

CHRISTINE L. BORGMAN

# Bibliometrics and Scholarly Communication

## *Editor's Introduction*

*In recent years there has been a resurgence of interest both in scholarly communication as a research area and in the application of bibliometrics as a research method. This special issue attempts to review current research that applies bibliometric techniques to research questions in scholarly communication. We consider scholarly communication to be the study of how scholars in any field use and disseminate information through formal and informal channels, whereas bibliometrics is the application of mathematics and statistical methods to books and other media of communication. We propose a matrix for the intersection of these two topics of variables studied (producers, artifacts, and concepts of communication) by research questions asked (characterizing scholarly communities, evolution of scholarly communities, evaluation of scholarly contributions, and the diffusion of ideas). Research in these areas is reviewed, and articles in this issue are set in the context of the matrix. Reliability and validity issues in the application of bibliometrics are reviewed briefly.*

Eight years after Kuhn's (1962) classic work on the nature of science was published, he wrote a postscript to a later edition as a "chance to sketch needed revisions, to comment on some reiterated criticism, and to suggest directions in which my own thought is presently developing." (Kuhn, 1970, p. 174). In this postscript he reiterates the central importance of the community structure of science and calls for empirical research, noting that "preliminary results, many of them still unpublished, suggest that the empirical techniques required for its exploration are non-trivial, but some are in hand and others are sure to be developed" (Kuhn, 1970, p. 176).

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Kuhn cites several studies in support of the latter point (Crane, 1969; Garfield, 1964; Hagstrom, 1965; Kessler, 1965; Mullins, 1966; Price, 1965; Price & Beaver, 1966). Each of these studies relied wholly or in large part on *bibliometrics*, or the application of mathematics and statistical methods to books and other media of communication (Pritchard, 1969), as a research method.

In the 20 years since Kuhn called for empirical research on the processes of communication in science, the research methods have matured, the amount and accessibility of the data have increased, and the research questions to be addressed have become richer and more central to the communication sciences. For all of these reasons, we found it timely to assemble this special issue on the application of bibliometric techniques to the study of scholarly communication.

### *Bibliometrics*

Bibliometrics have been applied in various forms for a century or more (Pritchard & Wittig, 1981), but until recently the data collection was an extremely tedious process and the methods often were lacking in rigor. The last two decades have seen the provision of vast portions of the scholarly record, both bibliographic and full-text data, available in computer-readable form. More than 3,000 publicly available databases exist already on commercial (e.g., Dialog, BRS, Lexis/Nexis) and government (e.g., Medlars) systems. Of particular interest for bibliometrics are the citation databases produced by the Institute for Scientific Information: *Science Citation Index*, *Social Sciences Citation Index*, and the *Arts and Humanities Citation Index*. The use of these large data sets makes possible analyses at a scale that cannot be achieved by traditional methods such as surveys and case studies.

As we have gained experience in bibliometrics, the methods have matured significantly, moving from mere counting of citations to an understanding of the content and purposes of citations and the relationships among different methods (Chubin, 1985; Narin & Moll, 1977). Bibliometrics encompass a number of empirical indicators that can be found in the formal record of scholarly communication, including authors, citations, and textual content.

### *Scholarly Communication*

Interest in scholarly communication has increased for reasons both external and internal to the communication sciences. Among the external reasons are

the increasing competition in science for scarce research funds and the pressures to show contributions to international competitiveness. Scholars and policymakers alike are concerned about understanding the flow of research findings and improving technology transfer.

Interest internal to communication research is exemplified by its continued introspection about its constituency and viability as a discipline (Delia, 1987; *Ferment in the Field*, 1983; Paisley, 1984; Wiemann, Hawkins, & Pingree, 1988). A field's interest in its own scholarly communication is a sign of its maturity. Fields such as physics, chemistry, and medicine have standing committees and/or publications concerned exclusively with the "fullness of communication" (Kuhn, 1970, p. 177; 1977, p. 461) within the field and with other fields.

Social sciences researchers have analyzed their own fields as well. Early notable work includes the multiyear "Project on Scientific Information Exchange in Psychology" conducted by the American Psychological Association (Garvey & Griffith, 1964) and the studies of sociology by Crane (1967) and of communication research by Parker and Paisley (1966).

Relatively young fields like communication research need to be aware of the strategies by which older fields manage their growth and assert their self-interest vis-à-vis institutional status, access to research support, recognition for their contributions to the whole of science, and so on. These strategies may not be entirely appropriate for all fields at all times, but they are a part of the "disciplinary self-awareness" that marks any maturing field.

