DOCUMENT RESUME

ED 363 499 SE 053 743

AUTHOR Hutchinson, Janet; Huberman, Michael
TITLE Knowledge Dissemination and Use in Science and Mathematics Education: A Literature Review.
INSTITUTION Network of Innovative Schools, Inc., Andover, Mass.
REPORT NO NSF-93-75
PUB DATE May 93
NOTE 36p.; Prepared by The Network, order number CB-2649X-00-0.
AVAILABLE FROM National Science Foundation, Washington, DC 20550.
PUB TYPE Reports - Research/Technical (143) -- Information Analyses (070)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Constructivism (Learning); Diffusion (Communication); Educational Research; Elementary Secondary Education; *Information Dissemination; Literature Reviews; *Mathematics Education; *Science Education; Science Instruction; Scientific Concepts; Teacher Education

ABSTRACT

Dissemination of educational research and effective practice has burgeoned in the past two decades. This report reviews the research on knowledge use in science and mathematics education and highlights approaches and strategies for dissemination which might be particularly useful to the National Science Foundation. In particular, the influence of constructivist perspectives in knowledge use and education on the dissemination of knowledge are highlighted. Literature on dissemination and use is reviewed in several fields, including physical sciences, architecture, waste management, and organizational management. Contains 90 references. (PR)

KNOWLEDGE DISSEMINATION AND USE IN SCIENCE AND MATHEMATICS EDUCATION: A LITERATURE REVIEW

NATIONAL • SCIENCE • FOUNDATION

May, 1993

STIS

What is STIS?

STIS is an electronic dissemination system that provides fast, easy access to National Science Foundation (NSF) publications. There is no cost to you except for possible long-distance phone charges. The service is available 24 hours a day, except for brief weekly maintenance periods.

What Publications are Available?

Publications currently available include:

- The *NSF Bulletin*
- Program announcements and "Dear Colleague" letters
- General publications and reports
- Press releases
- NSF organization charts and phone books
- NSF vacancy announcements
- Award abstracts (1989—now)

Our goal is for all printed publications to be available electronically.

Access Methods

There are many ways to access STIS. Choose the method that meets your needs and the communication facilities you have available.

Electronic Documents Via E-Mail. If you have access to Internet or BITNET e-mail, you can send a specially formatted message, and the document you request will be automatically returned to you via e-mail.

Anonymous FTP. Internet users who are familiar with this file transfer method can quickly and easily transfer STIS documents to their local system for browsing and printing.

On-Line STIS. If you have a VT100 emulator and an Internet connection or a modem, you can log on to the on-line system. The on-line system features full-text search and retrieval software to help you locate the documents and award abstracts that are of interest to you. Once you locate a document, you can browse through it on-line, or download it using the Kermit protocol, or request that it be mailed to you.

Direct E-Mail. You can request that STIS keep you informed, via e-mail, of all new documents on STIS. You can elect to get either a summary or the full text of new documents.

Internet Gopher and WAIS. If your campus has access to these Internet information resources, you can use your local client software to search and download NSF publications. If you have the capability, it is the easiest way to access STIS.

Getting Started With Documents Via E-Mail

Send a message to **stisserv@nsf.gov** (Internet) or **stisserv@NSF** (BITNET). The *text* of the message should be as follows (the Subject line is ignored):

get index

You will receive a list of all the documents on STIS and instructions for retrieving them. Please note that all requests for electronic documents should be sent to **stisserv**, as shown above. Requests for *printed* publications should be sent to *pubs@nsf.gov* (Internet) or *pubs@NSF* (BITNET).

Getting Started with Anonymous FTP

FTP to *stis.nsf.gov*. Enter *anonymous* for the username, and your e-mail address for the password. Retrieve the file *index*. This contains a list of the files available on STIS and additional instructions.

Getting Started with the On-Line System

If you are on the Internet: *telnet stis.nsf.gov*. At the login prompt, enter *public*.

If you are dialing in with a modem: Choose 1200, 2400, or 9600 baud, 7-E-1. Dial 202-357-0359 or 202-357-0360. When connected, press Enter. At the login prompt, enter *public*.

Getting Started with Direct E-Mail

Send an e-mail message to **stisserv@nsf.gov** (Internet) or **stisserv@NSF** (BITNET). Put the following in the text:

get stisdirm

You will receive instructions for this service.

Getting Started with Gopher and WAIS

The NSF Gopher server is on port 70 of *stis.nsf.gov*. The WAIS server is also on *stis.nsf.gov*. You can get the ".src" file from the "Directory of Servers" at quake.think.com. For more information, contact your local computer support organization.

For More Information

For additional assistance contact:

E-mail: *stis-request@nsf.gov* (Internet)
stis-req@NSF (BITNET)
Phone: 202-357-7555 (voice mail)
TDD: 202-357-7492

NSF 91-10 Revised 10/25/92

KNOWLEDGE DISSEMINATION AND USE IN SCIENCE AND MATHEMATICS EDUCATION: A LITERATURE REVIEW

Janet Hutchinson
Michael Huberman

Prepared for the Directorate of Education and Human Resources, Divison of Research, Evaluation and Dissemination, National Science Foundation by The Network under Order Number CB2649X-00-0

May, 1993

Knowledge Dissemination and Use in Science and Mathematics Education: A Literature Review

Janet Hutchinson, University of Pittsburgh, and M. Huberman, The NETWORK, Inc.

Introduction

Dissemination of educational research and effective practice is hardly a new endeavor in the United States. Its level of activity, however, along with its sophistication, have burgeoned in the past two decades. This report reviews the research on knowledge use in science and mathematics education and highlights approaches and strategies for dissemination which might be particularly useful to the National Science Foundation. In particular, the influence of constructivist perspectives in knowledge use and education on the dissemination of knowledge are highlighted.

It is, in effect, almost anachronistic to recall the earlier efforts to move scientific knowledge and its by-products into the schools. At that juncture, the regnant model comprised a progression from the "laboratory" to the educational "market place," in line with the models used to commercialize physical technology.

From here, educational developers followed the scenario of R. Havelock (1969) and other members of the Institute for Social Research at Michigan (see Figure 1). Havelock postulated a RDDE cycle, consisting of Research, Development of prototypes, Diffusion of the amended prototypes and Evaluation of the product. The model

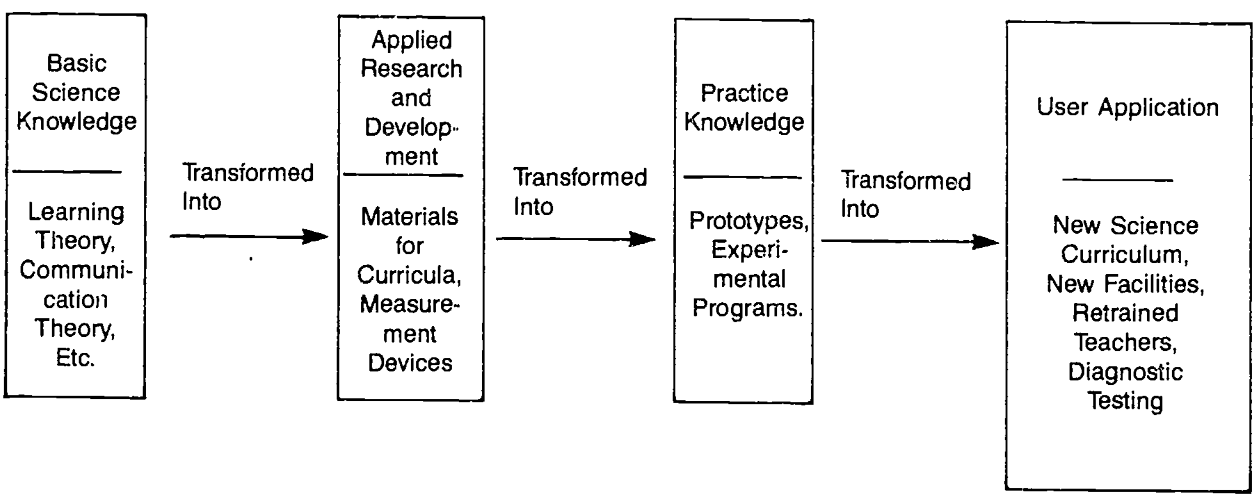

Figure 1: Progress From Basic Research to Application

was extremely influential—it even figured in the creation of the U.S. Department of Education's Laboratories and Centers—and it constituted a new starting point for a closer, more expeditious movement of research-based products to the universe of school practice (cf. Guba, 1968).

Critiques of this approach, based on studies done during the 1970s and published at the end of that decade, found that the RDDE model had fundamental problems (Berman and McLaughlin, 1979). For example, it cast the flow of knowledge as a one-way process, and did not take into account the motivations, contexts, and realities of the intended recipients. At the same time, educational researchers began to postulate factors that were important for successful dissemination. These factors reflect a shift in the knowledge use literature from a rational or "imperativist" perspective to a more conflict-theoretic and constructivist perspective (Dunn and Holzner, 1988; Huberman, 1990). The shift focuses on the ways that knowledge is mediated in particular settings and on the "schemata" and representations that "users" bring to bear on information and expertise presented to them. According to this approach, the user acts upon information by relating it to existing knowledge, imposing meaning and organization on experience and, in many cases, monitoring understanding throughout the process. This casts the user as an active problem-solver and a constructor of his or her own knowledge, rather than as a more passive receptacle of information and expertise.

Similarly, and almost coincidentally, researchers, scientists and teachers began debating the merits of using this perspective rather than other approaches to mathematics and science education (e.g., Schuell, 1986).

Clarification of Terms

The field labeled "knowledge use" includes a wide range of practices and perspectives, including those of "dissemination" and "diffusion." In particular, the term "knowledge dissemination" has different meanings to different people. Its most common definition is the transfer of knowledge within and across settings, with the expectation that the knowledge will be "used" conceptually (as learning, enlightenment, or the acquisition of new perspectives or attitudes) or instrumentally, (in the form of modified or new practices.) There are, however, those who see dissemination as having other legitimate outcomes. Some of these outcomes include: (1) increased awareness; (2) ability to make informed choices among alternatives; and (3) the exchange of information; materials or perspectives. In 1977, a conference of dissemination professionals, the Dissemination Analysis Group, defined dissemination as including these outcomes, as well as conceptual and instrumental use of new knowledge. The implication was also drawn that different strategies are needed to achieve each purpose. In this review we focus most of our attention on use as the ultimate goal of dissemination, with the recognition that validated knowledge is mediated.

Another clarification in this review has to do with what is being disseminated. In the studies reviewed, the object of study ranges from research results (e.g., a teacher's use of wait time or learning opportunities as applied to a classroom environment) to craft-validated knowledge, (such as constructs developed by teachers, then used by their peers), to products (e.g., curriculum materials, guidebooks, or videos). We will also take into account new practices (such as approaches to teaching scientific concepts or peer coaching), along with policies (such as state mandates), and new forms of cognition involved in science and mathematics teaching and learning. In the synthesis, we will also be discussing the extent to which factors found to influence successful dissemination do so for several of these units of analysis.

