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Building Electronic Bridges between Scholars and Information: New Roles for Librarians

ABSTRACT

Through a description of information science, communications, and knowledge utilization information models, this paper provides an introduction to the conceptual framework for the use of information in knowledge work activities and outlines one approach to studying knowledge work. The Gesher Project—a design effort undertaken by Brandeis librarians and Digital Equipment Corporation software engineers—is presented, with details of a group study of the Brandeis Radio Astronomy Group (BRAG). A prototype information management system developed by Digital Equipment Corporation researchers is also described.

INTRODUCTION

The traditional response of librarians to the study of information needs has been to study what users are doing in the library—studying how they are using information that is available. Maurice Line has suggested that we should instead hypothesize about need based on the nature of the activities in which individuals are involved (Line, Brittain, & Cranmer, 1971). Whether one is involved in designing a new bibliographic tool, designing a new approach to library instruction, or designing a new library system, it is important to understand what the needs of end-users are in relation to a specific information activity.

Libraries have been developing in an evolutionary process in relation to information products and information services. Each new product has been built upon the models of the past. Edward Tufte (1990) has suggested that we must envision information and information activities in a different manner in order to develop products and services that are truly revolutionary. If one assumes that a major library constituency is the scholars and researchers in the user community, then one can begin to think about their "needs." Instead of building better tools based upon historical precedent, librarians can begin to think beyond the confines of the past by beginning to examine the knowledge work of scholars.

This paper provides an introduction to the conceptual framework for the use of information in knowledge work activities, outlines one approach to studying knowledge work, and presents an overview of a design effort undertaken by Brandeis librarians and Digital Equipment Corporation software engineers.

INFORMATION AND KNOWLEDGE WORK

Consider three potential outcomes that are desirable and possible by examining "knowledge work":

- Through the process of examining scholarly activity, librarians may be able to assist in the development of scholarly support software that is not just an electronic analogue of existing electronic- or print-based library reference works but a medium for a kind of scholarly support activity that is genuinely new and three-dimensional.
- By examining how scholars use information, librarians can develop simulations of complex information activities. It is possible to simulate for the undergraduate the complex situation of a scholar analyzing a literary text. Librarians can develop truly innovative, interesting, and educational library instruction programs.
- By examining how scholars use information, we can begin to develop collections and connections to collections that truly reflect scholars' needs and support their scholarly work in an enabling fashion.

Elsewhere, the author (Gray, 1992) has suggested that information is a dynamic process with distinct phases forming a life cycle that can be defined, isolated, and examined. In this criterion, information is said to be a dynamic process, to be diverse and cumulative in effect, and to lead to informed action (Kochen, 1970; Taylor, 1980, 1986). Following are three types of models that contribute to understanding the dynamic nature of information. It may be helpful to view information as having a distinct life cycle that begins with creation, involves

dissemination, collection by a potential user, analysis, subsequent use, and storage. Various iterations of these phases in the information life cycle are present in the models described. To study the "information life cycle," one must combine elements of each of the models into an iterative model that includes data collection, analysis, action, and feedback loops.

To understand the concept of "information" as a dynamic process, various linear models that depict information on a continuum are reviewed. The Kochen (1970) model depicted in Figure 1 shows a progression from information to wisdom with two intermediate transformations along the way.

Information--> transformation into knowledge--> assimilation of knowledge into understanding--> fusion of understanding into wisdom

Figure 1. Kochen information model

Another version of the Kochen model can be seen in Taylor (1980) as he outlines four steps for refining data and transforming it into information for decision making. The first step is the *organization* of data, in which he includes collection, sorting, grouping, classifying, formatting, presenting, and displaying. The second step is *synthesizing*, which is a systematic approach to selecting, analyzing, interpreting, adopting, and compressing. The third step is *judgment*, which is a more critical act of selecting and evaluating against established parameters. The final step in the model is the *decision process*. In the decision process, useful knowledge is assessed and decisions are made based upon the goals of the organization or decision maker. Choosing among alternatives, compromising, bargaining, and consultation with experts are all elements of this final process.

