

# The Invisible College Reconsidered

## *Bibliometrics and the Development of Scientific Communication Theory*<sup>1</sup>

*In this article, the relationship of bibliometric techniques (especially citation analysis) to communication theory and research is examined, using the invisible college as the principal example. The invisible college is used because it is the best-known model of scientific communication, and because it is based in bibliometric studies of science. As such, the invisible college is typical of constructs that describe processes yet are founded on the study of structures; the ambiguity surrounding the use of the term is symptomatic of the confounding of structure and process in the study of scholarly communication. A revised definition of the invisible college is proposed that reemphasizes its fundamentally communicative nature, and issues for future theory building in scientific communication are suggested.*

Bibliometrics is defined by Pritchard (1969, p. 349) as “the application of mathematics and statistical methods to books and other media of communication,” and more recently, by Broadus (1987, p. 376) as “the quantitative study of physical published units, or of bibliographic units, or of the surrogates for either.” Bibliometric techniques have been used primarily by information scientists to study the growth and distribution of the scientific literature, Pritchard’s somewhat disingenuous reference to “media of communication” notwithstanding. However, occasionally, certain of these techniques (e.g., citation analysis) have been used by communication researchers studying scientific or other scholarly communication.<sup>2</sup>

In this article, the relation of bibliometrics to scientific communication processes is examined using the theoretical construct of the invisible college

as the focal example. Based on the pioneering bibliometric work of Price, Hagstrom, and Crane, the invisible college has been widely accepted as a description of certain social relationships in science. However, it is of particular interest here because it is possibly the best-known model of scientific communication.

It is also an important focus for study because despite its elegance and general heuristic usefulness it is difficult to operationalize, and so it tends to be defined differently by different researchers. The invisible college construct reflects a recurrent problem in the social studies of science generally, which tend to examine the *products* of science (e.g., artifacts such as published documents) in order to understand the social *processes* of science, which are essentially communicative in nature (e.g., interpersonal contact).

In the present article, the emphasis is on the processes of communication among scientists rather than on the structures of their relationships, in an attempt to demonstrate that although studies of scientific communication have benefited from bibliometric analyses of "the media of communication," such studies should also incorporate more direct observation of the communication behavior that produces those artifacts.

## The Relationship of Bibliometric Methods and Communication Processes in Science

In social science research, statistical clustering techniques are used to organize many types of data, such as family ties, bureaucratic structures, professional relationships, or economic dependencies. In social studies of science, clustering techniques are used to organize the relationships among communication artifacts (typically, research articles published in scholarly journals) and to represent that organization in a meaningful way (Chubin, 1983; Lievrouw, 1988; Paisley, 1965). The principal bibliometric technique employed for this purpose is citation analysis (Garfield, Malin, & Small, 1978, p. 180).

Bibliometric studies are therefore of interest to communication researchers because the communication *artifacts* result directly from a process that can be thought of as having two main steps. The first step is the authors' expression of their own and others' expert ideas. Scientific articles are written according to a strict set of conventions regarding the presentation of original concepts. In order to attribute credit to other scientists, the authors make specific bibliographic references to their works; and these references

(citations) are usually construed to stand for interaction among the authors and those whom they cite.<sup>3</sup> The second step is the subsequent review and evaluation of the author's expression by others with similar expertise, with publication contingent upon the evaluation. Scientific articles are published on the basis of this peer review, and appearance of the article in print is usually taken to indicate that communication has also occurred among the author and the evaluators.

