CHAPTER 1

PERSPECTIVES ON SCIENTIFIC KNOWLEDGE, COMMUNICATION,

AND UTILIZATION

"The importance of scientific communication is, in fact, so paramount that recent trends in sociological analysis of the scientific community or attempts to establish measures of scientific output are formulated in terms of scientific communication.

Apart from technological applications several steps removed from the underlying scientific research, the visible manifestation of scientific research is mainly the communication of research results.

The "product" of scientific activity is a new discovery or idea which, if it is to be utilized, must be communicated."

(Moravscik, 1976)

Overview of the Field

The irony about the field of scientific knowledge production, communication, and utilization is that while its beginnings can be traced to the dawn of science, its place as a research topic is of recent origin.

Yet credit for formulating the whole concept is due to Sir Francis Bacon, the seventeenth century father of modern science. Bacon, both a farmer and philosopher, not only devised the techniques of inquiry which formed the basis of scientific experimentation, but also demonstrated additional interests in communication and utilization, beyond the mere production of knowledge.

> "The purpose of (Bacon's Novum Organum) is to discover the nature of things and to produce arts and works... To produce works, man must know causes; and these he can discover only through what he observes of nature's structures and ways. What in knowledge is the cause is in operation the rule." (1)

In Bacon's view, these "rules" were part of the technologies to be used by people. Knowledge was thus to be treated in a purposeful way to solve the problems of the human race. By implication, communication and utilization were essential components in this process. The resultant society was described in his utopian New Atlantis.

Scant attention seems to have been paid to these propositions during the intervening four centuries. In fact, concerted scholarly efforts to explore the field largely span the past 25 years.

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1. Anderson, F.H. The Philosophy of Francis Bacon. Chicago: University of Chicago Press. 1948. p. 183.

The Havelock Review

The size of the field as a specialized domain for study became clear when Havelock wrote Planning for Innovation through Dissemination and Utilization of Knowledge in 1969. (1)

Havelock reviewed some 4,000 publications dealing with planned change to prepare this review, and it still remains the best overall entry to the field. This work, commissioned by the United States Office of Education, was the major product to come from the Center for Research on the Utilization of Scientific Knowledge (CRUSK) in the Institute for Social Research at the University of Michigan.

The particular advances for which we are indebted to Havelock were the derivation of three research perspectives. These were named:

* Research, development and diffusion (representing macromodelling and the systematized knowledge flow from research to practice group),
* Social interaction (representing the social communication group), and
* Problem solving (representing the human relations area).

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1. Havelock, R.G. , in collaboration with A. Guskin, M. Frohman, M. Havelock, M. Hill and J. Huber.
   Planning for Innovation through Dissemination and Utilization of Knowledge. (CRUSK) Institute for Social Research. Ann Arbor: University of Michigan. 1969.

Havelock noted that the hallmarks of the models comprising the first paradigm were that it was a rational process, that planning was obligatory, there was a division of labor, and high investment.

The prototype of the first perspective is the agricultural research and extension system, wherein agricultural extension is the essential scientific and technological transfer component.

Agricultural extension is the oldest, most elaborate, and, arguably, the most successful structured macrosystem for the utilization of knowledge. In the United States, the cooperative extension service, with the backing of the land grant universities, and the state experiment stations, operate, in concert, a well defined system for the generation, transfer, transformation and utilization of scientific and technological information about agriculture, home economics and youth development.

Built up over some 100 years, the system exhibits an elaborate arrangement of mechanisms and linking roles, highlighted by the agricultural extension officer and the extension specialist.

In summary, the main elements of the agricultural extension model are a "critical mass" of new agricultural technology; a utilization-oriented research sub-system; a high degree of user control over the knowledge transfer/research utilization process; structural linkages among the research utilization system's components; a high degree of client contact by the linking sub-system; a spannable social distance across the several interfaces, and its evolution as an integrated system.

The model, applied most successfully in the United States, became, with appropriate variations, an institution in other industrialized countries.

In the last 30 years, it has been "exported" to other parts of the world and imitated in whole or in part in many developing countries. (1,2.)

The second of Havelock's paradigms - social interaction - had its roots in anthropological studies of the diffusion of cultural traits, augmented by the then growing number of investigations on the diffusion and adoption of agricultural innovations.

Several major features were derived from the literature in this area. These were: the importance of the complex networks of social relations among individuals; the unique position, as exemplars and norm-setters, and in terms of prestige, of the users in such networks; the importance of face-to-face interpersonal contacts; the group identity of the individual and group loyalty; the essential irrelevance of the size of the adopting unit; and the significance of the phase sequence in the process of adoption.

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1. Rogers, E.M., J.D. Eveland and A.S. Bean. Extending the Agricultural Extension Model. Washington. D.C.: University Press of America. 1983.

2. Brien, J.P. "Some Reflections on the American Model of Agricultural Extension." Melbourne Notes on Agricultural Extension. No. 14. December 1977. pp 75-81.

The third perspective, that of problem solving, emanated from the human relations and organizational development literature, and represented, basically, a psychological and user-oriented approach to communication and utilization.

The aspects highlighted here included the user as the starting point in utilization; diagnosis before formulation of solutions; non-directive change agent involvement; the extent of existing knowledge within the individual; and the strength of user-initiated change.

Havelock integrated the research, development and diffusion, social interaction and problem solving perspectives into a single linkage model of knowledge production, exchange and utilization. He postulated that the key to linkage was an understanding of user needs by resource systems in general, and in turn, an understanding of resource systems needs by users. Such an agreement cleared the way for effective communication - indeed knowledge exchange - between users and resources.

He saw the user taking an active role and said:

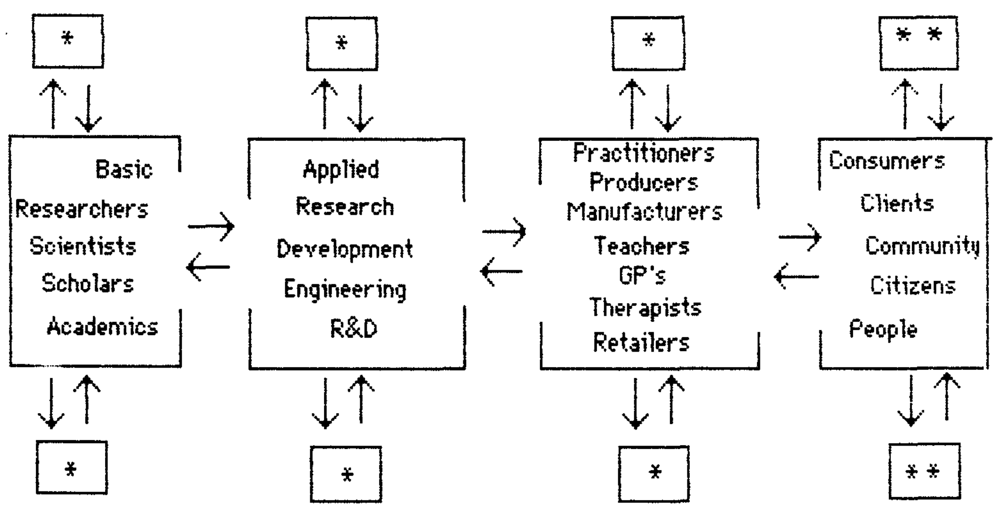
> "The concept of linkage starts with a focus on the user as a problem solver. The linkage model stresses that the user must be meaningfully related to outside resources. The user must enter into a reciprocal relationship with the resource system; this means that something must be going on inside the resource system that corresponds to what is happening in the user." (1)

1. Havelock, R.G. 1969. Ibid. p 11.

Havelock also presented the following model of the knowledge macrosystem.(1)

FIGURE 1

A PARADIGM FOR THE ANALYSIS OF THE KNOWLEDGE MACROSYSTEM



Key to Flow System Diagram:

* Intradisciplinary and interdisciplinary contacts.

* * Other consumers, friends, acquaintances, neighbors, opinion leaders.

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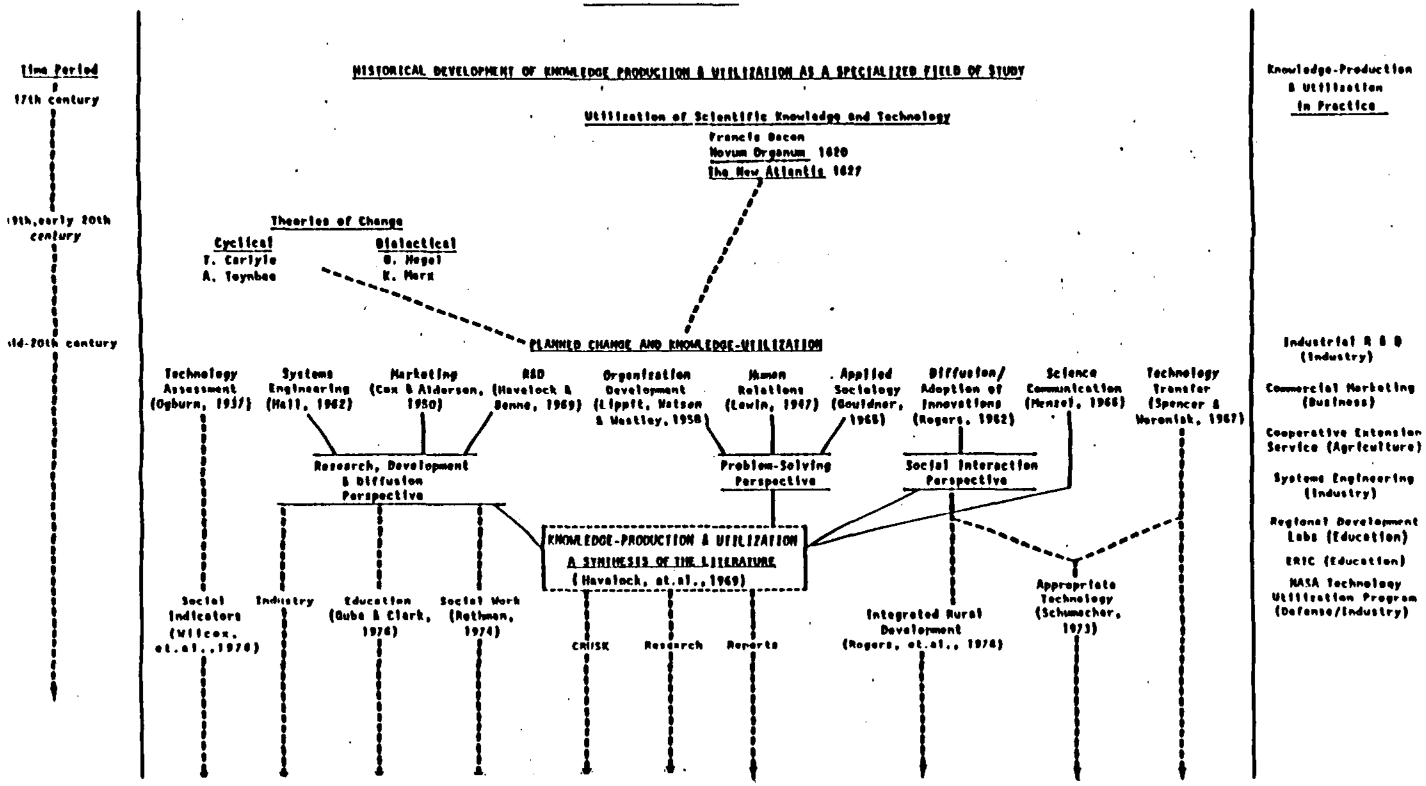
1. Havelock, R.G. Knowledge Utilization and Dissemination. A Bibliography. CRUSK. Institute for Social Research. Ann Arbor: University of Michigan. 1973. p viii.

