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Establishing a Research Agenda for Scientific and Technical Information (STI): Focus on the User

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ESTABLISHING A RESEARCH AGENDA FOR SCIENTIFIC AND TECHNICAL INFORMATION (STI): FOCUS ON THE USER

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Introduction

A body of knowledge derived from systematic inquiry is a prerequisite for any endeavor to gain acceptance as a scholarly field of inquiry. Good solid research advances the state of the art by contributing to the body of knowledge that, in turn, may be applied to solve the numerous problems faced each day by practitioners. Robert Smith (1984) points out that "[R]esearch and scholarship are the lifeblood of any profession that seeks to gain acceptance as a discipline. The members of that profession, at one time or another, will either be producers or consumers of research or both." He distinguishes between "research" and "scholarship," a distinction that can be very useful when establishing a research agenda for STI. **Research** is the "discovery of new knowledge" while **scholarship** is the "organization, criticism, and interpretation of facts and concepts" (Smith, 1984). According to Molly Stock (1985), both can lead to greater understanding and the extension of "traditions, authority, intuition, and the generation of new ideas."

Background

Library and information science, as a collective entity, is the endeavor most closely associated or identified with the provision of STI. However, when the production, transfer, and use of STI are considered, the envelope expands to include such widely diverse endeavors as computer science, communications, psychology, and technical communications. **Library science** and **information science** have been variously debated in terms of definition, content, status as a discipline, and quality of research and scholarship. The essential point is, perhaps, overlooked in such debates. A body of knowledge derived from **research** is the key to attaining acceptance as a discipline. Once this general body of knowledge has been developed, substantive research questions can be generated and systematically tested. The results of these tests are made available (published) and subjected to **scholarship** for review and evaluation so that the merit(s) of these findings can be judged. Each investigation contributes to the expansion of the overall knowledge of the discipline. The cumulative effort of this gradual process leads to verification; spurious information is identified and replaced by more accurate information.

The Concept of Research

At a basic or general level, the concept of research is fairly well understood. It is generally accepted that research implies the application of the scientific method. As Caudra (1982) points out, "most definitions of research contain two components: the **methodology** component, which includes the collection and analysis of data; and the **purpose** component, which includes the formulation, revision, and the rejection of hypotheses and conclusions based on the analyses of these data." Library science and information science research have been variously criticized for failing to meet the standards of "scientific inquiry" in both these areas.

The most frequent criticisms focus on the first component. Much of the early library science and information research was not conducted using the scientific method. While improvements have occurred over time, problems with **methodology** and **purpose** still exist. Perhaps even more critical are the alleged shortcomings in the second component. Numerous writers, such as Busha (1981), fault library science and information science for not asking the "right" questions or establishing a theoretical foundation for further research and application. Ennis (1967) commented that library science research is "noncumulative, fragmentary, generally weak, and relentlessly oriented to immediate practice." Rohde (1986) concurs stating that the "difficulty in applying the findings reported in the literature has been attributed to the lack of a unifying theory, standardized methodology, and common definitions." From the standpoint of the user, Holland (1991) and her colleagues concluded that "the literature regarding the information-seeking behavior of engineers is fragmented and superficial and the results of these [user] studies have not accumulated to form a significant body of knowledge that can be used by information professionals."

Linking Theory With Practice

What is or should be the relationship between library science and information science theory and practice, between the development of conceptual understanding, and the practical competence of information professionals? To elaborate on this point, a provocative note by Carl Keren (1984) appeared in the March issue of the *Journal of the American Society for Information Science (JASIS)* under the title "On Information Science." Keren raises interesting questions about the relationship between information science research and practice. Keren asks four questions (slightly paraphrased):

1. Do researchers in information science write about research that advances the state of the art?
2. How much of the research output has really contributed to our body of knowledge?
3. Is information science a name with a recognizable body attached to it? Is it a subject whose contents we can define?
4. Is there a lack of feedback between researchers and practitioners?

Gerald Salton's (1985) response appeared in the July issue of *JASIS* under the title "A Note About Information Science Research." Salton states that questions such as these "are, of course, not new, and they are reflective of legitimate concerns." Salton further states, generally agreeing with Keren, that "most of the published research in our field is probably not worth doing and ought to be forgotten." He further states that, on the other hand, "not all information science research is inferior and that [in general] not all information science research is useless." As evidence, Salton cites a number of topics which have been actively researched in information science. These include the vector processing retrieval strategy, probabilistic retrieval models, best match retrieval, query reformulation using relevance feedback, refinements of Boolean searching using term weights, and improved front-ends and expert system designs.