Still another variation in the studies reviewed involves the "target" of dissemination. Some analysts in research utilization see as the target those people traditionally called "users" or "subjects" of the study or evaluation. These are generally practitioners, often teachers. The dilemma here is that researchers typically study topics which may not be of obvious import to practitioners. Alternatively, the products being disseminated, such as reports or articles, do not necessarily read in ways that practitioners can understand and apply. How then does one maximize the usefulness of information derived from those from whom it was gathered in the first place?

Finally, other dissemination studies examine the spread or transfer of practices developed in one location to another. In this case the "targets" of dissemination are not at the site of development. Therefore, the core question becomes, how is knowledge mediated or "packaged" for use elsewhere from where it originated?

Context

The growth of the field of knowledge dissemination and utilization began with large-scale efforts to improve the nation's schools in the 1950s and 1960s. Some of the earliest efforts were a result of Sputnik, which mobilized the U.S. to invest in the development or invention of new classroom materials and methodologies for improving the education system, particularly the curriculum of mathematics and science. The dissemination strategies used were based on the simple conviction that if materials were good they would be used, and that their use would result (automatically) in further diffusion. To some extent, the task of improving schools was conceived to be a problem of getting such innovations adopted, and the prime locus of improvement was posited to be the classroom.

During this period, the National Science Foundation began to use teacher institutes to promote the use of the newly developed materials and methodologies. At the same time the U.S. Office of Education used another strategy: demonstration projects. It appeared that neither agency's strategy resulted in robust and durable changes at the classroom level.

As educators and researchers discovered that utilization of these materials and approaches was not automatic, they grew more interested in the successive "stages" of the dissemination and utilization processes. These include adoption—the decision to use innovations —(Rogers & Shoemaker, 1971); implementation—actual use—(Fullan & Pomfret, 1977); and institutionalization—"routinized" use—(Yin, 1978; Crandall, 1984).

In the next phase, roughly in the 1970s and early 1980s, two trends were evident in the knowledge use literature. One was the shift from centralized to decentralized knowledge transfer systems (Rogers, 1986), the apparent result of the adoption of a more systemic perspective on planned change. Another was the growing influence of constructivism. As noted earlier, constructivism, when applied to knowledge use, views the knowledge generated and used by policy makers and practitioners as largely self-constructed. In the sub-field of social constructivism, this construction of meaning is typically a product of social interaction (Dunn and Holzner, 1988; Rogers and Kincaid, 1981). In the classroom context, this perspective was construed as "mutual adaptation," when innovations designed for replication were implemented but were also modified by users (Fullan and Pomfret, 1977).

Similarly, efforts to restructure mathematics and science learning systems were being viewed differently at this juncture. For example, restructuring, as it is currently conceived, has to do with total systems change, all the way from individual practices through organizational levels, then up to senior policy makers. Schlechty (1990:xvi) defines restructuring as "altering systems of rules, roles, and relationships so that schools can serve existing purposes more effectively or serve new purposes altogether." In discussing the influential Concerns Based Adoption Model (CBAM) Hall and Hord (1987) and Loucks-Horsley and Stiegelbauer (1991) speak of total systems change: change involving people, processes, practices, policies, power [and empowerment], and philosophy. It is now argued that multiple perspectives from multiple disciplines are required to assess the needs of complex and multi-faceted systems. It is now accepted by many contributors to the mathematics and science literature that it is inadequate to focus on changing individuals [teachers] if the goal is long-term impact on a system. Nonetheless, individual change in the teaching and learning environments of science and mathematics still presents some persistent difficulties (Darling-Hammond, 1990; Cohen and Ball, 1990; Tobin and Espinet, 1989).

Staying for a moment with this theme, Davis, Maher and Noddings (1990) identify two schools of thought regarding current concerns about the quality of mathematics teaching in the United States. The first is characterized by increasingly explicit directives: more days per year and more math per week; more homework, more explicit identification of knowledge that students are meant to acquire. The second, almost antithetical to the first, proposes less testing, a less constrained learning environment, and a more natural fit with students' daily lives. The latter school of thought corresponds more to a constructivist perspective on the teaching and learning of mathematics. This, according to the authors, has become the prevailing view among mathematics education researchers. For example, Confrey (1990:108–111) describes constructivism in mathematics education as follows:

> Constructivism [is] essentially a theory about the limits of human knowledge, a belief that all knowledge is necessarily a product of our own cognitive acts . . . When one applies constructivism to the issue of teaching, one must reject the assumption that one can simply pass on information to a set of learners and expect that understanding will result. . . Thus as a constructivist, when I teach mathematics, I am not teaching students about the mathematical structures which underlie objects in the world; I am teaching them how to develop their cognition, how to see the world through a set of qualitative lenses which I believe provide a powerful way of making sense of the world, how to reflect on those lenses to create more and more powerful lenses and how to appreciate the role these lenses play in the development of their culture. I am trying to teach them to use one tool of the intellect, mathematics.

The systemic and constructivist perspectives now so prominent in the literature of knowledge use, as well as in the mathematics and science education literature, imply the need for reviewing and rethinking methods for disseminating knowledge related to the outcomes of teaching and learning in mathematics and science. The main point of this literature is that not only should new initiatives reflect this thinking, but also materials which were unsuccessfully disseminated during earlier initiatives might be introduced anew using a constructivist approach.

For example, it cannot be said with certainty that prior innovations were without benefit, since vestiges of the early policies in science and mathematics are very much in evidence in many of today's classrooms. Furthermore, in declaiming the benefits of earlier reform efforts, researchers may well have overlooked significant intervening variables which, as Davis (1990:94) posits in his review of the "new math" experience, might have cast earlier programs in a different, perhaps more positive, light.

Historical Development

The late 1950s and early 1960s began a period of unprecedented activism in education. The National Science Foundation supported major, large-scale curriculum development to improve science education. Using primarily teacher institutes and commercial publishers as the dissemination vehicles, the results were mixed. Some good materials were developed but rarely used—used, in fact, far less than the investment warranted. This was particularly true for the elementary level where ambitious programs were developed, but often sat unused in closets nationwide.

The Elementary and Secondary Education Act of 1965 also supported the major development of educational innovations. Arising out of uncertainty about just which "interventions" would improve education, the Act created demonstration programs in local schools. Great faith was placed in the inventive capacity of the people in demonstration schools to address the problems of schools in general. In fact, most sponsors at demonstration sites assumed that their programs would diffuse almost by "osmosis" to other schools. However, the evaluations carried out in the late 1960s and early 1970s found that while most demonstration sites had a dissemination plan, they did not put sufficient effort into creating awareness on the part of other schools.

As a result, U.S. Department of Education efforts in dissemination were expanded in the late 1970s, experiments were conducted; and new "delivery" systems were created. Most notable are:

- The Project Innovation Packages (PIPs) project, in which six complete innovation "packages" were created, representing new approaches to compensatory education in reading and mathematics. Having been proven effective in school district sites, the packages were designed to be implemented by teachers and administrators with no other information or assistance beyond the printed materials. (Ironically, they were delivered in custom-crafted plexiglas boxes, which still endure in many places long after the accompanying instructional materials which they contained have disappeared.) The evidence suggests that the PIPs resulted in little change. At best, teachers timidly implemented the approaches, adapting them so much that there appeared to be little difference from prior practice. (Horst et al, 1975).

- The Pilot State Dissemination Project (PSDP) set up "dissemination agents" in three States, each agent serving a school district or a county. The function of these agents, modeled on the county agents of the Agricultural Extension Service, was to provide a direct link between schools and researchers and their innovations. The project was highly successful, producing effective use of research-based practice in the targeted districts (Sieber, Louis, and Metzger, 1972). The cost, however, of extending the network to the whole country—by one estimate a billion dollars per year—prevented the program's expansion.

- The Research and Development Utilization (RDU) Program operated from 1976 to 1979. Its approach was neither as remote as PIPs nor as intensive as PSDP. Sponsored by the National Institute of Education to disseminate its educational research results to 300 schools, the program included several elements known to promote successful dissemination: on-site assistance (Havelock, 1969); matching of R&D to the schools' contexts; quality assurance and control of the information provided; and funding for school research utilization efforts. An evaluation of the program concluded that it was a model of a well-designed dissemination strategy which "can be effective in promoting improvements in schools, in educational practice, and in benefits to students" (Louis and Rosenblum, 1981).

- The National Diffusion Network (NDN) was set up in 1974 to create a delivery system for effective programs, and it still operates some 18 years later. The NDN was created with the hope that a broader educational community would benefit from the initial investment in program development made by the U.S. Department of Education, in order to create a national mechanism for dissemination of curricula and other instructional products. The system included the most promising features from the previous experiments. For example, programs were formally validated and judged by a panel of experts, and person-to-person assistance was built into the system (Crandall et al, 1982; Huberman and Miles, 1984). "State facilitators" (at least one for each of the 50 states and the territories) help schools in their State to learn about, assess and, when appropriate, to use innovations that are locally developed or generated. "Developer/demonstrators" (at least one representing each validated program) provide materials and training programs to facilitate adoption and implementation. Reviewers have concluded that the NDN represents "one of the few highly successful Federal efforts to make wide-scale use of important developmental improvements in educational state-of-the-art" (Emrick & Peterson, 1978). It is interesting to note that the NDN is currently spending more time on the later phases of implementation, e.g., consolidation, stabilization and routinization and is redesigning itself to focus more on these areas.

- The Educational Resources Information Center (ERIC) Clearinghouse system is another dissemination strategy created during the late 1960s and still functional today. Clearinghouses serve an archival function as well as a means of getting information out. It has been assumed that, generally, their impact is limited in that they produce mainly print materials (syntheses, analysis, etc.). However, when other support services are connected with these functions in the form of tailored searches with the help of people who are knowledgeable about the data base and understand the request, consequential use is increased, especially when the client has a specific reason for the information. ERIC also generates knowledge through information synthesis publications, such as monographs and digests on topical subjects.

- Commercial distribution is another widely used mechanism for disseminating educational information and programs. However, this strategy has been found to be ineffective in actually promoting use of educational materials (Crandall et al, 1982). In addition, the experiences of large-scale curriculum developers supported by the National Science Foundation in the 80s highlight the problems associated with commercial distribution when it is used as a unique vehicle for dissemination.

Each of these programs can be characterized by its approach to knowledge dissemination and diffusion: top-down, bottom-up and middle-out. Here, too, there is a relatively robust body of evidence. More globally, the pertinent questions to pose in reviewing these and similar knowledge dissemination and utilization efforts are fairly straightforward: what can be learned from these efforts? How can future dissemination designs capitalize on the successes and failures of prior work? What are the salient barriers to utilization? Which factors are the most systematically associated with successful use?

Barriers to Utilization

The experiments of the mid-1970s, along with program evaluations through the present time, indicate that top-down, linear models of dissemination, consonant with the RD&D or RDD&E models that were the starting points for the field of dissemination and use, were of limited value in making potential users aware of new information, and were generally ineffective in promoting institutionalization of ideas and incorporation of materials into the teaching curricula of local schools. In effect, a number of barriers to utilization associated with top-down approaches to dissemination are cited in the literature including a natural tendency on the part of school personnel to preserve ongoing norms and practices, and to cope with a set of confusing, sometimes contradictory policy and program directives. Clearly, when we look at the micro-politics of school life, including the tradeoffs between subgroups and the contrasting pressures on school staff, we are not operating in the realm of "rational" policy and practice. Or rather, this configuration may be functional for local staff, but exotically singular for external observers.

