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AUTHOR	Gerber, Michael M.
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ABSTRACT

This paper recommends a research and action agenda for the federal Office of Special Education Programs in examining instructional technology for individuals with disabilities, particularly as those activities relate to "system" change. Staff development programs and curriculum reform are stressed as concrete components of system change. A theoretical analysis of key concepts, such as "technology," and of how and why instructional technology has particular importance for special education is encouraged. Attention is then given to the following distinctions: (1) between technology as physical equipment and technology as productive capacity; (2) between physical and teaching variables (resources); (3) between technical and allocational efficiency in instructional settings; and (4) between control and ownership of technological innovations. Research into three cross-fertilizing strands of information and knowledge development is then recommended. These are: first, descriptive work that monitors and evaluates trends in technological development, application, and innovation; second, theory development, presentation, and debate as part of supporting empirical studies of innovative technology applications; and, third, more traditional instructional technology development, experiments, and demonstrations related to viable theory and empirical evidence. An 8-year timeframe for implementation is proposed. The critical questions of whether new technology extends or substitutes for existing school activities and whether new technology increases efficiency are suggested as central to research on curriculum reform and staff development. (51 references) (DB)

COSMOS
CORPORATION

1735 Eye Street, N.W. • Suite 613 • Washington, D.C., 20006 • (202) 728-3939

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A FRAMEWORK FOR A RESEARCH AND RELATED ACTIVITIES ON INSTRUCTIONAL TECHNOLOGY AND SYSTEMS CHANGE

Better Results for Individuals with Disabilities

Michael M. Gerber
University of California

Santa Barbara

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I. BACKDROP FOR THE RECOMMENDED RESEARCH AND ACTION AGENDA

The purpose of this paper is to recommend a research and "action" agenda for continued research, development and innovation of instructional technology for individuals with disabilities, particularly as these activities relate to "system" change. Thus, this paper is a macroanalysis pertinent to broad policy and implementation issues that bear on more effective application of instructional technology. Staff development programs and curriculum reform will receive specific attention as concrete components of system change. Topics relevant to classroom levels of practice are discussed in a companion paper authored by Dr. Cindy Okolo.

A. Overview of Approach

I begin with a general conceptual overview of technological innovation as a problem, followed by an analysis of the key concepts of "instructional technology" and "technological innovation." I have chosen to expend some space on these preliminaries because I am convinced that stronger conceptualization is as much needed in framing research in special education as there is need for a steadily accruing booy of empirical investigation. Much of current research and development is pursued with common sense and taken-for-granted notions about what constitutes technology, or even what constitutes important questions about technology. Likewise, underlying, though often unstated, assumptions about why technology is or should be a major concern particularly to special education--assumptions that certainly are crucial to establishing consensus on a research agendas--are rarely examined.

In the discussion that follows, my intention is to present a general conceptual and strategic approach to guide continuing federal investment rather than a specific proposal for discrete studies and related activities. In so doing, I have assumed that the major objective stimulate productive effort aimed at the joint issues of instructional technology innovation and systems change in the context of design and delivery of special education. I also assume that this objective emanates from an explicit concern for improving educational outcomes for children with disabilities. I also assume that potential improvements, in this regard, are sought both in terms of specific techniques, treatments, and interventions as well as in terms of organization, management, and policy.

Therefore, my approach is guided by, but not limited to, the framework established by this program sector's workgroup and schematized in Figure 1. In formulating relevant research and related activities scenerios for both the near and far term, I have drawn on what relevant empirical literature exists, my own observations and experiences as a researcher in this area, and, hopefully, on whatever logical conclusions are compelled by the conceptual overview offered in the first portion of the paper. Whenever feasible, and within space constraints, I have tried to make both my reasoning and any "evidence" supportive of some rather than other recommendations as explict as possible.

Figure 1

A FRAMEWORK FOR A RESEARCH AND DEVELOPMENT AGENDA ON INSTRUCTIONAL TECHNOLOGY*

Research and Development

Topical Dimensions	Developmental Phases	
	Timeframe 1	Timeframe 2
System Change • Staff Development Programs • Curriculum Reform		
Contextual Conditions: • Roles and Organizational Structure • Fiscal Resources • Community		
Classroom Change • Instructional Practices • Cognitive Skill • Subject and Grade Level • Classroom Technology Tools		

* The guiding mission for the framework was: "Better Results for Individuals with Disabilities."

B. A Conceptual Framework

More often than we'd like to admit, efforts to study, develop, but most of all to implement, new instructional technology, material, or procedures in natural school contexts have resulted in heightened awareness of our general ignorance about the complex and hierarchical dynamism that surrounds and conditions outcomes related to any specific student, teacher, or instructional activity in schools. Historically, researchers, administrators, and policy makers alike, often have been frustrated when, after attempting to insert new techniques into the real world of school practice, results fail to meet expectations. Such innovation "failures" from otherwise well-advertised and well-intentioned efforts frequently are attributed to resource inadequacy, resistance from teachers, or the maladaptiveness of modern school organization itself.

However, if we conceive such innovation "failure" as if only various actors or components have failed to behave as expected, we betray a very limited, or wholly incorrect, model of schools and school-based activity. We also reveal that we are predisposed towards rather poor models of how preference, choice, decision, and incentive operate on human behavior in such a system. It is particularly simplistic to describe teachers or administrators as "resistant" to change without examining system variables that condition apparent "resistance." About this, I think the following two observations deserve mention.

First, those who create and propose each new innovation often are not the same people on whom the success of innovation depends. The significance of this separation of roles--innovation creators and innovation implementors--is just as often minimized, as if merely conveying knowledge related to newly proposed techniques will in itself motivate adoption and effective use, and mere use will make benefits so self-evident to teachers that continued diffusion and adoption is a foregone conclusion. Second, we rarely hear candid admission that most "innovations" are simply too weak in competition with powerful pre-existing patterns of behavior, counter-incentives, or organizational constraints to produce dramatic improvements. As David Cohen has written, "computers are only the latest in a long line of mythologized machines, endowed with near miraculous powers (Cohen, 1987, p. 154; also see Cuban, 1986)."

We might excuse ourselves if we have been easily seduced by new technology, or if thinking about these matters has tended to be muddy, bearing in mind the enormous multivariate complexity of relationships that hinder any substantial change in our schooling system. Special education research and development is merely a part of this greater whole. Ironically though, special education research, because of its root concern for individual differences, may be unusual for its lack of a well-articulated model of the very system in which special education events are most naturally embedded. In fact, proposing instructional innovations that involve use of highly technical devices, such as microcomputers, tends to most powerfully reveal the inherent limitation of narrow, decontexualized child-behavior or teacher-behavior orientations. In the following section, I will argue that building a broader, more systems-oriented research agenda begins with a more theoretical analysis of key concepts, such as "technology," and of how and why instructional technology has particular importance for special education.

Continued confusion about the point and focus of much technology-oriented special education research threatens both its coherence and potential to contribute to practice. Broadly speaking, a worthwhile agenda for special education technology research, particularly research hoping to understand the context of technical innovation, must allocate substantial effort to address such issues as:

1. The distinction between technology as physical equipment and technology as productive capacity;

2. The distinction between physical and teaching variables (resources);

3. The distinction between technical and allocational efficiency in instructional settings (i.e., classrooms);

4. The distinction between control and ownership of technological innovations;

5. The distinction between production and distribution of technical knowledge, on one hand, and adoption and effective use, on the other; and

6. The distinction between innovation as simple acquisition of technology and innovation as the change in organizations, role, and effort that follow.

Technology: Physical Equipment or Productive Capacity

Technology, I am suggesting, refers to knowledge systematically applied in a reproducible and economically efficient manner. Instructional technology, therefore, invites analysis, not merely in terms of observable physical equipment, but rather as the embodiment of some (empirical or principled) instructional knowledge that, when used, molds the behavior of its user in a way that is both instructionally useful, repeatable, and more efficient than at least one competing mode of accomplishing the same ends. Thus, it can be argued that, while not localized in a physical product, applied behavior analysis represents an instructional technology. It embodies knowledge of student behavior in the form of logical and empirical principles. When applied by teachers, it molds their behavior in ways that teachers recognize as instructionally useful. It is demonstrably more efficient of teacher time and energy for some purposes than competing teacher behaviors that have the same intention.

Similarly, it can be seen that microcomputers (along with their programs of operation) certainly represent a general technology to the extent that they can perform various human functions, like coding, storing, and retrieving information, in a reliable and efficient manner. However, they are an instructional technology only to the extent that they embody instructional knowledge in such a way that their use results in repeatable instructional benefits that lower the "cost" of specifiable instructional functions.