FIGURE 2


Time Period
17th century
19th, early 20th century
mid-20th century
HISTORICAL DEVELOPMENT OF KNOWLEDGE PRODUCTION & UTILIZATION AS A SPECIALIZED FIELD OF STUDY
Utilization of Scientific Knowledge and Technology
Francis Bacon
Novum Organum 1620
The New Atlantis 1627
Theories of Change
Cyclical
T. Carlyle
A. Toynbee
Dialectical
G. Hegel
K. Marx
PLANNED CHANGE AND KNOWLEDGE-UTILIZATION
Technology Assessment (Ogburn, 1937)
Systems Engineering (Hall, 1962)
Marketing (Cox & Alderson, 1950)
R&D (Havelock & Benne, 1969)
Organization Development (Lippit, Watson & Westley, 1958)
Human Relations (Lewin, 1947)
Applied Sociology (Gouldner, 1965)
Diffusion/Adoption of Innovations (Rogers, 1962)
Science Communication (Menzel, 1966)
Technology Transfer (Spencer & Woroniak, 1967)
Research, Development & Diffusion Perspective
Problem-Solving Perspective
Social Interaction Perspective
KNOWLEDGE-PRODUCTION & UTILIZATION
A SYNTHESIS OF THE LITERATURE
(Havelock, et.al., 1969)
Social Indicators (Wilcox, et.al., 1976)
Industry
Education (Guba & Clark, 1976)
Social Work (Rothman, 1974)
CRUSK
Research
Reports
Integrated Rural Development (Rogers, et.al., 1976)
Appropriate Technology (Schumacher, 1973)
Knowledge-Production & Utilization in Practice
Industrial R & D (Industry)
Commercial Marketing (Business)
Cooperative Extension Service (Agriculture)
Systems Engineering (Industry)
Regional Development Labs (Education)
ERIC (Education)
NASA Technology Utilization Program (Defense/Industry)

The utilization of knowledge is, accordingly, an outcome of effective link between the system or sub-system with the problem, and the system or sub-system capable of assembling solutions. The underlying communication relationships assume paramount importance.

The Meehan and Beal Model

Meehan and Beal, who prepared the accompanying Figure depicting the historical growth of the field, also developed a further model of knowledge production and utilization. This comprised six stages, and continual, interactive communication.(1)

1. The scientific production of knowledge from basic and applied research;
2. Knowledge management involving the indexing and storing in retrieval form the scientific articles, reports and books resulting from activities in stage 1;
3. Knowledge translation involving the synthesing and transformation of research results into information for the solution of practical problems;
4. Development of the product;
5. Dissemination of information about the product; and
6. Adoption and utilization of the product.

The developers of this model emphasized:

> "The production and utilization of knowledge for the solution of individual and social problems is seen as a complicated, interactive, iterative process involving a number of stages, roles, functions, activities, opportunities and constraints.

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1. Meehan, P.M. and G.M. Beal. Knowledge Production & Utilization: A General Model. Third Approximation. Sociology Report No. 138. Iowa State University. Ames, Iowa. July 1977.

> Effective communication is at the heart of the process if relevant knowledge is to be generated, made available, integrated, adapted, packaged, disseminated and used." (1)

Communication in Science

Communication among scientists has long been acknowledged to have a vital role in the growth of science and, almost from its beginnings, a vast published literature exists which provides detailed reports of the scientific work pursued by its practitioners. It is only in the last 20 years or so, however, that communication among scientists themselves has begun to be studied with any degree objectivity and precision.

In Figure 1, scientific communication was listed as a specialised field of study in the area of knowledge production and utilization. Garvey and Griffith, for example, described scientific communication as a social system, and noted that the exchange of information on research itself evolves in a predictable manner. (2)

Menzel was convinced that communication in science was an area meriting further attention. (3)

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1. Beal, G.M. and P.M. Meehan. "The Role of Communication in Knowledge Production, Dissemination and Utilization." Paper to Ninth World Congress of Sociology, Uppsala, Sweden, September 1978.

2. Garvey, W.D. and B.C. Griffith. "Scientific Communication as a Social System." Science. 157: 1967. pp 1011-1016.

3. Menzel, H. "Scientific Communication: Five Themes from Social Science Research". American Psychologist. 21: 1966. pp 999-1004.

He noted five issues in this context: that aspects of scientific communication constitute a system; that several communication channels in science may act synergistically to bring about effective transmission of a message; that informal communication plays a crucial role in the science information system; that scientists constitute publics; and that science information systems serve multiple functions.

There have been some important studies undertaken, (e.g. 1,2,3, 4 and 5), and the field is still being traversed.

The investigation to be described in this thesis examines, as a case study, the communication and utilization of international agricultural science knowledge.

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1. Crane, D. Invisible Colleges: Diffusion of Knowledge in Scientific Communities. Chicago: University of Chicago Press. 1972.

2. Garvey, W.D. Communication: The Essence of Science. Oxford: Pergamon Press. 1979.

3. Hagstrom, W.O. The Scientific Community. New York: Basic Books. 1965.

4. Meadows, A.J. Communication in Science. London: Butterworths. 1974.

5. Passman, S. Scientific and Technological Communication. Oxford: Pergamon Press. 1969.

A Matter of Definitions

Definitions are an important starting point for any study in this area.

Knowledge has been defined succintly as:

> "understanding which is derived from experience of the physical world, the conscious world, and the logical contents of information within a process of communication among two or more persons. Understanding is the capacity to apprehend general relations or particulars; the power to make experience intelligible by applying concepts and categories." (1)

Machlup provided a classification of five major types of knowledge:

* practical knowledge,
* intellectual knowledge,
* small talk and past-time knowledge,
* spiritual knowledge, and
* unwanted knowledge. (2)

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1. Kincaid, D.L. "Networks as Knowledge Generation Systems." Paper presented at the Conference on Knowledge Utilization: Theory and Methodology, East-West Communication Institute, Honolulu, Hawaii, U.S.A. April 25-30, 1982. p 8.

2. Machlup, F. Knowledge and Knowledge Production. Princeton: Princeton University Press. 1980.

Practical knowledge denotes knowledge central to a person's work or profession. Intellectual knowledge satisfies one's intellectual curiosity. On the other hand, small talk knowledge meets a person's desire for light entertainment. Spiritual knowledge relates to one's religious beliefs, while unwanted knowledge is that which is accidentally acquired and remembered.

Before proposing this scheme, Machlup canvassed several dichotomous knowledge classifications such as basic and applied, enduring and ephemeral; abstract and concrete; theoretical and historical; and analytic and empirical. Machlup also considered the commonly used levels of mundane knowledge, scientific knowledge, social science knowledge, artistic knowledge and humanistic knowledge.

The term scientific knowledge, as used in Anglo Saxon countries, is, in Machlup's view, an extremely restrictive concept compared with its meaning in other cultures. While this and other types of knowledge lay various claims on what is "known" or "true knowledge", science, with its controlled experiments, has come to be viewed as a unique form of truth, since it offered a set of rules for inquiry which promised precision and procedures for eliminating bias and human error.

Scientific knowledge can be manipulated in various ways. It can be collected, sorted and summarized, possibly translated into another language, adapted to fit particular contexts, abstracted and generalized. Scientific knowledge is transferred to and received by other scientists, who, in the process probably pass through several sequential mental steps which might include awareness, interest, understanding, and then agreement or disagreement.

Scientific knowledge utilization can be seen, essentially, as a matter of building links between the production and utilization processes. Utilization then becomes, in generalized terms, an input/output procedure.

Depending on the needs of the user, the use of information can then be categorized as either instrumental (immediate and directly observable) and conceptual (less readily observable due to delayed and defused impact). (1, 2)

A common approach has been to view utilization in a simple, primitive, instrumental way.

Larsen and Werner consequently proposed an extended utilization/non utilization protocol. Thus, utilization could be classified as:

* complete implementation of the information presented;
* adaptation of the information;
* partial use of the information; or
* progress towards, but full implementation incomplete. (3)

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1. Caplan, N., A. Morrison and R.J. Stambaugh. The Use of Social Science Research Knowledge in Policy Decisions at the National Level. Ann Arbor: University of Michigan. 1975.

2. Weiss, C.H. "Research for Policy's Sake: The Enlightenment Function of Social Research." Policy Analysis. 3: 1977. pp 531-545.

3. Larsen, J.K. and P.D. Werner. "Measuring Utilization of Mental Health Program Consultation." in J.A. Ciarlo ed. Utilization Evaluation: Concept and Measurement Techniques. Beverly Hills, CA: Sage. 1981. pp 79-80.

Non-utilization was seen in these terms:

* the information having been considered by the potential user is rejected;
* nothing is done with the information; or
* implementation of the information has not occurred but is under consideration.

In a more general sense, types of utilization have been summed up in this dichotomous way:

* results which confirm a decision maker's beliefs, and
* results which challenge a decision maker's beliefs. (1)

These recent attempts at unravelling the dimensions of the concept of utilization stemmed from concern expressed in several places.

For example, Weiss, after reviewing the literature to assess the diverse array of meanings attached to the term, was convinced that :

> "much of the ambiguity in the discussion of research utilization - and conflicting interpretations of its prevalence and the routes by which it occurs - derives from conceptual confusion." (2)

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1. Zaltman. G. and R. Despande. "The Use of Marketing Research: An Exploratory Study of Manager and Research Perspectives." Report No. 80-115. Marketing Science Institute. Cambridge, MA. 1980.

2. Weiss, C.H. "The Many Meanings of Research Utilization." Public Administration Review. Sept. - Oct. 1979. p 426.

Weiss saw several different meanings which seemed attached to the concept. In addition to the knowledge-driven, problem-solving and interactive perspectives outlined by Havelock, she added political, tactical, enlightenment and intellectual exercise paradigms. Her conclusion was that deeper understanding of the process of utilization was essential if research in this area was to be pursued.

<u>Communication Bonds</u>

The communication and exchange of research findings and results is, clearly, a fundamental social process in science.

Ziman has argued forcefully that, in fact, the true goal of all scientific research is to contribute to the pool of knowledge, which in turn becomes universally accepted, and wherein the intellectual form is determined by the absolute need for scientists to communicate their findings and make them acceptable to other scientists.

> "The connecting links between members...are not commands, or legal obligations or financial transactions: They are bound together by the communication of information and knowledge. The nature of the communication system is thus vital to science: it lies at the very heart of the scientific method."(1)

A key communication outcome in science is publication and the so-called learned journal is of historical significance.

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1. Ziman, J. <u>The Force of Knowledge</u>. Cambridge: Cambridge University Press. 1976. p 90.

In fact, it seems that the scientific journal was a somewhat accidental innovation in science introduced virtually simultaneously in the seventeenth century by both the Royal Society of London and the Academie Royale des Scavans in Paris. The two publications, respectively, were the Philosophical Transactions and Journal des Scavans. (1)

Thousands of scientific journals have come into existence over the years. Some have lived a short time. Others have had a longer life. No accurate index of the world's scientific journals has been produced.

Ziman has clarified why the printed word is so important in science.

> "Science depends heavily on the printed word for two reasons. It is essential to keep a permanent record of results, observations, calculations, theories etc. for later reference by other scientists. It is also necessary to provide opportunities for criticism, refutation and further refinement of the supposed facts.
>
> In the elementary teaching of science, we lay emphasis on making an accurate record of our experimental results and the conclusions to be drawn from them, and we learn to keep tidy laboratory books.
>
> But the communication of the results of research to others is even more important. Science, by its very nature, is a body of public knowledge, to which each research worker makes his personal contribution, and which is corrected and clarified by mutual criticism. It is a corporate activity in which each of us builds upon the work of our predecessors, in competitive collaboration with our contemporaries." (2)

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1. Balaban, M. ed. Scientific Information Transfer: The Editor's Role. Boston: D. Reidel. 1977.