Other constraints to an orderly process of adoption and implementation include shortcomings in the mastery of subject-matter content on the part of individual teachers, as well as the inattention to more systemic issues in the school's social environment. Other barriers have to do with the mismatch between the demands of the product or program under review, and the core values and beliefs—the teaching and learning culture—in mathematics and science education on the part of local staff.

Let us return to the constraint of preserving the status quo. Prior research in knowledge use suggests that failures to institutionalize knowledge are attributable to what is known as "knowledge disavowal," particularly in the case of knowledge in the form of findings from research. Zaltman (1983:173) describes knowledge disavowal as avoiding knowledge "in order to preserve or maintain the status quo or to avoid a difficult choice or a threatening situation." (We should remind ourselves that such "disavowal" can occasionally be justified, i.e., that some people and organizations may have seen accurately that a given product or project might be detrimental to the organization or to themselves).

Another observation which persists in the literature on organizational research is that researchers and users belong to separate discourse communities, with very different values and ideologies. Oftentimes, the social and cultural distance between the two communities impedes utilization (Beyer and Trice, 1982).

Still, findings in studies of mental health and among social work professionals suggest a different pattern in the use of social science research. Weiss (1977, 1980) describes an "enlightenment" model in which research findings gradually become a useful part of the professional's frame of reference, and are called upon as needed in the conduct of policy- and decision-making. These findings were corroborated by Sunesson and Nilsson (1989), who found that circumstance and context were important indicators of research utilization and that scientific rigor was not necessarily a detriment to use.

Studies of the early, linear, one-way models of dissemination show while they resulted in educators' adapting innovations, this occurred often in unproductive ways. Educators were found to be more likely to modify an innovation than to use it as its developers had intended. While adaptation is often a way of enhancing the usefulness of new knowledge in a new setting, it can also result in "mutating" the form so greatly that it no longer has the shape, or the outcomes, that originally attracted the user (Hall & Loucks, 1978; Huberman & Miles, 1984). This appeared to be the case in the projects reviewed in these empirical studies.

Dissemination strategies are challenged by the need to make order out of confusion in schools. In referring to California's mathematics reform initiative, Cohen and Ball (1990) and Darling-Hammond (1990) point to the evidence of previous dissemination efforts which can be found in most American classrooms today. They suggest that the features of today's schools are an amalgam of prior instructional policies and programs, and that much of what is not right in today's classrooms reflects teachers' efforts to make sense of the layers of old and new policies and methods. This observation has concrete implications for the implementation process in the dissemination cycle. As Cohen and Ball (1990) suggest, changing teaching methods is not like changing one's socks. That is, it can not be done quickly or cavalierly, and when real implementation occurs, it will not be easy to undo it for the next wave of instructional reform.

Implementation can be elusive. For example, the Rand study of federal dissemination efforts (Berman & McLaughlin, 1978) found that specific project content did not insure program success. Nor did the amount of money or effort expended in dissemination. Similarly, external consultants and one-shot training approaches tended to fail. Finally, those innovations that did make it into the schools were adapted in some way, sometimes dramatically.

Findings from studies of use of innovations help to show why this is so. One of the classic studies of innovations at the classroom level (Hall and Loucks, 1978) found that when a new practice is introduced to the classroom, teachers deal with it on many different levels. Some would not use it at all; others would use the new product or practice in a more mechanical, yet disjointed, way. Still others would get farther in the process of technical mastery by integrating the innovation into their routine teaching practice, without, however, incorporating the more complex and demanding components of the innovation into their instructional repertoire.

These different Levels of Use (LOU) are now widely accepted as a description of the process through which individuals move as they become more comfortable and proficient in their use of an innovation. By inference, different dissemination mechanisms would be needed to address the differing needs teachers have as they move through the stages. The significant finding from the earlier studies is that, even when the linear models for dissemination were "successful" in getting a product through the classroom door, they were not decisive in firmly rooting the innovation in place (Hall and Loucks, 1978; Fullan and Stiegelbauer, 1991).

In effect, those innovations that do make it into practice may not be very long lived. The Rand study of large-scale, federally-sponsored innovations found that improvements dissipated quickly or even disappeared when the disseminated program came to an end. The end of financial support or the departure of key personnel may also be fatal. In addition, innovations that do last longer may revert to the original practices they were meant to supplant. In that way, the "innovative" practice gradually becomes indistinguishable from its predecessor.

A 1990 study of classroom experiences with "constructivist" mathematics reform suggests some reasons for this phenomenon. In this study of mathematics instruction following new policy and curriculum directives in California (Cohen and Ball, 1990) resume their research by pointing out that, "any teacher, in any system of schooling interprets and enacts new instructional policies in light of his or her own experience, beliefs, and knowledge . . . Teachers view themselves as independent, autonomous professionals . . . Even the most obedient and traditional teachers observed, enacted policies in their own ways and were proud of their contributions." (p. 253) These researchers suggest that local transformations occurred all along, and that developers who returned a few years later were surprised by transformations that did, apparently, harken back to the original practices. How far they got along the Hall & Loucks spectrum remains unclear.

Paradoxically, many of these innovations were meant to be implemented "faithfully." Darling-Hammond (1990) suggests that the adaptation of innovations in the classroom is a natural extension of the process by which dissemination occurs. "Teachers receive the message through a filter with much of the information and most of the contextual clues screened out. They are not expected to interpret the policy by constructing meaning for themselves, but only to implement the simplified version of it that reaches them (p. 236)." As we see with Cohen and Ball, this is not what transpires; there is a way to avoid the local reconstruction of the practice, as local staff make sense of it in their own context. Given the conditions of local "delivery," there was no way that a "faithful" version of the new practice could have been implemented.

Knowledge deficiencies, too, present a barrier. In studying the effects of coaching in high school science teaching, Tobin and Espinet (1989) cite teacher preparation as a significant impediment to change, notably when the teacher is poorly grounded in science and science pedagogy. A root problem may be that the teacher's qualifications in science and as a science teacher may be insufficient, making it doubly difficult to improve science teaching.

These findings are significant to science education because of enduring concerns for improving high-level cognitive learning in science (Tobin 1987) and the importance to effective science teaching of teachers' knowledge base (Arzi, White & Fensham, 1987). Science teachers frequently are encouraged to implement new curricula which utilize different approaches to teaching and learning. Many also endeavor to improve aspects of teaching through self-observation, informal feedback from peers, or through formal evaluations. These are imperfect mechanisms. There may well be no way to progress technically and to stay abreast of the successive waves of reform in curriculum and instruction without support from experienced science educators and peers (p. 119).

Organization or system-wide issues can also impede implementation of innovation. Use of innovative practices that have been in place several years, and that are clearly recognized as superior to previous practice may still be discontinued, essentially because systemic issues have not been adequately addressed or because the conditions in the setting do not support continued use. For example, successfully-introduced innovations may disappear because the requisite resources and supplies were not provided by the organization. In science education in particular, resupply of expendable materials used in hands-on science programs, particularly in elementary schools, is crucial. Its absence is likely to result in abandonment of the innovation (Anderson et al., 1992.)

These innovations may also disappear because the requisite funding never became a line-item in the organization's budget, or because job categories were not revised in order to make the coordinator's post a regular classification, or because other organizational arrangements were not "routinized (Yin et al., 1978). Additionally, innovations could fail because training practices within an organization were not changed to incorporate the necessary training routines leading to mastery of the innovation in question. Clearly, there are many reasons why an innovation that seems to be successful after an introductory period may nevertheless be abandoned. Thus successful dissemination efforts would lead to the creation of mechanisms for ensuring longer-term organizational support (Miles, 1983).

What was wrong, then, with the idea that superior knowledge, properly researched and developed, would diffuse into the appropriate settings, be recognized for the benefits it offered, and become a lasting part of a new user's routine? In summary, the top-down character of this approach "paid little attention to users' frames of reference and assumed —through a sort of magical hyper-rationalism—that strong findings would override countervailing policies and practices to which locals had been committed up to then" (Huberman, 1989). It did not work because the process of acquiring new knowledge is not a linear process. New understandings are grafted onto prior understandings. Individuals must have ample opportunity to experience the new information and develop their understanding of its meaning to their existing knowledge (Huberman, 1973). More generally, the notion that teachers are conduits for information and knowledge, not active participants in creation, dissemination and utilization, is flawed. Teaching cannot be controlled by prescriptions for practice embodied in texts, tests, and monitoring schemes. (Darling-Hammond and Berry, 1988).

So teachers are the agents who cause the instructional problems that State and federal policies seek to correct, yet, at the same time, they are the agents for their own correction. More often than not, the conditions for successful monitoring and correction are not met. Here is a pertinent excerpt from a study of the California mathematics reform initiative (Cohen and Ball, 1990).

> Few teachers had opportunities to see examples of the sort of teaching that the State thinks it wants. Few have been offered opportunities to learn a new mathematics. Few have been given opportunities to cultivate a new sort of teaching practice, and even fewer have been offered assistance in the endeavor. In a word, teachers have yet to be engaged in the sort of conversation—with themselves, with other teachers, with university mathematicians, and many others—that would support their efforts to learn a new mathematics, and a new mathematical pedagogy (p.254).

Top-down, linear prescriptions for knowledge transfer were self-evident in the earlier (1955–1975) knowledge use literature, just as they were evident in the science and mathematics education literature of the 1950s and 1960s. Davis (1990:104) suggests that during this period, when curriculum improvement projects' were being poorly implemented and incorrectly analyzed, the dominant psychology was behavioristic. Behavioral theory held that the concern for cognitive events —what was going on in a person's mind—was not scientific since it speculated about matters that were essentially unknowable. So teaching strategy focused on demonstrating and supervising and on tests and immediate reviews, much as in "drilling." Knowledge was viewed as the ability of the student to render factual and operational components successfully. Constructivism was generally unknown. Although scientists, mathematicians and teachers involved in the several curriculum improvement projects knew intuitively that a 'stimulus-response' approach misrepresented the complexity of real-life instruction and learning, a formalized conceptualization of the process of learning mathematics was not readily available. Davis argues that the reason for the "sudden eruption of 'constructivism' as a central concern of so many contemporary researchers" is the recognition of "very great need for a better way to think about how human beings deal with the subject called 'mathematics'." (p. 104) Science education researchers voice similar arguments for restructuring science learning and pedagogy (Wheatley, 1991, Lythcott and Duschl, 1990; Duschl, 1990; Driver, 1983; Pines and West, 1986, among others.)

Rejection of the 'stimulus-response' methods of teaching science and mathematics in favor of the constructivist approach also suggests another direction for the improvement of dissemination efforts. If people can interact with those who produce new knowledge, articulate how they might modify it, suggest how the originator of the program or project producer can revise it to make it more applicable, potential adopters might feel a greater sense of propriety over the knowledge base. In short, this theory of knowing leads to an explanation for the utilization of knowledge known as the problem-solving model, one including social interactions as well as a "dialogue" between the producer of information and the user, at several points in the problem-solving cycle (Huberman, 1973).