Unfortunately, for a lay audience, but also for many researchers, it has been irresistible to conceive of "technology" as being the technical devices or complex procedures that employ such devices. Under scrutiny, however, this concept of technology proves shallow and yields little analytical power.

For example, education researchers have tended to construct research questions like, "Are computers better than ________?," where the blank can be filled with a description of any nameable approach, practice, or technique. However, the empirical efforts that ensue pit use of equipment--say, a microcomputer--against a less tangible complex of instructional practices, routines, and setting. Thus, there is an "apples" versus "oranges" quality to such research that produces methodologically tortured attempts to force a kind of "treatment" equivalence on these dissimilar bundles of events. The point of this exercise is strongly conditioned, of course, by a need to apply conventional inferential statistical analyses and declare a "winner." Despite expenditure of countless research hours and dollars, the accumulated literature, viewed most positively, yields only equivocal findings.

More often than not, results are equivocal first because there is little clarity about the precise nature of the "technology" being investigated or, for that matter, the technology to which it is being compared. Under closer scrutiny microcomputer use, although treated in research imagination as an integral, breaks down into a complicated array of use variables, some quite concrete--e.g., type of student response required--and others more subtle--e.g., how information is presented on screen. What is the treatment in this case? Is it the software or the hardware? One of these two components of "microcomputer" is senseless without the other, but they can be analytically distinct. Moreover, both software and hardware themselves embody analyzable components, qualities, or dimensions. More complex still, although most studies explicitly sample students, they also implicitly sample from an array of variable instructional, classroom, and school conditions of use--what my colleagues and I in Project TEECh called "microeducational environments." These conditions are neither incidental nor trivial for answering the initial question, "Are microcomputers (with a specific configuration, in a specific context, with a specific use) better than ________?".

For example, there is a class of observable task-orientation behaviors that are reasonably correlated with attention to task by students who have learning handicaps (LH). This is merely to say that when these students are not cognitively engaged, they tend not to be behaviorally engaged either. On the other hand, several recent studies of microcomputer use appear to converge on the finding that students with learning handicaps are highly attentive to microcomputer tasks. However, attention to microcomputer, as noted by orienting behaviors, can be easily mistaken for true attention to appropriate cognitive elements of task. More significantly, though, the quality of attention may also vary as a function of microcomputer task and circumstance.

In one study conducted as part of Project TEECh (Christensen and Gerber, in press) we found that handicapped students engaged in simple arithmetic drill made measurable improvements with both an arcade game-like and a straight-foreward "plain vanilla" program. But, their performance was reliably and meaningfully superior on the task that had no gaming elements. Thus, something more about observed performance, such as conditions and outcomes of previous instruction, error rate and instructional level, must be known before we can make valid inferences about observed "attention" to task.

In a second study conducted as part of Project TEECh (Lieber and Semmel, 1987) attempted to unravel the complex relationships accounting for observed benefits from "cooperative learning." In their study, however, they were particularly interested not only in potential benefits of cooperative learning for students with learning handicaps, but also in the potential of microcomputer-based learning tasks in establishing, maintaining, or enhancing whatever psychological mechanism might operate to make "cooperative learning" successful for LH students.

Lieber and Semmel (1987) found that student characteristics, task characteristics, and grouping arrangements mixed in complex ways to produce both levels of task engagement and performance. Working alone was about as effective on all measures for students in this study, whether they were handicapped or normally achieving, working alone or in heterogeneous and homogeneous dyads. However, because time was controlled, each student working in a dyad had only half as many opportunities to actively respond. Thus, the technical arrangements studied in this research produced equivalent levels of performance while actually demanding lower levels of student effort, a counter-intuitive and intriguing finding.

These results can be explained, in part, by the fact that the particular microcomputer-based task they studied capitalized on unique capacities of computers to orchestrate, motivate, and pace attention and behavior independent of how variable peers function as effective tutors in cooperative learning situations.

Thus, when working alone, LH students were driven by the computer program to higher levels of active response with the program providing sufficient supportive feedback and help. On the other hand, "cooperative" situations permitted substitution of technically equivalent learning experiences; that is, observing behavior of one's partner to some degree replaces one's own need to actively respond and receive feedback. Moreover, when partners are not especially skilled at tutoring or communicating, the computer program operates in such a way as to "fill in" critical information gaps (e.g., performance monitoring, corrective feedback, hints).

The point to be made by these examples is that technical devices (e.g., microcomputers) are not themselves the technology. Rather they merely embody technology. Therefore, they should not be treated in research or practice simply as new instructionally-relevant "objects" added to an existing stock of instructional materiel available to classroom teachers. Instead, they must be seen as physical embodiments of a particular way of characterizing a relationship between some body of instructional knowledge and some desirable set of learning activities. The mere presence or absence of microcomputers, their use or non-use, cannot alone reliably predict anything important about educational effect without also knowing specific details about the circumstances of teachers' decisions to use them as part of ongoing instructional effort. Technology is an abstract, not a concrete, concept, and productive future research will not treat the distinction lightly.

I have argued thus far that existing research literature tends to confuse instructional technology in particular with technology in general. That is, few studies in special education are explicit about what instructional knowledge a particular system is meant to embody and systematically exhibit, or why, in a given situation, a microcomputer's presentation might be preferable to a teacher's presentation. Moreover, despite keen interest in evaluating outcomes associated with microcomputer use, too few systematic replications exist to gauge the range of child, teacher, task, or setting variations that might influence effectiveness. Virtually no research exists that directly tests implicit hypotheses of instructional efficiency, how or whether microcomputers will, under specified conditions of use, assist, expand, or replace some form of instructional activity.

Technology: Physical and Teaching Resources

My colleagues and I have offered elsewhere a theoretical formulation--a theory of instructional tolerance--that relates individual differences, desirable educational outcomes, instructional resources and technology in a microeconomic framework (Gerber, 1988; Gerber and Semmel, 1985). I will not repeat that discussion here, but I will recall briefly some it its propositions concerning technology because they are relevant for framing the research scenerios that follow.

From our perspective, an instructional technology must substitutes for or significantly extends the instructional productivity of teachers who use it. I choose to emphasize this perspective because it conveniently locates questions of technology within a theoretical framework that links questions of individual student performance to questions of policy. This is not, strictly speaking, an argument for federal investment of research resources in projects that take only an economic perspective. Rather, it is an argument for theoretical power in how technology is specified as a research topic. To this end, new approaches should be encouraged that focus on special education in its totality as a social enterprise, one that encompasses, but is not identical to, any specific clinical interventions or instructional practices. The approach discussed here is intended only to be illustrative of a class of new ways of asking special education questions.

Compared to other educational innovations, for example, American schools have acquired the raw material of microcomputer innovation--i.e., the computer hardware itself--at an unprecedented rate. Beyond questions of instructional substitution or extension, the sheer speed and scale of technological diffusion underscores the need to raise the level of research to better appreciate the contextual complexity of instructional innovation. However, rapid acquisition of equipment and associated pressure that it be visibly employed by teachers for instruction creates a huge demand for innovation without providing clear understanding of its ultimate shape or character.

Fewer than three percent of schools had begun using microcomputers between 1978 and 1980 (Rogers, 1983). By 1983-84, over 80 percent of all schools (Rogers, 1983), 86 percent by 1985 (Becker, 1987), were using microcompters. The median year of first computer acquisition was 1982, 1983 for elementary and 1980 for secondary schools (Becker, 1987). Between 1982 and 1985, there was a four-fold increase in the number of computers in schools. Spending about $415 million on hardware in 1986-87, U.S. schools increased their "installed base" of microcomputers 25 percent over that of the previous year to two million units (Goodspeed, 1988). In 1988, the student-to-microcomoter ratio (SMR) is estimated at about 20:1, compared to 33:1 only two years ago.

Recent surveys estimate that the typical superintendent is aiming at a 13:1 SMR in 1992-93, and as many as one computer for each eight students over the long term. A third of superintendents are targeting SMRs of 4:1 or less (Rickett, 1990). Moreover, as many as one-third of microcomputers currently used by schools are at least five years old and, in terms of their technical capacity, antiquated. And yet, fewer than half of surveyed superintendents indicate that their school districts have a specific budget line item for computer technology. Rickett (1990) estimates that current funding levels would have to increase seven-fold just to reduce the SMR to 3:1. These costs do not include related costs for training, software, technical support, and maintenance.

