Scholarly communication and bibliometrics: I. Scholarly communication model
Literature Review

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Abstract

This article represents a literature review that has two parts. Her is talking about the first part: scholarly communication model. 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 article is a compilation of scholarly communication models at the intersection of scholarly communication and bibliometrics.

Introduction

Information transfer has become an essential element in our obtaining the knowledge needed for scientific development, economic progress and social improvement. Dissemination of information has therefore become of extreme importance in our modern society (Garvey, 1979).

Investigating the relationship found in the documentation of a subject field is one method of examining the communication taking place in the field. Bibliometrics or " the application of mathematics and statistical methods to books and other media of communication" provide a method for examining communication among scholars in a field through their scholarly publications. As has been advanced by numerous studies, these relationships can by no means be assumed to represent all communication among scholars. Furthermore, documented communication may offer important insights into patterns of relationships, research focus, interdisciplinary links, and changes in communication over time. Bibliometric relationships such as citation, cocitation, co-reference, author cocitation, and coauthorship have been studied in attempts to provide documented evidence for communication within and between scholarly fields.

Scientific communication begins with an idea that is shared among colleagues who then help to shape the direction of that idea. The idea is presented to larger groups, usually at discipline-related meetings or conferences. The idea may be incorporated in a report or pre-print. Modified to varying degrees by all the prior inputs, the idea is then submitted in written form for publication in a scientific journal. Readers may respond to or in some way incorporate the article into their own thinking. The article continues to be available to anyone who is interested as it is cited by other writers, indexed, and described in annual reviews, encyclopedia articles, and citation indexes. Other people who are interested in the concept he or she presented, or can communicate with other people who are building on those concepts might contact the author of the article. The process of sharing scientific information among increasingly larger groups has traditionally been described as a continuum that ranges from informal to formal communication (Garvey, Lin and Tomita, 1994).

Bibliometrics as a method can map the scholarly communication process by tracing the formal communication (articles published in journal and citations). Formal communication is demonstrated to be one of the most important communication channels in scholarly research. Because informal communication is not represented by something as concrete as the written work, the units of analysis are the individual and the group. Self-reports, observation, and questionnaires are the methods to study informal communication but all of these have their inherent problems. Examination of the formal written literature is often accomplished through quantitative bibliometric techniques such as citation analysis. The unit of analysis is most often the journal article. Most of the articles are focus on formal communication by using bibliometric method, and really made great process in this research field.

Researchers in bibliometric and scholarly communication fields use models to explain processes to communication or flows of information. Here, the author generalised some useful scholarly communication models for bibliometrics and scholarly communication researchers.

Scholarly communication model

The first and perhaps most influential model was that due to the mathematician Shannon and Weaver (1949), who became interested in the problem of transmitting accurate messages over a communication channel. Although originally developed in an electrical engineering context, this model has been widely used in research fields that involve human communication. Essentially the model is a linear one, proceeding from the producer of the information to the encoding of a message, which is then transmitted as a signal that is received and decoded to become a message for the receiver or user. The model contains the concept of feedback, which emphasises that producer and user of the message will also become user and producer so that the process is circular. This circularity and feedback are characteristic of the scholarly communication process.

Shannon's mathematical communication model

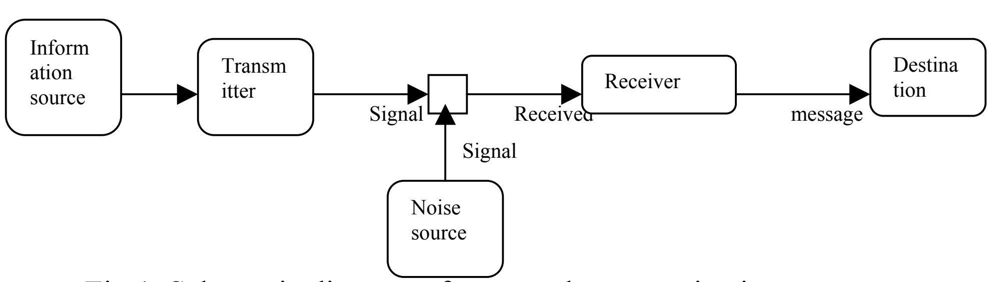


Fig 1. Schematic diagram of a general communication system

Shannon first published his mathematical theory of communication in 1949. While his theory has a profound influence on studies of information processing in many areas of science and technology, its impact on information science has been minimal. Shannon's statement about the efficiency of transmission of message—made particularly in regard to mechanical devices for the transmission and storage of information—indicates quite simply that the efficiency of transmission of information is greatest when the symbols of the message are equally frequent and statistically independent of one another. He provided a quantitative measure of this efficiency expressed as the entropy of the message.