According to this model, knowledge producers and users should belong to overlapping networks and have ongoing communication for utilization to occur (see Figure 2). Communication between knowledge producers and users as well as practitioners and program and product developers, then becomes a two-way street. The feedback by which users communicate their needs to knowledge producers becomes as important as the transfer of knowledge "downstream" from expert to user. The features missing from the R, D and D models—features that must be introduced into more effective dissemination strategies—are two-way communications, to provide feedback from the users of their needs, and iteration, so that users can learn new products (materials, practices, ways of thinking) by repeatedly readjusting their understandings, by checking as needed with the expert and designated intermediaries as new practices are introduced.

Louis and Dentler (1988:51–52) use the term "social processing" to describe how educators can use information more effectively. By testing the value of the information in terms of its 'fit' to the local setting, and by their involvement in adaptation and development activities local educators begin to build or affirm their commitment to information use. Impetus for social processing is likely to be gained through explicit requirements for meeting and planning activities and by the promise of concrete gains in terms of professional growth and rewards.

What Works?

Louis and Dentler (1988) cite criticisms of the bottom-up approaches to implementing innovations in the classroom, including impediments such as conservative school culture (Sarason 1971), competing pressures on teachers (Huberman 1983, 1985; Hargreaves 1984), the propensity to choose innovations of low quality (Nelson and Sieber 1976), and the recycling of reforms which lead to perpetually reinventing the wheel (Mann 1978). However, the authors disagree with these criticisms and argue that a school-focused knowledge use approach as a strategy for inducing change is well founded in the "classic" knowledge use studies in education (Mort 1964; Carlson, 1965; Sieber, Louis and Metzger 1972; Louis, Rosenblum and Molitor, 1981; Crandall et al., 1983; Sieber 1981; and Menlo 1985).

Louis, Dentler and Kell (1984) conducted a three year study of activities undertaken in Regional Education Laboratories and State Education Agencies. In revisiting their work, Louis and Dentler (1988) describe implementation problems that surfaced in the study findings and which led to developing a school-focused knowledge use model for implementing education reform policies promulgated by the State. The model "is school-focused in the sense that local conditions within specific schools are expected to influence the course of knowledge use and improvement in all phases of change (p. 37)."

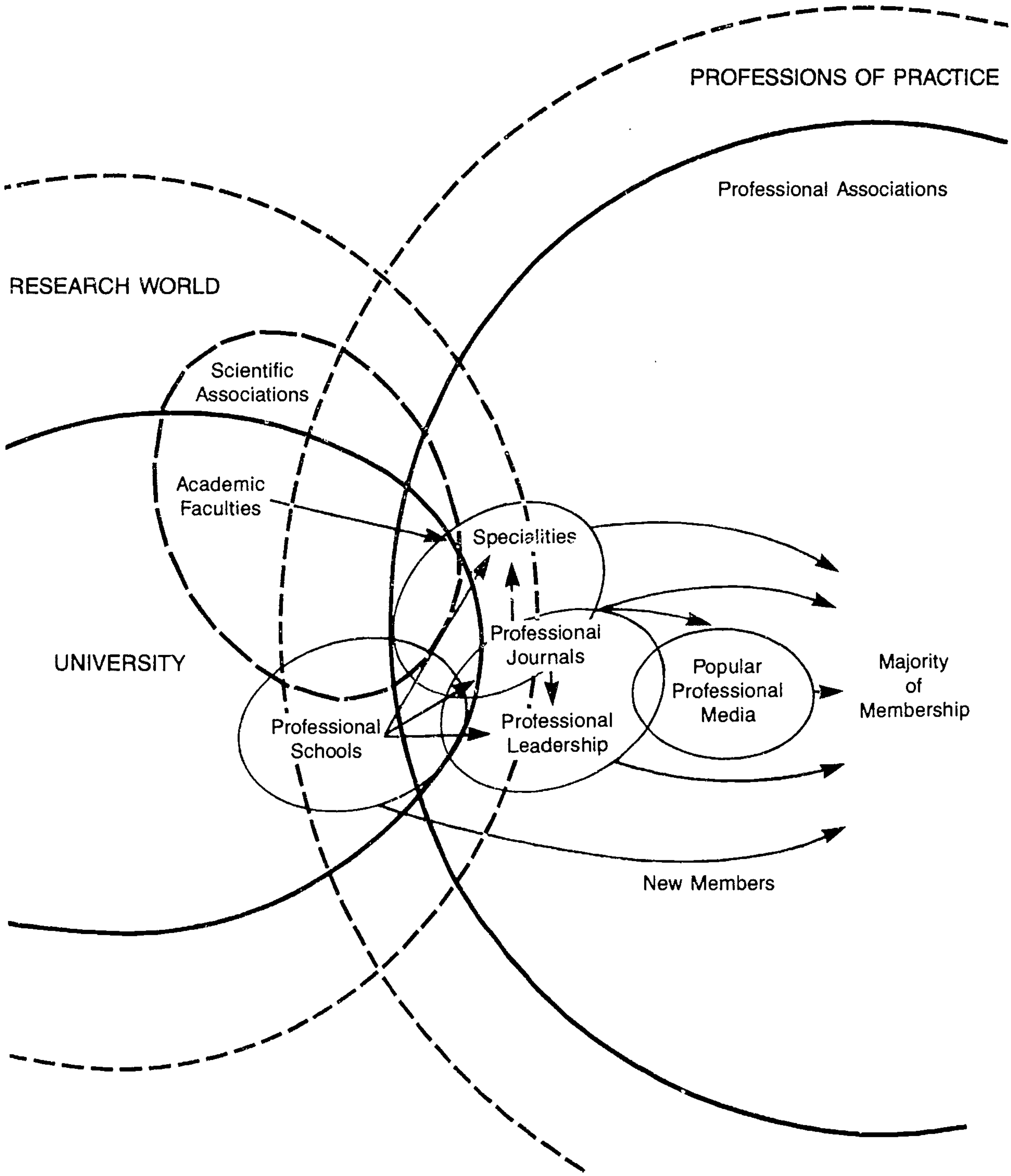

Figure 2: The Interface of Research and Practice

The authors suggest four elements based on their research which can constitute a knowledge use model for school improvement:

- capitalizing on known or identifiable incentives for change;
- providing information or knowledge that has characteristics that make it 'useable' by the relevant practitioners;
- creating or supporting opportunities for shared understandings of how new ideas could help to improve local practice; and
- stimulating increased diffusion of new ideas within and between educational agencies.

The model is neither a top-down nor a bottom-up approach, but combines aspects of each. It also reflects some of the concerns articulated by Cohen and Ball (1990) in their interviews with teacher change-agents, as mentioned above.

Louis and Dentler concur with other educational researchers that the process of implementation is a core issue in educational reform (Cuban, 1990; Sykes, 1990; Lieberman, 1990; Schlechty, 1990; Hall and Hord, 1987, among others). This is also the case for those writing specifically on mathematics and science pedagogy (Davis, 1990; Davis, Maher, and Noddings, 1990; Anderson et al, 1992; Anderson 1984). For example, several studies found that both personal incentives and organizational incentives were strongly associated with use, but that personal incentives were a more potent force. External stimuli alone have limited impact in producing the openness required for the adoption of new ideas. However, mandates, when combined with personal incentives, improve the prospects for implementation. Mandates may stimulate strong personal incentives when professional rewards are visible, concrete and personally meaningful.

This line of inquiry affirms the value of carefully mixed implementation strategies. Louis and Dentler (op. cit.) warn that mandates without resources to 'fit' new requirements to context in meaningful ways can have a damaging effect. "If time, money and knowledge resources of the right sort are available, school staff can often make good improvements without restrictive and potentially damaging new state statutes (p. 59)."

Observations on the value of personal-professional incentives appears to have been borne out in the personal experiences of K-8 mathematics teachers participating in an on-going project in New Jersey schools (Maher and Alston, 1990.) The project's constructivist perspective on learning was based on the concept that learning is contingent upon the activity and involvement of the learner. "Teachers-as-learners" and "teachers-as-researchers" were encouraged to communicate among themselves and with project staff their own mathematical thinking and that of their students. Profound changes were reported in both administrators and teachers over the course of the project, both in participants' willingness to assume leadership roles in diffusion of innovations, and in their professionalism as teachers of mathematics. Diffusion was widespread; teachers presented at professional conferences, consulted with colleagues, participated as workshop leaders in other projects and summer institutes, and regularly received visitors who came to observe children doing this kind of mathematics (p. 163).

With regard to diffusion strategies, Louis and Dentler note that indirect diffusion, when the strategy is well-planned and guided, works more effectively than direct diffusion strategies. Indirect diffusion involves information with educators who are trained to convey it to others. The authors also note that "diffusion behaviors tend to damp out as they move further from the initial source of communication" (p. 50–52)."

In studying the diffusion behaviors of educators in the so-called status hierarchy, the authors found that high diffusion behaviors were associated with R&D laboratories and universities, and that low diffusion behaviors were associated with teachers and administrators (p. 53). Although teachers are the intended audience for most educational reforms, the study findings indicate that information is rarely sent directly to them, but rather through intermediaries within the school, that is, school-based specialists and administrators. Principals, despite their role in mediating communications within schools, are the least likely role group to engage in frequent communication behavior. They tend to receive a great deal of information, but rarely pass it on, even to their teachers. This study also indicates that when teachers do receive information, they tend to share it with their peers. When information did not diffuse, it was perceived to be inappropriate or not useful. Summarizing their data, the authors conclude that "if teachers do not regularly receive information with positive pressures to use and discuss it, the opportunities for school-focused strategies for improvement are clearly limited (p. 54)."

Middle-Out Dissemination Strategies

Indirect diffusion strategies are not a new concept. Described in the knowledge use literature as "linking agents" (Havelock, 1973; Davis and Salasin, 1978; Louis 1980), people who act as intermediaries between knowledge producers (e.g. researchers) and users, these conveyers perform many useful functions for the user. They provide information, they cast it in forms relevant to the user, they answer questions, they provide a way for the user to test his or her understanding, and they can take questions back to the knowledge producers. An effective dissemination process may require linkage to more and more remote resource people, creating what Havelock called the "chain of knowledge utilization," or "chain of knowledge."

For the dissemination field that started with an "action-at-a-distance" model of information transmission, the notion of a series of person-to-person links between producers and users was a revolutionary one. The Research, Development and Utilization (RDU) program, with its emphasis on bottom-up decision making, was aimed at maximizing teacher involvement in selection and ownership of the program along the way, also incorporated these principles. If what has been learned about linkage were summed up in two points, they would be that 1) the nature of the material that is being disseminated is less important than the links all the way down the line, and 2) the shorter the chain of knowledge, that is, the fewer the number of links, the more effective the process is likely to be.

In the field of organizational research, many analysts have called for the development of new roles and occupations to provide linkages between researchers and users.

There is, however, a trade-off. Knowledge producers must weigh the advantages of completeness, accuracy, and strong advocacy in direct contact with a few potential users against a less complete, less accurate, less hortatory but wider dissemination via indirect linkages. When the goal of dissemination is replication of model programs, the concern for accuracy of the implementation of key elements of the model often outweighs the concern to reach large numbers of potential users. This has presented a dilemma for professionals associated with dissemination systems, like the National Diffusion Network, that often counted the numbers of adoptions—not the quality of adoptions—in making funding decisions. Ironically, it is the labor intensive use of linkers that has contributed so much to the NDN's success as a dissemination system.

