7.50
46	CUNY, Mt.Sinai	150	1,100	7.33
47	Univ. of So. California	139	1,015	7.30
48	Univ. of Tennessee, Memphis	123	870	7 07
49	Univ. of S. Florida	119	831	6.98
50	Univ. of Miami	145	999	6.89

Magyar cikkek kiváló természettudományos folyóiratokban

1980-1989

A természettudományi alapkutatás jelenlegi rendszere és a tudományos kommunikáció jelentős mértékben a primer folyóiratirodalomra épül. A modern tudomány a kommunikáció egy olyan sajátos mechanizmusát hozta létre, amely az első tudományos folyóiratok megjelenésével vette kezdetét a 17. században, és azóta alapjában véve nem változott. Röviden: ez a mechanizmus részeredmények szelektív publikálására alapul. A lényeg a részeredmények folyóiratcikkek formájában történő *válogatott* publikálása, amely lehetővé tette az alapkutatási tevékenység eredményes művelését, és ez a mechanizmus biztosította és biztosítja ma is a tudomány fejlődését.

Az a tény, hogy egy cikket publikálásra elfogadtak egy jól ismert, kiváló folyóiratban, valószínűleg a legjobb előjele annak, hogy értékes eredményeket közöl.

A fentiek tekintetbevételével az *Impakt* folyamatosan tájékoztatni kíván azokról a magyar szerzős közleményekről, amelyek kiváló természettudományos folyóiratokban elfogadásra és publikálásra kerültek.

Ahogyan az a felsorolásból látható, számos esetben a közleményekben leírt eredmények nemzetközi együttműködésben jöttek létre, mely a mai, korszerű kutatás egyik lényeges éltető eleme.

Braun Tibor, MTAK

(folytatás a következő oldalon)

ALAMGIR M, DEKEPPER P, ORBÁN M, EPSTEIN IR,
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The growing inaccessibility of science

That science has become more difficult for nonspecialists to understand is a truth universally acknowledged. Here is a measure of the extent of the process.

There is plenty of anecdotal evidence that large areas of the scientific literature are becoming incomprehensible to all but a few initiates. But how persuasive is anecdote? In this article I describe an objective way of looking at the matter and discuss its application to science journals over the past 145 years. The approach is a method for measuring text difficulty. The data are taken from articles describing research in four categories of publication: general science (*Nature*, *Science* and *Scientific American*); ten professional journals in astronomy, biology, chemistry, geology and physics; science textbooks for introductory college courses; and popular science magazines.

In a nutshell, the analyses conform impressions that research papers are written for specialists. This style means that authors can be explicit in their referencing and economical with space. But whereas the approach produces succinct papers for editors and referees, it makes tough reading for nonspecialists.

In measuring the difficulty of a piece of writing each sample text is assigned a difficulty scale score based on its choice of words from the full English lexicon (page 12). The higher the score the more difficult the text. The table indicates the scale's use, range and validity, and Fig. 1 shows the result of analysis of research articles in *Nature* and *Science*, and of articles in *Scientific American*, published between 1930 and 1990. *Scientific American* does not publish reports of original research, whereas the other two do.

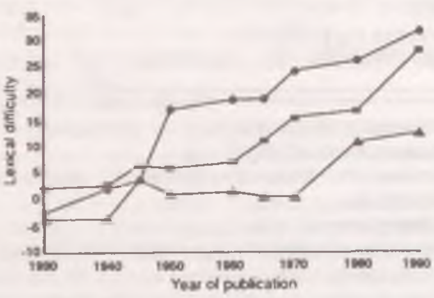

FIG. 1 The rise in lexical difficulty in *Nature* (●), *Science* (■) and *Scientific American* (▲) between 1930 and 1990.

For 125 years, between 1845 and 1970, the use of vocabulary in *Scientific American*, was at or slightly below the level of a modern newspaper (0.0); indeed, *Scientific American* for its first 75 years, *was* a weekly newspaper of technology and science. Its language began to resemble that used in professional science journals after 1970. Interestingly, when the difficulty of the average article approached 15, there was a decline of over 125,000 subscribers, implying that many readers found texts written at those levels too opaque. When the level of *Scientific American* later dropped towards 10, there was a coincident increase in subscribers.

During *Nature*'s first 78 years (1869 to 1947) it was not necessary to be trained in science to read its content because they were written near the 0.0 level. *Nature* became the first general science journal to show a change, and since 1947 its research articles have become harder to read in each successive decade. *Science* began, in 1883, at -8.5. In it first 77 years, the main articles remained at or slightly above newspaper levels. A change in the text difficulty in *Science* did not emerge until 1960, but since then its articles too have grown much more difficult.