What is the significance of these statistics? To be sure, they dramatically demonstrate how deceptively simple and apparently meaningful variables, such as the "SMR", can disguise an underlying web of implicit instructional motives, decisions, and mutual influences. In fact, when students cannot have unlimited individual access to computers because the SMR is relatively large, as in any condition of scarce resources, observed patterns of use reveal implicit instructional goals, strategies, and preferences.

For example, in our extensive observations and surveys of schools, many of which had newly acquired their first computers, we noted several ways in which limited numbers of computers resulted in limited or circumscribed access by mildly handicapped students, including limitations in time alloted for use, location of use, and type of computer available for use. Type of computer, in turn, tends to limit the nature of software available or purchased. In our first large scale survey, the vast majority of programs used by MH students and their normally achieving peers were "drill-and-practice" in basic skills (Cosden, Gerber, Goldman, Semmel, Semmel, 1986; Cosden, Gerber, Semmel, Goldman, and Semmel, 1987). Independent investigations by other special education researchers have replicated and extended this observation (MacArther, Haynes, and Malouf, 1986; Rieth, Bahr, Polsgrove, Okolo, and Eckert, 1987). Other educational researchers have presented data to suggest that differentiated patterns of use can be interpreted to mean differentiated instructional objectives in terms of both type of computer activity and student group. Several studies appear to support the concern that with low achieving students often have less access than higher achieving peers (e.g., Becker, 1987; Shavelson, Winkler, Stasz, and Feibel, 1985), even though available evidence shows that they experience greater learning effects with simple drill software than their higher achieving peers (e.g., Becker, 1987; Kulik, Bangert-Drowns, Willimas, 1983; Kulik, Kulik, and Bangert-Downs, 1985; Naron and Estes, 1986; Niemiec, Samson, Weinstein, and Walberg, 1987; Schmidt, Weinstein, Niemiec, and Walberg, 1986).

In a longitudinal follow-forward of several computer-using school districts studied in our earlier research (Cosden and Abernathy, 1990; Cosden and Semmel, 1987; Gerber and Cosden, 1989), patterns of differentiated use, while showing improved access overall, persisted. Moreover, differences are clearly emerging related to how schools configure their stock of computers to attain stated or unstated goals. One apparent trend has been to create centralized "laboratories" to supplement or replace the pattern of sharing few computers among classrooms. However, also emerging are different patterns of access for handicapped and non-handicapped students. Differences in percentage of laboratory-based computer use for MH students in resource classes, self-contained day classes, and mainstreamed classes ranged from 11 percent, 31 percent, and 43 percent, respectively (Cosden and Semmel, 1987). Two-thirds of principals responding to a recent survey indicated that they were concentrating microcomputers in laboratories (Gerber and Cosden, 1989). However, principals were divided when asked about the general direction and purpose of this trend. Thirty-nine percent described their schools as developing shared environments for computer use, while forty-six percent said that they were developing an array of computer use environments. Similar differences emerged regarding relationship of computer use with curriculum. Almost equal thirds of the sample said that computer use was tending to converge (36 percent), diverge (35 percent), or mix (24 percent) specific types of computer activities at their schools.

However, teachers' instructional involvement with students while they use computers is quite low, generally ten to twenty percent of the total engagement time. This particular finding has been remarkably stable across time and studies (Cosden and Semmel, 1987; MacArthur et al., 198; Rieth et al., 1987) and is consistent with the interpretation that technology innovation is a problem posed not solved for teachers by the delivery of microcomputers into typical classroom environments. The observed trend towards centralized laboratories and non-teaching laboratory coordinators/managers most likely reveals a decision by teachers not to attempt greater integration of microcomputers at the individual classroom level. As yet, it is unclear whether increased laboratory-based computer activity reflects teachers' revealed preference for limited involvement, or astute conclusion that limitations of current hardware and software makes greater involvement inefficient. However, while teachers who accompany classes to laboratories are still likely to have very low engagement with students' computer use (Cosden and Abernathy, 1990). In a controlled experiments (Gerber, Tan, Roth, and Semmel, 1986), teachers who otherwise emit key, effective teaching behaviors (e.g., monitoring and feedback) do not engage in these behaviors more than less effective teachers during students' computer use. Nor, in naturalistic observations, do computing-using teachers exhibit these behaviors with greater frequency than non-computing teachers (Rieth et al., 1987).

It is possible to see the outlines of schools' general response to this onslaught of technology and, by inference, the general goals and preferences these responses may represent. Shall all students have some, brief experience, or shall specific students or groups of students be targeted? What kind of computer activity is preferred? And, with respect to immediate instructional goals or special education's goals in general why? Behind the admittedly the imposing presence of hardware lies a realm of educational, not strictly technology, questions that are meritorious of much greater research investment.

Technology: Technical and Allocational Efficiency

Tolerance Theory (Gerber, 1988; Gerber and Semmel, 1985) is based essentially on a set of concepts borrowed and adapted from economic theory, particularly the notion of "joint production functions," and focusing on classrooms as the elementary unit of analysis (e.g., see Note 1). From this perspective, teachers' ability to transform their own knowledge and experience into "learning" or "achievement" or "social development" is limited by two broad, contextual constraints other than factors internal to the teacher (e.g., pedagogical skills, motivation, interest, verbal ability, energy). The first external constraint concerns the precise distribution of instructionally-relevant student characteristics confronting her in the form of the "class." The second external constraint concerns the exact nature of the array of administrative and other organizational variables that surround and, presumably, support her instructional effort. Moreover, the total usable resources available for instruction are, at least in the short run, fixed. In any case, tolerance theory locates the critical resources within teachers and not in the physical stock of materials or equipment around them. Without needing to describe it in detail, the type and level of instructional technology available in a given classroom also is assumed to be fixed. In this general context, then, teachers exert instructional effort and produce among students a range of instructional effects.

From these and a few other fundamental principles, Tolerance Theory can demonstrate logically that teachers can allocate instructional effort towards increasing mean outcomes or decreasing variance in outcomes, but not both (i.e., see Note 2). Classrooms are technically efficient when teachers, using available resources and technology, cannot obtain greater outcomes for one student without sacrificing desirable outcomes for another. Allocational, or economic, efficiency, on the other hand, exists when resources available to a classroom are optimal with respect to other classrooms. That is, resources cannot be reallocated from one classroom to another without harming the productivity of the first. Technical efficiency is most meaningful when discussing teachers' instructional decisions and use of technology. Allocational efficiency is most meaningful when looking at higher units, say schools or districts, to determine if available resources or technology are distributed as well as possible.

If a useful instructional technology were embodied by, say a microcomputer and its software, who should use it? When? For how long? Within the classroom, these are questions of technical efficiency. Again assuming a useful microcomputer-based instructional technology is available, we might ask: Is it better to place it in the special education classroom, the resource room, in a mainstream setting, or in a laboratory? In considering school systems, these are questions of allocational efficiency?

The answers in each case are not obvious. The decisions involved, whether implicit in habits of behavior or institutions or consciously deliberated, signal conflicts in goals and limits in resources. In general, any effort instructional exerted by teachers for normal or high achievers will increase the mean and effort for low achievers and students with disabilities will decrease the variance. That is, teachers are perpetually faced with a need to trade effort more beneficial for one student (or group) against effort more beneficial for another. This conclusion bears particular importance for special education when one realizes that special education, as opposed to a particular special treatment, therapy, intervention, or lesson, necessarily involves students with disabilities in some definable instructional group. Unless each such student has a teacher entirely to him or herself all of the time, the Tolerance model applies.

How can outcomes for students with disabilities be improved under these conditions? According to the logic of this model, only three strategies are available to teachers (and by extension, school administrators, policy makers, etc.) One, increase the general efficiency of current work. Two, wholly new resources can be allocated or appropriated for this class (see Note 3). Three, newer, more powerful instructional technology can be applied.

Simply adding new resources would seem to be the simplest solution. However, there are a number of reasons--political, budgetary, and structural--why substantial amounts of new resources are not likely to be made available to teachers over the short term. Moreover, even if net funding for education were to increase, disagreement exists about which resources are most desirable (e.g., paraprofessional time vs. microcomputers). Similarly, asking teachers to be more efficient with existing resources, like asking handicapped students to try harder, requires knowledge of useful strategies. Strategies for increasing instructional efficiency derive from a deeper analysis of instruction, just as strategies for more efficient learning derive from deeper analysis of learning. Because teaching entails complex, multidimensional behavior, efficiency seeking often involves reprioritizing and reallocating effort among competing instructional goals. For this reason, teachers have a natural interest in new techniques because use of an explicit technique helps to organize and clarify for them many of the unspoken elements, priorities, or constraints associated with teaching. Technological innovation, the third possible strategy for general improvement for all students in a class, is not only desirable, but quite necessary.