Because linkers also aid the flow of information across social and organizational boundaries, they are also called "boundary spanners." A review of the experience of the Agricultural Extension Service found that a "spannable social distance" between links in the chain of knowledge, where "distance reflects levels of professionalism, formal education, technical expertise, and specialization" was one of the elements that characterized the success of that dissemination model (Rogers, 1988).

A veritable industry of intermediaries who serve this function in education has grown up over the past twenty years. They are employed by State educational agencies, consulting firms, organizational entities created to carry out a specific dissemination program, schools or school districts, or research organizations. They serve varied roles that are meant to promote use of knowledge from practice and research. These roles include: convener, problem-solver, trainer, evaluator, and planner. More generically, we might call them "change agents." The experience of the field agents in the RDU program and that of the State Facilitators and Developer-Demonstrators of the National Diffusion Network illustrate the positive impact of dissemination programs that encourage sustained interactions with the users, and that stress the role of linkage agents in providing two-way communication.

In the RDU program, there has been a double linkage between the research organization and the users. Closest to the user is typically a "field agent," who engages in face-to-face contact with teachers in local schools. Another link is provided by a person in a given State, region, or consortium project office. This is a "knowledge-base staff," with extensive training in or experience with R&D products. A third link, used in some cases, is a still more highly-trained technical expert, perhaps one of the specialists who has developed one of the products under consideration.

Typically, a group is formed in each school which meets with the field agent to identify a problem to address. Consulting with the next link up the chain, the field agent would then select a set of up to 10 products for review. This array is then screened by the group and reduced to two or three. The knowledge-base staff would then typically be consulted directly by the teachers for more detailed information about the products selected. In addition, at some point in the implementation process, the field agent would arrange for the local group to get focused training (the third link). Depending on the project, this process might be repeated several times, with direct contacts by the users to higher links in the chain.

A process of choice among many alternatives was thus built into the RDU program, along with a process for exchange of information about the suitability of each of these alternatives. Furthermore, the exchange of information was seldom a one-time activity, such as a single training session, but a process to be repeated as needed. Finally, the users were active in the process, seldom being put in the classic mode of more or less passive recipients.

The National Diffusion Network relies on similar linkages to move validated programs from place to place. A "close-to-the-customer" logic prevails, with the State Facilitator serving as the linker for the schools throughout the State to literally hundreds of substantive experts representing the Deve per-Demonstrator projects (models) within the National Diffusion Network. The system is organized so that the first link (the State Facilitator) interacts with school personnel to identify areas of innovation which might respond to local needs and problems, typically by creating awareness of the set of validated programs and products available. The State Facilitator then provides linkage to the substantive trainers who can provide training, follow-up assistance, and coaching, along with the curriculum and other materials designed to support full implementation of the program.

The combination of elements such as choice, ample in-person assistance from a variety of people, and high-quality services, information, and use of craft (and oftentimes more scientific) validation of its programs appears to contribute to this relatively successful dissemination system. These ingredients were already in the formula for "what works, at least in middle-out dissemination strategies. In particular, the combination of "bottom-up" features (attention to local needs, connection to personal and professional incentives, focus on "useable" characteristics of the knowledge base) and the "middle-out" characteristics just reviewed, appears to predict fairly well the extent of implementation in a set of given school districts.

Dissemination Revisited

Generally, the pooled experience of those carrying out trial dissemination programs in the 1970s resulted in an understanding of the complexity of using dissemination as a means to improve education. In effect, disseminated products or programs tend to be multiple-purposed and to serve four basic functions—to spread information, to facilitate choice, to promote exchanges among practitioners and professionals, and to implement new programs, products, and ideas in new settings. The Dissemination Analysis Group (cf. Klein and Gwaltney, 1991) defined these four vehicles of dissemination as:

- Spread—the one-way broadcasting of information, in order to increase awareness;
- Choice—the provision of information on options intended to help users compare alternative resources;
- Exchange—interchange of information, materials or perspectives; and
- Implementation—technical assistance, training, or other forms of support designed to change attitudes or behavior and to institutionalize changes over time.

Different dissemination activities appear to work best for each of these functions. For example, when "spread" is the focus of the dissemination effort, the disseminator would make information available in a variety of forms (e.g. print, audio, video) and through a wide range of vehicles (e.g. publications, presentations, telecommunications). General purpose dissemination activities conducted by Regional Laboratories and R&D Centers often serve this purpose. In reporting findings on the characteristics of "often-used" research, Weiss (1986) cites brevity, timeliness, attractive formats, and good writing as important features.

"Choice" often is facilitated when an information center or library responds to client requests or queries. Still, this function can also be activated through publications, awareness sessions or conferences that select and describe programmatic options, along with their respective advantages and disadvantages.

"Exchange" occurs when there are sufficient opportunities for information, materials, or perspectives to be shared. These exchanges can include interactive feedback that is solicited and received through visits, meetings, field testing, or technology-assisted communication. In his survey of information consumers, Hood (1989) found that informal contacts with colleagues are the most frequently used and preferred information source. In effect, the educational information "market" is segmented by work roles that limit exchange of information, and the most preferred information gathering format is face-to-face, including workshops, seminars and one-to-one contact.

"Implementation" is fostered through direct assistance, training, and sustained support for changes in behavior in classrooms and schools. Context-specific applications are recommended here, where the questions asked are: "How will users apply this information?" and "How best can this information be tailored to these specific applications?"

These functions—from spread to implementation—form a continuum in terms of the level of effort required on the part of the disseminator. In other words, dissemination requires far fewer resources for materials available on a database than does the provision of person-to-person assistance. At the same time, the potential impact ranges from low to high. That is, there is a greater chance that actual change in practice will result from focused assistance than from access to print materials. And yet it is often the full range of activities, implemented in a staged fashion, that results in the most successful dissemination effort. To streamline this discussion, the continuum may be represented as follows:

spread . . . choice . . . exchange . . . implementation.

Activities aimed at "spread" alone may, in certain contexts, contribute to use of knowledge. In cases where there is a strong perceived need or a mandate for change, simply getting information to a teacher or administrator or school district may produce results (Louis and Dentler, 1988; Louis, Dentler, Kell, 1984). On the other hand, lasting implementation typically requires a more sustained effort, usually associated with dissemination activities on the right side of the dissemination continuum. It is here that the role of the user is substantially more interactive than in the R,D & D model. In the first phase, information flows primarily from the producer to the user, but in successive stages the flow of knowledge is a two-way or multiple-way flow, as the users ask questions and make choices among several options. Whereas the R,D & D approach can wander into casting the user as a "target" or "empty vessel," the current concept of dissemination recognizes that the user will play a role, whether intentional or not. Thus approaches which do not build in multiple ways for the user to interact with the information, program, or product being disseminated are more likely to fail.

Disseminators are often challenged to clarify—legitimately—the purpose of their dissemination effort before selecting the most appropriate dissemination activities. The objectives of dissemination would usually dictate which mechanisms, delivery systems, or activities would best support a given dissemination effort. In effect, one may not need to employ the full range of the continuum shown above if one is disseminating a discrete publication or research finding. For example, the U.S. Department of Education used "spread" strategies quite effectively in the early 1980s to release the findings of "A Nation At Risk" and recently repeated this strategy with a publication for parents: "Helping Your Child Learn Science." Yet as the object for dissemination becomes complex, products and processes such as integrated curriculum, teacher preparation, and mechanisms for systemic restructuring call for a more comprehensive organization of dissemination modes. Quite apart from the "delivery" aspect, one must take into account the high demands for communication, involvement, and participation of people in the schools, together with those of intermediaries in the flow of knowledge. Further, it appears that the dissemination strategy must be sensitive to the degree of change which are required in these more complex efforts on the part of students, teachers, and administrators.

A brief word on a complementary perspective to the set we have just examined. If one looks closely, several features are akin to what has come to be called the "social marketing" aspects of the change process. In this regard, Schlechty (1990:84–95) differentiates marketing from the 'sell and tell' approach: "Selling begins with a product and then endeavors to persuade customers that they want or need what the product offers. . . . Marketing, however, begins with the customer—what the customer values and needs." In the educational environment, however, "customer" values differ by constituency, and the critical tasks are those of determining the core values of the constituencies that will be affected. In particular, one wants to know which of these values are likely to be served by a particular change, and, which are likely to be threatened. Although it is impossible to satisfy everyone's needs, it is possible to convey an understanding of constituents' concerns, both to achieve participation and to show a healthy respect for professional collegiality in the process.

Factors Promoting Utilization

Clearly, the activities undertaken by disseminators contribute to the success of the dissemination effort. Successful dissemination is best characterized by seven factors drawn from our review of the research. Similar lists have been compiled by Havelock (1971), Rogers and Shoemaker (1971) and Louis and Dentler (1988).

- **Accessibility, Availability, and Adaptability**—this factor addresses the extent of availability of the material. For example, the ERIC users study found that "one- stop shopping" was critical in ensuring use. If a source was listed in a bibliography and was also available at the time of inquiry, it would typically be used. Also under investigation here was the accessibility of a given knowledge product to those who do not already share assumptions or frame of reference, and the degree to which a knowledge product encourages local adaptation or is specifically designed for local adaptation (Louis and Dentler, 1988).

- **Relevance, Compatibility**—this factor addresses the degree to which the ideas and information being disseminated actually fit the real-world contexts and concerns of practitioners. One might want to determine, for example, how user-friendly the materials are, how well they are matched to the user, how well-targeted they prove to be. Also expressed here is the degree to which the content of the material being disseminated is compatible with the concerns of users, is adaptable to local conditions, is accessible intellectually for inexperienced or uninitiated users, and has been field-tested or field developed.

- **Quality**—plays a key role in getting materials into certain dissemination systems, e.g., the National Diffusion Network, the Laboratory Network Program, and State dissemination systems which require programs and materials to undergo evaluation or validation. Empirical studies show, however, that people will not automatically use knowledge because of its quality or because of its lack thereof.

- **Redundancy of Messages**—This factor underscores the need of a variety of dissemination modes. Several modes of knowledge working together over time, through different channels and formats, and suited to different styles of learning, mixed with purposeful redundancy, facilitate adoption (Muthard and Felice, 1982).

- **Linkage among Users**—includes important strategies such as interpersonal exchanges and connections, along with interpersonal support. Research on knowledge utilization found ". . . a supporting social process . . . In other words, interaction with colleagues and peers about the value of information, its potential utility and how it might actually affect practice or planning was extremely important" in moving from initial levels of use—learning something new—to more active levels—deciding to change a practice or a policy (Louis, Dentler & Kell, 1984).

- **Engagement**—This factor addresses the extent to which users are given opportunities to actually engage with the new program, practice or knowledge product, e.g., hands-on activities to try out a new practice and to get comfortable in its use. This includes analyzing and reflecting about results, planning and making it one's own or even "reinventing" it, as well as linking with specialists who can facilitate engagement.

- **"Sustained Interactivity"**—Overall, the best single predictor of knowledge use and gain is intensity of contact(s) between disseminators and receivers. "The process that succeeds best . . . involves frequent contact, some face-to-face interaction, and an exchange between dissemination specialists and participants that lasts more than a few months over time (Louis, Dentler, Kell, 1984, p. 17)." Sustained interactivity was also illustrated by the RDU experience. The reviewers of that experience found that the amount of time that field agents spent with staff at the local schools, both before and after initial implementation, was one of the most important predictors of success in the effort (Louis, et al., 1981).