Table

Range of lexical difficulty in selected text categories

Nature (article on the transhydrogenase reaction, 1960)	55.5
Science (abstracts of Report articles, 1990)	44.8
Cell (articles, 1990)	38.0
Nature (research articles, 1990)	31.6
Science (research articles, 1990)	28.0
Physics Today (articles, 1990)	13.3
New Scientist (articles, 1986)	4.0
This manuscript	2.6
International English-language newspapers (N=30)	0.0
Discover (popularized science, 1990)	-4.7
Adults books, fiction, American	-19.3
Ranger Rick (natural history magazine for children)	-22.6
Comic books, British and Amarican	-26.8
Children's books, fiction, British, age 10-14	-27.4
Children's books, fiction, American, age 9-12	-32.3
Adult to adult conversations, casual	-41.1
Mothers talking to their 3 1/4-year old children	-48.3
Farm workers talking to dairy cows	-59.1

Although the impetus for this trend lies with research discoveries and theoretical developments, from the abruptness with which the changes in text difficulty occurred in all three publications it seems that editorial policy may have had something to do with it. Editorial policy affects how major articles and short reports are selected; how and for whom papers are written; and which fields in science are to be featured. One way in which the level of difficulty in *Nature* and *Science* changed was that fewer natural history papers were published (these are often descriptive and generally written at lower levels of difficulty), natural science papers (which are more analytical, and usually written at higher levels) being substituted instead.

What of the basic science journals? There too the trend is clear (Fig. 2). All ten of the journals analysed grew more difficult, and each was growing more difficult in every period between 1900 (or its founding) and 1990. There are few signs that the process is slowing.

The rate at which these journals changed and their most recent levels of difficulty, however, vary. For instance astronomy and physics journals are written at lower levels than those in biology, chemistry, and geology. But because

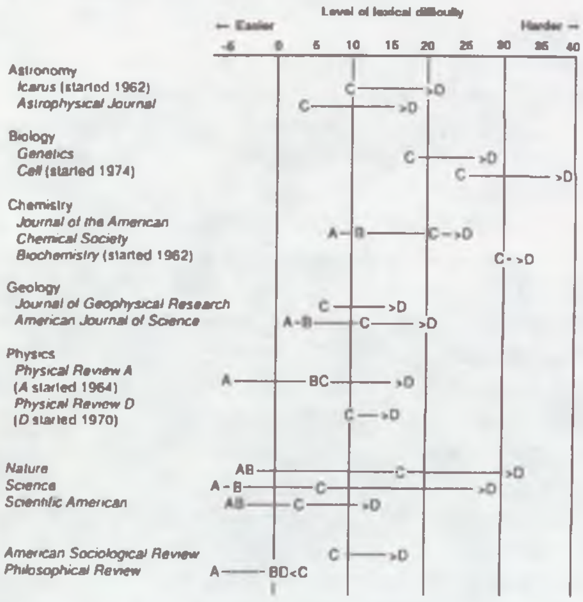

FIG. 2 Change in lexical difficulty in ten basic science journals, the three general journals and two journals dealing with other disciplines. A, 1900; B, 1925; C, 1950 or the first year of publication; D, 1990.

physics and related fields make the heaviest use of equations, their lower difficulty could well be an artefact – lexicographer do not consider equations to be words, and so exclude them from dictionaries and lexical analyses. Articles in biology, chemistry and geology, by contrast rely heavily on their exceptionally large technical lexicons to describe their complex and highly differentiated subject matter.

Conincidentally or not, major college textbooks for introductory physics (0.1) and astronomy (-6.5) were also written at lower levels than those for biology (4.5), chemistry (5.6) and geology (11.1). Equations were rare in all of those texts. Aside from the contribution formalizations make to text difficulty, every physics-related journal grew in lexical difficulty between 1950 and 1990: *Astrophysical Journal* rose from 3 to 18; *Icarus* 10 to 21; *Physical Review A* 6 to 17; *Physical Review D* 10 to 15; and *Journal of Geophysical Research* 7 to 16.

There are no doubt several contributory factors to science, as written, becoming tougher to understand. One of course is that scientific understanding has become ever more detailed. Another is the dynamics of publishing. Like fish on a reef, science magazines must compete for essential resources: important authors and papers, subscribers and, for some, advertisers. They may have to compete for or exploit lexical niches as well.