Concluding his response, Salton contends that, "as is the case in all other intellectual areas of endeavor, there are never any shortcuts in bridging the gap between research and practice (application)." It is necessary to *study* the literature; it is necessary to have sufficient know-how to discriminate and to put matters in context. Eventually the pieces will fit together, and the observer can judge the specifics instead of being forced to rely on superficial impressions and generalizations. Maybe Salton's final comment is the most telling. "Perhaps [library science and information science] would evolve even more rapidly if the practitioners would stop blaming the research side and asked instead 'What have we practitioners done for ourselves lately.' "

The Reality of Theory Based Practice

In March 1989, a symposium titled "Organizing a Research Agenda: Information Studies for the 1990s" was held at Dalhousie University in Halifax, Nova Scotia. In a paper delivered at this symposium, Edie Rasmussen (1989) responds to Salton's (1985) "A Note About Information Science Research" by stating that many of the procedures listed by Salton (1985) could be implemented directly in existing information retrieval (IR) systems, though, in fact, few have been. Thus, it would appear that very few research findings in IR have found their way into readily available IR systems. As Rasmussen (1989) insists "[I]t seems, therefore, that IR research has contributed considerably to knowledge but very little to practice, an outcome that has recently been recognized as a problem by researchers themselves." Rasmussen's sentiment is also echoed by Radecki (1988) who wrote:

> Despite the fact that considerable progress has been made in information retrieval research, particularly in the last decade or so, it has hardly affected commercial retrieval systems, which, as a rule, are founded on conventional Boolean logic (p. 219).

The reality is simple. In library and information science, theory has little to do with practice. Further, little relationship, if any, exists between the development of library science and information science theory and change in the practice of library and information science. To further develop this point, it is important to differentiate between changes due to new technologies and changes resulting from theoretical-based research (Rasmussen, 1989). The major changes that have occurred in libraries and technical information centers in the past 25 years are due more to advances in information technology than to advances in library science and information science research. While technology has altered *how* information professionals perform their tasks, it has done little to influence the *structure* or *nature* of those tasks (Molholt, 1987).

Why the Disconnect?

There are several views on this point. One perspective holds that in library science and information science there is too little interaction between the communities of researchers (e.g., schools of library and information science) and practitioners (e.g., librarians and technical information specialists). Specifically, there is far too little interaction between the academic community, where the bulk of the researchers abide, and the environment in which the provision of information takes place; the world in which the practitioners reside. Further, very few mechanisms exist for the transfer of information between the two worlds. Researchers publish their results in scholarly, not "trade" journals. Publication in "learned" journals is required for tenure and promotion. Though some might consider this a "sweeping and indefensible generalization," practitioners, if they peruse the literature at all, seldom read yet alone understand the articles appearing in such scholarly publications as *JASIS*.

Another perspective holds that professional schools, such as schools of library and information science and professional education (e.g., the preparation of librarians and technical information specialists), have no place in the university. The roots of this position, a position favoring non-occupational education, can be traced to English and German models of higher education. These are the models upon which U.S. colleges and universities are based. Although professional education programs have been added to the curriculums of many U.S. colleges and universities in recent years, these programs are frequently denigrated by the so-called "liberal arts." With the full expectation of gaining acceptance on the basis of scholarship, the members of the professional schools try to act and appear scholarly. This results in research that is more basic than applied and more theoretical and less practical and produces results that are simply not relevant to practitioners who constitute the bulk of the profession.

Another perspective holds that the "pull" of technology capability rather than the "push" of supporting theory has the greatest influence on the provision of information. The rapid pace of developments in four areas—communications, data storage, computing power, and computing cost—is leading the change in the information industry. Developments in these areas have combined to bring about the following trends: decentralization; larger and more varied data bases; a move from bibliographic to full text systems; an emphasis on document delivery rather than mere citation retrieval; and a proliferation of interfaces, especially those for end user searching (Rasmussen, 1989). None of these trends, however, involve any innovation or substantive change in the existing IR model which is essentially the same model developed in the late 1960s.

To expand on this point, Smit and Kocken (1988) undertook a survey to determine the impediments to innovation on the part of online data base vendors. Their research focused on how vendors made decisions to improve IR software. In addition, decisions on three particular innovations—ranking items in a search output in order of priority to the user, system-user adaption mechanisms, and menu-driven retrieval—which would be relatively easy to implement were examined. Perhaps more important than the answers given was the lack of knowledge about potential innovations amongst those responsible for the IR system. This lack of awareness lead Smit and Kocken to conclude that "online vendors differ from most high technology industries, where news about innovations is pursued with much dedication" (p. 283).

Finally, there is another perspective that views the user as the center of all information activities. Holders of this perspective believe that the needs of the user and the user's interaction with the information system were virtually ignored during the formative years of library science and information science research. Allen (1977) uses the following quote, attributed to Saul Herner (1954), to illustrate the importance of this perspective:

> Perhaps the most important and least considered factor in the design of information storage and retrieval systems is the user of such systems. Regardless of what other parameters are considered in the development of a storage and retrieval mechanism, it is necessary to consider its potential use and mode of use by the persons or groups for whom it is intended. It is necessary to either fashion the system to suit the user's needs, habits, and preferences, or to fashion the user to meet the needs, habits, and preferences of the system. Both approaches are possible but the second one,

involving education and reeducation of the user, is evolutionary and futuristic. A system designed for now should at least be able to serve the present user.

The Need for Research and Research Priorities

There are compelling reasons for conducting experimental, policy, and theoretical oriented STI research. **First**, STI is an essential ingredient of research and development (R&D). The ability of engineers and scientists to identify, acquire, and utilize STI is of paramount importance to the efficiency of the R&D process. Testimony to the central role of STI in the R&D process is found in numerous studies (Fischer, 1980). These studies show, among other things, that engineers and scientists devote more time, on the average, to the communication of technical information than to any other scientific or technical activity (Pinelli, et al., 1989). A number of studies have found strong relationships between the communication of STI and technical performance at both the individual (Allen, 1970; Hall and Ritchie, 1975; and Rothwell and Robertson, 1973) and group levels (Carter and Williams, 1957; Rubenstein, et al., 1971; and Smith, 1970).

