

In basic science the percentage of ‘authoritative’ references decreases as bibliographies become shorter

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The empirical question addressed in this contribution is: How does the relative frequency at which authors in a research field cite ‘authoritative’ documents in the reference lists in their papers vary with the number of references such papers contain? ‘Authoritative’ documents are defined as those that are among the ten percent most frequently cited items in a research field. It is assumed that authors who write papers with relatively short reference lists are more selective in what they cite than authors who compile long reference lists. Thus, by comparing in a research field the fraction of references of a particular type in short reference lists to that in longer lists, one can obtain an indication of the importance of that type. Our analysis suggests that in basic science fields such as physics or molecular biology the percentage of ‘authoritative’ references decreases as bibliographies become shorter. In other words, when basic scientists are selective in referencing behavior, references to ‘authoritative’ documents are dropped more readily than other types. The implications of this empirical finding for the debate on normative versus constructive citation theories are discussed.

Introduction

During the past decades, two competing theories of citation behavior were developed, both embodied in broader social theories of science. One is often denoted as the normative theory of citation, and a second as the social construction of citations. Normative theory of citation basically states that scientists cite to give credit where credit is due. This is expressed in the following statement by Merton:

“The reference serves both instrumental and symbolic functions in the transmission and enlargement of knowledge. Instrumentally, it tells us of work we may not have known before, some of which may hold further interest for us; symbolically, it registers in the enduring archives the intellectual property of the acknowledged source by providing a pellet of peer recognition of the knowledge claim, accepted or expressly rejected, that was made in that source” (MERTON, 1988, p. 622).

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Within this 'normative' framework, citation analysis can be used to trace intellectual or cognitive influence. Essentially, citations are viewed as approximate indicators of influence.

The constructive view takes the position that scientists cite to advance their interests, defend their claims against attack, convince others, and gain a dominant position in their scientific community. For instance, GILBERT (1977) introduced the idea that referencing is an aid to persuasion. In order to support their research findings, authors will tend to cite documents which they assume their audience will regard as 'authoritative'.

"[...] Such referencing of earlier research achieves more than the mere incorporation of the referenced work into the new paper; inasmuch as this work has already been accepted as 'valid science', it also provides a measure of persuasive support for the newly announced findings". "The participants in a mature field will share a belief that some published work is important and correct, some other work is trivial, perhaps some is erroneous, and much is irrelevant to their current interests. Hence, authors preparing papers will tend to cite the 'important and correct' papers, may cite 'erroneous' papers in order to challenge them and will avoid citing the 'trivial' and 'irrelevant' ones" (GILBERT, 1977, p. 116).

"While these remarks concerning the effectiveness of referring to other papers may be true for most scientific work, some research papers, – those whose prime purpose is to provide a 'blueprint' for the reader to build apparatus or instruments which are intended to perform certain stated functions do not need the use of references to demonstrate their validity" (GILBERT, 1977, p. 117).

In an explicit confrontation with the normative view, Gilbert stated:

"One can therefore argue that the scientific 'norm' that one should cite the research on which one's work depends, may not be a product of a pervasive concern to acknowledge 'property rights' but rather may arise from scientists' interest in persuading their colleagues by using all the resources available to them, including those respected papers which can be cited to bolster their own arguments" (GILBERT, 1977, p. 116).

From this perspective, citations measure authoritativeness of a paper, or, more general, its rhetorical strength, defined as the extent to which a cited paper fits into the rhetoric of the citing author.

In a reply to Gilbert, ZUCKERMAN (1987) defended the position of citations as proxies of cognitive influence in the following manner.

"The point, however, is not whether these authors *intended* to persuade by their choice of citations but, rather, what fraction of work that directly or indirectly influenced them is cited and whether citations appear which had no influence on

them of any kind. Even if the well-known work of a well-known scientist is cited in order to persuade – if, as Gilbert puts it, work “regarded as important and correct” is presumably persuasive – then citing it may reflect cognitive influence. Sociologists need not be reminded that motives and consequences are analytically distinct” (ZUCKERMAN, 1987, p 334).

“We now need to ask: What are the characteristics of those sources which can possibly be ‘persuasive’ citations in a clear sense of only providing ‘authority’ rather than relevant cognitive materials in support of the new work referring to it? Presumably, these *authoritative* sources have been assessed by the pertinent collectivity of peers having made sound and consequential contributions. As Gilbert himself observes, it is the papers seen as “important and correct” which are “selected because the author hopes that the referenced papers will be regarded as authoritative by the intended audience”. In short, it is peer recognition of the cognitive worth of the sources grown influential, initially reflected in high rates of citation, that makes them authoritative” (ZUCKERMAN, 1987, p 334).