## Bibliometrics and Scholarly Communication: Definitions

### *Bibliometrics*

The most widely accepted definition of bibliometrics is that of Pritchard (1969), which is quite broad in scope:

1. to shed light on the processes of written communication and of the nature and course of development of a discipline (in so far as this is displayed through written communication), by means of counting and analyzing the various facets of written communication. (Pritchard, 1968)
2. the assembling and interpretation of statistics relating to books and periodicals . . . to demonstrate historical movements, to determine the national or universal research use of books and journals, and to ascer-

tain in many local situations the general use of books and journals. (Raisig, 1962)

Citation analysis is the best-known bibliometric technique, though other analyses of written materials also fall within the scope of bibliometrics. We note that bibliometrics are empirical research methods and do not necessarily have any inherent social science content.

Bibliometrics have been applied not only to the study of scholarly communication but for various other purposes including the evaluation of library collections and as a basis for information retrieval algorithms (Belkin & Croft, 1987; Smith, 1981). Although these are important applications, they are outside the scope of our current interest.

### *Scholarly Communication*

By *scholarly communication* we mean the study of how scholars in any field (e.g., physical, biological, social, and behavioral sciences; humanities; technology) use and disseminate information through formal and informal channels. The study of scholarly communication includes the growth of scholarly information, the relationships among research areas and disciplines, the information needs and uses of individual user groups, and the relationships among formal and informal methods of communication (Compton, 1973; Crane, 1971, 1972; Garvey, 1979; Garvey & Griffith, 1966; Meadows, 1974; Paisley, 1968).

Bibliometrics are applicable only to the study of the *formal* channels of scholarly communication, that is, the written record of scholarship; but in combination with data gleaned from other methods, they can provide a large, rich characterization of communication processes not otherwise possible.

## A Model for the Intersection of Bibliometrics and Scholarly Communication

The single greatest difficulty in developing this special issue has been reaching a common understanding of the scope of the intersection of scholarly communication and bibliometrics among the editors, advisers, and contributors to the issue. Some view the intersection narrowly, constituted only by the use of clustering methods to map relationships among disciplines or to identify scholarly communities. Others view the intersection broadly, consid-

ering any bibliometric study necessarily to concern scholarly communication and almost any quantitative analysis of scholarly communication to be bibliometric.

As editors we have sought a middle ground. The papers we considered in scope incorporate quantitative analyses of the written record of communication, either the bibliographic description or the content of the communication artifact, *and* a behavioral interpretation of the communication process under study. We have included both empirical studies and analytical essays within these boundaries. Specifically excluded were studies that examine communication *structure* without examining the communication *process*.

We propose that research applying bibliometrics to scholarly communication can be organized into a two-dimensional matrix, with axes of "variables studied" and "research questions asked." The variables chosen largely define the bibliometric techniques applied, whereas the research questions are driven by the theoretical framework of the studies. Such a matrix is useful for organizing prior bibliometric studies of scholarly communication and for placing the articles in this issue in context.

### *Variables Studied*

Bibliometric studies of scholarly communication use one or more of three theoretical variables: *producers* of the communication, *artifacts* of communication, and communication *concepts*. Each of these variables may result in multiple operational definitions, resulting in different levels and types of analyses.

#### PRODUCERS

Producers of written communication may be operationalized as individual authors or as aggregates such as research teams, institutions, fields, or countries. In a communication context, producers are studied both as senders and as receivers of scholarly communications.

Bibliometric analyses typically represent producers by the embodiment of their ideas in one or more of their published documents. When precision is required in tracing the influence of a communicator's idea, one or a few documents will be used and citation patterns will be obtained. When the study is focused on a producer's overall influence, the unit of analysis will usually be the author's *oeuvre*, or body of work (White & Griffith, 1981).

### ARTIFACTS

Communication artifacts are the formal product, or output, from a sequence of informal communication activities—reading other documents, translating their ideas into their own terms, talking with others (Bazerman, 1988; Callon, Law, & Rip, 1986; Latour & Woolgar, 1979; Small, 1988)—as well as the input to the scholarly communication of others. Artifacts may be studied at the level of the individual article, conference paper, or book. They may also be studied at aggregate levels such as journals or conferences.

Most studies that use the individual article or book as a unit of analysis are considering the artifacts as the message, or the embodiment of an idea. Studies that use the journal as a unit of analysis are likely to view the artifact as the channel through which producers communicate with one another.