These findings support the conclusion that the role of scientific and technical communication is thus central to the success of the innovation process, in general, and the management of R&D activities, in particular. But there in lies the problem. While STI is crucial to successful R&D, linkages between the various sectors of the R&D infrastructure are weak and/or poorly defined. It is likely that an understanding of the process by which STI is communicated through certain channels over time among the members of the social system would contribute to increasing productivity, stimulating innovation, and improving and maintaining the professional competence of engineers and scientists.

Second, despite the vast amount of STI available to potential users, several major barriers to effective utilization exist. The very low level of support for STI transfer and use in comparison to STI production suggests that dissemination efforts are not viewed as an important component of the R&D process. There are mounting reports from users about difficulties in getting appropriate STI in forms useful for problem solving and decision making. Rapid advances in many areas of science and technology can be fully exploited only if they are quickly translated into further research and application. Current mechanisms are often inadequate to help users assess the quality of available information. The characteristics of actual usage behavior are not sufficiently taken into account in making available useful and easily retrieved STI.

Third, while various approaches have been tried, STI transfer activities continue to be driven by a "supply-side" dissemination model. The dissemination model emphasizes the need to transfer information to potential users and embraces the belief that the production of quality knowledge is not sufficient to ensure its fullest use. Linkage mechanisms, such as information intermediaries, are needed to identify useful knowledge and to transfer it to potential users. This model assumes that if these mechanisms are available to link potential users with knowledge producers, then better opportunities exist for users to determine what knowledge is available, acquire it, and apply it to their needs. The strength of this model rests with the recognition that STI transfer and use are critical elements of the process of technological innovation. Its weakness lies with the fact that it is passive, for it does not take users into consideration except when they enter the system and request assistance; however, user requirements are seldom known or considered in the design of information products and services. This model employs one-way, source-to-user transfer procedures that are seldom responsive in the user context.

In the U.S., the existing STI dissemination transfer mechanism is composed of two parts—the **informal** that relies on collegial contacts and the **formal** that relies on surrogates, information products, and information intermediaries to complete the "producer to user" transfer process. The producers are the Federal R&D "mission" agencies and their contractors and grantees. Producers depend upon surrogates and information intermediaries to operate the formal transfer component.

Surrogates serve as technical report repositories or clearinghouses for the producers and include the Defense Technical Information Center (DTIC), the NASA Center for AeroSpace Information (CASI), and the National Technical Information Service (NTIS). Information intermediaries are, in large part, librarians and technical information specialists in academia, government, and industry. Those representing the producers serve as what McGowan and Loveless (1981) call "knowledge brokers" or "linking agents." Information intermediaries connected with users act, according to Allen (1977), as "technological entrepreneurs" or "gatekeepers." The more "active" the intermediary, the more effective the transfer process (Goldhor and Lund, 1983). Active intermediaries take information from one place and move it to another, often face-to-face. Passive information intermediaries, on the other hand, "simply array information for the taking, relying on the initiative of the user to request or search out the information that may be needed" (Eveland, 1987, p. 4).

The major problem with the total STI system is "that the present system for transferring the results of government funded STI is passive, fragmented, and unfocused." Effective knowledge transfer is hindered by the fact the U.S. government "has no coherent or systematically designed approach to transferring the results of government funded R&D to the user" (Ballard, et al., 1986, pp. 2-3). Approaches to STI transfer vary considerably from agency to agency and, with any given agency, have changed significantly over time. These variations reflect differences between agencies (i.e., legislative mandates), the interpretation of their missions, and budgetary opportunities and constraints. In their study of issues and options in U.S. government funded STI, Bikson and her colleagues (Bikson, Quint, and Johnson, 1984) found that many interviewees considered dissemination activities "afterthoughts, undertaken without serious commitment by U.S. government agencies whose primary concerns were with [knowledge] production and not with knowledge transfer;" therefore, "much of what has been learned about knowledge transfer has not been incorporated into U.S. government supported STI transfer activities" (p. 22).

The specific problem with the **informal** part of the system is that knowledge users can learn from collegial contacts only what those contacts happen to know. Ample evidence supports the claim that researchers can know about or keep up with all the research in their area(s) of interest. Two problems exist with the **formal** part of the system. First, it employs one-way, source-to-user transmission. However, one-way, "supply-side" transfer procedures do not seem to be responsive to the user context (Bikson, Quint, and Johnson, 1984). Rather, these efforts appear to start with an information system into which the users' requirements are retrofit (Adam, 1975). The consensus of the findings from the empirical research is that interactive, two-way communications are required for effective information transfer. (Bikson, Quint, and Johnson, 1984).

Second, the **formal** part relies heavily on information intermediaries to complete the knowledge transfer process, but a strong methodological base for measuring or assessing the effectiveness of the information intermediary is lacking (Kitchen and Associates, 1989). The impact of information intermediaries is likely to be strongly conditional and limited to a specific institutional context. To date, empirical findings on the effectiveness of information intermediaries and the role(s) they play in knowledge transfer are sparse and inconclusive (Beyer and Trice, 1982).