The Taylor model is often depicted as a pyramid rather than as a linear model, with the raw data forming the base of the pyramid and the decision process forming the apex. In a later work, Taylor (1986) retains the steps but depicts the model as an hierarchical spectrum from data to action.

The Taylor model shown in Figure 2 illustrates the unrefined "data" at the base of the hierarchy, followed by "information," the first level of refinement or organization of data. "Informing knowledge" is

organized and synthesized to create in the recipient some greater understanding. "Productive knowledge" has attached to it some form of critical or evaluative element. The apex represents the action of the decision maker.

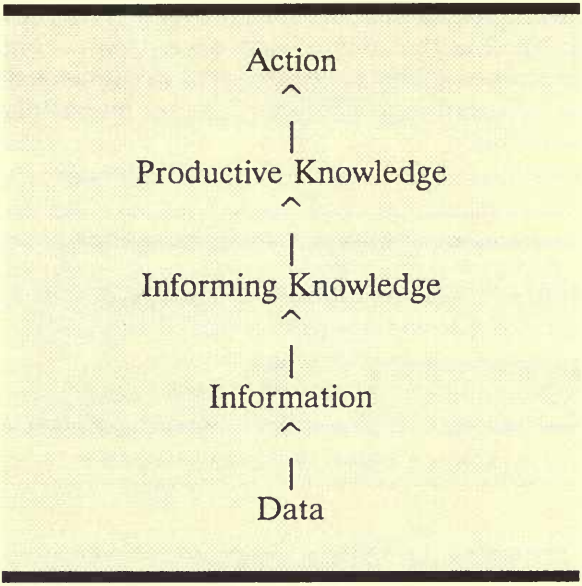

Figure 2. Taylor information model

Variations on these models can be found in the management information systems (MIS) literature. Boulton and Saladin (1983) and Hodge, Fleck, and Honess (1984) depict a flow from raw data to a decision point in their information system continuum illustrated in Figure 3. The "data processing" step is roughly analogous to the "informing knowledge," and "data output" corresponds to "productive knowledge" in the Taylor model. In the MIS school of research, "information utilization" has as an underlying assumption that some refining process has been undertaken to turn raw data into useful information.

One may contrast these models to a model used in communications theory as depicted in Davis and Olson's (1985) general model of a communication system. The above models place more emphasis upon the use, and Davis and Olson study the process. The communications school approach is depicted in Figure 4. The communications model begins with a message or information source, a transmission device, a channel or conduit through which the message travels, and a receiver

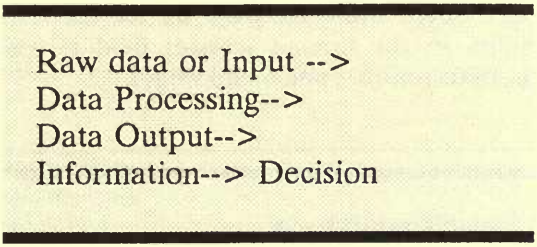

Figure 3. MIS information model

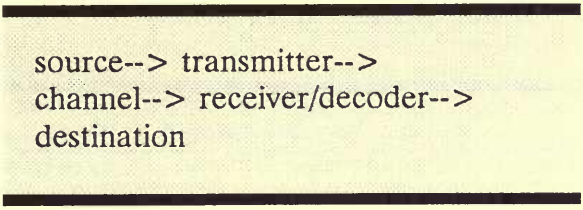

Figure 4. Communications model

that relays the message to its destination. In this model, there is concern that the message remain intact from source to destination. The ideal is for the "destination" to understand the message as it was intended by the "source." Noise and distortion often arise in the channel. Thus, the communication approach is concerned with maintaining the integrity of the message, and the information-processing approach focuses upon transformation.

These variations reflect the difference in approaches between the information scientist and the communications theorists. There is yet a third approach that arises out of the knowledge utilization literature. Havelock (1972, 1976) develops what he calls a knowledge flow system. The unique nature of this system is that it is not a strict linear model but has a series of "feedback loops."