In a further comment, Zuckerman points to distribution of received citations among cited articles.

“All this becomes evident (and with it, we come upon a genuine puzzle about the cognitive and persuasive significance of citations), when we examine statistical distributions, which I can do here only briefly. We start with the central question: If persuasion really were “the [sic] major motivation to cite”, would citation distributions look as they do? Plainly not” (ZUCKERMAN, 1987, p. 334).

GARFIELD (1985) showed that in the 1975–1979 Cumulated SCI about 6 per cent of all *cited items* receive 10 or more citations. Zuckerman interpreted this finding as showing that only 6% of all *references* went to such – in Gilbert’s terminology – authoritative papers cited 10 or more times. She argued that, if persuasion were the major motivation to cite, a much higher proportion of citations would go to such authoritative, persuasive, papers. Although Zuckerman does not specify how frequently cited a document should be in order to be ‘authoritative’, nor how large the proportion of references to ‘highly cited’ documents should be in order to conclude that persuasion were a major citer motivation, her argument is most interesting as it opens a promising perspective from which an attempt can be made to empirically test the normative against the constructive theories of citation using citation data.

Following Zuckerman’s argument, this paper aims at conducting such an empirical test, by examining citation distributions in basic science and applied science and engineering fields. It analyses reference lists in papers published in these fields, and determines the proportion of references to documents that are relatively highly cited in a particular year, and thus in Gilbert’s terminology can be denoted as ‘authoritative’.

This paper, however, adds a particular dimension to the analysis of citation distributions. A striking feature of referencing is the variability in the number of references papers contain, measured by the number of items in papers' bibliographies as endnotes and footnotes. It has been observed that differences exist in the average length of papers' reference lists among disciplines and types of document. Biochemical papers cite on average many more documents than mathematical or engineering papers do. The same holds for reviews compared to normal articles in all disciplines. However, even papers categorized as 'normal articles' in a single discipline show large variations in the number of references they contain.

In view of this, the proportion of references to 'authoritative' documents is analyzed in function of the length of the citing papers' reference lists, i.e., the number of references the papers contain. A basic assumption underlying this analysis holds that authors who write papers with relatively short reference lists are more selective in what they cite than authors who compile long reference lists. Thus, by comparing the fraction of references of a particular type in short reference lists to that in longer lists, one can obtain an indication of the importance of that type. The empirical question addressed is: How does the relative frequency at which authors in a research field cite 'authoritative' documents in the reference lists in their papers vary with the number of references such papers contain? If this proportion decreases as reference lists become shorter, it can be concluded that citing authoritative documents is less important than other types of citations, and is not a major motivation to cite.

Data and methods

References cited in all source items denoted as 'normal articles' included in the 2001 edition of the *Science Citation Index* (SCI) on CD-ROM produced by the Institute for Scientific Information (ISI) were analyzed. The source papers were arranged by research field, defined in terms of aggregates of journal categories. This paper focuses on four such fields: Molecular Biology & Biochemistry (MB&B), Physics & Astronomy (P&A), Applied Physics & Chemistry (AP&C) and Engineering (ENG). Results on other fields will be presented in future publications by the authors.

AP&C includes 15 journal categories, the most important ones being applied physics, materials science, optics, chemical engineering, mechanics, applied chemistry, acoustics and instruments & instrumentation. ENG consists of 34 engineering categories, including electrical engineering, nuclear science and technology, mechanical engineering, and computer science. MB&B includes the strongly overlapping journal categories biochemistry & molecular biology, cell biology, biophysics, biotechnology, developmental biology, and biochemical research methods. Finally, P&A contains the 'standard' categories related to physics and astronomy.

In our study the concept of 'authoritative' reference was operationalized in the following manner. Cited references were classified in two groups: those published in journals processed for the ISI indexes, and those published in non-ISI sources, including monographs, multi-authored books and proceedings volumes. In each research field the distribution of citations among cited items was compiled in each group separately, and the ninetieth percentile of that distribution was determined. Thus, the ten per cent most frequently cited items published in ISI journals, and the ten per cent most frequently cited documents published in non-ISI sources were identified. These two sets were combined. The combined set is assumed to represent the documents perceived in the year 2001 as 'authoritative' in a research field. Source articles were arranged in classes on the basis of the number of references they contain. For each class the percentage of references to 'authoritative' documents was calculated.