The **formal** part of the transfer mechanism is particularly ineffective because STI is not organized and structured according to problem relevance. More to the point, putting STI to use frequently requires transferring it in a use context that is quite different from the context in which it was produced or originally packaged. This problem is complicated by the fact that STI is organized along traditional disciplinary lines as are subject matter indexes, abstracts, and key words. This organizational scheme makes multidisciplinary retrieval extremely difficult for users and (typically non-technical) information intermediaries alike. The **formal** part of the transfer mechanism becomes even less effective when the user's environment is not well aligned with the standard disciplinary taxonomies (Bikson, Quint, and Johnson, 1984).

Fourth, although considerable research into technological innovation and policy analysis has been conducted by various disciplines and from numerous perspectives, policy implications from the results of this research and investigation are inconsistent, contradictory, and are simply not used for policy development. Moreover, there is a general consensus that current conceptual and empirical knowledge regarding both the process of technological innovation and government intervention is lacking. According to Curlee and Goel (1989), recognition is growing that technology transfer and diffusion is the "key" to the success of technological innovation. Consequently, understanding the factors that motivate innovation and channel its direction is necessary if intervention is to successfully increase the production of useful innovation. Nelson (1982) and Pavitt and Walker (1976), in separate reviews and analyses of government policies and programs toward technological innovation, state that government innovation policy and prescription encourage innovation, not its adoption; knowledge transfer and utilization [diffusion] are "very inadequately served by market forces and the incentives of the market place." They conclude government would better serve technology policy by assuming a more active role in the knowledge diffusion process and by formulating policies and programs that encourage and improve communications between users and producers of knowledge. However, it is obvious many of the industrialized nations lack a systematically designed approach to transferring the results of government funded R&D to the user (Ballard, 1986). Although U.S. technology policy efforts rely on a "dissemination-oriented" approach to STI transfer, other industrialized nations, such as Germany and Japan, are adopting "diffusion-oriented" policies which increase the power to absorb and employ new technologies productively.

The knowledge diffusion model is grounded in theory and practice associated with the diffusion of innovation and planned change research and the clinical models of social research and mental health. Knowledge diffusion emphasizes "active" intervention as opposed to dissemination and access; stresses intervention and reliance on interpersonal communications as a means of identifying and removing interpersonal barriers between users and producers; and assumes that knowledge production, transfer, and use are equally important components of the R&D process. This approach also emphasizes the link between producers, transfer agents, and users and seeks to develop user-oriented mechanisms (e.g., products and services) specifically tailored to the needs and circumstances of the user. It makes the assumption that the results of government funded R&D will be under utilized unless they are relevant to users and ongoing relationships are developed among users and producers. The problem with the knowledge diffusion model is that (1) it requires a large government role and presence and (2) it runs contrary to the dominant assumptions of the established "supply-side" R&D policy system.

Compelling reasons also exist for establishing STI research priorities. Shaughnessy (1976) noted some previous attempts in this article, "Library Research in the 70's; Problems and Prospects." He cites as examples Frank Schick's (1963) essay "Library Science Research Needs," Ralph Blasingame's (1965) contribution, "Some Research Questions," and Harold Borko's (1973) delphi study. Shaughnessy concluded that the main problem confronting the profession was not the absence of research priorities but, rather, how to communicate the results of research to practitioners in the field in a meaningful way. More recent attempts include the work undertaken by Cuadra Associates, Inc. (1982) entitled *A Library and Information Science Research Agenda for the 1980's*; the work by Griffiths and King (1985) entitled, *New Directions in Library and Information Science Education*; and Jane Robbins' (1987) article, "Another! Research Agenda." The more recent contributions include, *Rethinking the Library in the Information Age*, sponsored by the U.S. Department of Education (1988), a symposium at Dalhousie University (1989), and McClure and Hernon's (1991) book, *Library and Information Science Research: Perspectives and Strategies for Improvement*.

Focus on the User and Information-Seeking Behavior

There are many different information user communities. The differences between them may be great. Even within similar or related user communities there may be considerable differences among users. Thus, to meet the information needs of the user communities, information professionals must first understand the nature of the user community and become familiar with the information-seeking behavior of the user. For purposes of this paper, the users are aerospace engineers and scientists and the user community is aerospace.

Numerous studies concerned with information users and information-seeking behavior have been conducted. The general consensus is that this research is noncumulative, fragmentary, and generally weak. All and all, the literature regarding information-seeking behavior is fragmented and superficial. The results of these [user] studies have not accumulated to form a significant body of knowledge that can be used to develop practice based theory and information systems and services.

Part of the problem is definition. The two communities (engineering and science) and user groups (engineers and scientists) are not the same and the argument that scientist is a more generic term merely evades the fundamental issue. The practice of lumping the two groups [engineers and scientists] together is self-defeating in information [production, transfer, and] use studies because confusion over the characteristics of the sample has led to what appears to be conflicting results and to a greater difficulty in developing normative measures for improving information systems in either science or technology.

Further, the terms engineer and scientist are not synonymous. The difference in work environment and personal/professional goals between the engineer and scientist proves to be an important factor in determining their information-seeking habits and practices.