Figure 5 depicts a strict linear model, but in fact there are a series of feedback loops with information from applied research feeding back to basic research, e.g., engineers feeding information back to basic research scientists, information from consumers being fed back to practitioners or retailers, or practitioners feeding information to the applied researcher to create understanding of what is or is not working. The field of knowledge utilization is primarily concerned with studying the flow of research to practitioners. Some of the earliest studies in knowledge utilization were done in the agricultural field, which studies the

utilization of advances in applied agricultural techniques literally at the "grass roots" level. More recently, we see the use of knowledge utilization studies in the human services field to assess the use of innovations (both techniques and technology).

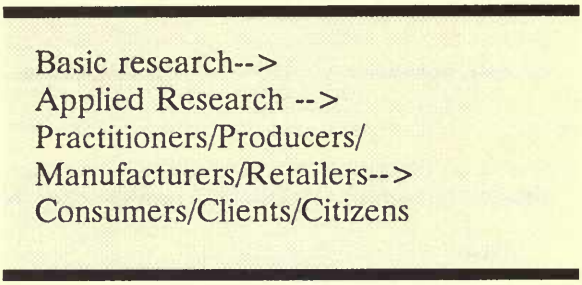

Figure 5. Havelock knowledge system

The information science, communications, and knowledge utilization information models contribute to understanding the dynamic nature of information. This conceptual framework is a part of the foundation needed for the study of knowledge work activity. Knowledge work may entail using the scientific method of research, or it may involve activities such as literary analysis that cannot be framed by the scientific method. Knowledge work assumes reliance upon information-intensive sources for "work" to be accomplished. It may be helpful to examine one attempt to frame the concept of knowledge work by analyzing the activities that may be involved when one engages in knowledge work. Davis and Olson (1985) identified seven major categories of knowledge work activity:

- Diagnosis and problem finding
- Planning and decision making
- Monitoring and control
- Organizing and scheduling
- Authoring and presentation
- Communication
- System development

Davis and Olson's divisions of knowledge work are complemented by Mackenzie Owen and van Halm's (1989) description of the information cycle that includes the following:

- Production
  processing of data

text processing
communication

- Distribution
  - editing (link between production and distribution)
  - quality control, e.g., peer review
  - marketing
  - physical production
- Acquisition (booksellers and libraries)
  - selection, physical acquisition, and storage of materials
  - cataloging and indexing
  - provision of documents by selling or lending
  - instruction and advice to the end-user
- Use
  - orientation
  - problem formulation
  - searching and selecting relevant information
  - acquisition of selected information
  - processing of information
  - establishing relationships between various items of acquired information
  - production of new information

The Gesher Project team began their research with this broad conceptual understanding of knowledge work. The project is designed to build a bridge between the information cycle and scholars to support their knowledge work.

GESHER PROJECT

What follows is a description of a joint project between Brandeis University Libraries and Digital Equipment Corporation's Cambridge Research Laboratory (CRL) that seeks to understand the changing nature of scholarly research and to develop computer-based tools to assist scholars in their research activities. This joint project is entitled the "Gesher Project." Gesher is a Hebrew word meaning bridge, which is intended to symbolize a link between the scholar and the scholarly information most traditionally found in libraries.

The Gesher Project had its birth when computer scientists at Digital's CRL and librarians at Brandeis began to discuss the possibility of building a personal information management system for scholars that would use bibliographic data from our online catalog. As discussions evolved, we tried to imagine what scholars might want to do and how a system might be designed to meet their scholarly information needs. A project was designed with the following broad goals:

1. to study the information-seeking process within a research university setting as a paradigm of how people locate and utilize information in the course of their work, and
2. to assist DEC/CRL staff in evaluating a personal information management system to be developed by CRL project members with participation by Brandeis faculty, doctoral candidates, and senior research librarians.

As the project team began work, a set of assumptions were developed that have helped to guide the research. These assumptions include the following:

1. Scholarly research is changing.
2. Understanding the scholarly research process can help librarians design services to address the changing needs of researchers. (See Belkin et al., 1990.)
3. Scholars must participate in the design of any new and improved system that aims to help manage their scholarly information.
4. Ethnographic field research techniques are useful in understanding the scholarly process.
5. The role of academic librarians in relation to scholarly research support is changing or needs to change.
6. Skills for librarianship are changing.