Lynch (1977) reinterpreted Shannon's model based on the definition of new symbols sets, comprising approximately equally-frequent strings of characters and then applied it in computer-processing of texts. It provides a more general formalism for considering methods of representing, storing and retrieving the subject content of documents. Even Shannon's model has not so much impact on information science, most of the impact is focus on information retrieval studies. Few researchers applied Shannon's model into scholarly communication study.

Scholarly communication process model

Hills (1983) set up a simple six-part model of scholarly communication process. The six parts of the model are 1) the scholar as producer of scholarly information and as user of scholarly information; 2) learned societies; 3) the publisher; 4) the product; 5) the librarian; and 6) the influence of the new communication technologies.

The scholarly communication process is an integral and complex interaction of all of these parts, but in terms of simple interactions, the scholar both produces and uses scholarly information, relying on formal and informal communications to keep abreast of relevant sources of information and ideas for his work. The scholar is the central point of the model without whom there can be no scholarly communication. The learned society provides the framework that brings together scholars who are working in similar fields and helps to disseminate information and to communicate effectively. The publisher is the agent of dissemination and may be the scholar himself, the learned society, or a commercial organisation. The product, the outcome of the desire to communicate, comes in many forms—e.g., books, monographs, journals, reports, grey literature, and theses. The librarian has traditionally stood between the scholar as user and the information, but this is now changing with the influence of the new communication technologies that extend to all aspects of the process.

Sullo, et al. (1979) improved and supplemented Hill's research. They concerned with information produced to satisfy a specified purpose or to achieve preconceived objectives. They utilized existing mathematical methods from reliability theory and identified the critical components in an information flow network and provided a quantitative assessment of their importance. The model incorporated explicitly the concept of an information producer contemplating a choice of action in an uncertain environment. The method is based on document usage network and graph theory, which can provide an extensive body of theory and methods for the analysis of information flow.

Informal and formal communication model

Information may be communicated informally by direct contact between individuals. Informal communication is independent of the literature and can be difficult to document and evaluate. However, certain informal processes become observable when individuals jointly publish the results of their research.

Coauthorship identifies a set of particularly effective informal communication channels that are associated with the generation and publication of new knowledge. If any two individuals coauthor a paper and if the second coauthor with a third, there exists a coauthor chain which links the first and third author. These coauthor chains represent existing and potential channels of documented informal communication.

Information may also be communicated formally through the literature. Direct citation of one author by another can have a variety of implications. It is taken to indicate that a formal channel of communication has been established between these two authors. The existence of this channel implies that information has been or could have been transmitted from the cited author to the citing author.

Mutual citation will be required to establish a formal communication link between any two authors, that is each must cite the other. Mutual citation provides further assurance that an exchange of information has occurred. Informal and formal communication occur simultaneously within a population of authors and can be treated simultaneously in the model set up by Shaw (1981). Informal communication can be linked if any member of one class formally communicates with any member of another, in this case, classes are formed which can be represented by a condensation graph whose elements are coauthor classes and whose links are mutual citation.

The results showed that the information theory could provide a highly selective measure of the contribution that authors and journals made to these processes. Authors can be evaluated in terms of their contribution to informal and formal communication processes manifest by coauthorship and mutual citation. Journals can be evaluated in terms of the formal communication process.

This model here can be used to monitor communication processes in a given field as function of time and to compare these processes in different subject fields and it is also possible to measure the influence of a given author or journal in different subject fields.