2. Ziman, J. Ibid. p 90.

While major reliance is placed on formal communication in science, it is not done to the exclusion of informal communication.

Formal and Informal Communication

Scientific communication involves both formal and informal channels of communication. Formal channels include articles in scientific journals, books, chapters in books, technical reports and bulletins, abstracts and preprints, and professional conference papers. Informal channels are usually oral, and include face-to face conversations, telephone discussions, correspondence and laboratory visits. These two mutually dependent entities differ in several respects.

For example, formal communication is:

* permanently stored and retrievable;
* public with large potential audiences;
* primarily user- selected;
* relatively dated when published;
* moderately redundant; and
* provides little direct feedback to authors.

On the other hand, informal communication is :

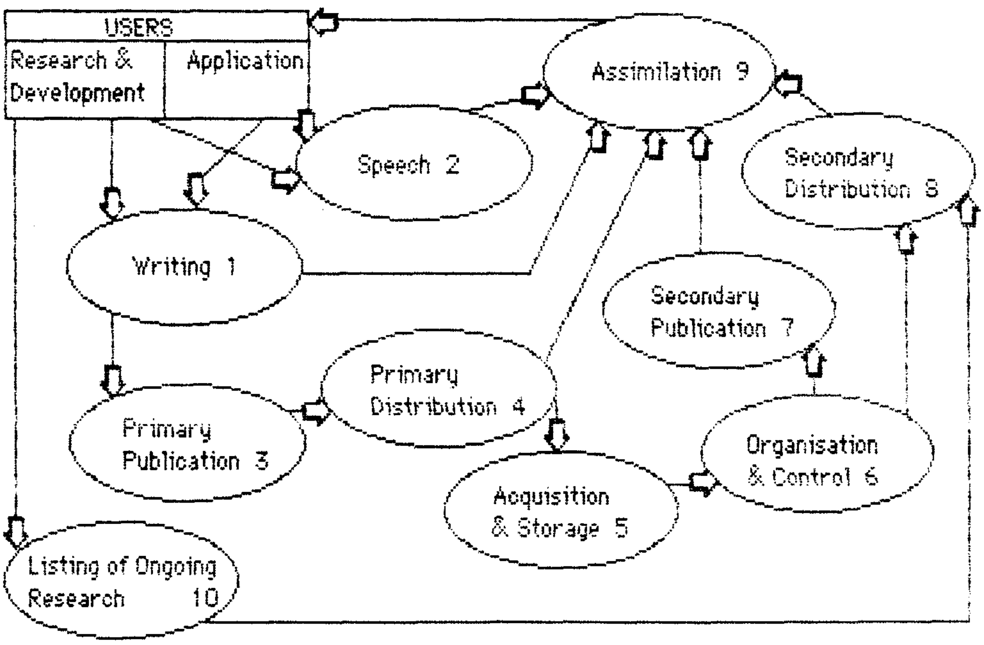
* Neither permanently stored nor retrievable;
* usually private with restricted audiences;
* timely and current; and
* usually able to provide considerable feedback.

The formal and informal channels by which research and application information is disseminated in science are depicted in Figure 3. Such information is needed by other people who, in turn, generate more information for dissemination.

The communication process represented in the Figure is thus a continuous and regenerative cycle, and science could not survive without an efficient communication cycle to support it.

FIGURE 3

THE RESEARCH COMMUNICATIONS CYCLE



1. Lancaster, F.W. and L.C. Smith. "Science Scholarship and the Communication of Knowledge". Library Trends. Winter 1978. pp 367-389.

Publication Stratification in Science

Viewed as a system, science is highly stratified, with power and resources held by a relatively few individuals. Indeed, Merton suggested that in science there is a "Matthew Effect" wherein the rich are likely to get richer i.e."in the accruing of greater increments of recognition for particular scientific contributions to scientists of considerable repute and the witholding of such recognition from scientists who have not yet made their mark." (1)

So that scientists can attain any degree of reputation, they must become visible by publishing scientific work and it must be favorably evaluated by colleagues. Scientists differ greatly in terms of their rates of publication.

Few publish many papers, and even fewer still, have their work completely assessed in a favorable way.

In general, the average rate of publication tends to be low, and the variation between scientists very high. Whether periods of a year, five years, or a professional lifetime are considered, productivity in terms of publications varies enormously among members of the scientific community.

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1. Merton, R.K. "The Matthew Effect in Science." Science. 159: 1968. pp 59-63.
The term comes from the Gospel according to St. Matthew: "For unto every one that hath shall be given, and he shall have abundance : but from him that hath not shall be taken away even that which he hath."

Following Lotka's observations on publication productivity among scientists and the existence of a highly skewed publication pattern (1), Price estimated that for every 100 scientists who produce one scientific paper, there are only 25 who produce two, 11 who produce three and so on. (2)

In other words, productivity conforms to an inverse square law wherein the square root of the population of publishing scientists produce half the scientific publications.

It can thus be estimated that 50 per cent. of all scientific papers are produced by about 10 per cent of the population of scientists.

There are numerous examples reported of low productivity. Ladd and Lipset reported that, among physical scientists who had appointments in American Universities and Colleges, almost a third had published nothing in the two years prior to their survey in 1977. (3)

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1 Lotka, A.J. "The Frequency Distribution of Scientific Productivity." Washington Academy of Science. 16: 1925. pp 317-323.

2. Price, D. DeS. Little Science, Big Science. New York: Columbia University Press. p 438.

3. Ladd, E.C. and Lipset, S.M. "Survey of 4,400 Faculty Members at 161 Colleges and Universities." The Chronicle of Higher Education. Vol. 15. November 21, 1977 and November 28, 1977.

Earlier, Yoel's study of American sociologists had showed that between one eighth and one third of the sample holding senior level University appointments had published no more than one article. (1)

The exact reasons for the great differences among scientists in terms of their production of scientific papers have not been completely analysed, but explanations probably lie within several parameters.

For example, there are individual variables such as psychological and demographic characteristics. Obviously, those that are strongly motivated, possess stamina, and have a drive towards precision and exactness are likely to be relatively productive. Further, productivity is likely to age-related.

Other characteristics stem from environmental location. Firstly, the socializing environment of a scientist's own training and education background gained through graduate school.

Clearly, too, the prestige of the department or faculty, or indeed institution, with which he is now affiliated is important. Finally, there is, at the micro- level, the scientific productivity environment within his own collegiate situation.

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1. Yoels, W.C. "On 'Publishing or Perishing': Fact or Fable?" American Sociologist. 8: 1973. pp 128-134.

There appear to be certain innate productivity and feedback processes, such as cumulative advantage and reinforcement, which are likely to have a distinct bearing on the number of publications that are produced by scientists. (1)

The Place of Agricultural Science

The totality of an effective science communication system is of special significance in the case of agricultural research.

Several aspects can be noted. For a start, agriculture was the first scientific field to receive long-term public funding, and as such, is a model of industrial science. Such support brings with it a communication obligation. (2)

In addition, the presence of a strong mission orientation in agricultural science commits it to a particular set of goals and structural forms.

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1. Fox, M.F. "Publication Productivity Among Scientists: A Critical Review," Social Studies of Science. 13: 1983. pp 285-305.

2. Ravetz, J.R. Scientific Knowledge and Its Social Problems. Cambridge: Oxford University Press. 1971. pp 31 - 68.

Busch has put the matter elegantly in these terms:

> "The suggestion that agricultural science should be institutionalized shifted the balance in favor of Bacon's model of science in three ways: First, the concept of agricultural science was explicitly utilitarian: knowledge was to be pursued for its usefulness in improving the material conditions of the population. Second, it was to be pursued by large numbers of people who had learned the proper methods...Third, it emphasised empirical results over theory.... A scientific experiment is made not for the purpose of sustaining a theory, but of learning a fact." (1)

The Layout of the Thesis

Intensively organized international agricultural research is of recent origin. The generation of scientific knowledge in this sector is of fundamental importance in helping to solve the food problems of the world. The communication and utilization of such knowledge is the focus of the study described in this thesis.

In particular, the investigation is concerned with the diffusion of scientific knowledge from the International Rice Research Institute, (IRRI), which is located at Los Banos, in the Province of Laguna, in the Philippines.

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1. Busch, L. "Structure and Negotiation in the Agricultural Sciences." Rural Sociology. 45:1: 1980. pp 26-48.

Chapter 2 looks at models and research approaches to scientific communication. Chapter 3 is concerned with the measurement of communication in science.

The generation of international agricultural science knowledge is the focus of Chapter 4.

In Chapter 5, the objectives of the study are described, together with the citation analysis, and the results, of the study on publications written by IRRI scientists.

The conclusions from the study are contained in Chapter 6 - "Understanding Knowledge Utilization in the Communication of International Agricultural Research."

CHAPTER 2

SCIENTIFIC COMMUNICATION – MODELS AND RESEARCH APPROACHES

> "Communication processes are basic to the nature and practice of science. They must therefore be considered not only by scientists, but by all those who study science as a human activity (e.g. sociologists and historians). From the point of view of these latter, scientific communication possesses the incomparable advantage of being assessable in more objective terms than most areas of human endeavour. Moreover, to the extent that the assessment can be carried out directly from an analysis of scientific literature, a vast mass of data is readily available; and these, unlike so many sociometric data, are not influenced by the process of acquisition."
>
> (Meadows, 1974)

Models of Communication

The word communication is derived from the Latin *communis*, meaning common. It has been defined as:

> "a process in which participants create and share information with one another in order to reach mutual understanding." (1)

It has also been said:

> "in the most general sense, we have communication whenever one system, a source, influences another, the destination, by manipulation of alternate symbols, which can be transmitted over the channel connecting them." (2)

A model seeks to show the main elements in a structure or process and the relationships between the elements. There are several distinct advantages in constructing models in the social sciences. Firstly, they have an organizing function by ordering and relating systems to each other, and providing total images that might not ordinarily be perceived. Thus, a model gives the general picture. Secondly, models assist in explanations, since they may offer a simplified portrayal eliminating ambiguities and complications. The resultant heuristic function can highlight the important parts of a process or structure.

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1. Rogers, E.M. Diffusion of Innovations. Third Edition. New York: Free Press. 1982. p 5.

2. Osgood, C.E., G.J. Suci and P.H. Tannenbaum. The Measurement of Meaning. Urbana: University of Illinois Press. 1957.

Thirdly, outcomes may be predicted from models, as well as suggesting various probabilities to alternative outcomes.(1) Models have been specially valuable in the study of communication, for, while communication can be viewed as the social web of life, it is intangible and often impermanent. Although the dynamic process of communication is not easy to encompass in models, the modelling of structure and linkages (even including strength and direction) in communication relationships has interested many scholars. (2)

Perhaps the first communication model can be attributed to Aristotle, who in his Rhetoric, named the speaker, the speech and the audience as the constituent elements of the act of communication. Organized attempts to develop modern communication models, and research the field, can be traced back more than 50 years, but modelling of communication was stepped up in the period immediately after the Second World War.

One of the first was the so-called Lasswell formula:

"Who
says what
in which channel
to whom
with what effect?" (3)

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1. Deutsch, K. The Nerves of Government. New York: Free Press. 1966.