The definition of authoritative references did not take into account the cited references' age distribution. It is assumed that highly cited references are authoritative regardless of their age. A more detailed follow-up study could categorize references into age groups, and analyze citation distributions and identify authoritative references per age group.

Results

Figure 1 plots for each research field the distribution of the number of references among source papers. Table 1 presents the approximate number of papers per research field, and the mean and mode of the distribution of the number of references among source articles. The last column gives the percentage of references to the ten per cent most frequently cited documents.

Table 1. Reference characteristics per research field

Research field	Number of papers	References per paper		% References to highly cited documents
		Mean	Mode	
Applied Phys & Chem.	92,000	16.0	10	29%
Engineering	56,000	16.0	9	26%
Mol Biol & Biochem	63,000	33.5	28	36%
Physics & Astron	67,000	21.5	13	39%

Table 1 reveals that the distribution of references among source papers in Applied Physics & Chemistry (AP&C) and in Engineering (ENG) are substantially different from that of papers in Molecular Biology & Biochemistry (MB&B) and, to a lesser

extent, Physics & Astronomy (P&A). The former two research fields have a mean number of references per paper of 16, while the distribution's mode is 10 or 9. MB&B has a mean of 33.5 and a mode of 28. The overall percentage of references to the ten per cent most frequently cited items ranges between 26 per cent in ENG to 39 per cent in P&A.

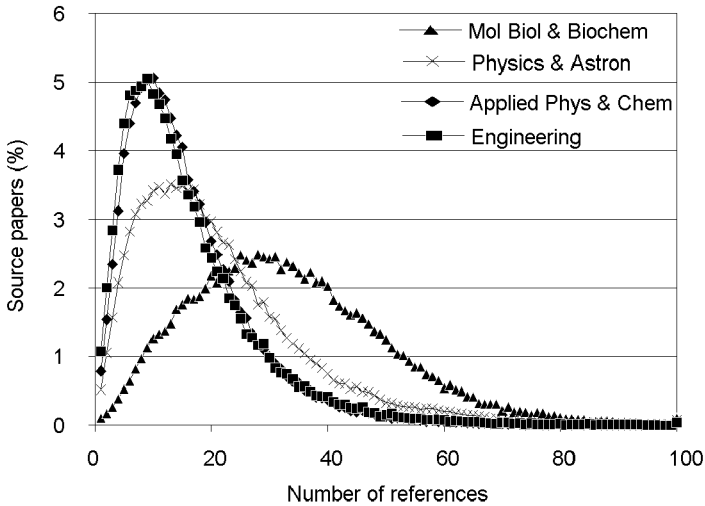


Figure 1. Distribution of the number of references among source papers in four research fields

Figure 2 shows the percentage of references to the most frequently cited, 'authoritative' documents in a research field, as a function of the number of references the citing papers contain. It reveals in MB&B that, as reference lists become longer, authors tend to add relatively more references to 'top' or 'authoritative' items. In papers with short reference lists, the percentage of references to the ten per cent most frequently cited documents in this research field is near 20 per cent. In papers with more than 60 references, this percentage seems to stabilize and fluctuate around a level of about 45 per cent. P&A shows a pattern similar to that of MB&B. The large fluctuations that occur in classes representing high number of references are due to the fact that the number of source articles containing such high number of references is low. In AP&C and ENG the percentage of references to highly cited documents hardly increases as reference lists become longer, and is in most classes between 20 and 30 per cent.

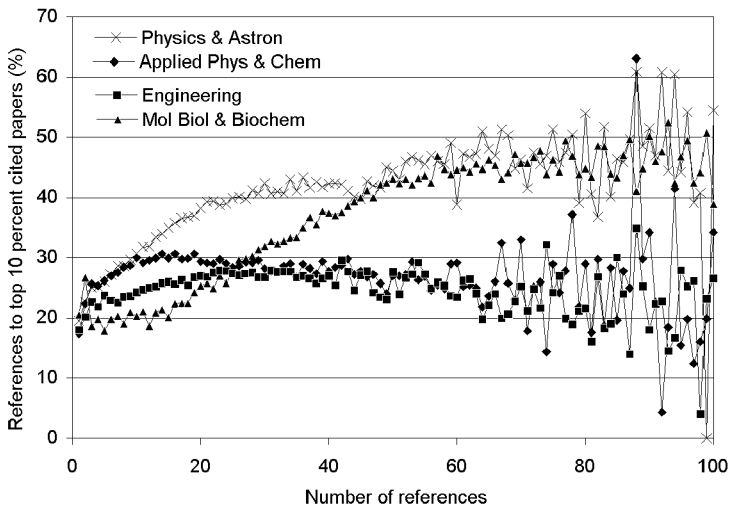


Figure 2. Percentage of references to highly cited documents in four research fields as a function of the number of references contained in the citing papers