Communication pattern model

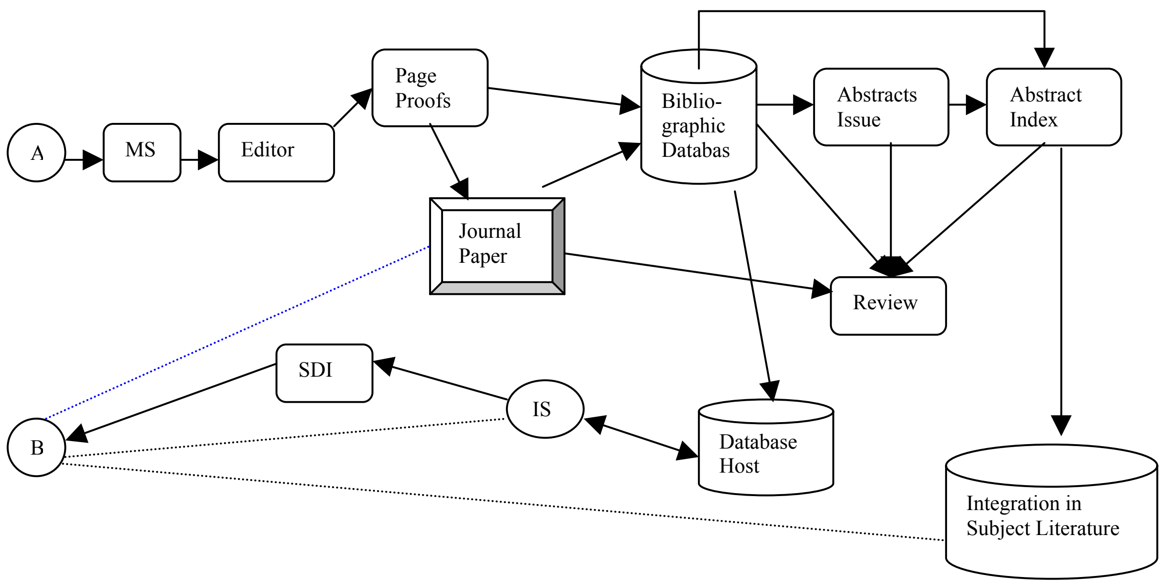


Fig 2. Communication Patterns Model (MS: Manuscript, IS: Information Scientist, A and B are users).

Bibliometric studies can provide much data for models of communication patterns. Garvey and Griffith's (1972) studies are well known and often cited. They set up a model of communication pattern and modified to incorporate the concept of transmission losses in the pathway from manuscript to integration into the subject literature. As the model incorporated both a time factor and an information yield factor, it shows some analogies with the reaction kinetics of a multistage process. Bottle (1983) used this model to study the changes in the communication of chemical information. The most important pathways in the model are show in Fig 2.

Information expert system model

An expert system can be viewed as a method of recording and displaying human competence where human competence is the agreed ideal behavior within specified environments. The expert system performance is closely related to the processes of the dissemination, exchange, and the utilization of scientific and technical information in the research field, as well as in the production activity area. Decision problems relating to scientific and technical information appear mainly in:

- the planning, initiating and evolving of scientific research, the planning of experiments, the interpretation of the results etc.
- the information transfer between research and industrial centers, especially in seeking solutions for construction and technological problems.
- The modernization and design of new constructions and products.

These areas indicated above concerning decision problems denote potential domains of activity for scientific and technical information expert systems.