Background

In their treatise, *The Positive Sum Strategy: Harnessing Technology for Economic Growth*, Landau and Rosenberg (1986) describe technological innovation as the critical factor in the long-term economic growth of modern industrial societies that functions successfully only within a larger social environment that provides an effective combination of incentives and complementary inputs into the innovation process. Technological innovation is a process in which the communication of STI is critical to the success of the enterprise (Fischer, 1980).

"**Technology**, unlike science, is an extroverted activity; it involves a search for workable solutions to problems. When it finds solutions that are workable and effective, it does not pursue the **why**? very hard. Moreover, the output of technology is a product, process, or service. **Science**, by contrast, is an introverted activity. It studies problems that are usually generated internally by logical discrepancies or internal inconsistencies or by anomalous observations that cannot be accounted for within the present intellectual framework" (Landau and Rosenberg, 1986). Technology is a process dominated by engineers, as opposed to scientists, which "leads to different philosophies and habits not only about contributing to the technical literature but also to using the technical literature and other sources of information" (Joenk, 1985). Consequently, an understanding of the relationship between science and technology and the information-seeking habits and practices of engineers is essential to the development and provision of information services for engineers.

The Nature of Science and Technology

The relationship between science and technology is often expressed as a continuous process or normal progression from basic research (science) through applied research (technology) to development (utilization). This relationship is based on the widely held assumption that technology grows out of or is dependent upon science for its development. However, the belief that technological change is somehow based on scientific advance has been challenged in recent years. Substantial evidence exists that refutes the relationship between science and technology.

Schmookler (1966) has attempted to show that the variation in inventive activity between different American industries is explicable in terms of the variation in demand, concluding that economic growth determines the rate of inventive activity rather than the reverse. Price (1965), in his investigation of citation patterns in both scientific and technical journals, found that scientific literature is cumulative and builds upon itself, whereas technical literature is not and does not build upon itself. Citations to previous work are fewer in technical journals and are often the author's own work.

Price (1965) concluded that science and technology progress independently of one another. Technology builds upon its own prior developments and advances in a manner independent of any link with the current scientific frontier and often without any necessity for an understanding of the basic science underlying it.

In summarizing the differences between science and technology, Price (1965) makes the following 12 points. **First**, science has a cumulating, close-knit structure; that is, new knowledge seems to flow from highly related and rather recent pieces of old knowledge, as displayed in the literature. **Second**, this property is what distinguishes science from technology and from humanistic scholarship. **Third**, this property accounts for many known social phenomena in science and also for its surefootedness and high rate of exponential growth. **Fourth**, technology shares with science the same high growth rate, but shows quite complementary social phenomena, particularly in its attitude to the literature. **Fifth**, technology therefore may have a similar, cumulating, close-knit structure to that of science, but it is of the state of the art rather than of the literature. **Sixth**, science and technology each therefore have their own separate cumulating structures. **Seventh**, a direct flow from the research front of science to that of technology, or vice versa, occurs only in special and traumatic cases since the structures are separate.

Eighth, it is probable that research-front technology is strongly related only to that part of scientific knowledge that has been packed down as part of ambient learning and education, not to research-front science. **Ninth**, research-front science is similarly related only to the ambient technological knowledge of the previous generation of students, not to the research front of the technological state of the art and its innovation. **Tenth**, this reciprocal relation between science and technology, involving the research front of one and the accrued archive of the other, is nevertheless sufficient to keep the two in phase in their separate growths within each otherwise independent cumulation. **Eleventh**, it is therefore naive to regard technology as applied science or clinical practice as applied medical science. **Twelfth**, because of this, one should be aware of any claims that a particular scientific research is needed for particular technological breakthroughs, and vice versa. Both cumulations can only be supported for their own separate ends.

Allen (1977), who studied the transfer of technology and the dissemination of technological information in R&D organizations, finds little evidence to support the relationship between science and technology as a continuous relationship. Allen concludes that the relationship between science and technology is best described as a series of interactions that are based on need rather than on a normal progression.

Allen (1977) states that the independent nature of science and technology (S&T) and the different functions performed by engineers and scientists directly influence the flow of information in science and technology. Science and technology are ardent consumers of information. Both engineers and scientists require large quantities of information to perform their work. At this level, there is a strong similarity between the information input needs of engineers and scientists. However, the difference between engineers and scientists in terms of information processing becomes apparent upon examination of their outputs (Allen, 1977).

According to Allen (1977), information processing in S&T is depicted in the form of an input-output model. Scientists use information to produce information. From a system standpoint, the input and output, which are both verbal, are compatible. The output from one stage is in a form required for the next stage. Engineers use information to produce some physical change in the world. Engineers consume information, transform it, and produce a product that is information bearing; however, the information is no longer in verbal form. Whereas scientists consume and produce information in the form of human language, engineers transform information from a verbal format to a physically encoded form. Verbal information is produced only as a by-product to document the hardware and other physical products produced.

According to Allen (1977), there is an inherent compatibility between the inputs and outputs of the information-processing system of science. He further states that since both are in a verbal format, the output of one stage is in the format required for the next stage. The problem of supplying information to the scientist becomes a matter of collecting and organizing these outputs and making them accessible. Since science operates for the most part on the premise of free and open access to information, the problem of collecting outputs is made easier.

