

A tribute to Eugene Garfield – Discovering the intellectual base of his discipline

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THE number of citations that a scientific paper gets from other papers is a well-known indicator of scientific impact. In any discipline, we can expect to find a small number of papers that are frequently cited and a large set that are cited only once or twice. Many papers may not be cited at all. Similarly if we distribute citations among the authors of papers we usually get a core of highly influential individuals.

Citation analysis is a well-established research method in the field of science studies. *Scientometrics* is one of the core journals of this research field reporting on various types of bibliometric studies, most of them including the study of citations. Since its beginning in 1978, *Scientometrics* has published 1062 papers till the end of 1999. The most cited authors, or to be more exact the most cited first authors, are listed in Table 1. At the top we find D. Price and E. Garfield who are the founders of the scientometric research field. Price is cited in every third paper and Garfield in every fourth. Below them there are authors having made substantial contributions to the field and most of them have already received the 'Derek Price Award'. My impression is that this list has great face validity, and it is really hard to come up with other names that should enter the first ten ranks or so.

Then if we want to discover the structure of this research field we can count the number of times the listed authors appear together in the same reference lists of papers. This technique is called co-citation analysis, first discovered by Henry Small¹, and assumes that authors that are frequently co-cited are more related in terms of specialization than authors that seldom or never occur in the same reference list.

A co-citation matrix was constructed that gives the number of papers in which each pair of authors has been co-cited. Then this matrix was taken as input to a Multi Dimensional Scaling algorithm (MDS), that led to a two-dimensional graphical representation of the co-citation matrix. Each author got an x - and y -coordinate which defines the map. Distances between the authors are shorter the more co-cited they are, since co-citation frequencies are treated as similarities by the MDS-routine.

The map (Figure 1), drawn using bibliometric software BIBEXCEL², shows the positions of the listed authors

relative to one another. The area of the circles is proportional to the citation frequency, and the lines between them indicate if they are co-cited, and the width of the lines indicates the co-citation frequency.

At the very centre we find Price and Garfield. To the right there is a concentration of US authors, including well-known sociologists of science Merton, Cole and Cole, Zuckerman and Crane and information scientists Small, Moravcsik and Griffith. The integration of scientometrics and sociology of science is not visible in the left part of the map, which contains mostly European researchers

Table 1. Most cited first authors in the 1062 papers published in *Scientometrics* from its start in 1978 to 1999

Number of citations	Cited first author
343	Price, D.
245	Garfield, E.*
178	Narin, F.*
155	Schubert, A.*
152	Small, H.*
124	Braun, T.*
96	Moed, H. F.*
83	Frame, J. D.
82	Moravcsik, M. J.*
78	Egghe, L.
73	Martin, B. R.*
71	Callon, M.
70	Leydesdorff, L.
69	Merton, R. K.*
61	Cole, S.
56	Van Raan, A. F. J.*
56	Cole, J. R.
56	Zuckerman, H.
55	Vlachy, J.*
55	Brookes, B. C.*
50	Glanzel, W.*
49	Crane, D.
49	Bradford, S. C.
48	Irvine, J.*
48	Carpenter, M. P.
47	Griffith, B. C.*
46	Lotka, A. J.
45	Nederhof, A. J.
43	Vinkler, P.
43	Lawani, S. M.
42	Luukkonen, T.
41	Arunachalam, S.
40	Lindsey, D.
40	Beaver, D. D.

*Indicates authors who have received the 'Derek Price Award'.

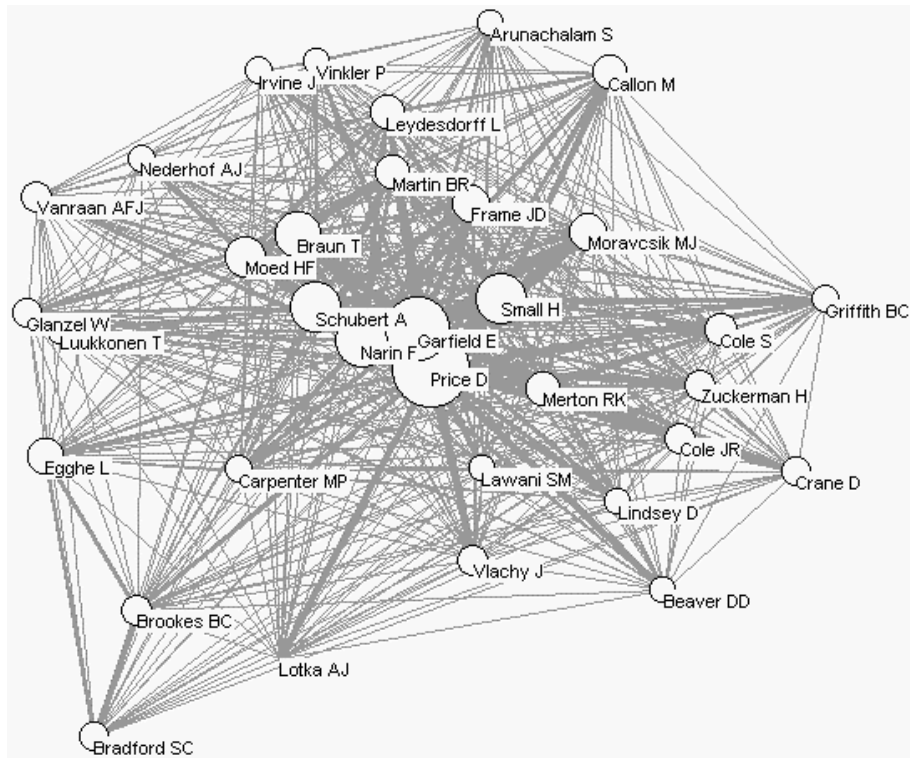


Figure 1. Intellectual base of scientometrics 1978–1999. First author co-citations made by 1062 papers in the journal *Scientometrics*.

specializing in science indicators and science evaluation. Francis Narin appears to be the leader of this segment and is placed to the left of Garfield and Price. The lower left part forms a small group of authors, mostly practitioners of library science, specializing in scientometric distributions (Bradford, Lotka, Brookes, Egghe).

To conclude, the field of scientometrics is structured by geography and specialization. There is a clear divide between US and Europe, although the links show several interconnections. The founding fathers of the field, Gar-

field and Price, appear to keep the field together which would otherwise split even more.

Co-citation-based mapping is one visualization technique that profits from Garfield's invention of citation indexing which assumes that cited documents are valid representations of the content of research. Without him we could simply not see what we now can!

1. Small, H., *J. Am. Soc. Inf. Sci.*, 1973, **24**, 265–269.
2. Persson, O., BIBEXCEL, a tool-box for scientometric analysis; <http://www.umu.se/inforsk/Bibexcel>.