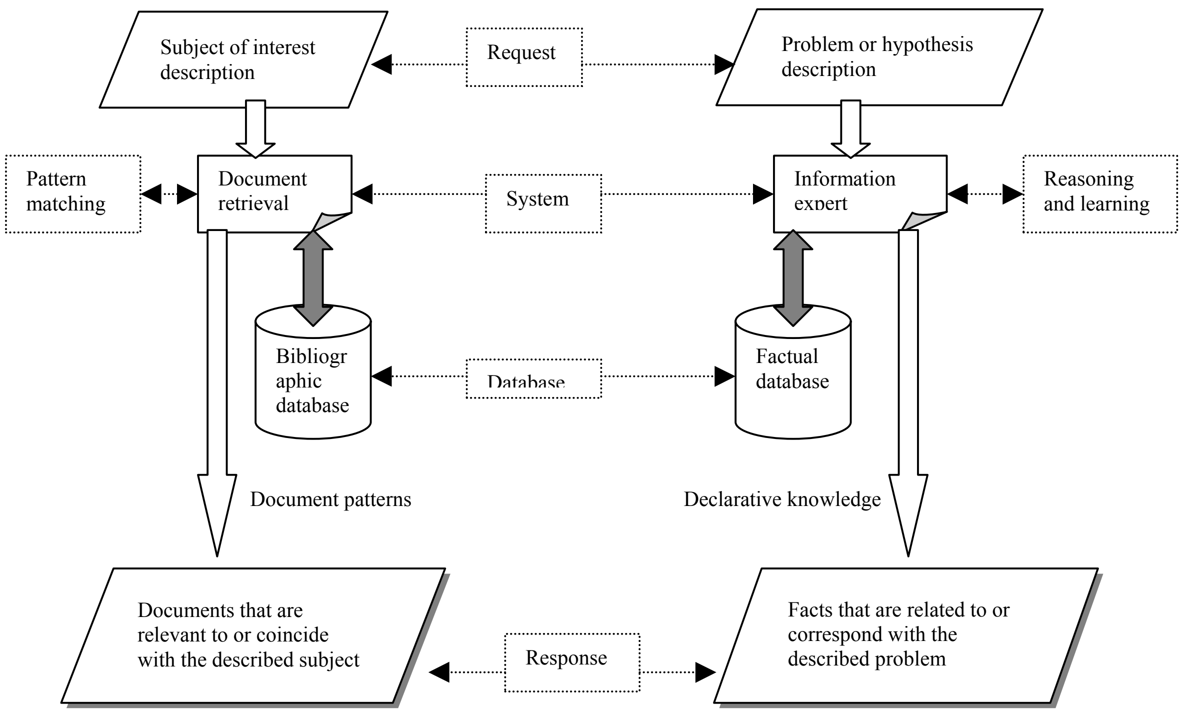


Fig 3. Document retrieval vs. information expert system

Information expert systems the most representative tasks will be similar to those of interpretation and diagnosis. The interpretation task is usually understood as the analysis of data to determine their meaning while diagnosis is defined as the process of fault-finding in some systems and is based on the interpretation of potentially noisy data.

It should be noted that data analysis in the information expert system may be only fairly precise but should be rigorously complete. This is due to the fact that insufficient precision of a system may in many cases be considerably improved by well-designed feedback to the user, there is practically no possibility to compensate for a lack of completeness. The information expert system, as with most of the existing expert systems, should organize knowledge on three levels: data, knowledge base and control. The development of scientific and technical information expert systems may considerably improve information transfer, thus increasing the effectiveness of its utilization in the scientific as well as in the production areas of activity. This situation may in coming years have a strong impact on the rate of the further development in science and technology. More detailed information can be seen in the work of Nowak and Szablowski (1984).

Formal Communication Model based on Generalized Nets

Various studies of the communication network in science have been carried out (Atherton, 1975; Garvey, 1972a, Garvey and Gottfredson, 1976; Hills 1983; etc.). Different models have been used to explain the informal and/or the formal communication processes. The models of formal communication in science are predominantly linear and emphasize variously media (articles, journals, books, etc.), participants (individuals and institutions) or functions (activities). Todorov and Atanassov (1986) presented in outline form a formal communication process by stressing the specific functions and participants required for the traditional transfer of article manuscripts from the author (originator) to the reader (consumer). They chose a mathematical model with a time component based on Generalized Nets (GN) to describe of this process. GN is a graphically oriented tool for modeling, including as particular case the Petri nets, the E-nets, etc.

The dynamic components of the GN are called TOKENS in this model representing the article manuscripts in the process of publication or the journal articles as a final product. The tokens enter the net with initial characteristics, which then change with any transition from one place (position, station, or location), to another in the net. The PLACES symbolised the participants in the communication process. A TRANSITION is defined by a triplet: input (input places), transit condition and output (output places). Fig 4 shows a transition comprising two input and three output places.