### CONCEPTS

We combine two somewhat disparate types of research under the label of communication concepts: studies that use the authors' own terms (i.e., words in the title or text) or assigned terminology or classification added through the publication process and studies that focus on the purpose or motivation of a citation. Both ascribe meaning to the content of the artifact—one to the substantive content, one to the links made to other artifacts.

Research on authors' terminology or assigned terminology is most often used to trace the flow of ideas within and across disciplines and is closely related to content analysis (Paisley, this issue). Research on the context of citations includes that on citer motivation (e.g., Moravcsik & Murugesan, 1975) and that which studies the actual content of citations as symbols (Small, 1978).

### *Research Questions Asked*

The range of research questions asked in bibliometric studies of scholarly communication does not fall into categories as neatly as do the variables studied, nor can the list be fully enumerated. Many of the research questions can be addressed at different levels of analysis, using different variables. Other questions are closely linked to a unit of analysis, thus leaving some cells in the matrix empty. Here we discuss four of the major research questions that have been addressed, providing examples from past work. A subsequent section places the articles in this issue within the same matrix.

## CHARACTERIZING SCHOLARLY COMMUNITIES

The most commonly asked research questions are of the form, What is the scholarly community of X? and, Of what types of scholars is the community composed? Studies asking these questions attempt to characterize a scholarly community as it exists at some moment in time. Longitudinal studies of a scientific community usually are asking questions about the growth or evolution of an area, and we treat these separately below.

We are combining studies of invisible colleges and studies of research specialties, which although theoretically distinct, have much in common methodologically. Invisible colleges are composed of social and other links among scholars, although the concept of "invisible college" has never been well-explicated (Lievrouw, 1988, this issue). Research specialties, in the sense used by Kuhn (1970), are formed by the focus on a common problem. The cluster of scholars focusing on that problem may or may not have a full complement of social links.

Scholarly communities have been studied through producers, artifacts, and concepts. Most common are artifact studies, counting either individual links among journal articles as was done by Price (1965) or overall counts of links among journals, as was done by Reeves and Borgman (1983) for journals in the field of communication, later replicated by Rice, Borgman, and Reeves (1988) and So (1988). These journal citation maps reveal distinct clusters of mass and interpersonal communication research with a citation "bridge" between the two communities; the maps are further explicated by Reardon and Rogers (1988) and Wiemann, Hawkins, and Pingree (1988).

Much of the mapping of communication artifacts relies on clustering of documents. Bibliographic coupling (Kessler, 1965) and document co-citation analysis (Griffith & Mullins, 1972; Small, 1973; Small & Griffith, 1974) both involve the distance between authors in an intellectual space on the basis of citations they give to or receive from other authors.

Authors may be studied directly to characterize scholarly communities. These studies usually begin with a list of authors generated from one or more sources. The authors are then mapped directly, as in sociometric maps, or clustered using author co-citation analysis (White & Griffith, 1981).

Concepts, in either of the senses used above, may be applied to define scholarly communities. Lievrouw, Rogers, Lowe, and Nadel (1987) identified invisible colleges among lipid metabolism researchers through the use of co-word analysis of document texts combined with co-citation, sociometric, and qualitative analyses and interviews. Small and Greenlee (1980) mapped

the community of researchers studying recombinant DNA by combining context analysis of citations with document co-citation analysis.

#### EVOLUTION OF SCHOLARLY COMMUNITIES

Most of the work that has followed scientific communities over time has relied on citation analysis of artifacts, especially document co-citation analysis. By comparing the rate at which clusters of co-cited documents change in composition, it is possible to identify both the rate and direction of change in research topics. Garfield, Malin, and Small (1978) report on four years of data (1970-1973) for 31 specialties, finding an average 55% change in the constituency of the clusters over that period, with about one-third experiencing major shifts in research direction with an almost entirely new set of documents appearing. The quantitative record of such shifts may be compared to results of interviews with scholars about trends in their research areas, as was done by Small (1973). Changes over time in the composition and relationships among entire disciplines can be mapped also, as demonstrated visually in a videotape produced by Small (1988).

#### EVALUATING SCHOLARLY CONTRIBUTIONS

Bibliometrics have been used widely to evaluate the contributions of producers and of artifacts. Most studies of producers' influence appear to rely on citations received by particular pieces they have written, although direct studies of an author's body of work are possible (White, 1988). An example is Garfield (1985), who analyzed Price's influence through a citation analysis of *Little Science, Big Science*.