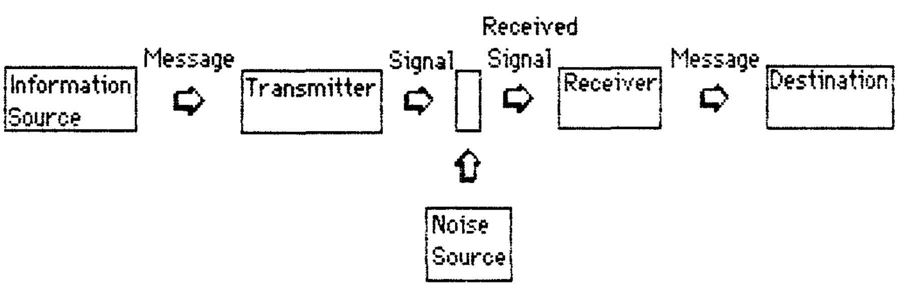
2. Lerner, D. and L.M. Nelson. Communication Research – a Half Century Appraisal Honolulu: University Press of Hawaii. 1977.

3. Lasswell, H.D. "The Structure and Function of Communication in Society" in L. Bryson, ed. The Communication of Ideas. New York: Institute for Religious and Social Studies. 1948.

An important step occurred with the publication of The Mathematical Theory of Communication in 1949. Here, Shannon and Weaver presented a so-called information theory, and although its base was in electrical engineering, it seemed to present a beguiling type of fit in human communication settings. The model is shown in the following Figure.

FIGURE 4

THE SHANNON AND WEAVER MODEL



According to this model, an information source produced a message which was transformed into a signal by a transmitter, and the signal adapted to a channel. Subsequently, a receiver reconstructed the message on the basis of the signal, and sent it on to receiver. The signal was susceptible to interference from noise.

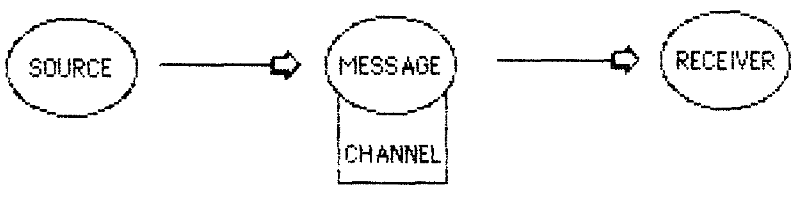
1. Shannon, C.E. and W. Weaver. The Mathematical Theory of Communication. Urbana : University of Illinois Press. 1949.

The model introduced a valuable concept regarding information: the difference in matter-energy affecting uncertainty in a situation, where choice exists among alternatives. However, when applied to human communication settings, the elements of feedback, noise, and the subjectivity of communication presented difficulties. The model emphasized linear, one-way communication.

Models followed from Osgood (1), and Westley and MacLean (2). In 1960, Berlo produced his influential S-M-C-R model which is shown in the next Figure. (3)

FIGURE 5

THE BERLO S-M-C-R MODEL



Here, the elements of an act of communication were identified where the intention was to bring about changes in the behaviour of a receiver. The key elements were source, message, channel and receiver.

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1. Osgood, C.E. The Measurement of Meaning. Urbana: University of Illinois Press. 1957.

2. Westley, B. and M. MacLean. "A Conceptual Model for Communication Research." Journalism Quarterly. 34: 1957. pp 31-38.

3. Berlo, D.K. The Process of Communication. New York: Holt, Rinehart, and Winston. 1960

Deficiencies in Linear Models

These essentially linear models followed a components approach in viewing communication effects. They emphasized a description of the communication act, but did not accurately portray the communication process.

Kincaid has pointed to the biases which resulted:

"1. A view of communication as a linear one way act (usually vertical) rather than a cyclical two way process over time.

2. A source bias based on dependency rather than focussing on the relationship of those who communicate and their fundamental interdependency.

3. A tendency to focus on objects of communication as simple, isolated physical objects at the expense of the context in which they exist.

4. A tendency to focus on the messages, per se, at the expense of silence and the punctuation and timing of messages.

5. A tendency to consider the primary function of communication to be persuasion rather than mutual understanding, concensus and collective action.

6. A tendency to concentrate on the psychological effects of communication on separate individuals rather than on the social effects and the relationships among individuals within networks." (1)

In general, the linear models convey a mechanistic approach where the sources are subjects using communication to affect change in receivers as objects. (2)

In 1973, Schramm provided a departure from the strict linear paradigm with a relational model which introduced the concept of active receivers of communications within a participant relationship. (3)

The Convergence Model

Kincaid's convergence model viewed human communication as a dynamic, cyclical process occurring over time emphasizing mutual causation, rather than the relatively simple, one way, mechanistic causation, and highlighting the interdependent relationship of the participants, rather than leaning towards either the source or receiver of messages.

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1. Kincaid, D.L. The Convergence Model of Communication. Honolulu: East- West Communication Institute. 1979.

2. Friere, P. "Extension or Communication" in Education for Critical Consciousness. New York: Seabury Press. 1973.

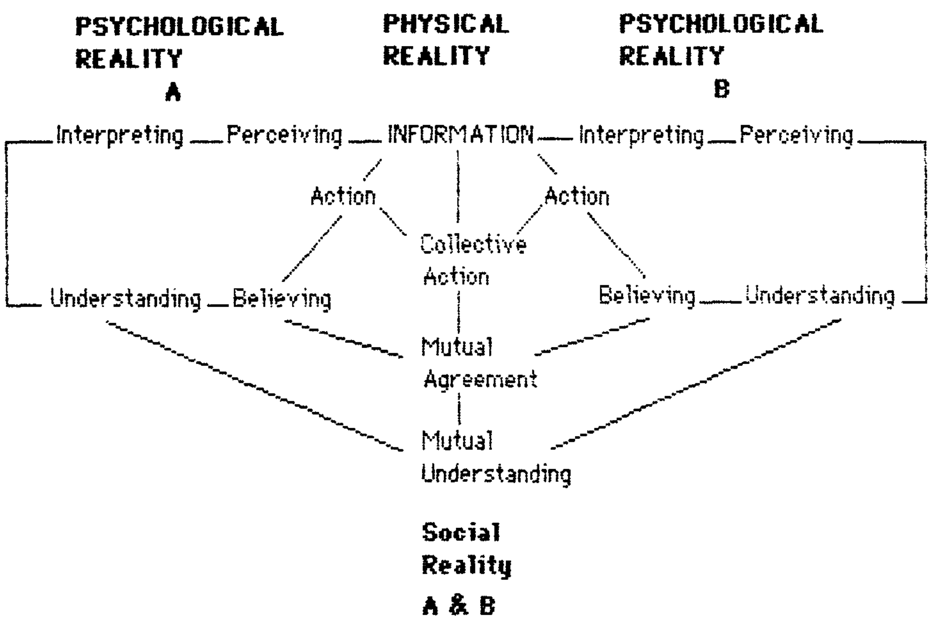
3. Schramm, W. Men, Messages and Media: A Look at Human Communication. New York: Harper and Row. 1973.

Kincaid stated:

> "The convergence model of communication leads to a relational perspective of human communication because of the shift to information as opposed to messages as the content that is created and shaped by participants...Information is about the objects and events in the environment and about relationships in the environment, intercepted through the application of available codes and concepts. Once the interpretation and understanding of information is raised to the level of shared interpretations and mutual understanding, what was considered as individual information-processing becomes human communication among two or more persons who hold the common purpose of understanding one another. The participants may converge or diverge, that is reach a mutual understanding or misunderstanding." (1)

FIGURE 7

THE CONVERGENCE MODEL



1. Rogers, E.M. and D.L.Kincaid. Communication Networks. Towards a New Paradigm for Research. New York: Free Press. 1982. p 69.

The following Table summarizes the various models of communication. (1)

TABLE 1

COMPARISON OF THE COMMUNICATION MODELS

SOURCES	MODEL TYPE	MAIN COMPONENTS	COMMUNICATION DEFINITIONS
1. Shannon & Weaver	Linear	source encoder message decoder destination noise feedback	All procedures by which one mind may affect another
2. Osgood	Linear	message decoder interpreter encoder message decoder	One system, a source, influences another, the destination, by minipulation of alternative signals transmitted over channel
3. Westley & MacLean	Linear	messages sources gatekeepers receivers feedback	Person A transmits messages about object X to person B through gatekeeper C
4. Berlo	Linear	source message channel receiver	A process by which a source intentionally changes behavior of a receiver
5. Schramm	Relational	informational signs relationship among participants active receivers	A set of communication acts focussed on a set of informational signs within a particular relationship
6. Kincaid	Convergence	information uncertainty convergence mutual understanding mutual agreement	A process of convergence in which information is shared by participants in order to reach mutual understanding

1. Rogers, E.M. and D.L. Kincaid. Ibid. p 35.

Application to Scientific Communication

Communication occupies a central element in science and the convergence model offers a suitable scheme appropriate to this field.

Rogers and Kincaid stated that communication network analysis is a method for identifying communication structure in a system, wherein relational data about communication flows can be studied by using some type of interpersonal relationship as the unit of analysis. A link is the communication relationship between two units, usually individuals, and the link becomes the basic datum in any type of network analysis. Clearly, this approach is specially relevant to an investigation in the field of scientific communication.

There are three main methods of measuring network data: survey sociometry, observation, and unobtrusive methods (e.g. citation analysis).(1) Survey sociometry has been the most widely used method in past network research.

An unobtrusive method is a measure that directly removes the observer from the events being studied, and there are a variety of such methods available for measuring communication links in a system. An unobtrusive method has the distinct advantage of employing usually unquestioned valid data. (2)

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1. Rogers and Kincaid. Ibid. p 118.

2. Webb, E.J., D.T. Campbell, R.D. Schwartz and L. Sechrest. Unobtrusive Measures: Non Reactive Research in the Social Sciences. Chicago: Rand McNally. 1966

Information Science

Since, in scientific communication so much reliance is placed on formal communication, reference needs to be made to information science, which is the name of the discipline that investigates the properties and behavior of information, together with the means of processing information for optimum accessibility and usability. The origin, diffusion, organization of the collection of knowledge in a field, its storage and retrieval, interpretation and use, are the foci for studies in this discipline.

A specific term, bibliometrics, coined by Pritchard, describes studies in the field of recorded knowledge, as aiming:

> "to shed light on the processes of the written communication and of the nature and source of development of a discipline (in so far as this is displayed through the written communication) by means of counting and analyzing the various facets of written communication." (1)

Quantitative analyses of the bibliographic features of literature have been found to conform rather closely to a number of laws and mathematical distributions and these form the foundations of information science. The most important are the Bradford, Zipf and Lotka Laws.

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1. Pritchard, A. "Statistical Bibliography or Bibliometrics?" Journal of Documentation. 25:4: 1969. pp 348-349.

Bradford's Law of Scatter stated that:

> "the aggregate number of articles in a given subject, apart from those produced by the large producers (periodicals) is proportional to the logarithm of the number of producers concerned, when these are arranged in order of decreasing productivity." (1)

Lawani has interpreted this law in these terms:

> "if periodicals contributing to a subject are ranked and then grouped in such a way that each group contributes the same number of articles, the numbers of periodicals in each group increase geometrically." (2)

The Law can be illustrated as follows:

TABLE 2

LITERATURE SCATTER

Groups	Number of Journals	Number of Papers
1	9	429
2	59	499
3	258	404

There are various reasons for the occurrence of the Bradford distribution. For a start, although editors want to publish papers from as many authors as possible, a narrow subject area is mandatory, and this will limit the number of authors whose papers appear in one journal. Authors, too, want to get into core journals.