On the other hand, while there is much informal experimentation, there is also reason to believe that diffusion and adoption of innovations in schools are low probability events. That is, the classroom teachers effective use of a new technology, embedded as it is in a system of hierarchically ordered influences, is at the end of a long series of probablistic conditions. In fact, Lantz (1984) adds that:

> ... one definition of an innovative idea is that no single organizational entity exists that can implement it (p. 60).

Her point was that new activities that can be accomodated within existing levels of school organization without much disruption, dislocation, or friction, are activities that must already fit the general behaviors, goals, and preferences of individual actors in those units. In Lantz's sense of the term, a true innovation forces restatement of organizational parameters, and may also force significant restructuring and realignment within and across organizational units. Innovation, in this sense, represents a process, the success of which depends necessarily on local circumstances.

But such local dependence also restricts the degree to which innovations, successful in one locale, reasonably might be expected to transfer to a different locale. Frustrated with apparent lack of generalizability of educational innovations, some policy analysts have called for radical rethinking of what general evaluation criteria ought to be applied in these cases. Pogrow, fo. example, suggests that

> ...cost-effectiveness analysis needs to begin to treat effectiveness as essentially a constant, and examine the effects of substantially varying the cost structure of education (Pogrow, 1983, p. 75, original emphasis).

With regard to technological innovation, this is often because what gets diffused and adopted is the form not the substance of the technology. Pogrow's main point is that efficiency rather than effectiveness should be the focus of policy analysis and evaluations of educational innovations. This view is compatible with Tolerance Theory which, by extension, would further urge that efficiency ought to be an a priori objective of educational innovation.

But for reasons discussed above, efficiency seeking in instruction is an uncertain exercise. Often what motivates adoption of new technology, like adoption of new instructional practice generally, is command or pressure from authority external to classrooms (e.g., school administration, government agencies, universities). That is, if there are information signals for technological innovation emerging naturally from the teaching process, they either are difficult for teachers to "read" or are masked by priorities set by authority external to classrooms.

One reason for teachers' so-called "resistance" to change, therefore, is found in differences in how technical (i.e., productivity-related) information flows through systems of organized activity not disciplined by the dynamics of a market. Economists have long understood how departures from market conditions influence decision-making and productivity in schools. In particular, they make compelling arguments about the role of technological innovation, arguments that barely inform current special education research. According to Michaelson, for example,

> Ambiguity about goals and concomitant uncertainty about technology are probably inherent in all public enterprise. In contrast to a competitive industry where managers need only know how to operate their organization profitably for the public's interest in efficient production to be served, in a public bureau an explicit plan or understanding of how to achieve optimality is necessary, since there is no counterpart to automatic market forces to move unwilling or unknowning bureaucrats toward it. Thus, the information required about what is in the public's interest to produce and how best to produce it is much more extensive in a public setting than a private one. Because of this, public managers may only infrequently, if at all, possess an authoritative plan capable of keeping the bureau's activities focused on producing the optimal output mix at least cost (Michaelson, 1980, p. 212,).

What scant research on administrators' perceptions and policies regarding microcomputer technology exists tends to support Michaelson's general argument. According to AASA's survey of school superintendent's, sixty percent of districts surveyed have long-range plans (Ricketts, 1990). Forty percent of reporting districts had computer advisory committees. Our survey of school principals revealed a similar percentage of schools (i.e., 70 percent) whose principals claimed that they were proceeding with computer acquisition and use according to a plan. Although these data indicate an underlying expenditure of substantial amounts of money and time, there is little evidence that existence of school or district level plans correlates with general type, level, or quality (Gerber and Cosden, 1989).

If planning can replace for schools the normal innovation signal system of a market, why are schools with extensive plans no more likely than others to be innovative or effective in their computer applications? Although it may be true that some specific teachers and administrators lack some undefined set of requisite skills to implement plans effectively, this cannot explain the general problem of innovation failure.

Technology: Ownership and Control of Innovation

Pogrow offers an alternative explanation for what might be called the structural nature of technical innovation failure in schools.

> It is difficult (impossible?) to find precedents in any field where it has been possible to diffuse new techniques throughout a highly labor intensive activity with fairly fixed financial incentives simply via information transfer In most historical examples where diffusion was successful in improving the quality of services and products, the knowledge diffusion was accomplished by an economically compelling technology to reduce dependence on labor (p. 76)."

In essence, he is saying that providing information to teachers about computers--e.g., by means of traditional staff development activities--is unlikely to impact significantly on practice. If valid, this point seems critical for setting future special education technology research priorities, especially with regard to staff development, because it helps separate issues of ownership and control.

Teaching, as Pogrow's statement suggests, is indeed labor intensive activity. Moreover, as a role in the public sector, it is organized in such a way that available "incentives" for altering or reorganizing its core behaviors (however one cares to think about "incentives") are simply insufficient to support and sustain the change process (Cohen, 1987). Instead, it would seem, change can occur only if teachers themselves realize and recognize a savings in instructional time and effort associated with innovative practices.

For example, "curriculum-based measurement" and monitoring of student progress involves an instructional technology, in the sense discussed here, that enjoys superb empirical support (Fuchs and Fuchs, 1986). Despite clear evidence of its worth in organizing and informing decision-making, its implementation requires substantial allocation of teachers' time to the task. The fact that the developers recently have sought a computer-based system (Fuchs, Fuchs, Hamlett, and Hasselbring, 1987) is itself evidence that the authors understand the need to facilitate use as a means for encouraging adoption. They, therefore, have studied their computer-based system in an attempt to marshal persuasive evidence that adoption entails no significant requirement for additonal time and effort, or at least that time and effort required is worthwhile (i.e., adoption can replace other teacher activities judged to have less utility).

In one recent computer-based application of this technology, teachers required only about two minutes per student in one academic domain (Fuchs et al., 1987). Despite the prevailing image of computers as superior systems for managing data, about 25 percent of this time was spent charting data by computer-using teachers, significantly more time, on average, than time needed for the same chore by a paper-and-pencil contrast group. Nevertheless, these result nicely illustrate the pivotal importance of how teachers' perceive utility of new technology. In the words of the authors,

> ...introduction of the computer to progress monitoring decreased teachers' efficiency in implementing the procedures, but improved teachers' perceptions of the efficiency of monitoring (p. 26).

The authors speculate that teachers might be inclined to adopt the technology in this case because of their relatively positive perception of the computer-based version. This presupposes, of course, that teachers believe that curriculum monitoring of this sort is of value to them when more than a few students and one content domain is considered. But, I won't take issue with the authors' general reasoning; it is, after all, an issue that can be pursued empirically. This study does substantiate and extend the general argument I have developed here. Information transfer, by itself, may not move teaching practice towards higher levels of efficiency or effectiveness. But, when there is no "bottom line" to provide critical feedback, perception of a technology's benefit can be uncoupled from its actual benefits or costs.

Computer technology in the schools may be yet another dramatic example that classrooms are more vulnerable to the perceived utility of "innovations" than productive units in the private sector to disruption and dislocation of effort. The fact may be that opportunity costs of such innovations (i.e., what alternative uses exist for the same teacher time and effort) are really very high. Drift towards such technical innovations in belief that they are economical may be a particular problem for administrative decision-making at all levels of public schooling. There is no profit to be maximized. Educational "product" is multivariate and the relative value of any particular distribution of outcomes is itself variable depending upon which group of "consumers" are being addressed. Therefore, superintendents and principals, to the extent that they are goal-oriented in their decision making (Hoy and Ferguson, 1985), may really seek to maximize perceived rather than actual quality of school activity (Michaelson, 1980).

If true, this explanation sheds light on why school administrators somewhat reluctantly followed early calls to purchase and apply computer technology, and why they are now more clearly leading (e.g., Gerber and Cosden, 1989; Goldman, Semmel, Cosden, Gerber, and Semmel, 1987; Martin, 1988; Ricketts, 1990). School ownership and visible use of computer technology, thanks in no small part to marketing by computer and software manufacturers, is perceived by the public as a strong indicator that a school is modern, innovative, and, probably, providing a high quality education (Martin, 1988).