In science communication research, the published patterns of references are used as an operationalization of the authors' interpersonal interaction, and bibliometric analysis can clarify those patterns. However, citation analysis is often criticized on the grounds that the citation links from one academic paper to another may not actually represent communication among the papers' authors. As Chubin (1976, p. 452) explains it, the assumption is made that "authors are homogeneous with respect to their referencing behavior." Mulkay (1974, p. 111) calls this the "implicit theory of citing"; it is also referred to as the "normative theory of citing" (MacRoberts & MacRoberts, 1987). Regardless of terminology, critics of this assumption point out that the reasons for citing another scholar can vary so broadly from researcher to researcher that the whole concept of "citation" becomes suspect as an operational measure (Edge, 1968, 1977). Likewise, citation analysis has been demonstrated to produce skewed or inconsistent clusters (Rice, Hart, Borgman, & Bednarski, in press). Therefore, some consider it to be a questionable tool for policymakers concerned with the productivity of science or other scholarship (Chubin, 1987; Hicks, 1987).

However, it would be a mistake to conclude on the grounds of these criticisms that citing behavior has *no* communicative meaning and, therefore, that bibliometric citation analysis yields interesting but invalid snapshots of the literature. Citing behavior as it is understood by the researchers themselves might be reexamined instead, or how their referrals to one another may be a simple indicator of more complex behaviors or social relationships.

The real strength of citation analysis in communication research is that clusters or maps of research articles can be *interpreted* as networks of interpersonal contacts. Such maps can be suggestive conceptually (for example, see those in Small & Garfield, 1985). They seem to imply *communicative* interaction among members of the network, which is often neglected in the effort to describe concrete social structures.

The impulse to interpret maps is an especially interesting aspect of any type of clustering analysis, which is considered relatively objective in nature.

As Rogers (1987) points out, all researchers engage in interpretation to some extent; and accordingly, there is a strong temptation to infer social contact (i.e., communication) from clusters of documents. Indeed, citation analyses have inspired a number of structural analogies for the shape or “geography” of science, including the research front, the social circle, the leading edge, frontiers, fields, scientific communities, and of course the invisible college.

It is also interesting that constructs like these—especially as they imply communicative processes—have not arisen from communication research *per se*. Bibliometrics has been a useful tool in several research traditions, including the history and sociology of science and information science, as well as communication research. In fact, communication research is a relative latecomer to the use of citation analysis (Griffith, 1987; Thackray, 1978); communication researchers became interested in citation analysis only in the 1960s (Parker, Paisley, & Garrett, 1967).

Nonetheless, it can be argued that the fundamental process of science (or other scholarship) is communication. Several scholars have pointed out that without communication, science itself cannot exist (Garvey, 1979, in information science; Paisley, 1984, in communication; Whitley, 1969, in sociology). Yet relatively fewer scholars have studied communication *processes* among scientists than have studied the social *structures* of science. Crane has been one of the most influential researchers in this area (Chubin, 1983; see also Crane, in press); yet even her strong emphasis on communication in *Invisible Colleges* did not reorient social studies of science away from structures and toward communicative action. In short, the opportunity still exists for science studies to be reconsidered from a communication standpoint. The invisible college, as a familiar communication-based theoretical construct grounded in bibliometric analysis, provides a helpful starting place.

## Invisible Colleges and Communication in Science

The term *invisible college* has been used since the founding of the Royal Society of London in the 17th century (Lingwood, 1969; Paisley, 1972; Price, 1961), but in a modern context it was revived by Price (1963) in his book *Little Science, Big Science*. The members of the early Royal Society adopted the term to emphasize the fact that they were geographically close together, and shared common scientific interests, yet had no institution of their own (Lingwood, 1969). In contrast, Price (1961, 1963) used “invisible college” to denote the informal affiliation of scientists with common interests who were

already strongly embedded in other institutions—indeed, had risen to the upper ranks of those institutions—and who might live some distance from one another.

Following Price's lead and the work of Hagstrom (1968) in sociology, Crane published her watershed work, *Invisible Colleges*, in 1972. In this book Crane documented the growth of communication networks among rural sociologists and mathematicians specializing in finite group theory, using both survey and citation data to support her conclusions.