1. Bradford, S.C. Documentation. 2 ed. London: Crosby Lockwood. 1953.

2. Lawani, S.M. "Bibliometrics: Foundations, Methods and Applications." Libri. 31: 4: 1981. pp 294-315.

In the case of the Science Citation Index, Garfield has shown that out of a total of 2,000 publications, 100 will yield 43 per cent. of all relevant papers, and 23 per cent of the journals in the sciences provides 70 per cent. of the coverage. (1)

Zipf's law states that:

> "if words are ranked according to their frequency of occurrence (f) the n th ranking word will appear approximately k/n times where k is a constant, or f(n) = K/n. (2)

Price has shown that Zipf's law is a special case of a general distribution to which the Bradford and Lotka laws belong. (3) Lotka's law, already mentioned, concerns authorships and publication productivity.

TABLE 3

AUTHOR PRODUCTIVITY

Number of Authors	Number of Papers
100	1
25	2
11	3
6	4
4	5

1. Garfield, E. "Citation Analysis as a Tool in Journal Evaluation." Science. 178. 1972. pp 471-479.

2. Zipf, G.H. Human Behavior and the Principle of Least Effort. New York: Addison Wesley. 1949.

3. Price, D. deS. "A General Theory of Bibliometrics and Other Cumulative Advantage Processes." Journal of the American Society of Information Science. 27: 5: Sept.-Oct. 1976. pp 292-306.

Lotka stated that:

> "the number of persons making two contributions is almost about one fourth of the total, and the number making n contributions is about $1/n^2$ of those making one: and the proportion of all contributors that make a single contribution is about 60 per cent." (1)

Considerable research has already established that Lotka's Law applies in a wide variety of disciplines, and that it is consistent with Bradford's Law.

After an extensive review of investigations on these fundamental biblometric laws and distributions, Lawani concluded that, if Price's general theory and other cumulative advantage processes hold, then Lotka's Law should apply to all disciplines. (2)

Bibliometric studies can be classified in several ways, one of which is on the type of data on which the studies are based.

The sources of data for bibliometric studies include bibliographies as well as citations.

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1. Lotka, A.J. Ibid. p 317.

2. Lawani, S.M. Ibid. p 299.

In the case of the former, a relevant bibliography, abstracting or indexing service can be selected and appropriate entries - authors, titles, publishers, publication year, place of publication, type of publication, etc. - are analysed.

Research based on citations are called citation analyses. (1)

The Meaning of Citation

According to the Macquarie Dictionary, to cite means:

1. to quote (a passage, book etc.) esp. as an authority;
2. to mention in support, proof or confirmation; refer to as an authority;
3. to summon officially or authoritatively to appear in court;
4. to summon or call; rouse to action, cited to the field of battle;
5. to call to mind; mention: citing my own praise;
6. Mil. to mention (a soldier, unit, etc.) in orders as for gallantry." (2)

Citations constitute a rich source of bibliometric data and constitute, in effect, raw material for research into language and communication. It should be noted that entries in a bibliography are references, and, in the strictly technical sense, are not citations.

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1. Lawani, S.M. Ibid. p 301.

2. Macquarie Dictionary. 1982. p 128.

By definition:

> "The true citation analysis deals with works cited as having actually been used in the preparation of or having otherwise contributed to the source papers." (1)

Price defined citation explicitly in these terms:

> "...if paper R contains a bibliographic footnote using and describing paper C, then R contains a reference to C, and C has a citation from R. The number of references a paper has is measured by the number of items in its bibliography as end notes, footnotes etc. while the number of citations a paper has is found by looking it up in some sort of citation index and seeing how many papers mention it." (2)

Thus, the word citation is used to indicate not only the fact that a document has been cited in a reference in another document, but also for the description of the original document in the subsequent reference. In this particular sense, the words citation and reference are frequently used interchangeably.

Originally, citation analyses were undertaken by accumulating primary data from articles in scientific journals. The approach had limitations.

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1. Broadus, R.N. "The Application of Citation Analyses to Library Collection Building". Advances in Librarianship. 7: 1977. pp 299-335.

2. Price, D. deS. "Citation Measures of Hard Science, Soft Science, Technology and Non Science." in C.E. Nelson and D.E. Pollak eds. Communication Among Scientists and Engineers. Lexington, MA: Heath Lexington. 1970.

Citation Indexes

The development of citation indexes has facilitated the aggregation of citation data and results of studies on such data are more generalizable. A citation index is an alphabetical list of references obtained from bibliographies and footnotes, arranged in first author order. Each cited work is followed by a list of source publications which subsequently cite it.

The Science Citation Index (SCI), founded by E. Garfield of the Institute for Scientific Information in Philadelphia (ISI) in 1961, has become the foremost citation index in science. The production of SCI is a formidable undertaking. In 1982, for example, ISI processed some 540,000 research articles, reviews, notes, letters, editorials, and other scientific communications to prepare the Index. The names and addresses of some 1.5 m. authors were gathered, together with the details of almost 3,000 odd scientific journals in which they published their papers. In addition, details were listed of the 9 m. references they cited. (1)

It should be noted that the idea of a citation index itself is not new. Shepard's United States Citations, a legal reference tool, dates from 1873.

This is a complete citation system dealing with the history of each case, and the subsequent treatment of it .

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1. Garfield, E." Mapping Science in the Third World" Science and Public Policy. 10: 3. June 1983. pp 112-127.

The concept behind any index is that citations to a particular work will be, ipso facto, intellectually related to that work.

However, where mere bibliographic details of the citation linkage are recorded, the exact nature of the conceptual linkage between two documents will not be readily apparent.

World Scientific Literature Network

Some 20 years ago, a portrayal of the world scientific literature network was provided in an influential paper written by Price.

In this seminal paper, Price showed that the overall collection of scientific papers were linked through the citations they contained.

It depicted the pattern scientists follow in referring to previously published documents, and described the way new science is built on recorded knowledge.

Price said that, in large measure, papers in a particular discipline represent either research-front literature, or background taxonomic material.

He asserted that:

> "...most papers, through citations, are knit together rather tightly. The total research front of science has never, however, been a single row of knitting.

> It is instead divided by dropped stitches into
> quite small segments and strips...
> most of these strips correspond to the work of,
> at most, a few hundred men at any one time. Such strips
> represent objectively defined subjects...
>
> If one could work out the nature of such strips,
> it might lead to a method for delineating the topography of
> current scientific literature.
>
> With such a topography established, one could
> perhaps indicate the overlay and relative importance of
> journals, and indeed of countries, authors or individual
> papers by the place they occupied within the map and by
> their degree of strategic centralness within a given strip." (1)

Key issues raised in the paper concerned building of science, the laying down of a knowledge archive, the appearance of new scientific information, and the recognition of a scientific elitism.

Implied also was the usefulness of research on scientific communication to assess scientific progress, research fronts and elitism.

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1. Price, D. deS. "Networks of Scientific Papers." Science. 149: 1965. pp 510-515.

Later, using extensive data accumulated from the from the Science Citation Index, Price developed a " Citation Cycle" for the world's scientific literature. This is shown on the accompanying page. In brief, the Figure indicates that the Index draws on some 2,700 source journals, containing a yearly total of 500,000 articles. The journal collection is estimated to be 6.7 per cent. of the world total, and the listings are gauged to contain about 0.75 of all cited papers. The journals contain an average of 162+/- 5 source items a year, 0.55 of which are written by primary authors.

Each source item contains an average of 14 references which relate to the published work archive.

Only about half of the archive is cited in a particular year, and the majority, some 72.8 per cent., are cited once only.

Further, there appear to be about 1.92 citations per cited item.

The cycle also covers the relationship between cited authors and source authors.

Only about half of the source authors in any one year are also cited, and of the source authors as a whole, some 70 per cent. are of long standing, while the remainder are newcomers.

The pattern also highlights the structural links in the scientific paper network.

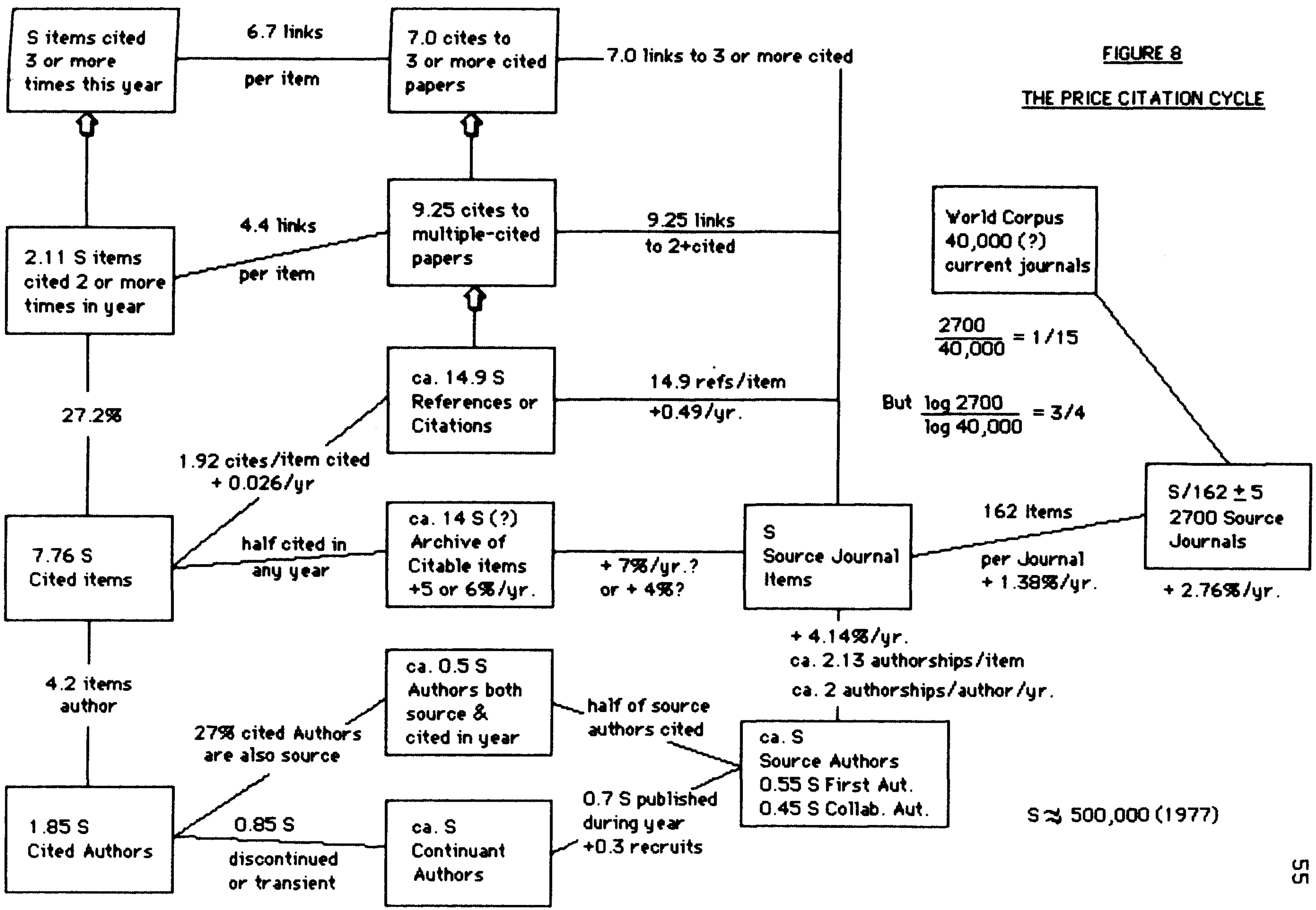

FIGURE 8

THE PRICE CITATION CYCLE

To quote Price:

> "Items that are cited only once in the Index are only tacked on to the source item that cites them...Multiple-cited papers are comparatively rare, constituting about 27.2 per cent.of those in the annual Index.
>
> Since we have 7.76 S cited items...there must be 2.11 S multiple-cited items which are connected to the S source items by about 7.63 links of reference/citation; there are therefore 7.63 links per source item and 7.63/2.11 = 3.6 links per multiple-cited item.
>
> Going to the next higher level of papers cited three or more times, it turns out that the number of such papers is approximately equal to S and the number of links at this level will be about 5.5 for the source or multiple cited paper." (1)

Citation analyses have been used in communication research, and applications in the study of scientific communication were noted by Parker and others. (2)

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1. Price, D.deS." The Citation Cycle." in B.C. Griffith ed. Key Papers in Information Science. White Plains, NY: Knowledge Industry Publications. 1980. p 16.