Efficient (or effective) use of technology in special education requires a process that first identifies and grasps the potential utility of the new technology for solving instructional problems or freeing other instructional resources (e.g., teachers' time). Thereafter, those most responsible for the innovation, teachers, need sufficient time and support to define appropriate conditions and hone techniques of use. Only when ownership and control are joined in this way are innovations likely to succeed. The general staff development strategy for empowering teachers in this way as part of a process of technical innovation is actually well understood (e.g., for recent discussions see Durkin, 1990; Glatthorn, 1990; also see current and pending reports from OSERS-sponsored technology integration projects for secondary, middle, and elementary school: respectively, Louise Appell, Macro Systems, Inc.; Catherine Morocco, Education Development Center, Inc.; Marion Panyan, Johns Hopkins University Center for Technology and Human Disability).

Summary

To summarize the concepts I've used to construct this framework thus far, a worthwhile agenda for future research investment in special education technology must demand and yield stronger conceptualization of what we mean by "instructional technology." It must look beneath and behind physical devices, products, and hardware to uncover what instructional principles are being applied, in what context, and towards what goals. Goals, in turn , must be justified in terms of their relationship to a set of core special education values and concerns. Researchers need to begin articulating these concerns explicitly and in such a way that generalizability of empirical work as it accrues can be assessed. In essence, there needs to be as much attention to theory as there is to empirical method. Specifically, in seeking improved outcomes for students with disabilities through special education technology, researchers must pursue evidence that what is described as an instructional technology captures and applies valid instructional knowledge in a manner that is reproducible across a specifiable range of student, domain, or environment variations, and measurably increases instructional efficiency.

II. SCENARIOS FOR RESEARCH INVESTMENT

In this Section of the paper, I will present research "scenerios" I believe follow from the logic of this conceptual framework. Following the recommendations of this program sector's workgroup, I will address the specific agenda items related to context, curriculum reform, and staff development both in short (i.e., one to three years) and longer timeframes (i.e., four to eight years).

The general strategy re mended here calls for support of three, cross-fertilizing strands of information and knowledge development. First, support a strand of descriptive work that monitors and evaluates trends in technological development, application, and innovation in schools. Changes in technology or its status in practice (e.g., witness the rapid evolution of microcomputer technology) occur quite rapidly. For knowledge about technological innovation, and policy in support of such innovation, to progress, it is critical that researchers, practitioners, and policy makers monitor the pulse of change in special education practice, especially as that practice interacts with ongoing changes in schooling itself (e.g., REI, full integration, dropout prevention, minimum competency requirements, curricular and testing reform). If reliable and timely information about both the state of technology (i.e., potential) and states of current technology-related practices is not available, ongoing experimental, development, or demonstration projects are at risk for becoming quickly irrelevant or trivial. On the other hand, ongoing monitoring projects will help solve the persistent research/development dilemma: Should special education technology research seek innovative and optimal application of technology actually available and used in schools, or should such research focus on state of the art demonstrations despite the fact that such technology is, for practical purposes, unavailable to schools?

Some of this dilemma is caused by lack of information about technology state of the art, but much of it stems from not knowing what instructional characteristics new technologies do or could possess that would facilitate effective use as well as acquisition by schools. One component of the overall strategy for specifying these characteristics is to invest in cross-sectional and longitudinal research on technology adoption, innovation, and change processes as they really occur. For example, it is not yet clear if a trend for development of centralized computer laboratories and related, technical assistance personnel reflects a "cause" or "effect" element in the configuration of microcomputer innovation.

On the other hand, it is also impossible to specify a priori what constitutes "barriers" (e.g., "lack of knowledge or agreement on effective instructional practices") or "opportunities" (e.g., "specific technologies, such as videodisc programs in mathematics and science") to directing technology towards the needs of students with disabilities in schools. Existence of centralized computer laboratories again provides a relevant example. Rather than force the issue of teachers' limited computer knowledge, many schools apparently have chosen to relocate needed computer expertise outside the classroom teacher and, in fact, outside the classroom. This decision, in turn, can and does influence decisions about the characteristics of hardware, software, curriculum integration, and target student population that follow. To say that teachers' lack of knowledge was a barrier in this case begs a great issue. Conversely, technologies with clear instructional potential and some empirical evidence of utility, such as videodisc, may become barriers, rather than opportunities, if accomodation of technical equipment, rather than integration of technical principles, becomes the primary focus of instructional innovation.

The point to be made is that any a priori identification of "barriers" and "opportunities" presupposes both a set of arguable assumptions and a disputable policy position. The only resonable position is that technology be developed and used to "improve desirable outcomes for students with disabilities." In this sense, it is more strategic to assume only that there exists a technological potential that, when proposed as an extension or substitution for some aspect of instruction, transacts dynamically with school context, structure, and purposes. Special education research investment, therefore, should primarily support efforts to better understand the dynamics of that transaction, and seek valid ways of shaping it to the benefit of students with disabilities. The foundation of this effort must be research that develops, systematizes, and interprets information about how schools and teachers make decisions about applying technology for special education. The resulting data will in turn permit a far stronger basis for identifying best or likely strategies for narrowing gaps between technological potential and actual practice.

A second strand of research investment should be directed towards theory development, presentation, and debate as a critical and necessary part of ongoing support for empirical studies of innovative technology applications. Investment in theory construction provides a rational and economical means for organizing, relating, and evaluating cross-cutting research activities and specific research projects. The current cost of investing in theory development (i.e., a somewhat smaller portfolio of current empirical studies) pays for itself many times over by facilitating integration of studies and their policy translation over the longer term.

A third and final strand should support more traditional instructional technology development, experiments and demonstrations. However, these should be related clearly not only to extant literature on instructional technology, but also to viable theories and their supporting empirical evidence. Because I am recommending a theory development strand to run concurrently, proposers of new studies must carry some of this burden in the short term (i.e., Timeframe 1). In particular, they must offer sufficiently detailed theoretical argument, derived from extant literature, to support the priority claim of their proposed research. This requirement assures that both the theoretical specifications as well as resulting empirical data become parameters for evaluating priorities and proposals in the next cycle of activity. What I am suggesting is that the level of theorizing needed to regain momentum must reach beyond the narrow confines of a single study and researchers' normal methodological concern for internal validity.

Rather, a new theoretical effort must be made to address questions of external validity in a way that both justifies a specifically focused study, but also usefully guides researchers that follow in selecting and relating their own proposals to achieving better results for children with disabilities, OSER's overarching mission statement.

Because the stock of extant theories of special education (as opposed to theories of handicapped children) is certainly limited, if existing at all, and because there is probably limited consensus about how such theories should be specified to accomplish the general goals described above, "start-up" investment is recommended (i.e., during the first years of Timeframe 1) in the form of a series of related activities, including but not limited to a series of commissioned papers together with extensive, representative peer commentary, all of which can be disseminated, technical conferences to discuss and debate matters of formal specification and methodological implications, establishment of a data base format explicitly supporting theoretical development and the refined relationships among the three strands I have outlined above. The major purpose of investment in these support activities would be focus future research by identifying or developing specific and alternative theories of how instructional technology in special education might improve outcomes for students with disabilities. While theories can, of course, compete in their formalisms or specifics, they should all derive from explicit definitions of such constructs as "instruction," "technology," "special education," "disabilities," "outcomes," and "improvement." In particular, three classes of variables related to context, curricum, and staff development should each receive formal, detailed treatment. The model(s) resulting from this effort should organize a body of work to address these two critical questions:

1. Does new technology extend or substitute for existing school activity?

2. Does new technology increase efficiency?

Contextual Conditions

The "context" of technological innovation in special education refers to the organization, structure, fiscal resources, and aspects of community that surround and envelop practice. These factors, which I have discussed in the most general way in the previous discussion, are distal from the point of instructional contact with students and therefore often treated by special education technology research as irrelevant or trivial with respect to instructional outcomes. I have argued in this paper that their collective impact on instructional events is indeed relevant, but complex. For example, I have discussed why, theoretically at least, comprehensive planning at the district and school building levels is necessary to guide adoption of new technology. However, I have also discussed why mere existence of microcomputer acquisition and allocation plans, for example, does not relate very strongly to the nature or quality of actual use, often for equally simple reasons. Rickett (1990), for example, found that despite plans, few districts included microcomputer technology as a unique line item in their budgets, nor were amounts allocated for microcomputer acquisition consistent with achieving stated SMR-reduction goals.

A number of identifiable variables mediate the process of technological innovation in schools, not the least important of which are variables related to teachers and their teaching in classrooms. Apparent reluctance of teachers to use and integrate microcomputers in their classrooms may reflect not only knowledge limitations, but also the relatively costly innovative behaviors that are being urged on them from outside the classroom. That is, they are being asked explicitly to be compliant adopters and implementers, but also are being pressed implicitly to be creative experimenters in designing and validating modes of instructional integration. However, they are never fully free to adapt to these demands as training and experience might dictate. Instead, an externally provided set of resources, goals, and practical limitations impose upon their ability and willingness to solve innovation problems.