The importance of an idea is measured by the number of citations received by the document(s) in which it is embodied. In this way a reference to an artifact is viewed as a sociometric choice (Garfield et al., 1978). Garfield systematically reports on highly cited documents, or "citation classics," in his regular column in *Current Contents*. The reports are complemented by comments from their authors about the origin of the article and their views of its subsequent impact.

Bibliometric analyses are particularly useful when compared to influence measures obtained from other methods, as was done by Latour and Woolgar (1979) in conducting an anthropological study of scientists in a laboratory. Among the bibliometrics they used to measure the scientists' productivity were the proportion of literature in the specialty being produced by the



laboratory, the channels through which papers were disseminated, the audience to which they were directed, and computations of the production cost per article as a portion of the total laboratory budget.

Other research evaluates artifacts, principally scholarly journals, as channels of communication. Rather than producing maps, most of these measures are applied to journals individually, assessing their influence relative to other journals. Todorov and Glanzel (1988) review the many measures of journal impact that have been applied, such as "impact factors," "immediacy index," and "half-life."

#### DIFFUSION STUDIES

Bibliometrics may be used to trace the evolution of an idea within and across disciplines. At the earliest stages of diffusion, the idea is linked with the document in which it was first presented, thus allowing tracing through citations. As an idea diffuses further, it may become disassociated from its bibliographic origins, thus requiring tracing through terminology.

Among the ideas traced through citations are the "double helix" (Winstanley, 1976), Shannon's information theory (Dahling, 1962), and topics relevant to psychiatry originating in related fields (Davis, 1970).

Several studies of the diffusion of ideas have been done within the field of communication. Paisley (1984) traced the concepts "information society," "uses and gratifications," and "knowledge gap" from their origins in communication research through their appearance in the publications of other disciplines. Using citation indexes, Beniger (1988) recently traced the concept of "information" across a wide range of disciplines, then analyzed the context in which the terminology was applied.

#### Articles in This Issue

Our goal for the composition of this issue was to achieve a balance between empirical studies that cut across these types of analyses and critical reviews of the state of bibliometrics and scholarly communication.

We first present three analytical articles, each of which incorporates some bibliometric analyses in support of its arguments (Griffith; Lievrouw; Miyamoto, Midorikawa, & Nakayama). The analytical pieces cover history and explicate various concepts that have been studied at the intersection of scholarly communication and bibliometrics. They are joined by their common

interest in setting this research area into the larger context of its external influences, both theoretical and methodological.

The analytical articles are placed first to provide background for the four primarily empirical pieces (Small & Greenlee; McCain; Brooks; Zsindely & Schubert), which address questions of the growth and evolution of fields, of the boundaries of scholarly communities, and of the influence of communication channels. Variables in each category are used in these researches: authors, editors, articles, journals, books, concepts, and citation context. Each structural analysis is complemented by one or more analyses of the underlying communication processes. The issue closes with an essay by Paisley on future directions for the use of bibliometrics in the study of scholarly communication.

### *Analytical Articles*

We open the issue with the article by Griffith, who sets bibliometrics in the context of the sociology of science by tracing the influences of three primary figures: Merton, Kuhn, and Price.

The article by Lievrouw focuses on the intersection of four fields concerned with the sociology of science by examining their treatment of the concept of "invisible college." In doing so, she proposes a formal definition for the concept and a set of research questions to be addressed within the field of communication research.

Whereas the Griffith and Lievrouw articles set the topic of this issue in a theoretical context, the article by Miyamoto, Midorikawa, and Nakayama sets the topic in a methodological context. They review the recent activity in bibliometrics in Japan, organizing the research questions addressed by the methods that have been applied.

### *Empirical Articles*

We begin this section with Small and Greenlee's comprehensive study of AIDS research, using the document co-citation technique first developed by Small (1973) and others (Griffith & Mullins, 1972; Small & Griffith, 1974). They document the evolution of AIDS research from its first identification as a clinical disease in 1981 through its state as a full-blown research area in 1987. This is a massive study, providing maps of the emergence of this important new research area at multiple levels of detail. The structural analyses are complemented by contextual analysis of the references, thus

showing the intellectual content of each shift in research direction. The Small and Greenlee article is the first publication (to our knowledge) of a bibliometric analysis of AIDS research.

Complementing Small and Greenlee's document co-citation study we have McCain's author co-citation study of population genetics researchers. She attempts both to validate research trends identified by other means and to validate a developmental model of the growth of science, comparing the structural maps produced by bibliometrics to prior sources and to results of interviews with authors studied.