2. Parker, E.B., W.J. Paisley and R. Garrett. Bibliographic Citations as Unobtrusive Measures of Scientific Communication. Institute for Communication Research. Stanford: Stanford University. 1967.

The authors pointed out that citation analysis, as an unobtrusive research methodology, represented a highly pragmatic and imaginative research strategy. They noted, too, that there was no danger of the behavior under study being atypical, the responses of the population under study could not be distorted to fit the predispositions of the person undertaking the research, and the natural behavior was not affected by the presence of the observer.

Clearly, detailed studies of the formal communication networks that have been established in the rice sciences could throw light on the nature of the linkages that are involved in the communication and utilization of scientific knowledge in this field.

Summary of Chapter

Chapter 2 has considered the various models of communication that have been put forward. Concentration in the past has been placed on the linear models and the components approach and while these have value, they are nevertheless subject to limitations.

The convergence model of communication is more satisfactory, and has special significance in relation to science. The communication network system which serves as a foundation in the convergence model can be studied using various approaches. e.g. surveys, observation, or unobtrusive methods.

Bibliometric studies have already produced a series of laws derived from bibliographic and citation data. Citations, themselves, are specially valuable in the study of science. Indeed, the extensive citation system in science has been used to develop a picture of the world scientific literature.

Citation analyses, an example of an unobtrusive method for studying networks, have been noted as specially suited to investigations in the field of scientific communication, though the number of reported studies is small. The use of this research methodology has been facilitated by the development of the Science Citation Index.

A citation analysis of formal communications in the rice sciences is, accordingly, the methodology selected for the investigation reported on in this thesis.

CHAPTER 3

THE MEASUREMENT OF COMMUNICATION IN AGRICULTURAL SCIENCE

"If I have seen further, it is by standing on the shoulders of giants."

(I. Newton, quoted by Merton, 1973)

Information - The Key Factor

The development of better food technologies in the world is complex, involving a multitude of endeavors, some independent, others complementary, by individuals, groups and institutions working in a variety of situations.

But as Kramer and Williams pointed out:

> "The key ingredient to independency and continuity is information; it is the glue which holds the various efforts together." (1)

The institutionally-oriented sequences include: generating organized knowledge in agricultural research establishments; undertaking fundamental and applied research by international agricultural research agencies; synthesizing and adapting applied research by national research bodies; delivering materials and methods from local agricultural extension centres; and applying the resultant agricultural technology by primary producers.

Scientists working in the earliest phases of this sequence are in agricultural research establishments, are traditionally oriented towards expanding the body of organized knowledge and do not take any active responsibility for the diffusion and adoption of any resultant technologies to primary producers.

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1. Kramer, F. and R.J. Williams. "Scientist to Scientist Communication in the Context of International Agricultural Development." Paper to the Conference on the Communication Responsibilities of the International Agricultural Research Centers. Los Banos: IRRI. 1979.

Institutions and scientific societies do, however, maintain the journals, and conduct the conferences which allow the interchange of scientific information among members in particular disciplines.

In addition, it has been suggested that scientists belong to one or more so-called invisible colleges, a notion which was first mentioned by Price in 1961. (1)

The Invisible College

Subsequently, Price produced this prototype definition:

> "The basic phenomenom seems to be that in each of the more actively pursued and highly competitive specialities in the sciences, the more there seems to exist an "in group." The people in such a group claim to be reasonably in touch with everyone else who is contributing materially to research on this subject, not merely on a national scale, but usually including all other countries in which that speciality is strong.
>
> The body of people meet in select conferences (usually held in rather pleasant places) commute between one center and another, and they circulate preprints and reprints to each other and they collaborate in research.
>
> Since they constitute a power group of everybody who is really somebody in a field, they might at the local and national level actually control personal prestige and the fate of new scientific ideas, and intentionally or unintentionally they may decide the general strategy of attack in an area." (2)

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1. Price, D. deS. Science Since Babylon. Yale: Yale University Press. 1961. p 99.

2. Price, D. DeS. and B. Beaver. "Collaboration in an Invisible College." American Psychologist. 21: 11: 1966. pp 1011-17.

In other words, a semi-institutionalized, informal scientific network was postulated.

Crane's later investigation of scientists studying the communication of agricultural technology indicated that the interactions among them approximated a social circle, differing somewhat to the concept of an elite of mutually interactive, highly visible scientists. Among members of this scientific group, extensive communication took place between the the most productive members and the others, with the implication that the select group held the network together. In addition, group members maintained many ties with others outside this sub-discipline within rural sociology. (1)

However, precise assessment was hampered by the loose manner in which the supposed social circles emerge, grow, and then dissolve.

Cronin concluded, after reviewing the investigations made in this area, that:

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1. Crane, D. Invisible Colleges: Diffusion of Knowledge in Scientific Communities. Chicago: University of Chicago Press. 1972.

> "It is perhaps more helpful to think of the invisible college as an optional feature of a developing research field or an ancillary communication conduit in a mature discipline...This necessarily brief and selective overview of research into invisible colleges shows two things. First, that the concept, though difficult to pin down, is not a chimera, and second, that an agreed and standardized definition is lacking." (1)

Regardless of the existence, or not, at any time, of invisible colleges in the disciplines which comprise agricultural science, it is clear, that to use the substantial exchange mechanism through which scientists convey information to one another, takes considerable time.

In the survey undertaken by Kramer and Williams in 1979, it was shown that a typical international agricultural research scientist spends more than half of a working week in a variety of communication activities. An average of 16 hours a week was spent reading scientific literature, gathering and assembling scientific data, and preparing written manuscripts for scientific publications. An additional 14 hours a week was spent, on average, engaged in verbal communication of a professional nature.

Some three quarters of the resultant scientific papers were published either in the higher developed countries or in the publications emanating from the scientist's own research institute; the remaining one quarter of the publications appeared in the lesser developed countries. (2)

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1. Cronin, B. "Invisible Colleges and Information Transfer." Journal of Documentation. 38: 3: Sept. 1982. pp 212-236.

2. Kramer, F. and Williams, R.J. Op. Cit. p 6.

The Informal Communication System

In a random sample of some 1,431 agricultural scientists in the United States, Lacy and Busch found that while particular individuals in the informal communication network were viewed as important sources of influence for a variety of research decisions, such as choice of problem, methods, key concepts and theoretical orientation, informal scientific communication appeared to occur infrequently, and to be primarily limited to one's own discipline. The scientists reported that communication with others outside their own department, clients and extension staff was limited to less than once a month. In addition, the nature and frequency of the informal scientific communication was highly related to the criteria utilized in establishing research agendas, and the publication products.

In general, Lacy and Busch considered that informal communication in the agricultural sciences appeared to be problematic, relatively infrequent, specialized and insular. Proximity of other scientists was a key factor; informal communication beyond one's own research establishment was rare. Because of the low level of communication in this sector of the system, measurement of the actual flow presented difficulties due to mobility and memory lapses on the part of individual scientists. (1)

Formal communication, on the other hand, represented a structured system, with contributions, as noted, coming predominantly from an elite section of the community of scientists.

---

1. Lacy, W.B. and L. Busch. "Informal Communication in the Agricultural Sciences." Information Processing and Management. 19: 4: 1980. pp 193-202.

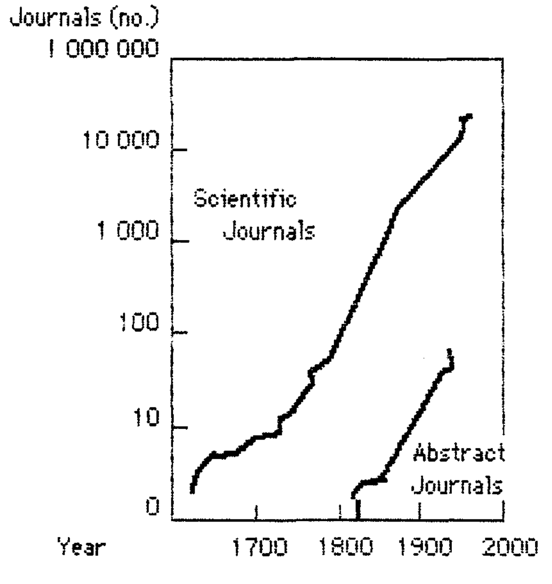
The Size of the Formal Communication System

Scientific communication has been dominated by the sheer "bulk" of the predominant channel, the journal. Indeed, from the earliest days of science, concern has frequently been expressed about the problem of keeping up with the formal scientific literature. Scientific journals have existed for more than 300 years, and for half of that time, additional abstract journals have been available to help scientists keep abreast of developments in their respective disciplines.

Price showed that there was an exponential growth in the scientific literature as a whole.

FIGURE 9

NUMBER OF SCIENTIFIC AND ABSTRACT JOURNALS

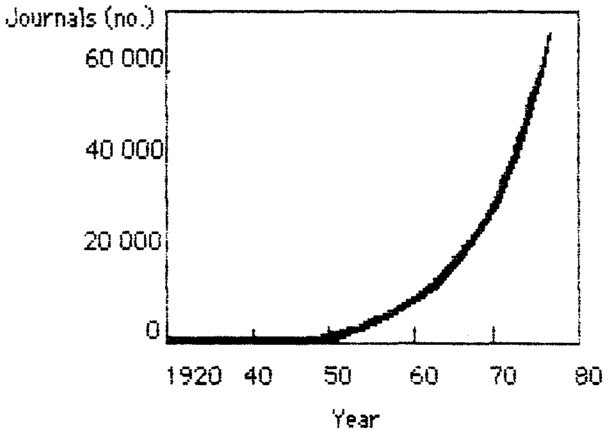


1. Price, D. DeS. "Diseases of Science" in J. Sherrod and A. Hodina. eds. Reader in Science Information. Washington, D.C.: Microcard Edition Books. 1973.

Even in specific fields, for example rice science, a similar exponential growth pattern in the production of publications has been demonstrated. This was shown by Lawani and Seraki. (1)

FIGURE 10

GROWTH OF THE WORLD RICE LITERATURE

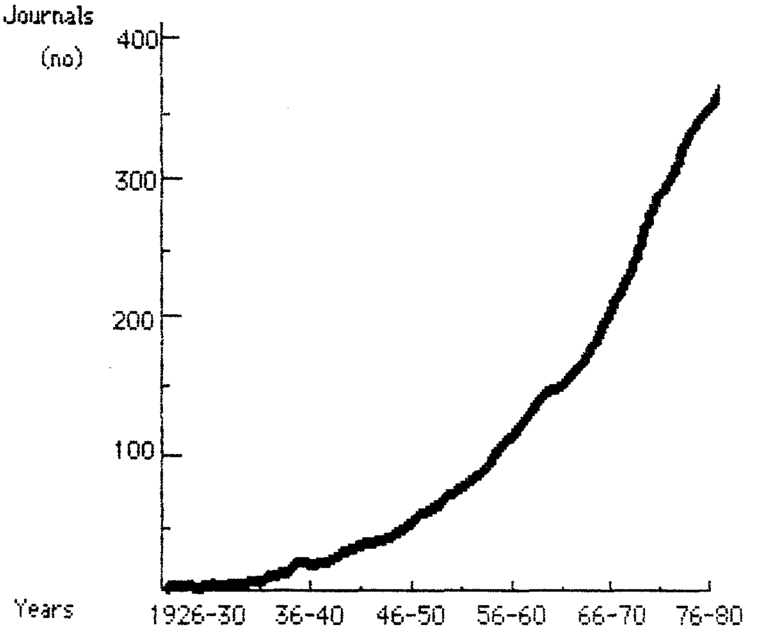


1. Lawani, S.M. and T.A.B. Seraki. "Some Characteristics of the World's Literature on Rice." International Rice Commission Newsletter. 23: 1: 1974. pp 1-15.