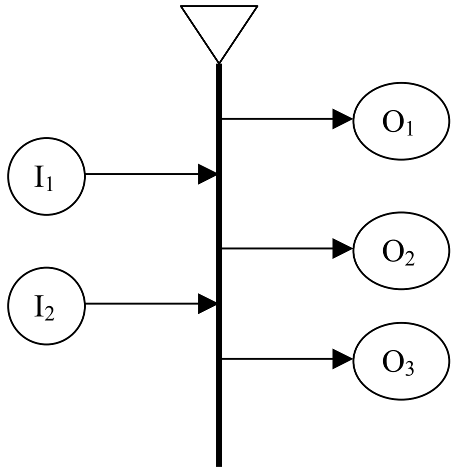


Fig 4. Main structure component of the Generalized Nets including transition condition (t), input places (I_1, I_2) and output places (O_1, O_2, O_3).

The transition condition is expressed by means of a matrix of predicates R_{ij}. In the case of Fig 4., the matrix is:

$$\begin{vmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \end{vmatrix}$$

The two rows and the three columns correspond to the two input and three output places. The predicate R_{ij} expresses the possibility of the tokens to pass from the input place I_i to the output place O_j. Correspondingly, the predicate has two possible values 1 and 0. If the predicate R_{ij} takes the value 0, then a transition form I_i to O_j cannot be realized. A predicate could be false (r_0): with only one possible value 0. The predicate could also be a logical truth ($\overline{r_0}$) and then its value is always 1. $\overline{r_0}$ represents the negation of r_0.

The GN includes two time components: one that corresponds to the total duration of the net functioning and the other that is the so-called time and is related to the transition processes. The model based on GN is sufficiently powerful to be used for the description of the whole (complex) structure and dynamic picture of knowledge generation, representation, distribution and use or for the detailed representation of a specific part of the communication process. This model remedies the major shortcomings of traditional (linear) models that ignore the fate of individual manuscripts, and lack a time framework, etc. By means of the GN specific actions and interactions could be determined (quantitatively, qualitatively, and in time). The practical importance of the model based on GN is growing with the increased use of computers by all concerned with formal communication in science.

Viable Information transfer system model

De Raadt (1990) examined the process of information transmission in adaptive, viable organizational systems by using Beer's viable system model (Beer, 1979). The elements of a viable system include operational system and metasystem, adaptation and transmission of information, systemic cohesion. The operational system that corresponds closely to the concept of task in organization theory, the main characteristic of the operational systems is that it is the part of the organization that does the 'work'.

The metasystem infuses information into the operational system and provides cohesion between one operational system and another. The ability of the operational system to perform an operation on an input and obtain a desired output is due to the availability of a model containing stored information in the form of operational instructions. The amount of information contained in a model is referred to as " task information" and is expressed as a ratio between the correct operational instructions stored in a model and the number of inputs from the environment (de Raadt, 1988):

From a systems point of view, organizational cohesion is defined as the dependence that exists between two systems. That is, given an operational system and its metasystem, the cohesion between them is reflected by the degree to which the actions of one system determine the actions of the other. Cohesion is at least partially determined by the level of information transfer between systems. The transfer of information will increase the operational variety of the system until the system becomes viable. De Raadt (1990) empirically tested the model with data collected from insurance agents in Australia.

Information physical diffusion model

The formal theory undergone a certain development is considered as the diffusion of scientific and technical information which is analogous to that of heat in solids, and applies the Fourier law to the information (Avramescu, 1973). The Fourier law is a mathematical formula for finding the quantity of heat that diffuses through a solid (or a fluid) when two sides are at different temperatures (a temperature gradient exists):

$q = -\lambda * grad\mu$ or in linear form $q_x = -\lambda * \partial\mu / \partial X$

In a space of three dimensions, the heat flux q (the quantity of heat per unit of time and per unit surface) is proportional to a potential μ (here, the temperature) and to a factor λ that characterizes the conductivity of the material. In the same way, by formal analogy, the flux of information q is proportional to a potential μ representing the interest that readers show in an article, and a factor λ measuring the accessibility of the information, which depends on the circulation of the journal, on the language in which the article is written, and on the level and style of the article.