Table 2. Percentage of references to authoritative documents in 4 research fields

Research field	Mode	% References to highly cited documents at			
		0.5×mode	1×mode	2×mode	3×mode
Applied Phys & Chem.	10	26.1	30.0	29.3	29.6
Engineering	9	22.8	23.6	25.4	27.1
Mol Biol & Biochem	28	21.4	30.2	42.4	44.0
Physics & Astron	13	27.9	33.4	40.2	41.8

As observed in Table 1, the distribution of the number of references among citing papers differs considerably from one research field to another. Table 2 takes these into account as it gives the percentage of references to the ten per cent most frequently cited documents in papers in which the number of references equals 0.5, 1, 2 and 3 times the mode of the distribution. Table 2 shows that when papers have a number of references of half the mode, – such reference lists can be denoted as short –, the percentages of references to highly cited documents in the four research fields are more similar one to another, whereas in papers with long lists with a number of references that equals two or three times the mode, this percentage in MB&B and P&A (between 40 and 45 per cent) clearly diverges from that in AP&C and ENG (between 25 and 30 per cent).

Discussion

It is extremely difficult, if not impossible, to specify how frequently documents should be cited in order to be 'authoritative', or to determine how many references to such documents should be given in order to characterize persuasion as the major motive for citing. In this paper, the percentage of references to the ten per cent most frequently cited documents in two basic science research fields is less than 50, even in papers with long reference lists. Obviously, if the citation frequency threshold used to identify 'authoritative' documents is lowered, this percentage increases.

The outcomes provide evidence that authors in basic science research fields overall cite more authoritative documents than scientists or technicians from applied or engineering fields do. This observation is consistent with Gilbert's conjecture that "'blueprints' to build apparatus or instruments which are intended to perform certain stated functions do not need the use of references to demonstrate their validity" (GILBERT, 1977, p. 117). One may argue that in mathematics references do not normally demonstrate the validity of claims. Thus, one would expect to find in mathematics papers a reference pattern similar to that observed in engineering. It would be interesting, in a follow-up study, to analyze mathematics. (ROUSSEAU, 1998).

The analysis presented above does not explain why some papers have longer reference lists than others. Reference conventions in a discipline, individual authors' reference styles, the amount of information contained in a paper, the paper's length (ABT & GARFIELD, 2002), or limits imposed by journal editors may influence the frequency at which papers cite other documents. Nevertheless, it seems plausible to assume that if authors have to be selective in their referencing, they tend to include the cognitively most relevant ones. Such an assumption underlies what could be termed a gradual concentration model.

In terms of this model, our analysis suggests that in basic science papers the percentage of 'authoritative' references decreases as bibliographies become shorter. In other words, when basic science authors are selective in referencing behavior, references to 'authoritative' documents are dropped more readily than other types. In this sense, persuasion is not the major motivation to cite.

On the other hand, it can be argued that apparently a substantial portion of cited references are 'authoritative', at least in the basic fields analyzed in this paper, even though – as argued above – it is extremely difficult if not impossible to give a precise quantitative estimate of this portion. If there were not so many references of this type, it would not have been possible to identify authoritative documents from a quantitative analysis of bibliographies.

Thus, one could interpret our results also in terms of a dilution model rather than a concentration model. Basic scientists do to some extent dilute their bibliographies with references that are usually present in bibliographies of papers in similar topics. In this sense, bibliographies at least partly do reflect authoritativeness as suggested by Gilbert.

It should be noted that the highly cited documents identified in this paper include review articles. A follow up study could focus on review articles and determine their proportion among the ten per cent most frequently cited ones.

It would also be illuminating to expand the analysis to research fields in the social sciences and humanities, in order to examine differences between these domains of scholarship and basic, applied and engineering sciences. Finally, citation context analyses could provide a distinct, useful perspective for analyzing the role of highly cited or 'authoritative' documents. An interesting research question would be to which extent the context of citations to 'authoritative' documents differs from that of citations to other documents.

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