Brooks bounds an active research area, superconductivity, by articles indexed under that terminology in a major indexing and abstracting source. He then analyzes the distribution of journals in which they appeared, comparing the results to an established empirical law of bibliometrics (Bradford's law), thus assessing the influence of these journals as communication channels.

The last empirical article, by Zsindely and Schubert, assesses the role of editors of medical journals as gatekeepers. They are clearly authorities, by nature of their positions, but are they also experts—are they now or were they ever highly cited scholars in their fields? The answer can be found in this short and tightly focused article.

## Reliability and Validity Issues

Bibliometrics have been heralded as providing invaluable insights into the scholarly communication process that could not be obtained by any other method. At the same time, the methods have been criticized as being overly rationalized and promoting a positivist, realist view of science (Edge, 1979) and as being both unreliable and invalid (e.g., MacRoberts & MacRoberts, 1987, in press).

Reliability, or the amount of error in measurement, and validity, or the degree to which we are measuring what we think we are measuring, are an inseparable pair of issues in assessing the value of bibliometrics or any other research method.

### *Reliability*

One of the major strengths of bibliometrics is their high reliability. Bibliometrics rely on unobtrusive measurement of readily accessible data, and results can be replicated easily. Although reliability problems do exist

in individual data sources (e.g., Rice, Borgman, Hart, & Bednarski, 1989), they generally can be identified and corrected by the careful researcher.

### *Validity*

Critiques of the validity of bibliometrics have focused on the assumptions underlying citation analysis. Although citation analysis assumes *some relation* between a citing and a cited document, it does not assume that all citations are made for the same purpose or that all citations are thus equal (Cole, 1970; Smith, 1981; White, 1988). Although critiques of citation analysis have attributed such assumptions to citation researchers (notably Edge, 1979; MacRoberts & MacRoberts, in press), a close analysis of citation studies rarely reveals such assumptions (Smith, 1981; White, 1988).

Citation analysis is most useful for achieving the macro perspective of scholarly communication processes through the use of voluminous data sets. In doing so we are seeking the aggregate of links among authors or their writings that emerges. Citation analysis assumes that authors or documents that are frequently cited have some importance, even if the reasons for the citations vary. Study of the individual links between authors or documents is better pursued by methods that provide more behavioral insights.

On one central point both citation researchers and its detractors agree: citation data are most useful when they are supported by other evidence (Edge, 1979; White, 1988). As reviewed earlier, the results of bibliometric analyses have been compared to sociometric data, survey data, case studies, usage statistics, and various other indicators, often with very strong results.

Reviews of correlations among bibliometric and other measures include Narin and Moll (1977), Todorov and Glanzel (1988), O'Connor and Voos (1981), Chubin (1987), Garfield et al. (1978), and Pritchard (1980). As most of these authors note, any comparison between citation measures and subjective measures must also compare the objectives of study. Differing results often can be explained by differing research motives. Pritchard (1980) uses the example of comparisons between bibliometric and journal usage studies on factors such as ranking of journals and obsolescence rates. Although the variables appear similar, the citation studies are measuring formal communication (documents publicly cited as a source of information), whereas the journal usage studies are measuring informal communication (browsing documents for various purposes). The existence or lack of correlation between these measures is meaningful in and of itself and may be used to address such questions as the degree to which scanned journals are actually cited later.

Because bibliometrics capture data on a scale larger than that of other social science methods, full validation of bibliometric results by other methods is virtually impossible. Conversely, however, we can use bibliometric data to validate other measures, such as sociometrics, because they use a subset of the respondents provided by bibliometrics.

In selecting articles for this issue we have carefully chosen work that reflects a sensitivity to reliability and validity issues, providing support from other data sources and interpreting the communication processes studied. Each article addresses the validity of its method in some way; we have not included any articles that focus wholly or in large part on validity issues, however. Useful reviews of these issues can be found in Smith (1981), White (1988), and a recent issue of *Scientometrics* (1987, 12[5-6]) that contains a critique of one aspect of citation analysis (MacRoberts & MacRoberts, 1987) and 16 responses to the critique.

## Conclusions

This article has attempted to provide an overview of the substance of bibliometrics and of the ways in which it may be applied to the study of scholarly communication. The large volume of work published in this area has given us many insights into the nature of the scholarly communication process and of the community structure of science. At the same time, past research has generated an ever larger number of research questions, of increasing urgency. The rapidly increasing data sources, improved tools, and increased understanding of the research questions involved offer exciting and challenging directions for the communication sciences.

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