Roger and Kulasooriya showed the same pattern for the literature on the role of nitrogen fixing blue- green algae in rice. (1)

FIGURE 11

CUMULATION OF WORLD LITERATURE ON BLUE-GREEN ALGAE IN RICE



1. Roger, P.A. and S.A. Kulasooriya. Blue Green Algae and Rice. Los Banos: IRRI. 1980.

As well as in the applied areas in agricultural science, frequent reference has been made in the past to the problems of coping with the overwhelming expansion in the formal channels of communication in the basic disciplines.

For example, Webb, in an address to the Australian Biochemical Society some 15 years ago said that publications growth in that field was so substantial that new ways would have to be found for presenting and retrieving information if biochemists were to survive the crisis brought about by the seemingly uninhibited expansion of the published literature. In the case of the journal, Biochemica et Biophysica Acta, the increase from its inception had been virtually logarithmic with a doubling time of 4.6 years. As time went on, it attracted more and longer contributions. (1)

Apart from particular cases, the recent rate of growth of the scientific literature is not known with any degree of precision. Through the late 1960s, the increase of serials was estimated at about 4 per cent. a year, but it is thought to have slowed in more recent times to a net figure (allowing for discontinuations) of between 2 and 3 per cent. a year. While a serial is not a standardized unit in terms of numbers of pages, investigations have indicated that a collection of typical serials that grew in number from 1,000 in 1960 to about 1,700 in in 1974, would have expanded in shelf length from 57 to 124 metres over the period. The evidence suggested that the scientific literature doubled in bulk over a decade and a half. (2)

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1. Webb, E.C. "Communication in Biochemistry". Nature. 225. January 10, 1970. pp 132-35.
2. Wootton, C.B. "Trends in Size, Growth and Cost of the Literature Since 1955." British Library Research and Development Report. No. 5323 HC. 1977

Ziman has contended that the proliferation of the scientific literature should not be seen necessarily as a sign of ill health in science, but rather as a natural consequence of scientific progress. (1) With the slow down in the rate of growth of the primary literature, however, further strain in the scientific information system has occurred with the establishment of a large number of specialized journals to accommodate the expansion that has taken place in many areas of science. It is the appearance of these serials which give rise to a sense of continuing excessive proliferation in the scientific literature. Aside from these changes, there remain the established core journals in each discipline.

In recent years, new developments in computers have allowed scientific knowledge to be published much more rapidly, and computerized retrieval processes have been introduced to aid in the systematic and rapid movement of information among scientists. An important advantage consequent on the latter development has been to allow readers of science to "zero in" on the bibliographic details of specific items required. Obtaining the full documents, if these are required, remains, however, another and possibly lengthy step in the process.

Scholarly Output Measurement

Since members of the community of scientists are both readers and authors of the the literature, efforts have often been made to determine more precisely the productivity of scientists, and/or assess the overall importance of their contributions to scholarship.

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1. Ziman, J. "The Proliferation of Scientific Literature: A Natural Process." Science. 208: 1980. pp 369-371.

When investigation in agricultural science is viewed in simple terms as a production process, any success which results from such research endeavors can be seen in an output which is new knowledge, and this broad brush approach has often been used.

A notable example of this approach occurred in an investigation published as Agricultural Research and Productivity by Evenson and Kislev, who noted that:

> "the output of the (agricultural research) system is the knowledge created or borrowed and transferred from other countries or disciplines by the agricultural scientists (and) this knowledge is a factor of production affecting productivity in agriculture." (1)

Here publications data was used as a surrogate measure for the creation of new agricultural knowledge.

These researchers considered that publications data:

1) are a "real measure" free of exchange rate difficulties;

2) measure research accomplishment or output rather than input;

3) provide the only measure of the commodity orientation of research;

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1. Evenson, R.E. and Y. Kislev. Agricultural Research and Productivity. New Haven, CO: Yale University Press. 1975. p 20.

4) convey the implicit assumption of what research is in the standards applied by the abstracting journal for inclusion. The journals have as their stated purpose, international coverage of all literature of scientific significance;

5) since they are compiled basically from only three abstracting journals, the publications data are less subject to reporting errors and unstandardized data.

But the technique has some serious flaws, for example:

1) a poorly conceived paper published in a badly edited journal will count as much as a major contribution to a field which appears in a core journal of international repute in a particular discipline;

2) it is difficult to assign an a priori weighting system relating say scientific journal papers to books or to chapters in books;

3) comparing publication counts across fields also brings problems since publication norms differ from discipline to discipline. Some items in chemical journals, for example, can be in the form of short notes, and some scholar can lay claim to hundreds of articles. The situation differs in other fields.

Given this set of problems, bibliometricians have sought other measures of scholarly productivity with the result that a principal objective criterion presently employed is frequency of citation.

Citing in Formal Scientific Communication

Citing behavior has a long history, but Garfield has pointed out that as far as science is concerned, the practices of referencing and citing in the scientific literature have only been established conventions in scientific writing since the beginning of this century. (1)

The practice of citing in the scientific literature was described by Price as a public declaration of scholarly brick laying since science grows in a cumulative way by successive contributions to scholarship adding, or building on, to earlier contributions to knowledge. (2) Merton suggested that recognition through citation is not only one of the principal rewards in science, but also underpins the paradox in science, where the more freely a scientist offers the knowledge he has gained, the more surely it becomes recognized as his intellectual property.

Merton declared:

> "...a scientist's claim resides only in the recognition accorded his work by peers in the social system of science through reference to his work. In those rare cases where it is judged to be of major cognitive significance, recognition takes the lofty form of the commemorative eponym, as with the Copernican System, Boyle's Law, Darwinian Evolution or Planck's Constant. Since recognition of the worth of one's work by qualified peers is, in science, the basic form of reward (all other rewards deriving from it) and since it can only be widely accorded within the social system in science when the attributed work is widely known, this provides institutional incentive for the open publication, without direct financial reward, of scientific work." (3)

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1. Garfield, E. Citation Indexing: Its Theory and Application in Science, Technology, and the Humanities. New York: John Wiley. 1979.

2. Price, D. deS. Little Science, Big Science. New York: Columbia University Press. 1963.

3. Merton, R.K. "The Sociology of Science: An Episodic Memoir." in Merton, R.K. and J. Gaston. eds. The Sociology of Science in Europe. Carbondale: Southern Illinois University Press. 1977.

This viewpoint implies that the citation frequency of a scientific paper or report could be taken as a measure of the relative importance of that paper or report.

Garfield summed up this approach in this way:

> "since authors refer to previous material to support, illustrate, or elaborate on a particular point, the act of citing is an expression of the importance of the material." (1)

Given this general assessment of citation function does not, however, exclude the possibility of errors and omissions in the practice of citing.

Not all authors, all of the time, will be accurate and consistent.

For example, some may employ excessive citations to their own work; and relevant work may go uncited, not the least because some publications with significant knowledge may become so integrated into the literature of the discipline that, in effect, they are "foregone."

Assessment of the practice accordingly requires considerable care.

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1. Garfield, E. Citation Indexing.Its Theory and Application in Science, Technology and Humanities. New York: John Wiley. 1979. p 20.

Weinstock, in fact, nominated some 15 reasons why authors may cite others. They are:

1. paying homage to pioneers;
2. giving credit for related work;
3. identifying methodology, equipment, etc.;
4. providing background reading;
5. correcting one's own work;
6. correcting the work of others;
7. criticizing previous work;
8. substantiating claims;
9. alerting researchers to forthcoming work;
10. providing leads to poorly disseminated, poorly indexed, or uncited work;
11. authenticating data and classes of fact-physical constants, etc.;
12. identifying original publications in which an idea or concept was discussed;
13. identifying the original publication describing an eponymic concept or term.
14. disclaiming works or ideas of others; and
15. disputing priority claims of others. (1)

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1. Weinstock, M. "Citation Indexes" in Encyclopaedia of Library and Information Science. New York: Marcel Dekker. Vol 15. 1971. pp 16-40.

However, while the validity and use of citations as a gauge or indicator has sometimes been debated, the existence of high numbers of citations within the scientific literature has been consistently shown to be *not* a random event. On balance, the likelihood is that, in many instances, only a small percentage of citations in the literature are frivolous and spurious, though their possible presence needs to be recognized.

Considerable research exists to show that citations can provide an objective measure of utility. The studies have used a variety of criterion measures, especially that of peer assessment in relation to citation frequency. Small, for example, took 73 papers in chemistry where 61 were highly cited, and had these evaluated by some 48 chemists. No uncited paper received a high rating, while 15 papers cited 40 or more times were judged high in quality. This is 5.5 times more than chance. (1) Lawani and Bayer took 870 cancer research papers, divided into three categories of importance, and showed that highly rated papers were more highly cited over the ensuing five years after publication, or when controls were introduced to deal with self-citation, the influence of listing in the Year Book of Cancer, and for language and country of authorship. (2)

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1. Small, H.G. "Characteristics of Frequently Cited Papers in Chamistry." Report on Contract NSF - C795. Philadelphia: Institute for Scientific Information. 1974.

2. Lawani, S.M. and Bayer, A.E. "Validity of Citation Criteria for Assessing the Influence of Scientific Publications: New Evidence with Peer Assessment." Journal of the American Society of Information Science. 34: 1: 1983. pp 59-66.

Analysis of citations in the scientific literature have been undertaken, in fact, over the past 60 years. The first study using such procedures was that by Gross and Gross who counted and analysed the citations that were appended to articles in a chemistry journal, and ranked the journal titles according to the number of citations received. In this way, they produced a list of journals which they claimed were "indispensable to chemical education." (1) This type of study has been repeated in other fields to assess the quality of a given journal.

In general, it can be said that citations are attractive subjects of study because they are both unobtrusive and readily available. In contrast to data obtained by interview and survey schedule, they are unobtrusive measures not needing the cooperation of the respondent and not themselves contaminating the response. Recent years has seen marked expansion of the use of this investigatory technique with the development of new tools (such as the Science Citation Index) and the introduction of new approaches to measurement. The citation count remains the most used unit of measurement. A journal impact factor (average number of citations received by articles published in a journal over a period of time) is yet anothermeasure.

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1. Gross, P.L.K. and E.M. Gross." College Libraries and Chemical Education." Science. 66: 1925. pp 385-389.

Smith has classed the recent uses of citations by librarians and communication researchers, as follows:

1. "Literature of" studies where citations in a particular field are examined to determine patterns;

2. "Type of Literature" studies where citation analysis can be used to gauge the dissemination of results reported in certain types of scientific literature;

3. User studies which provide descriptions of the way readers have drawn on past literature;

4. Historical studies which are based on a literary model of the scientific process in which scientific work is represented by papers written as reports, while relationships between the papers are represented by references in the papers;

5. Communication patterns where citations are recognised as plausible indicators of scientific communication patterns;

6. Evaluative bibliometrics where citation analysis is defined as the evaluation and interpretation of the citations received, and which are used as a measure of scientific influence and productivity;

7. Information retrieval where citation relationships have been used to enhance traditional approaches to information retrieval; and

8. Collection development of journals for scientific libraries. (1)

Thus, it can be stated with impunity that the analysis of citations, in drawing on relatively objective data, has led to a wide range of applications. The technique can be especially attractive to researchers.