Grounded in the conceptual foundations of knowledge work, with the broad project goals in mind, and these diverse assumptions, the project team began its research.

Participative Design

Librarians in the project have concentrated on the goal of understanding the scholarly information management process. The research team from CRL and Brandeis decided to use a participative design technique in the system development. To understand our initial work, it is helpful to have a general knowledge of the tenets of participative design. Participative design is a technique pioneered by Mumford and MacDonald in the 1980s in their expert system design efforts. Participative systems design means giving responsibility for all, or part, of the design of a new system to the group who will use it.

Participative design is a concept that is best applied in a single organization where workers are engaged in a common pursuit. Scholarly research, of course, varies by discipline. But as Mumford and MacDonald (1989) point out, "Participation is a means to an end and not an end in itself. It is there to assist the creation of good systems that work efficiently, increase human effectiveness and contribute to a stimulating and satisfying work environment" (p. 27).

The participative design technique developed by Mumford and MacDonald is called "The ETHICS Method." (ETHICS stands for *E*ffective *T*echnical and *H*uman *I*mplementation of *C*omputer-based *S*ystems.) Initial examination made it apparent that the ETHICS method was not appropriate to adopt wholesale for the Gesher Project, but rather it was decided to use the elements of the method that seemed to match project needs. The five steps in participative design follow:

Step 1. Diagnosis of Need
Step 2. Discrepancy Analysis
Step 3. Agreeing on Objectives
Step 4. Designing the System
Step 5. Implementing the System

The initial research efforts concentrated on step 1, which involves the following:

- *Describing* the existing scholarly research systems being used by scholars at Brandeis. In this descriptive process, it is important to look at day-to-day tasks in the scholarly process of collecting information, storage, and retrieval.
- It is important to assess the *efficiency needs* of the scholar by asking such questions as the following: What are the problems impeding progress in the scholarly process? Slowing it down? Causing errors?
- It is important to assess the *effectiveness needs* by describing the key tasks and establishing which contribute to scholarly goals. One can do this by asking two questions: Are the tasks being performed effectively? Are there tasks that are not being performed that should be introduced? In scholarly work, effectiveness may be related to the coordination of activities of other scholars in the same discipline locally or at other institutions.
- It is important to understand *future change:* How is scholarship changing in general, and how will this impact the individual scholar or institution?
- It is important to understand the needs of the scholar on several different levels:

  Knowledge needs. How, ideally, would each scholar or group like their existing skills and knowledge to be used? What opportunities for developing them further would be advantageous? How well are needs being met?

  Psychological needs. What are scholars' needs for responsibility, status, esteem, security, and advancement, and how do they define these needs?

  Support and control needs. What kind of support services would enable them to carry out their work responsibilities more efficiently?

Task needs. What kinds of task structures and role responsibilities do different kinds of scholars find motivating, interesting, and challenging? What opportunities exist for self management, for developing new methods and services? This area is very relevant to the teaching role of faculty and an area where new working relationships can be developed among teaching faculty, computer professionals, and librarians.

Ethical needs. How do scholars wish to be treated by the library? Do policies on communication, consultation, and participation meet their expectations?

An examination of the ETHICS method helped to clarify project staff understanding of what kinds of questions to ask about the scholar's work, but this method did not help in knowing "how to ask" to ensure that the eventual design solves the right problem or set of problems. After an examination of alternative methods of surveying or interviewing faculty, it was decided to use ethnographic field research techniques as a way to interview scholars.

To carry out the research, a two-stage process of interviews was designed. The first stage of interviews involves an in-depth small group study in a specific discipline. The second stage involves using the findings from initial interviews to design a broader survey in other disciplines.

Ethnographic field research techniques were adopted for this study for four primary reasons. First, the method helps the researcher to understand behaviors according to how they are embedded in social and historical fabric of everyday life. The focus is on the relationships between the parts. The design of any component has implications for the rest of the system. Scholarly research is thus placed in the context of the discipline and the day-to-day work life of the scholar.