Huberman (1989, 1990) provides a conceptual basis for the idea of sustained interactivity for the use of research results. He defines sustained interactivity as "multiple exchanges between researchers and potential users of that research at different phases of a given study." He also identifies the decisive interactions, interventions and exchanges between researchers and users at each of the following stages of a research project's development:

- prior to the actual conduct of the study;
- during the conduct of the study;
- during analysis and write-up; and
- during the dissemination phase, when study findings are brought to the user's environment.

Huberman connects this conceptualization and "meta-analysis' with work by cognitive psychologists in developing alternative theories of knowing, which explains both the nonlinear nature of this process and the need for a highly interactive component to make sure that disseminated knowledge is correctly represented in the mind of the user.

Robert Yin and Gwendolyn Moore (1985) conducted case studies of the utilization of knowledge resulting from research in the natural hazards field (earthquake, flood and other natural disasters) and found that the social interactions of researcher with users was the best predictor of consequential use of the knowledge generated. Interestingly, informal contacts, even before the research projects were underway contributed to a research use, a finding also mentioned in Huberman's literature review (1987). They summarized their description of successful projects as follows:

> What was discovered in these case studies was the persistent role of social interactions—between investigators doing the research and the potential users of research results. The interactions led to a continued exchange of ideas, creating what might be called a "market-place of ideas," in which investigators learn more about users' conditions, and users learn more about the ongoing array of research. In some cases, the exchange of ideas was facilitated by the activities sponsored by professional associations. In other cases, the exchange was the result of an active and communicative principal investigator. Overall, communications started earlier than and continued far beyond the ending of a specific research project. Further-more, the project design and conduct could be influenced by information from users, making the research more relevant to users' needs. Where, in contrast, research projects were conducted in a more traditional manner— i.e., far removed from potential users—utilization was impaired.
>
> *(Yin and Moore, 1985, p. 18)*

A similar finding comes from the field of electronics research. Drawing upon the characteristics of the projects they observed, Yin and Moore formulated a set of specific guidelines for principal investigators to follow in order to promote interaction with users. In normative or prescriptive terms, at least:

- Investigators should join and become active in associations and other organizations to which both knowledge producers and knowledge users belong.
- During the design of a new research project, investigators should identify the specific groups that may use the results of the project.
- In the course of a research project, investigators should be sensitive to the ways in which the research design might be modified, without compromising the integrity or the quality of the work, to meet the needs of the potential user groups.
- Investigators should plan on producing a major product, aimed directly at user groups, rather than only at research groups.

Any one of these actions on the part of research-funding organizations, the authors observed is likely to increase the chances of utilization.

There are analogous recommendations from research in the field of organizational sociology. At the end of their synthesis piece, Beyer and Trice (1982) postulate that, if researchers genuinely want their work to be used outside the scientific community itself, they should be operating as their own best advocates, for example, by placing research findings in magazines read by non-researchers, as well as in professional journals. The authors also recommend that researchers engage in long-term efforts of consulting and training for the levels of management appropriate to the subjects under study.

The Respective Worlds of Researchers and Users

Sustained interactivity has its limits. For one thing, it assumes that the researchers will communicate directly with the users, which means that the level of sophistication in the dissemination process is assured. This cannot be taken for granted. One of the reasons, in fact, that intermediaries are used so often is precisely because the will, the competence or the requisite time for interactivity is wanting on the researchers' end, the users' end, or both. Typically, researchers are given the responsibility for dissemination, but allowed—sometimes encouraged—to hire out intermediaries to actually carry the dissemination effort beyond the scientific community. This, too, has its problems. As noted above, the more links added to the formula, the more uncertain the result. Also, intermediaries typically have lower substantive mastery of the research they are disseminating, but often enjoy high credibility among user groups. This can result in simplified or even in distorted dissemination.

Let us explore for a moment the universes of researchers and users, using a study in mathematics. Cobb et al. (1990) have described a research program supported by the National Science Foundation and designed to match a constructivist view of learning mathematics with an analysis of children's mathematics instruction in a public school setting. In one of the key studies, researchers (Steffe and Cobbe, 1983; Steffe, 1983) designed the extension of a "constructivist teaching experiment" to the classroom. The transfer of research-based models to school professionals was abandoned when it became clear that researchers interpreted the responses of teachers as resistance, while for the teachers, there was the perception that this so-called "unwillingness to adopt" reflected an attempt to make sense of the approach in light of the ensuing changes in classroom interactions in class, the sequencing of units and the constraints of time and pupil management.

In concluding, the authors direct attention to the variant modes of reasoning and the different evidential criteria used respectively by researchers and teachers. In particular, they contrast teachers' context of "pragmatic pedagogical problem-solving," characterized by the necessity to make on-the-spot-decisions in specific, but often uncertain situations, with the more formalized, abstract universe of cognition in which researchers operate. This is a question also treated at some length by Huberman (1983) in his text on the school environment, "Recipes for Busy Kitchens." Here, too, a situational analysis of everyday life in the classroom yields an understanding of the "press" of classroom life (simultaneity, immediacy, personal involvement, etc.) and a map of the forms in which information and expertise need to be shaped in particular forms in order for research-based and craft-validated knowledge to be used routinely.

The "coda" in the Cobb et al. study merits some attention. The authors spend some time on the power-authority relationships between researchers and teachers. Their study brings to light the implicit asymmetry between role incumbents of different status, in this case, researchers and teachers (but in other cases intermediary specialists and teachers). One set has expert "authority" and the other set is meant is fall in line with "the right way" indicated by the extrapolations from research findings. The process is a subtle but insidious one; many teachers actively seek out the prescribed pedagogical activity, and discount reflections on their prior experience and understanding.

In this research program, the authors report that, gradually, researchers and teachers "mutually constructed" a social context, and researchers gradually revised their view that teachers could be readily transformed into social constructivists, neatly aligned with the researchers' epistemology. At the end, the goal was to work with teachers in the development of several forms of practice that would improve the quality of pupils' mathematical education, without insisting on an epistemological alignment.

Concluding Remarks: The Sweep of D&U

We have reviewed the literature on D&U in several fields, including physical sciences, architecture, waste management, and organizational management. The best fruit of those syntheses, perhaps, for those working in this arena, has been the list of factors in the section on "promoting utilization:" availability, relevance, quality, redundancy, linkage, engagement, interactivity.

We have also insisted on the importance of a social constructivist approach to dissemination and use of knowledge. In effect, much earlier work simply assumed that intermediaries and users were relatively passive "targets" to whom information and expertise could be transferred faithfully. We know better. For one thing, work on organizational life has shown clearly that, within any given social setting, there are a sufficient number of tensions, differences in perception, differences in influence or authority, etc. to preclude any "straightforward" communication of information or innovation. Also, a constructivist view of knowledge use shows us that users must transform inputs simply to apprehend them, even if they are as unaware of the process as was the teacher in the Cobb & Steffe study. When we look at "outcomes," then, we must assume that users have reconfigured their understanding and use of a given practice simply to integrate it into their repertoire.

There may be one final point to make about the infrastructure of dissemination and utilization of knowledge. Up to now, we have focused our attention on the adoption and use of discrete programs or practices. There is a school of thought that holds that these mechanisms need to be buffered by tighter links between researchers and users. The stronger the linkage between these two universes, it is claimed, the easier it will be to run new research along this conduit, which would gradually comprise more people at different levels both in the practitioner and researcher communities. In a European study, Huberman (1990) showed that fairly intensive dissemination among researchers and users could lead to closer ties between the two organizations, whereas weaker dissemination left few traces of any relationship at all. Figure 3 shows the initial relationships between a research institute and two "target publics" (guidance and counseling centers). One sees that the links are weak ones, and that they tend to be restricted for the most part to senior administrators. Figure 4 shows the relationship 18 months after the study. One sees the increase for one of the target publics —in which interactivity was the greater—not only in the strength and number of ties, but also in the hierarchical levels and the nature of the new interactions beyond a conduit exclusively for research.

For others, (e.g., Sarason et al., 1977) institutional ties can be more burdensome than networks between individuals and units which are physically remote. Some of the same ties can be forged, it is claimed, at far less cost and effort. True, in-person contacts would need to be provided for, if the aim were to go beyond information, exchange and simple coordinating experiments, e.g., conduct of an experiment in real time by a subset of people and units in the network. If one considers the possibilities at present with telecommunications, the idea of a "network" linking intermediaries, users and researchers is a plausible option. It might, however, need multiple forms of contact (telephone, mail, meeting to 'launch' a project or to include one) along with the kinds most often associated with telecommunications (video conferencing, electronic mail, access to and discussions around remote libraries or data bases).

This leaves us with a plurality of options: the dissemination of knowledge, of products, of research findings, of full-scale science/math projects. This knowledge, as we saw, can be packaged and disseminated in multiple ways. Then, too, there are instances in which we are trying at the same time to disseminate knowledge and strengthen inter-institutional links or informal networks. In other words, things can get complex when we cross all the questions: what are we disseminating? to whom

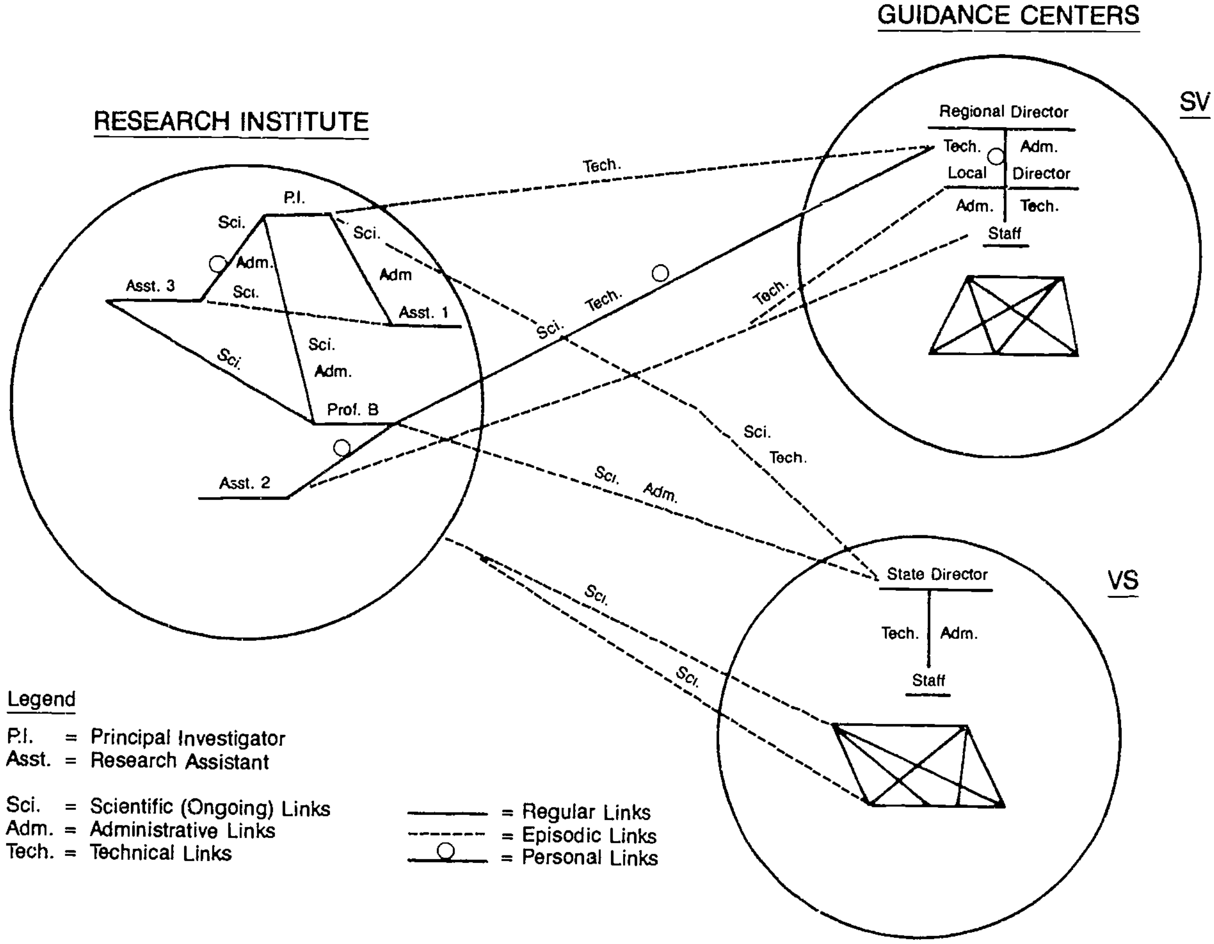

Figure 3: Types and Extent of Linkage Between Research Institute and Two Target Publics in Vocational Education: Initial Mapping

it is going? what effects are we after? how might we do it? These questions can be answered—they will probably need to be answered before a dissemination plan can be drawn up.