For example, in the late 1970s it must have become apparent to other publishers that *Scientific American* had left its old niche at 0.0 and was not going to return. In the United States, four general science magazines were created to fill the gap. *Science Digest* transformed itself from a *Readers' Digest* format into a *Scientific American* lookalike (-2.6 in 1986). The American Chemical Society changed the name of the publication *Chemistry* to *SciQuest*, and broadened its message, coverage and appeal (2.2 in 1986). The American Association for the Advancement of Science (publisher of *Science*) developed *Science-80* (-1.0 in 1986) to fill a void in part created when the research articles in *Science* had risen in difficulty from 7 in 1960 to 17 in 1980. Only *Discover* survives (-0.4 in 1986, but -3.6 in 1992). For a brief period, all four magazines occupied the 0.0 niche.

The growth of science has greatly enlarged the audience for general and technical science publications. As their technical articles became more difficult, the general science journals and magazines vacated their former lexical niches. These were soon filled (coincidentally at the vacated levels) by new publications or by ones which moved there from some other niche. Such publications now fill most niches between -22.6 and 38. In particular, professional societies and science publishers have produced several single-science magazines tailored to specific audiences (for example *Physics Today* 13.3, *BioScience* 16.8, *Geology Today* 11.2, and *Chemistry in Britain* 12.6). There is even a chemistry newspaper, *Reaction Times* (7.8). A final adaptation to this trend has been for journals to differentiate parts of each issue, setting each section to a different lexical level, so all readers will find something they can read.

What, though, are the consequences of the drift toward inaccessibility? Specialization in science has produced unprecedented levels of knowledge, but the unwelcome side-effects are clear. These days, more expertise than ever is required to understand published research and theory in other fields and to referee papers and proposals in one's own discipline. The broad consequences are that ideas flow less freely across and within the sciences, and the public's access to (and maybe trust in) science is diminished.

To scientists this trend represents a narrowing of their range of expertise, even while the depth of their knowledge grows. So they may change specialities less often as the costs of becoming expert in another area are grow. One response, I suspect, has been an increase in collaboration with scientists in other specialities. Another has been to develop still more complex research teams whose members have complementary skills and knowledge. Complicated sociological structures such as this can be productive but they introduce new kinds of tension, for instance disputes over the order in which the names appear on a paper.

Projecting the trend summarized in Fig. 2, there will soon be basic science journals whose average article difficulty will exceed 40, and before long some journal may consistently exceed 50 (indeed, many articles in *Cell* currently exceed 40, and a few now exceed 50). No mainstream science journal was as high as 10 in 1900. And of the nine journals examined and published as recently as 1950, only one was above 20. This erection of higher and higher barriers to the comprehension of scientific affairs must surely diminish science itself. Above all, it is a threat to an essential characteristic of the endeavour – its openness to outside examination and appraisal.

D.P. Hayes, Nature, 356(1992, April 30) 740.

Text analysis

One of the main contributors to a text's difficulty is its pattern of word choice. In English, this choice is from an estimated 600,000 word-types (terms having unique orthography). A log-normal model [1] of word choice predicts that the words from a large representative sample of texts are arrayed by the log of their frequency of use, the resulting cumulative distribution will be linear. British and US newspapers have closely followed this pattern of word choice since at least 1730. Because of this stability, the pattern's simplicity and their wide readership, newspapers were adopted as the standard for comparison.

Taking social interactions into account, however, leads to a more complex and general model. Speakers and authors normally tailor texts to their intended audience's interests and knowledge. Compared to newspaper word choice, texts of spontaneous speech underuse the more common grammatical words, overuse the more common substantive words and underuse the rarer substantive words, producing an S-shaped cumulative distribution. Difficult technical texts have the opposite biases, producing the reverse S-shaped distribution. Lexical difficulty is represented by this spectrum of lexical patterns.

The software used in the work described here calculates the discrepancy between a specific text's pattern of word choice and the linear pattern of newspapers. First, each text of 1500+ words is derived by multistage stratified simple random sampling and edited to a common standard. Second, a cumulative curve is generated from the words in that text beginning with the proportion of the most common English word 'the'; to which is added the proportion of the second ('of'); the third ('and'); and so on through the 10000th most common word. (Reliable estimates for word frequencies beyond 10000 are not available.) Third, the 75 most common words in English, accounting for about half the words in texts, are deleted as they contain little information.

Finally, the area beneath that text's cumulative curve is integrated and subtracted from the corresponding area beneath the cumulative curve for newspapers. Texts with negative lexical difficulty scores are skewed towards common words; those with positive scores are skewed towards rare words. The values quoted in this article represent the extent to which word choice is skewed relative to that of newspapers.

D.P.H.

1. **Herdan, G.:** *Language as Choice and Chance*, Noordhoff, Groningen, 1956
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"English and BASIC – we have bilingual education after all."

"This is Dr. Grumbacher, professor emeritus of comparative philology. Perhaps *he* could tell you the difference between an adverb and an adjective."

Készült az MTAK bázi sokszorosító részlegében

Felelős kiadó: az MTAK főigazgatója