Second, because the method is descriptive, the researcher withholds judgment about the behavior described or observed. The researcher can look for how seemingly inefficient behavior is embedded in the social system. By describing first, the researcher does not jump to offer technical solutions.

Third, ethnographic research helps researchers understand other people's behavior from their point of view. The researcher must focus on how they categorize their activities and functions and not on artifacts of the environment. The interviewer must not impose her view of the world on the situation being observed.

And fourth, researchers learn about others by encountering their situation firsthand. Researchers look at everyday, naturally occurring talk and action. An important part of a work group's interaction may occur around the coffeepot or watercooler. By making naturalistic

observations, researchers can record and understand the use of technology within the environment of its use.

In studying the ethnographic approach, the project team learned that it is not a method to generate good questions in a mechanical way; that is, researchers cannot go into every interview with a script to be followed for three reasons. First, good questions emerge from an understanding of the group. Second, good questions emerge in the course of the interview. And third, results emerge from the interaction between interviewer and interviewee.

The Small Group Study

The following case study was prepared by Sue Woodson-Marks who has training and experience in ethnographic research. The assignment to the research team was to describe the research habits of a single research group in terms of their use of information.

The group studied was the Brandeis Radio Astronomy Group (BRAG) that includes the following:

- two faculty members;
- one advanced graduate student;
- two post-docs, one who is still working at Brandeis and one who has already moved to another area university but returns to Brandeis to attend "Astrolunch";
- several lower-level graduate students who are in the process of deciding whether they want to join the group; and
- one honors undergraduate student.

For Gesher Project purposes, the faculty and advanced graduate students are considered the core members of the group—the ones concentrated on in the interviews. They are all working on various aspects of a single issue: measuring the linear polarization of astronomical objects. In his dissertation work, the senior scientist devised a means of measuring this aspect of astronomical objects that has not been previously recorded. Their work now involves developing the technology for taking these measurements and using the data they gather to better understand the structure and function of these radio sources.

The approach used was to conduct in-depth interviews of the core group with an eye towards understanding how BRAG works as a group, what work they do, and how they do it. Project team members also observed at two "Astrolunches," the lunchtime forum for reviewing current literature in the field and presenting work done for the group. This report is based upon five interviews in all, lasting from one to three hours, which have been conducted by a team including the ethnographer and a librarian with the software engineer participating in one interview.

Although the BRAG members are each individually involved in a number of different activities (e.g., teaching, taking classes, serving on university committees, etc.), this project has concerned itself primarily with the work they do as researchers in astrophysics. The information-related tasks involved in this research include designing research projects, gathering and organizing data, producing and refining tools for analyzing the data, analyzing the data, and disseminating the results of their work.

Designing New Observations and Writing Proposals for Grant Money and for Time on the Radio Telescopes

Like most other astronomers, BRAG members collect their data using groups of radio telescopes owned by other institutions. They must not only petition for funds to support their research, they must compete with other radio astronomers around the world for time on these telescopes. Although one particular grant may cover more than one year, proposals for research funds and time on the telescopes are generally written each year. These proposals are generally written by the faculty, although graduate students may be writing their own grant proposals as well. In either case, the writer must not only have a clear notion of the work being proposed, he must also know what has been done in the field recently and how the proposed work fits into ongoing, already funded, research.

A weekly lunch seminar, Astrolunch, serves, in part, the function of keeping BRAG members up to date on current literature. Members of the group are assigned individual responsibility for reporting on particular journals in this seminar. When new issues of a journal arrive, the responsible member reviews the abstracts and table of contents of the new issues and reports on any articles that would be of interest to members of the group. Faculty members also use this venue to report to students on current funding issues. Although this may seem a rather labor-intensive means of reviewing the literature, project staff cannot recommend a streamlining of this process through computerization because it seems clear that the Astrolunch serves an important teaching function. The field of issues covered in this seminar is much greater than "the most recent developments in astrophysics." Here students learn about the values that guide research, the appropriate ways of evaluating other researchers' work, the nature of collegiality, and the history of the field including important personal information about the researchers that would not easily be available otherwise.