How is the interest measured? By counting the number of times it is cited elsewhere. Through what space does the information in the article diffuse? These are the articles interrelated with each other by references and citations, concerning the same subject and which are contained in different scientific journals (Avramescu, 1975). Pursuing the analogy, it is possible to determine the information gain obtained after reading an article, which will allow an author to produce new articles:

$$q = \chi \bullet \partial\mu / \partial \mathrm{t}$$

Where χ is the information assimilation capacity (heat accumulation). From the above equations, we can deduce the famous Fourier equation that applies to all physical

$$\partial \mu / \partial t = a \bullet \partial^2 \mu / \partial^2 X$$

diffusion phenomena:

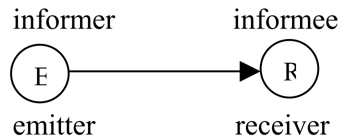
Where $a = \lambda / \chi$ is the diffusion coefficient, or diffusivity.

The first results obtained with this model of diffusion have made it possible to confirm a major bibliometric law, the Broadfrod's Law, to confirm the law of obsolescence of articles and to propose new definitions of informational energy and entropy that are consistent with their counterpart concepts in classical thermodynamics.

The condition for information transfer is that there must be the difference of information energy of information sources. If no, there will be an unsteady equivalence. The information energy and information entropy will not change. If yes, information transfer will happen between the two information sources and the result is that through this convection, the two information sources are going to achieve the same information energy and information entropy. This process can be easily understood by applying physical thermodynamics model into information science.

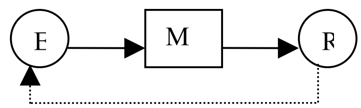
Information technical transmission model

The somewhat simplistic modeling of the mass media that preceded it limited the communication to a directive, unidirectional, informer-informee relationship, expressed immediately by an emitter-receiver analogy: the theory of information has maintained the linear form of this relation but has mechanized it by inserting the message.



The resulting model, very widely accepted, is:

Technical model



This relates an emitter E, which 'communicates' a message M, to the receiver R. The ideas of code, channel, noise and feedback are brought in to refine this idea, but without making it into a model of social communication. The signal transmission analogy has impeded progress in our knowledge of the communication of information. Adding to the conceptual difficulties like the confusion already pointed out between the 'information' concept in electronic communication and its counterpart in human communication, this analogy sets up an epistemological obstacle to the science of information.

Information social communication model

This time, biology serves as the reference science. A formal analogy is made between the diffusion of epidemics and the diffusion of information in a population of scientific researchers. Using epidemiological properties, we can thus represent an information distribution process by an epidemic or contagion process (Goffman, 1964). One of the simplified mathematical models of contagion is the logistic one, with a deterministic expression as follows:

$$\frac{dn}{dt} = \beta \bullet n(N - n)$$

Where N is the total population of researchers, n is the number of people who have received the information, (N-n) is the number who have not, t is time and β is the coefficient of interpersonal communication. Now the written communication is ignored. Moreover, the logistic model is more a descriptive model than an explanatory one. The processes of social communication are generally too complex to be reduced to mechanical processes of contagion.

As sociology has become mathematised, attempts to formalize the phenomena of communicating rumors, ideas, attitudes, behaviors and information have led to deterministic and stochastic (or probabilistic) models of inductive impact. This mathematical model was successfully used to analyze the diffusion of scientific articles in chemistry (Le Coadic, 1979). The communication efficiency in research and development is also discussed by Wilson (1993).

Epidemic model

It is plausible to try to analyze the development of various subareas of logic by means of the mathematical techniques of epidemiology. A necessary condition for an area of being in an epidemic phase during a period Δt is that the numbers of active contributors and publications increase exponentially and that the share of output of the area in relation to the general expansion of mathematical logic increases at least linearly during Δt.

This model is based on generalized Lotka's Law:

$$f(x) = f(1) / x^{\gamma}$$

Where x (the number of contributions) and f(x) (the number of authors with x contributions) are non-negative integers, γ is a positive real number, if γ equals 2, the basic equation expresses the so-called Law of Lotka.