The research reviewed above has provided a filter for answering all of these questions and, in particular, the last one: how to do it? Here, the most useful contribution in this text might be the six factors which appear to be the most predictive for successful implementation in general: accessibility, relevance, quality, redundancy of messages, linkage, and engagement.

We would need, however, to determine whether these variables play out differently in more extensive ("spread") or intensive "(implementation") scenarios. Just as important, we need to be clearer about the shifts in perspective and strategy from a more "engineered" design for dissemination to a more constructivist one, and the programmatic implications. It may well be that many of explanatory factors in the "D & U" literature were derived from a perspective that has now given way to a very different one. We don't know whether the two perspectives are conciliable or, if they are not, what a set of key components in a constructivist dissemination plan might look like.

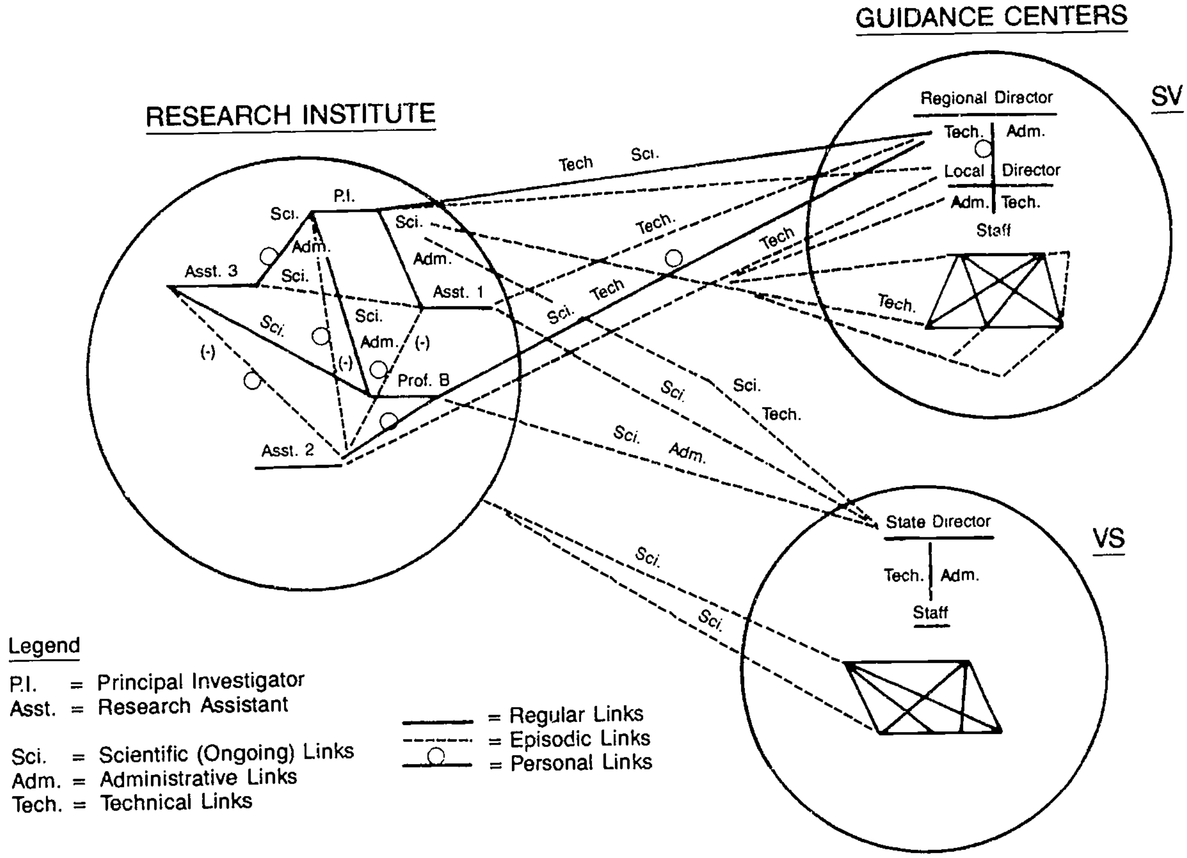

Figure 4: Types and Extent of Linkage Between Research Institute and Two Target Publics in Vocational Education: Mapping 12 Months After Dissemination of the Study

REFERENCES

Arzi, H.J., R.T. White, and Fensham, P.J. "Teachers' Knowledge of Science: An Account of a Longitudinal Study in Progress". Paper presented at the annual meeting of the American Educational Research Association, Washington, D.C, (quoted in Tobin and Espinet, 1989), 1987.

Anderson, R.S., et al. "Review of the Literature Pertaining to Curriculum Reform in Science, Mathematics and Higher-Order Thinking Across the Disciplines", The Curriculum Reform Project, The University of Colorado, 1992.

Anderson, R.D., et al. "Selecting interventions for improving science education". In Bybee, R.W., Carlson, J. and McCormack, A.J. (eds.), *NSTA Yearbook: Redesigning Science and Technology Education*. Washington, DC: National Science Teachers Association, 1984.

Berman, P., and McLaughlin, M. *Federal Programs Supporting Educational Change*. Vol.3. Santa Monica: Rand Corporation, 1978.

Beyer, M., and Trice, H. "The utilization process: A conceptual framework and synthesis of empirical findings." *Administrative Science Quarterly*, 27:597–622, 1982.

Carlson, R. *Adoption of Educational Innovations*. Eugene: University of Oregon Press, 1965.

Cohen, D.K., and Ball, D.L. "Relations between policy and practice: A commentary." *Educational Evaluation and Policy Analysis*, 12:3, 249–256, 1990.

Confrey, J. "What constructivism implies for teaching." In Davis, R., Maher C. and Noddings, N. (eds.), *Constructivist Views on the Teaching and Learning of Mathematics. Journal for Research in Mathematics Education*, Monograph No.4:107–122. Reston, VA: National Council of Teachers of Mathematics, 1990.

Cox. P.L., Kahn, K.A., and French, L.C. "A study of clients of informational service providers and their use of ERIC-based resources and services." *Making the Match for Use of Educational Information: A Multimethodological Study of Providers and Users of ERIC-based Resources and Services*, (vol. 3. June, 1985). Andover, MA: The NETWORK, Inc., 1985.

Crandall, D.P. "School improvement: What the research says." Keynote address presented at the April 1984 conference on School Excellence, sponsored by the Appalachia Educational Laboratory, 1984.

Crandall, D.P. et al. *People, Policies and Practices: Examining the Chain of School Improvement*, (vols. I-X). Andover, MA: The NETWORK, Inc., (quoted in Louis and Dentler, 1988), 1983.

Crandall, D.P. et al. *A Study of Dissemination Efforts Supporting School Improvement*, (vols. 3–4). Andover, MA: The NETWORK, Inc, 1982.

Cuban, L. "A fundamental puzzle of school reform.", 71–77. In Lieberman, A. (ed.), *Schools as Collaborative Cultures: Creating the Future Now*. New York: The Falmer Press, 1990.

Darling-Hammond, L. "Instructional policy into practice: 'The power of the bottom over the top' ". *Educational Evaluation and Policy Analysis*, 12:3, 233–241, 1990.

Darling-Hammond, L. and Berry, B. *The Evolution of Teacher Policy*. Santa Monica, CA: RAND Corporation. (quoted in Darling- Hammond, 1990.), 1988.

Davis, H.R. and Salasin, S.E. "Strengthening the contribution of social R&D to policy making." In Lynn, Jr., L.E. (ed.), *Knowledge and Policy: The Uncertain Connection*. Washington, D.C.: National Academy of Sciences, 1978.

Davis, R.B. "Discovery learning and constructivism." In Davis, R., Maher, C. and Noddings, N. (eds), *Constructivist Views on the Teaching and Learning of Mathematics: Journal for Research in Mathematics Education*, Monograph No. 4:93-106. Reston, VA: National Council of Teachers of Mathematics, 1990.

Davis, R., Maher, C. and Noddings, N. (eds.), *Constructivist Views on the Teaching and Learning of Mathematics: Journal for Research in Mathematics Education*, Reston, VA: National Council of Teachers of Mathematics, 1990.

Driver, R. *The Pupil as Scientist?*, Milton Keynes, England: The Open University Press, 1983.

Dunn, W.N. and Holzner, B. "Knowledge in society: Anatomy of an emergent field." *Knowledge in Society*, (Spring 1988), 3–26, 1988.

Duschl, R.A. *Restructuring Science Education: The Important of Theories and Their Development*, New York: Teachers College Press, Columbia University, 1990.