In technology, however, there is an inherent incompatibility between inputs and outputs. Since outputs are usually in a form different from inputs, they usually cannot serve as inputs for the next stage. Further, the outputs are usually in two parts, one physically encoded and the other verbally encoded. The verbally encoded part usually cannot serve as input for the next stage because it is a by-product of the process and is itself incomplete (Allen, 1977). Those unacquainted with the development of the hardware or physical product therefore require some human intervention to supplement and interpret the information contained in the documentation. Since technology operates to a large extent on the premise of restricted access to information, the problem of collecting the documentation and obtaining the necessary human intervention becomes difficult (Allen, 1988).

Distinguishing Engineers From Scientists

In their study of the values and career orientation of engineering and science undergraduate students, Krulee and Nadler (1960) found that engineering and science students have certain aspirations in common: to better themselves and to achieve a higher socio-economic status than that of their parents. They reported that science students place a higher value on independence and on learning for its own sake while engineering students are more concerned with success and professional preparation. Many engineering students expect their families to be more important than their careers as a source of satisfaction, but the reverse pattern is more typical for science students.

Krulee and Nadler (1960) also determined that engineering students are less concerned than science students with what one does in a given position and more concerned with the certainty of the rewards to be obtained. They reported that, overall, engineering students place less emphasis on independence, career satisfaction, and the inherent interest their specialty holds for them and place more value on success, family life, and avoiding a low-level job. Engineering students appear to be prepared to sacrifice some of their independence and opportunities for innovation in order to realize their primary objectives. Engineering students are more willing to accept positions that will involve them in complex organizational responsibilities and they assume that success in such positions will depend upon practical knowledge, administrative ability, and human relation skills (Krulee and Nadler, 1960).

In his study of engineers in industry, Ritti (1971) found marked contrast between the work goals of engineers and scientists. Ritti draws the following three conclusions from his study: (1) the goals of engineers in industry are very much in line with meeting schedules, developing products that will be successful in the marketplace, and helping the company expand its activities; (2) while both engineers and scientists desire career development or advancement, for the engineer advancement is tied to activities within the organization, while advancement for the scientist is dependent upon the reputation established outside of the organization; and (3) while publication of results and professional autonomy are clearly valued goals of the Ph.D. scientist, they are clearly the least valued goals of the baccalaureate engineer.

Allen (1988) states that the type of person who is attracted to a career in engineering is fundamentally different from the type of person who pursues a career as a scientist. He writes that "perhaps the single most important difference between the two is the level of education. Engineers are generally educated to the baccalaureate level; some have a master's degree while some have no college degree. The research scientist is usually assumed to have a doctorate. The long, complex process of academic socialization involved in obtaining the Ph.D. is bound to result in persons who differ considerably in their lifeviews." According to Allen (1988), these differences in values and attitudes toward work will almost certainly be reflected in the behavior of the individual, especially in their use and production of information.

According to Blade (1963), engineers and scientists differ in training, values, and methods of thought. Further, Blade states that the following differences exist in their individual creative processes and in their creative products: (1) scientists are concerned with discovering and explaining nature; engineers use and exploit nature; (2) scientists are searching for theories and principles; engineers seek to develop and make things; (3) scientists are seeking a result for its own ends; engineers are engaged in solving a problem for the practical operating results; and (4) scientists create new unities of thought; engineers invent things and solve problems. Blade states that "this is a different order of creativity."

Finally, communication in engineering and science is fundamentally different. Communication patterns differ because of the fundamental differences between engineering and science and because of the social systems associated with the two disciplines. With one exception, the following characteristics of the social systems as they apply to the engineer and scientist are based on Holmfeld's (1970) investigation of the communication behavior of engineers and scientists.

Engineer

- Contribution is [technical] knowledge used to produce end-items or products.
- New and original knowledge is not a requirement.
- Reward is monetary or materialistic and serves as an inducement to continue to make further contributions to technical knowledge.
- Seeking rewards that are not part of the social system of technology is quite proper and also encouraged.
- The value of technical knowledge lies in its value as a commodity of indirect exchange.
- Exchange networks found in the social system of technology are based on end-item products, not knowledge.
- Strong norms against free exchange or open access to knowledge with others outside the organization exist in the social system of technology.
- Restriction, security classification, and proprietary claims to knowledge characterize the social system of technology.

Scientist

- Contribution is new and original knowledge.
- Reward is social approval in the form of professional [collegial] recognition.
- Recognition is established through publication and claim of discovery.
- A well-developed communication system based on unrestricted access is imperative to recognition and claim of discovery.
- Since recognition and priority of discovery are critical, strong norms against any restriction to free and open communication exist in the social system of science.
- Seeking rewards that are not part of the social system of science in return for scientific contribution

is not considered proper within the social system of science.

- Exchange networks commonly referred to as "invisible colleges" exist in the social system of science; in these networks the commodities are knowledge and recognition (Price, 1961; Crane, 1972).