We can say that a scientific discipline is in an epidemic phase during an interval Δt if and only if all distributions during Δt exceed the prolific elite limit with a negative slope for all exponential regression lines of γ and if the parameter curves of concentration, persistence, length, and dilution form an ascending sheaf during Δt (Berg and Wagner-Dobler, 1996).

Model of manifested communication through publications (MCP)

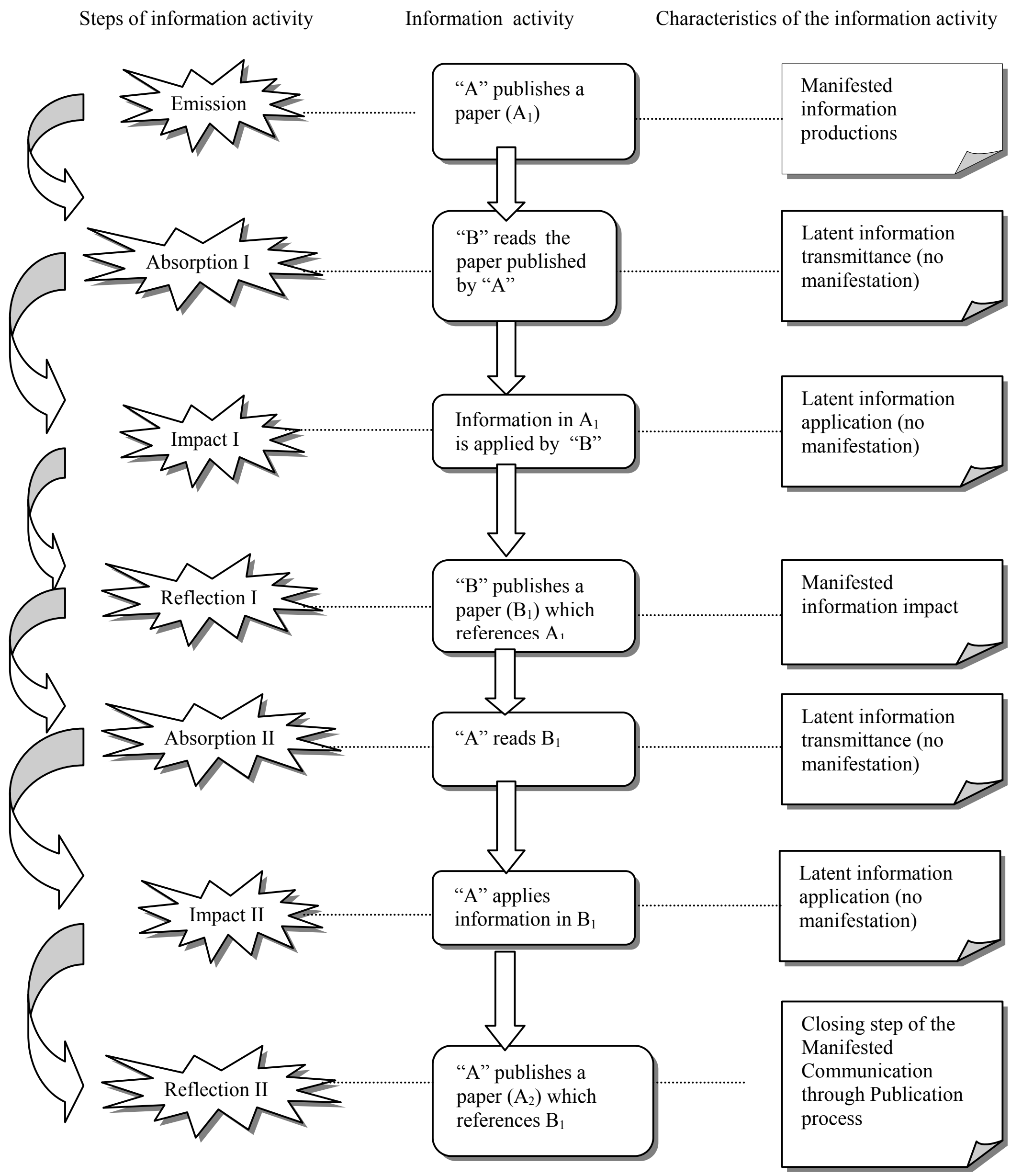


Fig 5. Steps of information activities in the Manifested Communication through Publication model (MCP)

Information processes in scientific research assume information emitters and absorbers (researchers), and pieces and channels of information as a proxy unit of information produced by information emitters. Main channels for transmitting information are periodicals and books. Vinkler (1994) suggested a communication model (model of manifested communication through publication) in order to quantitatively describe bilateral communication processes of researchers through scientific papers. The communication process performed through publications involves producing, disseminating, absorbing, applying and registering.