Price's definition of the invisible college seems to be a strong influence on Crane's understanding of the term. In an article that preceded the publication of *Invisible Colleges*, she says that Price uses the term "invisible college" which refers to an *élite* of mutually interacting and productive scientists within a research area" (Crane, 1970, p. 34) (emphasis added). In her book, Crane's citation data are striking. Dramatic curves illustrate the growth of the two specialties' literatures (confirming Price's earlier findings.) By the same token, her survey data suggest that *informal* communication relationships may explain the bibliometric results. She visualizes these communication relations as networks and dubs them "invisible colleges" because of the geographic scatter of their members. Though she borrowed the term from Price, Crane integrates it with the idea of informal communication in science as articulated by Menzel (1968) and the construct of the social circle (Kadushin, 1966).

The first apparent difficulty with Crane's treatment of "informal" communication is that she uses the self-reports of scientists about their communication behavior (survey data) in lieu of the direct observation of scientists as they communicate. The principal problem, however, is that Crane does not explicitly define the invisible college, although she describes the activities of invisible college members (such as the exchange of preprints, coauthorship, etc.). She focuses on the formal communication channels among scientists because such channels facilitate the production of documents, which are themselves construed as representations of other informal behaviors. The lack of "real" information about informal communication in Crane's book prompted one critic to note, "Crane presents almost nothing about the intellectual content or the personalities working in diffusion theory or finite groups" (Hagstrom, 1973; quoted in Chubin, 1983, p. 6).

Subsequent invisible college studies (such as those reviewed by Chubin, 1983, 1985) continued to focus on network structures among individuals, institutions, or documents, rather than on communication processes or the content of those structures. Griffith (1987, p. 9) points out that the invisible

college concept eventually lost Price's "implied, but accurate, historical reference and became overused and problematic." Of course, structural data *can* indicate the presence of communication relationships; however, they do not in themselves reveal the *nature* of those relations, or how specific types of communicative acts might lead to corresponding social structures.

Crane's analysis may be confounded for this reason. She proposes that invisible colleges are informal structures that serve as conduits for both formal and informal communication, yet she implies that such informal structures can grow only from preexisting formal structures. Significantly, Crane frames her argument in terms of "institutions that produce scientific ideas" (1972, p. 3) rather than the reverse, that is, ideas that produce institutions via communicative behavior. She adopts Price's general definition of the invisible college, that is, informal links across *existing* formal social structures, rather than the original definition of links established in the *absence* of formal social structures. Therefore, Crane's findings tend to obscure the central role of communication behavior and interpersonal processes and emphasize the mapping of institutional structures. She uses citation data as evidence of the informal communication relations among her subjects, yet by using structural data she reinforces the primacy of structure over process.

Other researchers had already attempted to define the invisible college or other informal social structures, only to discover similar difficulties. Crawford contrasts informal communication—"a person-to-person relation in which a scientist selects out of the population other scientists to communicate with on aspects of his work" (1971, p. 301) with "formal or *organized* methods of communication" (italics added), including publishing and the presentation of papers at meetings. Essentially, this distinguishes communication in terms of the channels used (and social organizations that support them), not in terms of the behavior involved. Crawford's operational measure of informal communication is sociometric; subjects were asked to name "all persons they contacted at least three times during the past year concerning their work" (p. 302). From the point of view of communication behavior, the issue of contact is problematic, because it does not describe what scientists actually did in the course of communicating and instead measures the frequency or strength of the relation. As a result, Crawford's findings are fundamentally sociometric. Although her sociograms of sleep researchers again illustrate structure, the processes of communication that might constitute or result in such a structure are much less clear.

Mullins (1968) found that every scientist in his sample of the *American Men of Science* defined his or her own group of social contacts differently,

leading him to conclude that invisible colleges did not exist as Price had defined them. Instead, he suggested that a single large network may exist for all science and that the part of that whole that the individual scientist “sees” is what the scientist considers his or her invisible college. However, Mullins did not find any grouping or structure that corresponded to the invisible college, at least as seen from outside the perceptions of individual scientists.