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1. Smith, L.C. "Citation Analysis." Library Trends. Summer 1981. pp 81-105.

As Cronin concluded

> "Metaphorically speaking, citations are frozen footprints in the frozen landscape of scholarly achievement; footprints which bear witness to the passage of ideas. From footprints it is possible to deduce direction; from the configuration and depth of the imprint it should be possible to construct a picture of those who have passed by, whilst the distribution and variety furnish clues as to whether the advance was orderly and purposive.
>
> 56So it is with citations in respect of the growth of human knowledge; they give substantive expression to the process of innovation, and, if properly marshalled, can provide the researcher with a forensic tool of seductive power and versatility." (1)

Theories of Citing in Science

Although there is no doubt that citing in science is an important aspect in the exchange of knowledge among scientists, there has been a great need to underpin this behavior with a satisfactory theory of citing. After all, while citing demonstrates public recognition, the actualprocess involved remains hidden.

Many scholars have therefore commented on the need for more secure epistemological foundations in this area.

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1. Cronin, B. "The Need for a Theory of Citing." Journal of Documentation. 37: 1. March 1981. pp 16-24.

One of the first was Kaplan who said that:

> "The citation is probably among the more important institutional devices for coping with the maintenance of the imperative to communicate one's findings freely as a contribution to the common property of science while protecting 'individual property rights' with respect to recognition and claims of property."(1)

Writing in 1965, Kaplan placed this view within the context of the sociology of science at the time, especially in relation to the notion of "communism", wherein scientific knowledge is produced , essentially, as a result of common endeavors of the scientific community, and becomes accepted within that community.

According to this line, members of the community, should they use previous results in producing their own, assign credit to the original author by way of citation.

Kaplan did admit possible other citation roles: scientific communication, status for the citing paper, and increased visibility for the cited paper, for example. But the substantive argument concerned the relationship between citation and the scientific reward system.

Studies of citation behavior rules, perhaps when disputes occur, and citing procedures, where rewards were to suitably noted, would be two avenues in which Kaplan's theory could presumably be tested.

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1. Kaplan, N. "The Norms of Citation Behavior: Prolegomena to the Footnote." <u>American Documentation</u>. 16: 1965. pp 179-184.

In line with Kaplan, Ravetz also stated that citing is a method of dividing intellectual property in a scientific paper, and providing something akin to "income" to the owner, thereby showing that the work was useful. (1)

Gilbert's Theory of Citing

Writing in 1977, Gilbert proposed another theory, related in part, to that of Kaplan.

Gilbert contended that since the importance of new knowledge from a scientific experiment may not be immediately self evident, the author is likely to embark on persuading the reader of this position.

Referencing was, in fact, a tool of persuasion.

> "Accordingly, authors typically show the results of their work to the current literature of their field; and they provide evidence and argument to persuade their audience that their work has not been vitiated by error, that appropriate techniques and theories have been employed, and that alternative, contradictory hypotheses have been rejected." (2)

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1. Ravetz, J.R. Op Cit. p 257.

2. Gilbert, G.N. "Referencing as Persuasion." Social Studies of Science. 7: 1977. pp 113-122.

While emphasizing that references could increase the persuasiveness of a scientific paper, Gilbert noted, however, that:

> "..not all relevant articles that might be cited are equally valuable in providing such support. In order to justify an argument to an audience of potentially interested readers, it is most effective to cite a selection of those papers...The participants in a mature field will share a belief that some published work is important and correct, some other work is trivial, 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 erroneous one. Indeed, respected papers may be cited in order to shine in the reflected glory even if they do not seem closely related to the substantive content of the report." (1)

Gilbert also pointed out that in choosing the selection of papers to cite, the author is not only providing support for his own paper, but also demonstrating his allegiance to a particular section of the scientific community, which is collectively of the opinion that the cited papers deserve citation, be it affirmative or negative. From citing some particular papers, the author could be seen, as well, as reflecting his own opinion of the validity of the findings of the cited papers.

In so doing, according to Gilbert, the author is contributing, perhaps only in a small measure, to overall concensus in his own research area.

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1. Gilbert, G.N. Op Cit. p 116.

Cozzens, in a later review, emphasized that:

> "If Gilbert's arguments are correct, then we would expect to find that the most perfunctory sorts of references, those that seem least closely related to the substantive content of the report would be the most highly cited documents... When less highly cited documents are used, one would expect them to play a more integral role in the argument......"(1)

A somewhat different theory has been proposed by Small who, in a paper entitled "Cited Documents as Concept Symbols", said:

> "The footnote number has the function of pointing to the portion of the text in which it is embedded and at the same time corresponding to specific documents usually given at the bottom of the page or grouped at the end of the article." (2)

Small pointed out that most citations are an author's private symbols for certain ideas that he uses in the course of his scientific research. This accounted for items cited only a few times.

Other citations, however, are more akin to standard symbols which have the same meaning for members of a group or community of scientists. In this case, the same word or phrase in a cited document is likely to be pinpointed in the citation relationship. Many documents are standard symbols for a single concept; others are used in connection with multiple concepts.

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1. Cozzens S. "Taking the Measure of Science: A Review of Citation Theories." ISSK Newsletter on New Directions in the Sociology of Science. S. Restivo, ed. Vol 7. pp 16-21.

2. Small, H.G. "Cited Documents as Concept Symbols." Social Studies of Science. 8: 1978. pp 327-340.

Small's theory has linguistical connotations since the act of citing in scientific publication is perceived as a symbol-designating process.

References are, in effect, symbolic resources embedded in the vocabulary and texts used to express scientific knowledge.

The review of citation theories by Cozzens concluded that:

> "Kaplan, Gilbert and Small have approached the phenomena of citing from three different analytical perspectives, but they have not created competing theories of citation. In the course of the actual work of writing a paper, scientists' actions are consistent with all three perspectives. Of course, they use references to refer to specific words in the text. Of course, they try to persuade each other of the importance of their results. And of course, they are following the general practice of "giving credit where credit is due" according to the current concensus within their reference group. " (1)

Small has explored two further aspects of citation context analysis, as follows:

1. using the semantic content of the citing passage to characterize the cited work, and

2. classifying the functions of references in scholarly work so as to examine the relationships citing authors perceive between theirs and earlier scholarly work. (2)

This second area is of special significance in this reported investigation of the generation, communication and utilization of international agricultural research information.

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1. Cozzens, S. <u>Op Cit.</u> p 19.

2. Small, H.G. Institute for Scientific Information, Philadelphia, U.S.A. Pers. Com.

The earliest scientific classification scheme was that outlined by Lipetz. (1)

The scheme was strongly influenced by the system used in Shepard's Citations, the citation index used in law, wherein the court decisions citing a specific preceding decision are coded to indicate whether the later decision, affirmed the earlier one, or questioned, clarified, modified or over-ruled it.

Lipetz felt that categories similar to these could be applied to citations in the scientific literature, and included in citation indexes, thus improving the selectivity of citation index searches.

Lipetz considered that an indexer could apply the system of categories to references contained in the citing work.

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1. Lipetz, B.A. "Improvement of the Selectivity of Citation Indexes to Science Literature Through the Inclusion of Citation Relationship Indicators." American Documentation 6:2: 1965. pp 81-90.

The following Table lists the various categories, according to Lipetz.

TABLE 4

DISPOSITION OF THE SCIENTIFIC CONTRIBUTION OF THE CITED PAPER IN THE CITING PAPER

* Noted only
* Distinguished
* Reviewed or compared
* Applied
* Improved or modified
* Replaced
* Changed the precision (plus or minus)
* Changed the scope or applicability (plus or minus)
* Questioned
* Affirmed
* Refuted

The Lipetz system was not deployed, however, because its application on a large scale could not be easily mechanized for information retrieval purposes.

Moravscik and Murugesan, in 1975, began a series of studies applying a specific set of categories to classify citations. The investigations were prompted by the increasing use of citation counts as a measure of importance in scientific publications, and the need to examine the reasons references are made in scientific papers. (1)

This classification scheme involved a set of eight categories, arranged in four dichotomous groups.

The paired categories were seen as polar opposites, but the groups were not mutually exclusive. One group (conceptual/operational) did not specify a citing/cited relationship.

The other pairs, however, reflected relational properties. One (organic/perfunctory) denoted the degree of use that the citing work made of the cited work. Another (evolutionary/juxtapositional) was concerned with whether a citing work is an extension, or an alternative, of the cited work.

The final category (confirmational/negational) indicated an approval-disapproval dimension.

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1. Moravscsik, P and P. Murugesan. "Some Results on the Function and Quality of Citations." Social Studies of Science. 5: 1975. pp 86-92.

In a study of scientific papers in physics, Moravscik and Murugesan, using the eight categories in the four dichotomous groups, found a 54/43 per cent. split on the conceptual/operational dimension; a 60/40 per cent. split on both the organic/perfunctory and evolutionary/juxtapositional dimensions; and a 87/13 per cent. split on the confirmational/negational dimension. One third of the references were redundant. This study represented the first quantitative anaylsis of types.

Chubin and Motra refined the scheme still further, with exclusive categories, and a six stage, one dimensional system, from complete affirmation to total negation.

The categories were: basic, subsidiary, added information, perfunctory, partially negational, and totally negational. (1)

Chubin and Motra, in a study of scientific papers in physics, found that negational references were rare. Some 20 per cent. were perfunctory.

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1. Chubin, D.E. and S.D. Motra. "Content Analysis of References: Adjunct or Alternative to Citation Counting?" Social Studies of Science. 5: 1975. pp 423-441.

Using yet another classification scheme, Cole investigated social science papers. His scheme involved nine categories, as follows: part of relevant literature; serves no explicit role in the analysis; supports idea of author; legitimates author's ideas and interpretations; uses original concept; extends or modifies theory or used as part of author's theory; used in interpreting results of study; used in formulating research problems; attempts to test a derivative theory; attempts to test part of original theory; and critical of original theory. (1)

Cole's first category "part of relevant literature" was similar to that of Lipetz's "noted only", and Moravcsik's, "perfunctory".

In a study on citations accorded Merton's theory of social structure and anomie, Cole found that 42 per cent. of the citations fell into the first two categories, which he termed "ceremonial."

This compared with 41 per cent. "perfunctory" in the Moravcsik investigation. Cole considered that an important way for authors to legitimize their work in this area was to use Merton's theory in a "ceremonial" manner.

Such an interpretation fits in with Gilbert's theory of citing which interprets citation practices as principally serving to persuade readers.

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1. Cole, S. "The Growth of Scientific Knowledge: Theories of Deviance as a Case Study." in The Idea of Social Structure: Papers in Honor of Robert K. Merton. New York: Harcourt, Brace, Jovanovich. 1975.

The important conclusions from these investigations included the fact that negational citings were rare, and, importantly, that there were often a large number which fitted the category of perfunctory citations.

Summary of Chapter

The chapter on measurement of communication in agricultural science began with a consideration of the concept of the invisible college in science, before turning to analyze the pattern of formal communication in science.

There has been an substantial growth in the number of publications in both the basic and applied sciences over many years. However, the retrieval of scientific information has been enhanced in recent times following the introduction and rapid development of computerized systems.

While the output of scientific papers has been used as an indicator of research productivity, citations in scientific papers have been used to indicate the presence of information of scientific importance or utility. Applications of the technique of citation analysis were carefully considered.

Three theories of citing in science - those of Kaplan, Gilbert and Small - were reviewed, as were three citation classification schemes - those of Lipetz, Moravscik and Murugesan and Cole.