The complete cycle of MCP is show in Fig 5. A disrupted or aborted cycle at Emission or Absorption can be characterized as information production and information transmittance, respectively. The former act is manifested by the appearance of the publication itself, whereas the latter cannot be observed by an outside person. The situation is the same at Impact I, where the impact of the information embodies in paper A_1 can not be traced. There can be found, however, proofs of the impact outside the literature, like personal communications, lectures held etc. which are, however, hard to follow by outside persons. The step, Reflection I, of the information activity manifests the use (impact) of the published information (A_1) by "B". This activity step may represent the starting act of the second half of a whole MCP cycle.

The next step (Absorption II) of the MCP cycle is the absorption of the information emitted by "B" which is followed by Impact II and Reflection II done by "A". It is to be noticed that both reflection steps involve manifested information production as well, similarly to Emission. It has to be stressed that an information process containing all of the seven steps mentioned is needed to form a single MCP cycle.

The whole MCP cycle is a long process, the duration of which is hard to predict. Publishing a paper by team "A", dissemination of the respective journal, its noticing and reading, then applying pieces of information embodied in the paper by team "B" take time, sometimes only some months, but more frequently one or several years depending on many objective and subjective factors. Publishing a paper by "B" containing reflection to that of "A" would last several months or even years as well.

The second half of the MCP cycle would require a similar period. The whole process may be performed in about 6-36 months in average by authors (or teams) working independently from one another from organizational and hierarchical aspects. The MCP model makes it possible to determine not only information emission and absorption but also real communication between papers in the game of international scientific research.

Measurement of scholarly communication links

There are also many ways to measure the strength of the communication links.

Burt (1982) investigated networks of persons ("actors") in given systems. He defined a structural proximity coefficient (h_{ij}) varying between 0 and 1. Swanson (1987) and Chen (1993) investigated connections between documents.

Ritchie (1977) elaborated a method for the application of communication matrixes to explore technical information flows within a laboratory. The entries ($s_{ij} = k/f_{ij}$) of his basic communication F matrix measure the strength of the communication link between two scientists (i, j), where f_{ij} is the number of communications between the two persons, whereas k is a suitable scaling constant.

Crawford (1971) combined sociometric and bibliometric methods and found a high correlation between sociometric data on informal communications and data obtained from an analysis of citations appearing in the literature.

Garfield (1979) suggested the potential usefulness of references for history of science. The network diagrams (e.g. how the DNA theory was developed and proved, as defined by citation connections) were named as "historiograms".

Pinski and Narin (1976) constructed a matrix containing the number of references given and citations received by journals and introduced several indicators for the interaction of journals. Reference based on measures for determining interactivity of journals of Pinski and Narin (1976) were improved by Kretschmer (1990). Information flows through the citation network by computing influence weights were studied by Noma (1988).

Carpenter and Narin (1973) defined a measure characterizing information distance (D) between two journals (a, b). Robinson (1991) applied the mentioned techniques for economic journals.

One of the most successfully applied techniques to find information links between documents is co-word analysis, which counts the most frequently used keywords common in the documents investigated. In order to reveal relationships between publications of patents, van Raan (1988) introduced the method of combined clustering and multidimensional scaling based on co-word analysis.

Summary

The visibility and importance of formal communication in science makes the use of literature-based measures a natural and valid approach to the study of communication phenomenon. The scholarly communication models help researchers to deep analyze the scholarly communication process. Researchers also can measure the strength of scholarly communication quantitatively. Based on scholarly communication models and quantitative measurement of scholarly communication strength, the results of such researches will have strong reliability and validity.

Acknowledgment

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