Influence on Information-Seeking Habits and Practices of Engineers

The nature of science and technology and differences between engineers and scientists influence their information-seeking habits, practices, needs, and preferences and have significant implications for planning information services for these two groups (1966). Taylor (1986), who quotes Brinberg (1980), offers the following characteristics for engineers and scientists: "Unlike scientists, the goal of the engineer is to produce or design a product, process, or system; not to publish and make original contributions to the literature. Engineers, unlike scientists, work within time constraints; they are not interested in theory, source data, and guides to the literature nearly so much as they are in reliable answers to specific questions. Engineers prefer informal sources of information, especially conversations with individuals within their organization. Finally, engineers tend to minimize loss rather than maximize gain when seeking information."

Anthony, et al., (1969) suggest that engineers may have psychological traits that predispose them to solve problems alone or with the help of colleagues rather than finding answers in the literature. They further state that "engineers like to solve their own problems. They draw on past experiences, use the trial and error method, and ask colleagues known to be efficient and reliable instead of searching or having someone search the literature for them. They are highly independent and self-reliant without being positively anti-social."

According to Allen (1977), "Engineers read less than scientists, they use literature and libraries less, and seldom use information services which are directly oriented to them. They are more likely to use specific forms of literature such as handbooks, standards, specifications, and technical reports." What an engineer usually wants, according to Cairns and Compton (1970), is "a specific answer, in terms and format, that are intelligible to him—not a collection of documents that he must sift, evaluate, and translate before he can apply them." Young and Harriott (1979) report that "the engineer's search for information seems to be based more on a need for specific problem solving than around a search for general opportunity. When engineers use the library, it is more in a personal-search mode, generally not involving the professional (but "nontechnical") librarian." Young and Harriott conclude by saying that "when engineers need technical information, they usually use the most accessible sources rather than searching for the highest quality sources. These accessible sources are respected colleagues, vendors, a familiar but possibly outdated text, and internal company [technical] reports. He [the engineer] prefers informal information networks to the more formal search of publicly available and cataloged information."

Evidence exists to support the hypothesis that differences between science and technology and scientists and engineers directly influence information-seeking habits, practices, needs, and preferences. The results of a study conducted by the System Development Corporation (1966) determined that "an individual differs systematically from others in his use of STI" for a variety of reasons. Chief among these are five institutional variables—type of researcher, engineer or scientist; type of discipline, basic or applied; stage of project, task, or problem completeness; the kind of organization, fundamentally thought of as academia, government, and industry; and the years of professional work experience."

NASA/DoD Aerospace Knowledge Diffusion Research Project

This four-phase project is providing descriptive and analytical data regarding the flow of STI at the individual, organizational, national, and international levels. It is examining both the channels used to communicate STI and the social system of the aerospace knowledge diffusion process. Phase 1 investigates the information-seeking habits and practices of U.S. aerospace engineers and scientists and places particular emphasis on their use of government funded aerospace STI. Phase 2 examines the industry-government interface and places special emphasis on the role of the information intermediary in the knowledge diffusion process. Phase 3 concerns the academic-government interface and places specific emphasis on the information intermediary-faculty-student interface. Phase 4 explores the information-seeking behavior of non-U.S. aerospace engineers and scientists from Brazil, Western Europe, India, Israel, Japan, and Russia.

The results will help us to understand the flow of STI at the individual, organizational, national, and international levels. The results of our research will contribute to increasing productivity and to improving and maintaining the professional competence of aerospace engineers and scientists. They can be used to identify and correct deficiencies, to improve access and use, to plan new aerospace STI systems, and should provide useful information to R&D managers, information managers, and others concerned with improving access to and utilization of STI. The results of our research are being shared freely with those who participate in the study (Pinelli, et al., 1990).

A User-Oriented Research Agenda for STI: Topics for Consideration

How people seek information is the most fundamental theoretical and overarching issue in library and information science. Its importance stems from the practitioners concern for efficient and economic operation of library and information science services. The dramatic rise in the availability and kinds of computer and information technology has brought about the need to rethink and reexamine this issue. Aloni (1985) makes the point that library and information science research continues to focus on the problems related to the mechanization and automation of library and information services and less on the user. He contends that a "basic grounding in the behavioral sciences and organizational science is a prerequisite because such an understanding is needed to understand the user." The following quotation from Allen and Cooney (1973) serves to support this position:

> Although considerable effort has been devoted to evaluating the effectiveness of information acquisition mechanisms, the effort has been, for the most part, restricted to the evaluation of hardware and software systems. Little is known about the human element in the acquisition process... Since research into the dissemination process has shown the overwhelming importance of personal contact, such approaches to acquisition will have a natural kinship with the dissemination system. In fact, they may prove to be more effective than all the hardware, software, and print-oriented devices combined.

The user, then, becomes the central component to the provision of information and the theme of this agenda.

Emphasis on the user is based on the premise that an understanding of information-seeking behavior is essential to the design and provision of information policy, products, services, and systems. Regardless of what other parameters are considered in the design and provision, it is necessary to consider the potential use and mode of use by the person(s) and groups for whom the policy, products, services, and systems are intended.

Background

Considerable research and numerous "user" studies have been conducted over the past 35 years. The generally held belief is that (1) the results of this research and these studies have not accumulated to form a significant body of knowledge that can be used by information professionals and (2) the "results that are usable" have been virtually ignored by those concerned with the design and provision of information policy, products, services, and systems.