Collecting and Organizing Data on Radio Sources

Though this is central to the activities of BRAG, it does not serve the purposes of this paper to describe this process in detail. Suffice

it to say that there are two types of data that are collected and organized—the group's own data and data from other radio astronomy groups. The control over the BRAG members' data is managed in-house and seems to work quite well.

More problematic is the retrieval, recording, and organization of information gathered from other researchers. It is the understanding of the needs in this area where the Gesher Project may be able to provide some assistance. The need for information generated by others is a relatively common bibliographic problem—finding a work in which the desired data is reported. Access to NASA's intergalactic database may prove to be the best bibliographic solution.

The other half of the problem is capturing the needed information in a useful form. The data may be in the form of a spreadsheet with many different observations of a number of different objects, and no one is interested in keying pages and pages of this data into their own computers. Project staff have recommended that rather than investing time and money in solving this technical problem, BRAG would be better off using a service that scans documents for a fee.

Writing Software for the Analysis of Data Collected by the Group

Although BRAG members use a number of programs from other institutions to manage their software, a substantial portion of the group's work seems to involve writing and updating computer programs developed by the group for reducing their data and representing it graphically. This constant "tinkering" can cause significant difficulties; a proliferation of versions develops, and one loses track of which version is the appropriate one to use. The software engineer on the Gesher Project has proposed a software management program solution to this problem.

Disseminating the Results of the Group's Work through Published Writings, Attendance at Meetings, Correspondence with Other Radio Astronomers, and Public Lectures

Though the Gesher Project may have design components that aid in the development of formal papers, such as creating bibliographies, this was not explored very extensively in the initial interviews.

Conclusions from the Small Group Study

The approach of asking how the whole process of doing research in astrophysics works allowed project staff to place information needs in context. Without spending time at the Astrolunch seminar—just relying on interviews—there would only have been evidence like one scientist's complaint that even having the journals delivered to his

mailbox is inconvenient—he wants someone to read the journals and tell him which articles to read. Project staff would not have been able to see the broader role that Astrolunch plays in the process of keeping abreast of the literature.

Spending the time up front, trying to learn the basics of their research project, and doing multiple interviews within a single research group are strategies that paid off in the end. The issues of loading masses of data into spreadsheets and managing software updates both came out of the last interview with the senior researcher. Both had been mentioned in passing in earlier interviews, but their importance was only evident in the last interview because one could see the research in a larger context.

This was not an in-depth ethnographic study. Project staff were only able to conduct a few interviews and attend a couple of seminars. If there were more time, it would be good to attend more seminars besides Astrolunch and some graduate level classes. Even with this minimal work, the Gesher Project team was able to come up with several interesting ideas about how the BRAG team members do their research and what some of their information needs are.

SYSTEMS DESIGN IMPLICATIONS

Digital Equipment Corporation researchers are developing a prototype information management system. The prototype has been developed using a medical model and was first previewed publicly at DEC World in Boston in April-May 1992. The medical model includes menuing capability, live links to in-room patient monitors, graphic images such as radiology reports, patient records, physician records, databases resident at various locations, security levels, and links out to external sources such as MEDLINE. The system is running on a DecStation 5000 as a server with DecStation 2000s as primary workstations. Primary requirements of the system design include high-resolution graphics terminals with windowing capabilities.

The library system, yet to be programmed, includes the following design elements:

- a menu of possible activities that can be customized for a scholar or group of scholars;
- network links to bibliographic databases, catalogs, indexing and abstracting services;
- links to local custom programs and files such as BRAG's own data analysis system;
- personal databases created with pointers to external files;
- bibliography-formatting software;

- PC/fax to receive scanned images; and
- high-resolution graphics capability and links to image files.

CONCLUSION

The work presented here is preliminary and reflects research-in-progress at Brandeis University. The work offers one model of how librarians can be involved in the design of new computer products for library users. The primary contribution at this time is methodological. Using qualitative research techniques, involving users in the design of systems, and librarian participation in research and design reflect new roles for librarians.

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