For this reason, a federal research agenda in special education should have as one of its overarching aims construction and empirical studies in support of contextual models of technological innovation by teachers, specifically as it pertains to instruction of children with disabilities. It is true that such an agenda item requires asking questions that properly are viewed as basic to the problem of instructional innovation more generally. However, two compelling arguments support this approach nonetheless. First, without knowledge of how variations in organization conditionalizes impact of attempts to innovate with high technology, there is little reason to hope for better success in the future than we have seen in the past. Second, there has been an historical tendency for special education research to accumulate without naturally or easily integrating. This tendency, I would argue, reflects an unusual discontinuity in conceptualizing special education. Although there are a relatively large number of competing psycho-educational theories of handicapping conditions, there is dearth of educational, organizational, and instructional theories of special education as a large-scale, school-based multilevel activity. It is precisely this multivariate nature of technological innovation in complex organizations like schools, however, compels greater effort to establish theoretical and empirical correspondences between micro-studies of students and their instruction, on one hand, and more macro-studies of the instructional structure and organization that contexualizes special education practices, on the other.

This latter type of special education technology research--what I have called, macro-studies--is centrally concerned with decisions, at levels above that of the classroom, related to resource acquisition, allocation, and use. How are these decisions made? What information, events, or perceptions predict them? Do they have the effect of substituting or extending existing school activities critical for students with disabilities? Does instruction of students with disabilities become objectively more efficient as a consequence of these decisions?

I recommend that these questions related to the context of technological innovation in special education be pursued over the next eight years. This effort should conform to the three general strands of research recommended and described above--descriptive and survey of current practice, theory development, empirical experiment, development, and/or demonstration. Most needed across strands are studies of how special education technology and innovation are developed, defined, acquired, allocated and controlled by school or district level administrators, their explicit o· "revealed" decision and policy preferences, what forms administrative controls and incentives to implement policy decisions take and how these controls function, how such decisions and policies articulate with other, more general special education roles, goals, and structures, and finally, what effects of these decisions and policies on technology-related teacher behaviors and student outcomes can be discerned and forecast.

A reasonable scenerio in this regard might be:

Timeframe 1: 1-3 years:

- Related Activity: Commissioned papers and Review conference;
- Strand 1: Cross-sectional and longitudinal studies of technology decision-making;
- Strand 2: Development of testable theories (e.g., goal-oriented vs. systems models [e.g., Hoy and Furgeson, 1985]) to account for technology decision and policy evolution; and
- Strand 3: Three-year programs of research on how variations in administrative/community differences (e.g., student SES, funding mechanisms, administrative structure) produce or interact with differences in systems of controls and incentives for technological

innovation in special education, and the associated teacher and/or student outcomes.

Timeframe 2: 4-8 years

- Strand 1: Cross-sectional and longitudinal studies of technology decision-making;
- Strand 2: Research to integrate literature, assess theories, reconstruct, revise, and refine models relating special education technology acquisition, allocation, use, and effectiveness; and
- Strand 3: Continued research directly addressing factors related to stable and changing effects of specific state, local, school policies on special education technology adoption and effectiveness.

Curriculum Reform

Contemporary curriculum reform in the United States has three major elements: a desire to make the curriculum more "relevant," more consistent, and more potent. The first of these elements concerns what reformers see as a mismatch between classroom learning and world-of-work demands. Specifically, this means not only that general content related to contemporary community and national life and values should be enhanced, but also that curriculum should be designed to meet diverse needs of ethnolinguistic minorities, in part to promote achievement, prevent dropout, and enhance life opportunities for these students.

The second element relates to reformer's desire to assure, first, that certain "basic" or fundamental components are adequately represented across schools, states, and minimum competencies are obtained by all students. Second, reformers desire that this basic curriculum be aligned with modes of assessment so that local and national monitoring of educational progress can more easily be accomplished, and instructional prescriptions can more easily be inferred.

The third element of contemporary curriculum reform is concerned to increase the breadth, depth, and general rigor of what is learned in school. Reformers argue that changing world economic conditions require that we produce students with greater knowledge, skills, and awareness than previous generations. The element, therefore, revolves around higher standards, more content integration, and higher levels of achievement, specifically higher levels of creativity, ability, and technical skills. An important, frequently discussed, recommendation proposes that curriculum should be infused with greater opportunity for students to learn how to think and express themselves well, especially with regard to scientific, creative, and general problem solving skill.

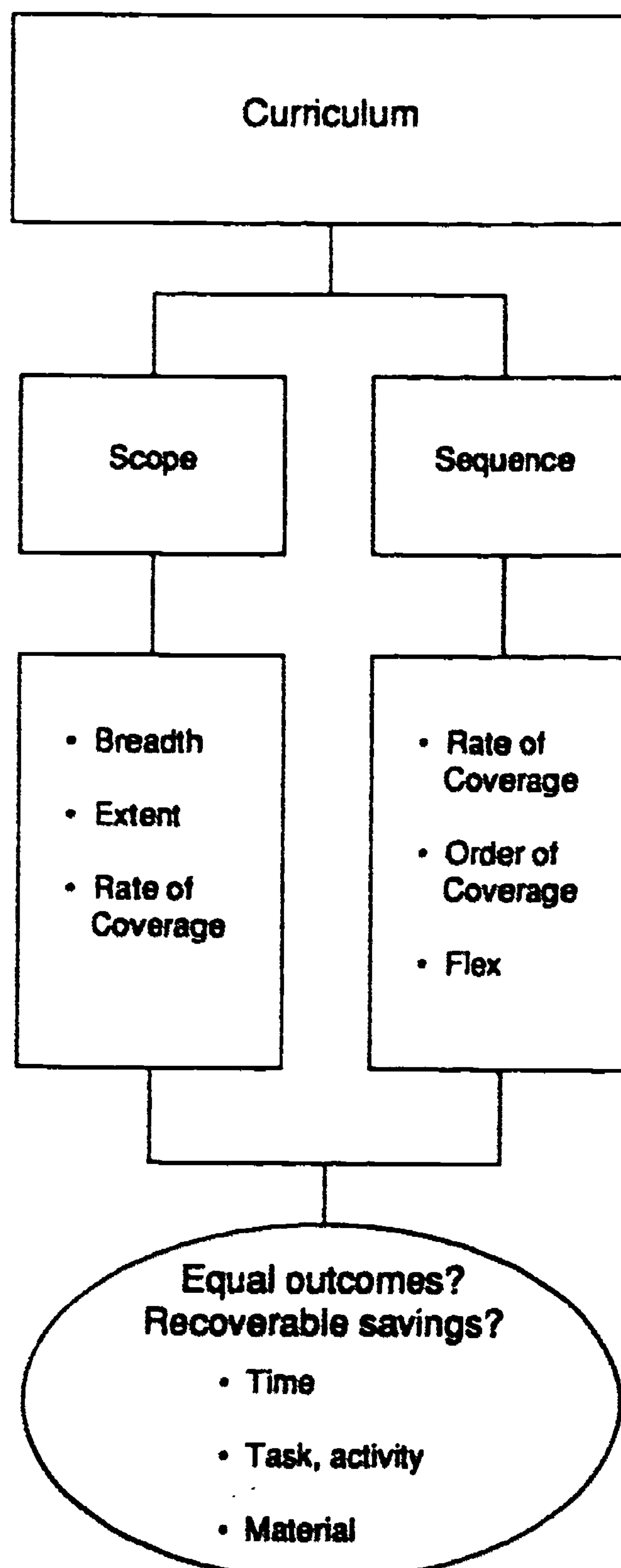
These laudable curriculum reform goals receive little criticism. However, they, together with related policy reform directly bearing on special education, such as the "regular education initiative" and the "full inclusion model," do provide a significant challenge to special education. One immediate and general effect of these reform proposals, particularly in an environment of resource scarcity, is to underscore special education as a process that requires more intensive and/or extensive use of instructional resources to obtain reliable achievement for students with disabilities. In terms of the present discussion, special education is called upon to search for ever greater gains with fixed resources or to maintain gains with decreased levels of resources. This demand creates a natural press in special education for technological innovation. Legitimate instructional technologies in special education, therefore, substitute or expand some worthwhile instructional activity in an inherently efficient manner.