Despite the expenditure of considerable funds and effort, there is no generally accepted or systematically acquired body of research that can accurately describe or explain information-seeking behavior or predict the use of information other than at the most elementary levels. A variety of environmental and structural changes, including the growth of computer and information technology, combine to significantly weaken the relevance and reliability of this research. Hence there is the need for a user oriented research agenda.

An acquired body of research is vital to the development of theory and the solution of professional problems, to the formation of tools and methods for analyzing organizations, services, environments, and behaviors, for determining the cost and benefits of information products, services, and systems, for establishing and developing theories upon which to base practice, and for contributing paradigms, models, and radically new conceptualizations of library science and information science phenomena.

Research Agenda

The goal is the creation of a generally accepted, systematically developed and implemented, but user focused, research agenda for AGARD (Advisory Group for Aerospace Research and Development) TIP (Technical Information Panel) member countries. (The creation of another "laundry list" of things that should be done, is not included as a part of this research agenda.) The term **user** includes any person(s) or groups of persons involved in the production, transfer, use, and management of information. Finally, information use seldom exists as an isolated incident. Information use usually takes place within organizational and interpersonal contexts. Therefore, it should not be studied in isolation but rather in an holistic environment.

Once implemented, this research agenda could be completed within 3–5 years. The results would be generalizable to AGARD member nations, would form the basis for the development of theory-based practice, and would form a significant body of knowledge that can be used by AGARD information professionals for policy, practice, product, and systems development.

1. Previous research regarding the information-seeking behavior of "users" is noncumulative, has been variously criticized, and has largely been dismissed on the basis of research and scholarship.
   - A. Conduct a "critical" review, analysis, and evaluation of previous research, identify and remove spurious research findings, and establish a starting point or foundation for "what is known and accepted as fact" vis-a-vis information-seeking behavior.
   - B. Identify the criticisms and deficiencies of previously used research designs and methodologies and compile a "lessons learned" to guard against committing the same or similar mistakes.
   - C. Consider lessons learned in the context of existing research designs and methodologies and identify those that correct or compensate for previous mistakes.
2. Previous research regarding the information-seeking behavior of "users" has been limited to a particular system, product, or service in a particular organization or environment. Hence, the results are often confusing, conflicting, and are not sufficient to form the basis for the development of theory.
   - A. Develop standard definitions, terms, and terminologies.
   - B. Develop, test, and validate research tools, instruments, and techniques.
   - C. Develop a standard set of variables.
     1. Types of Users
        a. Engineers
        b. Scientists
        c. Intermediaries
        d. Gatekeepers
        e. Managers
     2. Types of Organizations
        a. Academic
        b. Government
        c. Industry
     3. Size of Organization
        a. Small
        b. Medium
        c. Large
     4. Types of Environment
        a. Research
        b. Development
        c. Design
        d. Manufacturing
        e. Production
        f. Test and Evaluation
        g. Marketing and Sales
        h. Service and Maintenance
        i. Management
     5. Types of Data
        a. Textural
        b. Numeric
        c. Factual
     6. Types of Product/Service
        a. Print
        b. Nonprint
        c. Electronic
     7. Types of Discipline
        a. Engineering
        b. Science
   - D. Determine which variable(s) best describe and explain the use of information in a variety of environments.
3. What is known about the information-seeking behavior of users appears not to explain information use and nonuse. Hence, there is little knowledge that can be used for testing existing and developing new paradigms.
   - A. Conduct information-seeking behavior "user" research within a conceptual framework that embraces the production, transfer, use, and management of information. One possible outcome could be the identification of barriers that prohibit or restrict the use of information.

B. Seek to understand the diffusion of knowledge as a precursor to describing and explaining user behavior.

C. Develop and test hypotheses, the results of which can lead to the formation of theory that can be used to predict the use of information.

D. Develop a series of experiments, the results of which will lead to the formation of paradigms, models, and radically new conceptualizations of library and information science phenomena.

4. Conventional wisdom states that a "disconnect" exists between theory and practice/researchers and practitioners in the fields of library science and information science.

A. Develop a mechanism that couples the results of basic and applied research with users in the field.

B. Develop the means by which researchers and practitioners will have greater interaction.

Concluding Remarks

Research in library science and information science cannot be viewed as a luxury. It is vital to the solution of professional problems; the development of tools and methods for analysis of organizations, behavior, and services; to determining the costs and benefits of library and information services; to establishing and developing theories on which to base practice; or providing the field with paradigms or radically new conceptualizations of library and information science phenomena.

A number of library science and information science research agendas have been proposed and/or developed over the 20 years. Despite such attempts, there is a lack of consensus regarding what should be researched. A lack of consensus is, perhaps, to be expected in a maturing area such as library and information science. What is missing, however, is a generally agreed upon list of problems or questions important to library and information science. Consequently, there is no agreement on the significant questions concerning the development of theory and the design of research. Both the questions and the answers may be painful. But both are important to the further development of theory and paradigms.

What is needed is to determine what we know and where we are. Use this knowledge as a starting point to determine the questions that must be asked, the answers to which will form the elements of a basic research program and the development of theory-based practice. Applied research can be used to validate and otherwise test this theory. A mechanism is needed to link (communicate) researchers and practitioners and to translate the results of research into practice.

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