Mullins’s findings, in fact, raise a critical question about invisible colleges, that is, are they structures (discernible and measurable from outside) or are they processes (in which only the scientists involved might participate and, therefore, perceivable only by them)? The dilemma illustrates yet again how difficult it is to look for informal communication processes by identifying and measuring social structures. It may be that if invisible colleges are seen as the constructions of the scientists involved, then they can only be known, as it were, from inside the college itself. The large “network” of science, as measured via its publications or other structural indicators, is interesting, but ultimately the individual scientists’ views of the college may say more about the reality of the communication processes they engage in.

Lingwood (1969, p. 172) used a more open-ended definition: “An invisible college may be defined as a system of scientist-units interacting frequently about some shared topic of research interest.” He relied on a sociometric criterion (the frequency of interaction) to determine the existence of an invisible college among his “scientist-units,” leaving the nature of the interaction as an open question.

Similarly, in his discussion of the conceptualization of “scientific specialties” in the wake of Crane’s book, Chubin (1976, p. 449) outlines what he believes to be the critical questions for social studies of science. His use of the term *specialty* implies the technical nature of the work being done, whereas *invisible college* has a more social, informal connotation. Nonetheless, Chubin sees them as closely related concepts. The prominence of structural issues in his list, and the corresponding secondary role of communication, is clear:

1. What are the social and intellectual properties of a specialty?
2. How do specialties grow, stabilize and decline?
3. What are the temporal and spatial dimensions of a specialty?
4. How do specialties vary in size, scope and life expectancy?
5. What are the institutional arrangements that support specialties?
6. What impact does funding have on the kind and volume of research produced in a specialty?

7. What kinds of communication relations sustain research activities in a specialty?

Chubin's list reiterates some of Crane's assumptions, for example, that institutions precede communication relations; that specialties have specific boundaries apart from human actions; and that communication "sustains" social structures, instead of being the fundamental activity that constitutes those structures.

Crane's principal legacy for communication research, then, is a theoretical construct that is highly suggestive but that is difficult to operationalize. Paradoxically, the term *invisible college* describes an informal communication process, yet researchers look for it in formal social structures and documents. The resulting ambiguity, built into the construct in the absence of a clear definition, has led researchers to use the term very differently from study to study. We are led to ask, why has a construct as popular and apparently as rich as the invisible college yielded such a scattered and unfocused body of studies of communication in science? Would a more coherent definition help to reestablish communication as the central concern in invisible college studies as well as other social studies of science?

### Future Directions for Communication Research in Invisible College Studies

If the invisible college is considered to be an informal social phenomenon, then a preliminary definition can be proposed:

*An invisible college is a set of informal communication relations among scientists or other scholars who share a specific common interest or goal.*

Essentially, this definition removes a number of assumptions that have grown up around the invisible college concept, such as prerequisite formal institutional structures or the importance of geographic distance. The definition refocuses the concept theoretically around communication processes and suggests a related set of research issues:

- What kinds of communication behavior produce an invisible college? Is the presence of certain kinds of communication acts (e.g., the exchange

- of article preprints, or face-to-face meetings) sufficient for a group of acquaintances to be considered an invisible college?
- How do individuals perceive their interactions with others within, versus outside, the invisible college? Do outsiders perceive the invisible college the same way that insiders do? How do insiders' perceptions vary from person to person?
  - What is the effect of time on the communication processes in an invisible college? What measures might be developed for observing this effect?
  - What does *closeness* mean within an invisible college? What amount of cohesion must members experience in order to define themselves as a group?
  - Is cohesion within an invisible college based on the sharing of information, on interpersonal/emotional affinity, or both? Are the members of invisible colleges emotionally involved with one another to a greater or lesser degree than other kinds of social groups?
  - Is the invisible college a freestanding information system, or does it relate to other systems that act as information resources for its members? Do individuals use invisible colleges as resources to help fulfill their information needs?