Figure 2 shows in schematic form what kind of research agenda flows from pursuit of this goal. When abstracted from a particular content domain (e.g., reading, mathematics, science), a curriculum is composed of a general plan for instructional activity, including teaching, use of learning materials, and generic learning tasks, that is mapped onto a delineated scope and sequence of domain-specific knowledge and skills thought to be appropriate for a given class of students. Teachers knowledge and use of the curriculum assists them in

Figure 2

Critical Question #1: Does new technology extend or substitute?

Critical Question #2: Does new technology increase efficiency?



selecting and ordering appropriate instructional activities, as well as evaluating effects of these activities on students relative to age or grade-related expectations.

Figure 2 also outlines ways in which technology by efficient substitution or extension can meaningfully impact on curriculum. Instructional technology can increase the breadth, extent, or rate of coverage of learning objectives comprising the curriculum's scope. Likewise, new technology may have its effects on curriculum sequence, increasing the rate at which the entire curriculum is completed, permitting rearrangement of the order of instructional objectives or events, and greater flexibility in tailoring this order to individual needs.

For example, replacing workbooks with microcomputers programmed to cover the same or more of the same material may constitute an efficient technological substitution if, for example, in the same instructional period, the microcomputer system fosters learning of more material or the same material in richer, more elaborated, more personally tailored detail. Conversely, the material to be learned may be equivalent, but the microcomputer system may promote the same level of learning in a shorter period of time. Here, we must be cautious though. Mere saving of either student or teacher time may or may not constitute a real savings unless that time is reclaimable, at least, and in a strict test, reallocated to the increased benefit of the same or another student. Figure 2, therefore, proposes a research agenda that focuses on the critical problem: do technological innovations in special education, undertaken with respect to aspects of curriculum reform, in fact result in savings recoverable by so that they then can be applied elsewhere or to the same student for another, equally desirable purpose?

A reasonable scenerio in this regard might be:

<u>Timeframe 1: 1-3 years</u>

- <u>Related Activity</u>: Commissioned papers and review conference;

- Strand 1: Cross-sectional and longitudinal studies of technology innovation intentionally or logically related to one or more aspects of curriculum reform;

- Strand 2: Development of testable theories describing what instructional principles combine in what technologies to produce greater integration in normal curriculum or greater benefit from specialized curriculum for students with disabilities; and

- Strand 3: Three-year programs of research on how variations in (identifiable instructional principles in) technologies affect beneficial changes in scope and sequence of curriculum in various content domains.

Timeframe 2: 4-8 years

- Strand 1: Cross-sectional and longitudinal studies of technology innovation intentionally or logically related to one or more aspects of curriculum reform;

- Strand 2: Research to integrate literature, assess theories, reconstruct, revise, and refine models relating special education technology and scope and sequence parameters of curriculum in various domains; and

- Strand 3: Continued research directly addressing variations in instructional technology's underlying principles relate to stable and changing effects on progress of students with disabilities through curriculum scope and sequence in various domains.

Staff Development Programs

Dennis Mithaug (1990) has drawn a useful distinction between research "translators" (i.e., those who play roles as knowledge producers, users, and beneficiaries) and the process of translating research into practice. It should be quite clear that at the core of any and all efforts to introduce technical innovations into schools and school curriculum is the classroom teacher. However, it is also well known that many "innovative" techniques have failed because teachers have implicitly or explicitly rejected them. More research, it seems, is needed to better understand and address the research translation process. In this regard, we are again faced with a dearth of good models of special education as a school-based, school-embedded enterprise. For the purpose of illustration, I will continue to follow here the general economic logic I presented earlier in this paper.

It may seem a truism those personnel who must actively and skillfully employ a new technique, whether it is embodied in "hardware" or not, are ultimately responsible for the success of an innovation. However, teachers as technology users are different from, say, office workers as technology users for both obvious and less obvious reasons. Office workers, like teachers can fear and harbor suspicions about microcomputers. They similarly can remain unresponsive, or even resist, management's best efforts to train them to use the new technology. However, at least two aspects of teachers' circumstances are very different from that of office workers. One difference is the ability of private sector management, unlike school management, to describe and prioritize critical production tasks with great precision. A second difference that bears directly on job description and staff development is the proverbial "bottom line". That is, where competitive markets drive and discipline organizational behavior, knowledge useful for increasing productivity while maintaining costs or maintaining productivity at lower costs, is highly valued, rapidly identified, and readily exploited. Businesses (and employees) that fail to capitalize on availability of more productive techniques are dispassionately eliminated from the market place.

This is not to suggest that teachers, or any working person, should be coerced by fear of job loss into learning and productively using new technologies. Private sector managers, too, understand that they must share responsibility for success of new innovations not only by carefully targeting and planning each stage of innovation, but also by maintaining an array of incentives that clearly "signal" desirability of certain behaviors while motivating their occurrence.

Therefore, to obtain parallel success in informing teachers and motivating their use of instructional innovations, we need a better set of specific working hypotheses about how microcomputer technology efficiently replaces (i.e., substitutability criterion) or enhances (i.e., extension criterion) classroom instruction, and about what arrangement of incentives best signal and motivate desirable change. A satisfactory agenda for future federal research support and investment aimed at increasingly efficient or productive technological innovation for students with disabilities should reflect this need.

Figure 3 presents in schematic form a research agenda that follows from the ideas discussed thus far. Staff development is conceived as impacting teachers' knowledge, use, and integration of instructional technology. (Integration, here, refers to instructional integration, meaning that the technology in question is directly manipulated by the teacher to further her instructional goals.)

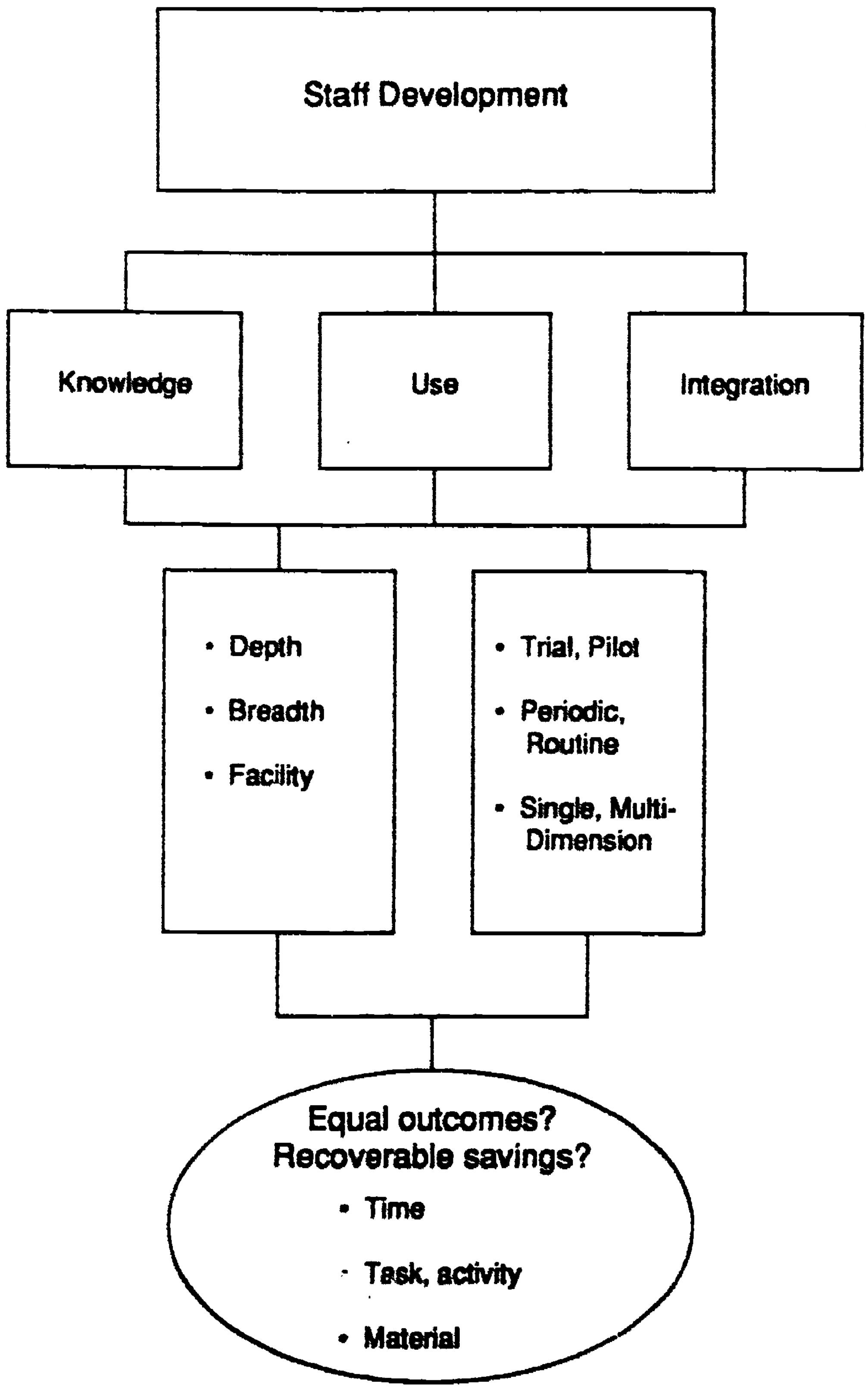
The schema in Figure 3 portrays six potential effects of enhanced knowledge, use, or integration of technology. Depth, breadth, and facility are meant to represent an interface between instructional method and content domain, although there are certain generic aspects to knowledge, use, and integration of, say, microcomputers. Generally speaking though, knowledge of technology use (i.e., application) in a domain may increase, as may actual use or integration of technology in that domain. An "increase" may represent increasingly detailed or greater penetration of domain knowledge (i.e., depth), an increased scope of material within that domain (i.e., breadth), and increased ability to cognitively or materially manipulate content in the domain (i.e., facility).