Emrick, J. and Peterson, S. *A Synthesis of Findings Across Five Recent Studies in Educational Dissemination and Change.* San Francisco: Far West Laboratory for Educational Research and Development, 1978.
Fullan, M. and Pomfret, A. "Research on curriculum and instruction implementation." *Review of Educational Research*, 47, 1:335–397, 1977.
Fullan, J.G. and Steigelbauer, S. *The New Meaning of Educational Change*, New York: Teachers College Press, Columbia University, 1991.
Guba, E. "The process of educational innovation." In Goulet, R. (ed.), *Educational Change.* New York: Citation Press. 136–153, 1968.
Hall, G.E. and Hord, S.M. *Change in Schools: Facilitating the Process.* Albany: State University of New York Press, 1987.
Hall, G. and Loucks, S. "Teacher concerns as a basis for facilitating and personalizing staff development." *Teachers College Record*, 80(1):36–53, 1978.
Hargreaves, A. "Experience counts, theory doesn't: How teachers talk about their work." *Sociology of Education*, 57:244–254. (quoted in Louis and Dentler, 1988.), 1984.
Havelock, R. *Planning for Innovation Through Dissemination and Utilization of Knowledge.* Ann Arbor, MI: Institute for Social Research, 1969.
Havelock, R.G. *Planning for Innovation through Dissemination and utilization of Knowledge*, Ann Arbor: University of Michigan Center for Research on Utilization of Scientific Knowledge, Institute for Social Research, 1973.
Havelock, R.G. "The Utilization of Educational Research and Development." *British Journal of Educational Technology*, 2(2, 1971): 84–98, 1971.
Hood, Paul D. "How can studies of information consumers be used to improve the education communication systems?" Presentation at the 1989 Annual Meeting of the American Education Research Association in San Francisco, 1989.
Hord, S.M. "Facilitating change in secondary schools—myths and management." *NASSP Bulletin*, 173 (516): 68–73, 1989.
Horst, D.P. et al. *Evaluation of the Field Test of Project Information Packages, Volume II: Recommendations for Revisions*, Los Altos, CA: RMC Research Corp., and Menlo Park, CA: Stanford Research Institute, 1975.
Huberman, M. "Experiments and innovation in education." *Understanding Change in Education: An Introduction*, Paris: The Unesco Press, 1973.
Huberman, M. "Linkage between Researchers and Practitioners, a Qualitative Study." *American Education Research Journal*, 27(2): 363–391, 1990.
Huberman, M. "Experiments and innovation in education". *Understanding Change in Education: An Introduction.* Paris: The Unesco Press, 1973.
Huberman, M. "Recipes for busy kitchens: A situational analysis of routine knowledge use in schools." *Knowledge*, 4(4):478–510, 1983.
Huberman, M. "What knowledge is of most worth to teachers: A knowledge use perspective." Paper presented at the American Educational Research Association Meetings, April, (quoted in Louis and Dentler, 1988), 1985.
Huberman, M. "Steps toward an integrated model of knowledge utilization." *Knowledge*, 18, 4:586–611, 1987.
Huberman, M. "Predictors of conceptual effects in research utilization." *Knowledge in Society*, 2:3:6-24, 1989.
Huberman, M. "Linkage between researchers and practitioners: A qualitative study." *American Educational Research Journal*, 27, 2:363–391, 1990.
Huberman, M., and Crandall, D.P. *People, Policies, and Practices: Examining the Chain of School Improvement, Vol. IX: Implications for Action.* Andover, MA: The NETWORK, Inc, 1982.
Huberman, M., and Miles, M. *Innovation Up Close: How School Improvement Works.* New York: Plenum.
Klein, S.S. and Gwaltney, M.K. "Charting the Education Dissemination System: Where we are and where we go from here." *Knowledge: Creation, Diffusion, Utilization*, 12(3): 241–265, 1991.

Lieberman, A. and Miller, L. (eds.), *Staff Development for Education in the 90s: New Demands, New Realities, New Perspectives*, New York: Teachers College Press, Columbia University, 1991.
Lieberman, A. (ed.), *Schools as Collaborative Cultures: Creating the Future Now*. New York: The Falmer Press, 1990.
Loucks, S. *Planning for Dissemination*. Chapel Hill: TADS, 1983.
Loucks-Horsley, S. and Stiegelbauer, S. "Using knowledge of change to guide staff development. In Lieberman, A. and Miller, L. (eds.), *Staff Development for Education in the '90s: New Demands, New Realities, New Perspectives*. New York: Teachers College, Columbia University.
Louis, K.S. and Dentler, R.A. "Knowledge use and school improvement. *Curriculum Inquiry*, 18:1, 34–62. The Ontario Institute for Studies in Education. New York: John Wiley & Sons, Inc., 1988.
Louis, K.S., Dentler, R.A. and Kell, D.G. "Putting knowledge to work, issues in education dissemination." Final report, NIE, AAI. No. 85-6. Cambridge, MA: Abt Associates, 1984.
Louis, K.S., Rosenblum, S., Molitor, J.A. and others. *Strategies for Knowledge Use and School Improvement*. Washington, DC: National Institute of Education, 1981.
Louis, K.S., and Rosenblum, S. *Designing and Managing Interorganizational Networks*. Cambridge, MA: Abt Associates, Inc., 1981.
Louis, K.S. *The Role of External Agents in Knowledge Utilization, Problem Solving and Implementation of New Programs in Local School Contexts*, San Francisco: Far West Lab for Educational Research and Development, (ERIC ED203462), 1980.
Lynn, L.E., Jr. (ed.), *Knowledge and Policy: The Uncertain Connection*. Washington, D.C.: National Academy of Sciences, 1978.
Lvthcott. J. and Duschl, R. "Qualitative research: From methods to conclusions." *Science Education*, 74(4): 445–460, 1990.
Maher, C. and A. Alston. "Teacher development in mathematics in a constructivist framework". In Davis, R.B., Maher, C. and Noddings, N. (eds.), *Constructivist Views on the Teaching and Learning of Mathematics: Journal for Research in Mathematics Education*. Monograph No.4:147–165. Reston, VA: National Council of Teachers of Mathematics, 1990.
Mann, D. "The user driven systems and a modest proposal." In *Making Change Happen*, Mann, D. (ed.), 285–307. New York: Teachers College Press, (quoted in Louis and Dentler, 1988), 1978.
McClure, R.M. "Individual growth and institutional renewal." In Lieberman, A. and Miller, L. (eds.), *Staff Development for Education in the '90s: New Demands, New Realities, New Perspectives*, 221–241. New York: Teachers College, Columbia University, 1991.
Menlo, A. "A reconceptualization of resistance to change and its application to the institutionalization process." Paper presented to the International School Improvement Project, Lucerne, Switzerland, June. (quoted in Louis and Dentler, 1988), 1985.
Miles, M. "Unraveling the mystery of institutionalization." *Education Leadership*, (vol. 41, no. 3, November):14–19, 1983.
Miles M., and Huberman, M. "Qualitative data analysis." *Knowledge*. Beverly Hills, CA: Sage, 1984.
Mort, P. "Studies in educational innovation from the Institute of Administrative Research." In Miles, M. (ed.), *Innovation in Education*. New York: Teachers College Press, 1964.
Muthard, J. and Felice, K. "Assessing activities for utilization of rehabilitation research." *Knowledge*, 4(2):309–328. Sage Publications, Inc., 1982.
Murphy, S. "Problems in research utilization: A review." *Rehabilitation Counseling Bull*, 18(4):365–376, 1975.
Nelson, M. and Sieber, S. "Innovation in urban secondary schools." *School Review*, 27:101–119, (quoted in Louis and Dentler 1988), 1976.
Pines, A.L. and West, L.H. "Conceptual understanding and science learning: An interpretation of research within a sources-of-knowledge framework." *Science Education*, 70(5):583–604, 1986.
Rogers, E, and Shoemaker, F.F. *Communications of Innovations*. New York: Free Press, 1971.
Rogers, E. *Diffusion of Innovations*. New York: Macmillan, 1962.
Rogers, E. "The intellectual foundation and history of the agricultural extension model." *Knowledge*, 9(4):492–510, 1988.
Rogers, E.M. and Kincaid, D.L. *Communication Networks: Toward a New Paradigm for Research*, New York: Free Press, 1981.

Sarason, S. *The Culture of the School and the Problem of Change*, Boston: Allyn & Bacon, 1971.
Sarason, S., Carroll, D., Maton, K., Cohen, S. and Lorentz, E. *Human Services and Resource Networks*, San Francisco: Jossey-Bass, 1977.
Schlechty, P.C. *Schools for the Twenty-First Century*, San Francisco: Jossey-Bass Publishers, 1990.
Schuell, T. "Cognitive conceptions of learning". *Review of Educational Research*, 56: 411–436, 1986.
Sieber, S.D. "Knowledge utilization in public education: Incentives and disincentives." In Lehming, R. and Kane, M. (eds.), *Improving Schools: Using What we Know*, 115–167, Beverly Hills, CA: Sage, (quoted in Louis and Dentler, 1988), 1981.
Sieber, S., Louis, K. and Mertzger, L. *The Use of Educational Knowledge: Evaluation of the Pilot State Dissemination Program*, (vols. 1 & 2), New York: Columbia University, Bureau of Applied Social Research, 1972.
Steffe, L.P. "The teaching experiment methodology in a constructivist research program.", Zweng, M., Green, T., Kilpatrick, J., Pollak, H. and Suydam, M. (eds.), *Proceedings of the Fourth International Congress on Mathematical Education*, Boston: Birkhauser, 469–471, 1983.
Sunesson, S. and Nilsson, K. "Intervening factors in the utilization of social research." *Knowledge in Society: The International Journal of Knowledge Transfer*, 2:1, 42–56, 1989.
Sykes, G. "Teaching incentives: Constraint and variety." In A. Lieberman (ed.), *Schools as Collaborative Cultures: Creating the Future Now*, 103–125. New York: The Falmer Press.
Tobin, K. and Espinet, M. "Impediments to change: Applications of coaching in high school science teaching." *Journal of Research in Science Teaching*, 26:2, 105–120. National Association for Research in Science Teaching, John Wiley & Sons, Inc., 1989.
Tobin, K. "Teaching for high-level cognitive learning in high school science?" Paper presented at the annual meeting of the National Association for Research in Science Teaching, Washington, D.C., 1987.
Weiss, C.H. "Research for policy's sake: The enlightenment function of social research." *Policy Analysis*, 3, 531–545, 1977a.
Weiss, C.H. with Bucuvalas, M.J. *Social Science Research and Decision-Making*, New York: Columbia University Press, 1980.
Weiss, C.H. "The circuity of enlightenment: Diffusion of social science research to policy makers." *Knowledge: Creation, Diffusion, Utilization*, 8(2):274–281, 1986.
Wheatley, G.J. "Contructivist perspectives on science and mathematics learning," *Science Education*, 75(1): 9–21, 1991.
Yin, R. and Moore, G. *The Utilization of Research: Lessons for the Natural Hazards Field*, Washington, DC: Cosmos Corp, 1985.
Yin, R.K. with Quick, S.K., Bateman, P.M., and Marks, E.L. *Changing Urban Bureaucracies: How New Practices Become Routinized*, Santa Monica, CA: Rand Corporation; and 1979. Lexington, MA: D.C. Heath, 1978.
Zaltman, G. *Theory-in-use Among Change Agents in Handbook of Community and Social Intervention*, Seidman, E. (ed.), Beverly Hills: Sage Publications, 1983.
Zaltman, G., Duncan, R., and Holbek, J. *Innovations and Organizations*, New York: Wiley, 1973.

The National Science Foundation has TDD (Telephonic Device for the Deaf) capability which enables individuals with hearing impairments to communicate with the Divison of Personnel and Management for information relating to NSF programs, employment, or for general information. This number is (202) 357-7492.

NATIONAL SCIENCE FOUNDATION
WASHINGTON, D.C. 20550

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

RETURN THIS COVER SHEET TO ROOM 233A IF YOU DO NOT WISH TO RECEIVE THIS MATERIAL ☐, OR IF CHANGE OF ADDRESS IS NEEDED ☐, INDICATE CHANGE, INCLUDING ZIP CODE ON THE LABEL (DO NOT REMOVE LABEL).

Gail L. Messineo
Acquisitions/Database Coordinator, ERIC
Ohio State University
1929 Kenny RD
Columbus OH 43210

NSF 93-75 (new)