## Discussion: Methodological Implications for the Study of Communication in Science

Where, then, does this leave bibliometrics as a methodological tool for studying communication behavior?

Obviously, few of the questions listed above can be answered using only the measurement techniques that have dominated invisible college studies in the past. The bibliometric links among publications or (by the same token) the sociometric links among the members of the professional societies or the faculties of certain institutions may provide clues about the existence of an invisible college, but by definition an informal relationship would not appear fully formed in its formal products or structures.

Certainly, bibliometric techniques are important because they give analysts the ability to crystallize abstract ideas into apparently concrete forms. They can inspire theoretical thinking—and in this respect, the durability of the invisible college construct testifies to the fundamental value of bibliometric analysis for communication research. By allowing us to construct maps of documents, bibliometrics gives us a systematic glimpse of the communication acts that produced the documents in the first place.

However, scholarship is a multilayered social world composed of and driven along by the communication behavior of individuals. Scientific and scholarly communication might be explored in more depth using the fieldwork techniques typical of ethnographic studies of communication in neighborhoods or families, for example. Participant observation and interviewing seldom have been used to understand the unique nature of scholarly processes like mentoring, coauthorship, or collegiality. Discourse analysis of face-to-face conversations, phone calls, or even presentations at professional meetings might reveal communication patterns that distinguish one specialty from another (e.g., the work in progress by Knorr-Cetina, 1988). These methods offer the communication researcher a great deal of interpretive and heuristic power when combined with the results of structural (bibliometric or sociometric) analysis.

Moreover, the ethnographic approach is a separate issue from the dichotomy between formal and informal scholarly communication that has been emphasized in social studies of science since at least the 1960s. Griffith (1987, p. 9) notes that, like bibliometric studies, studies of informal communication in science have been "infected with Price's ideas about counting people and acts of communication and bits of information." The typical informal communication study might be characterized as a quintessential "artifact" or "user" study (Lievrouw, 1988), in which the assumption is that information (and communication) are materialistic commodities that can be operationalized and counted.

Alternatively, communication researchers might take the example of constructivist sociologists such as Knorr-Cetina (1981, 1988), Restivo (1983), or Latour and Woolgar (1979), who in their "lab studies" of science, assume instead that knowledge is phenomenological and ephemeral, a social construction of the scientists involved. From this perspective, documents are data without intrinsic meaning of their own. They remain data until individual scholars make sense of them—until scholars engage in the act of informing themselves and their colleagues via communication.

The main advantage, then, of an ethnographic methodology in studies of scholarly communication is that it would allow researchers to make more powerful interpretations of the quantitative analysis of communication artifacts. In a famous essay on the use of ethnographic methods in organizational communication research, Van Maanen points out (1983), "The territory is not the map." Nor, we might add, is the territory of scholarly communication to be found intact in the maps of bibliometrics. However, we also know that the territory cannot easily be navigated without a map, and that the map is

meaningless unless the traveler can interpret it. Both the bibliographic map and its ethnographic interpretation are necessary to move through the territory of scholarly communication.

## Notes

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2. Historically, there has been an overwhelming emphasis on the study of science as opposed to other scholarly specialties, and this imbalance is clearly reflected in the present article. However, despite their overrepresentation in social science studies, the sciences are not necessarily more important than the humanities, arts, or social sciences as subjects of research. The biomedical sciences are a particular research interest of the author, but no special preference for the sciences over other subject areas is intended.

3. For example, co-citation analysis relies on the patterns of documents in which the same two papers are cited together (Griffith, Small, Stonehill, & Dey, 1974; Mullins, Hargens, Hecht, & Kick, 1977; Small, 1973). This consistent relationship of two papers together in other papers is usually interpreted to mean that the two papers have something to do with each other, and therefore that there may be a social link between the authors of the two papers (see also Lievrouw, Rogers, Lowe, & Nadel, 1987).

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