A second set of potential teacher effects are somewhat more behavioral. Trial/pilot refers to a technology's potential use for a single or limited occasion. Thus, teachers, following an inservice demonstration for example, may have knowledge of an application based upon a single or limited number of occassions. Knowledge, in this case, is based on observation, reading, or discussion only. Or using a

Figure 3

Critical Question #1: Does new technology extend or substitute?

Critical Question #2: Does new technology increase efficiency?



technology for a single or limited number of occasions may characterize the extent of their own experience of technology use. Periodic/routine, on the other hand, refers to repeated occasions of use. Single or multidimensional effects refer to the variety of instructional purposes (not domains) that characterize a teacher's experience. Thus, teachers may have knowledge about how microcomputers might be used for reinforcement, practice, problem solving, social integration, and so forth, but may have used microcomputers herself only to assign drill and practice. Integration in the context of periodic/routine and single/multidimensional effects means that use of the technology in each circumstance is equiprobable with other high frequency instructional behaviors displayed by a given teacher. For example, although Teacher A knows about and uses microcomputers in her class, she automatically uses the chalkboard to illustrate a point during math lessons. Teacher B, on the other hand, turns to the computer and its overhead display with equal frequency. Teacher B would be described as being at an Integration level of proficiency, whereas Teacher A is at a Use level.

A reasonable scenerio following from this schema, therefore, might be:

Timeframe 1: 1-3 years

- Related Activity: Commissioned papers and Review conference
- Strand 1: Cross-sectional and longitudinal studies of teachers' patterns of technology knowledge and use across curriculum domains;
- Strand 2: Development of testable theories describing what experiences affect levels of proficiency across curriculum domains and instructional activities (e.g., lecture, tutorial, discussion, testing, etc.); and
- Strand 3: Three-year programs of research on how variations in teachers' formal and informal experiences with technology influence levels of proficiency.

Timeframe 2: 4-8 years

- Strand 1: Cross-sectional and longitudinal studies of teachers' patterns of technology knowledge and use across curriculum domains;

- Strand 2: Research to integrate literature, assess theories, reconstruct, revise, and refine models relating special education teachers' experiences with technology to their instructional knowledge and behavior; and

- Strand 3: Continued research directly addressing variations in teachers' technology experiences as they related to stable and changing effects on the level of their proficiency in instruction of students with disabilities.

III. FINAL COMMENTS

Even a cursory review of current literature on implementing microcomputer technology to improve outcomes for students with disabilities reveals a number of unspoken, and largely, untested assumptions that are paralleled in educators' views of technology generally. Among these are the following:

1. Teachers know, understand, and can articulate how microcomputer (technology) use in classrooms has high benefits, either for them (the teachers), selected students, or both;

2. Conveying to teachers general, or even specific, kinds of computer-related knowledge is both necessary and sufficient to motivate and activate effective, well-integrated use of microcomputers (technology);

3. Teachers avoid, reject or only superficially use high technology because they fear its apparent complexity and need to be convinced, conjoled, or otherwise motivated by administrators; and,

4. Teachers who are enthusiastic and knowledgeable users of technology obtain markedly improved outcomes from students with disabilities, directly relatable to use of technology per se.

Experience and empirical work make these assumptions highly suspect. They do represent, however, core issues that should be the basis of a focal, mission-oriented agenda for technology research in special education over the next eight years. As I've attempted to show, researchers need to see teachers as both a part but at the same time the pivot of a system that yields instructional effects. Not only should teachers' technology and technology effects knowledge be probed and itemized, but also the source(s), form(s), real and perceived utility(ies), and meaning(s) of that knowledge should be characterized in ways that are compatible with research on curriculum and school context. These investigations might be predicated on various (and competing) cognitive, behavioral, sociological, or anthropological theoretical orientations towards professional knowledge acquisition and its use, curriculum definition, scope and sequence, and organization and structure of schooling. The utility of these approaches for policy formation ultimately rests on their ability to portray how (if) knowledge about and use of technology influences special education practice in ways that clearly benefit students with disabilities.

A broad consensus seems to be forming, reflected in part by the workgroup's selection of staff development as a system variable or topic, that teachers failure to make effective use of technology stems from insufficient knowledge or training. It is frequently proposed that they simply require much more and better exposure, training, and opportunity to use microcomputers before anticipated educational benefits will occur. But what is to be trained? What opportunities for use are demonstrably better for improving outcomes for students with disabilities?

In seeking answers to these questions, I have proposed in this framework that microcomputers, or any other purported technology, achieve status as an instructional technology only by means of a process that necessarily transforms not just teachers but also teachers' working environments. In part, this occurs because each new technology constrains user behavior to a specific repetoire of behaviors anticipated by the very design of each device (or formal procedure). Every computer-use behavior, for example, is correlated with some delimitation of use inherent to computer system design. The computer and its programs can do some things, not others. It must be operated in specific ways, with little or no tolerance for variation. Moreover, the specific physical features of this technology imposes a related set of location, orientation, and other spatial-environmental requirements that further shape its use. For this reason, a federal research agenda needs to refocus technology research in special education on the core issues of instructional efficiency and content in special education, not on the attractive devices that represent general technological capacity or potential. I have argued, furthermore, that continual reification of the term "technology" as a synonym for hardware, equipment, or technical device, is an analytically barren, dead end.

Instead, I've urged in this framework that significant attention and resources be invested in theory development, theories that encompass the complexity of special education practices in situ, and that these theories be deliberately and systematically linked to ongoing programs of empirical work. In asking how to best arrange, schedule, configure, operate, or monitor technology-based practices for the benefit of students with disabilities, these empirical studies should seek to understand that instructional effectiveness and efficiency conditions and is conditioned by available technology. Each technology imposes unique constraints--conditions of use--on schools as organizations and on teachers as primary users wishing to employ technology for instructional purposes. It is the tension between goals, attitudes, values, motives, knowledge, on one side, and technical constraints, on the other, that challenges schools and teachers to discover or invent instructional principles of use that are both convenient and compatible with each school's and teacher's general knowledge and goals. In this sense, special education technology research, like innovation, depends to a high degree on creativity and knowledge about the instructional process and principles captured as a "technology," and very little, ultimately, on attention to technical devices themselves.

NOTES

1. Important to this discussion is the work by Byron Brown and David Saks (e.g., see Brown and Saks, (1975, 1980, 1981, 1984, 1987). Also, recently there have been some interesting, though problemmatic, attempts to estimate cost-benefit relationships for schools using computer-assisted instruction by Henry Levin and his colleagues at Stanford University (e.g., see Levin, 1988; Levin, Glass, and Meister, 1987; Levin, Leitner, and Meister, 1986; Levin and Woo, 1981.

2. Technically, this dilemma occurs only when teachers are already operating at an instructionally efficient point--that is, there are no other resources, either material or skill-related, that are not being used. In recent a recent study, though, Levin (1988) reported finding only one school in eight that fully used its actual CAI capacity, thereby casting doubt on some attempts to evaluate effectiveness.

3. In a very real sense, both Chapter 1 and EHA subsidies to schools attempt to foster improvement in exactly this way--by obtaining from taxpayers and appropriating additional resources. For example, at the school building level, special education services, including resource and self-contained classrooms fulfill the same function.

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