Analysis of the Federal Role in Instruction Technology in the Era of the New Federalism

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The primary aim of this analysis is to determine how the federal government might best promote excellence in education via instructional technology. More specifically, the purposes of this inquiry are threefold: 1) to identify strengths and weaknesses of instructional technology during the 1980’s, 2) to indicate how technology might aid the teaching and learning process and 3) to determine how the federal government might best assist states and localities in utilizing technology to improve educational achievement. In the latter regard, a reassessment of the roles and responsibilities of federal, state and local governments, of business and of parents seems imperative.

Any such analysis will necessarily depend heavily on the ways in which "educational technology" and "the new federalism" are defined. We begin, therefore, by defining these terms.

Educational technology connotes different things to different people. To some it refers to the use of technology in the educational process. This interpretation, not surprisingly, is favored by those charged most directly with the delivery of instruction: administrators, teachers, audio/video specialists, computer specialists, etc. To others, the term "education technology" refers primarily to the principles and techniques used in designing instructional systems. The resulting systems frequently, but not necessarily, are intended for delivery via technology. Not surprisingly, the latter interpretation tends to be preferred by those associated with academic and research environments: universities, research laboratories and centers, and even centralized instructional development centers associated with large school districts and states. Those R & D specialists who are most directly involved in instructional systems development tend to emphasize relatively familiar educational design procedures such as behavioral objectives, criterion referenced testing, and task analysis. Correspondingly, academic leaders in the field tend to place more emphasis on basic instructional theory and design techniques derived therefrom (e.g., Gagne & Briggs, 1974; Scandura, 1977).
In this analysis, “educational technology” refers to both instructional theory and design and the use of technology in the delivery of instruction. For several decades, beginning with the 1960’s, the federal government has come to play an increasing role in education. Initially, funds provided for research at universities and later for innovation in schools came relatively free of explicit federal controls. Gradually, regulation and direction came to be increasingly centralized so that by the late 1970’s a large proportion of funds were being used explicitly to dictate social ends by means of education. By 1980, the federal role in education was sufficiently pervasive as to greatly restrict and often control the activities of states and local governments. This progressive loss of self-determination frequently made it difficult to achieve local ends and, in many cases, angered parents who felt that their role was being usurped by a large bureaucracy over which they had no effective control.

In the present context, the “new federalism” refers to the return of educational responsibilities from the federal level to the state and local governments. Indirectly, it also refers to the reassignment of educational roles among government, private enterprise and independent agencies, and students’ parents so as to more efficiently, effectively and responsibly promote excellence in education. Special attention is given to the role the federal government should play in promoting instructional technology.

The remainder of the analysis builds on these definitions and preliminary observations:

I. Early Developments in Instruction Design and CBI
II. A Brief History of Federal Support for Educational Research and its Consequences
III. Instructional Technology: Current Strengths and Weaknesses
IV. Using Instructional Systems Design in CBI Development
V. The Use of Technology in Instruction
VI. Conclusions and Recommendations

I. EARLY DEVELOPMENTS IN INSTRUCTIONAL DESIGN AND CBI

Much was heard during the late 1950’s and early 1960’s about the science of learning and the technology of teaching (C.F., Melton et. al., 1959). Early realizatons of educational technology (e.g., involving programmed learning and teaching machines) were frequently based directly on existing learning theories of the day.

Skinnerians, for example, sought to convince us that schedules of reinforcement, shown to work so successfully with pigeons and lower mammals, would almost certainly save the day for human education as well. Many educators rightly saw the folly of this approach but had very little substantive scientific information on which to base their objections. An alternative idea of instructional “branching” was advanced by individuals like Robert Crowder (e.g., 1959), for example, but little other than intuition was advanced as a basis for such branching.

Early Developments in Computer-Based Instruction. – This was the milieu into which computer-based instruction (CBI) was introduced in the 1960’s (e.g., by Suppes and his colleagues at Stanford and Stolourow at Illinois). At that time many were predicting that CBI would revolutionize education, changing radically and permanently the means by which education would be delivered to the mass of our youth. Alas, the predicted revolution did not take place at that time for three major reasons.

1) The costs for hardware and for software development during this early period were prohibitive. Still, many demonstrations and some implementations of CBI systems were developed at several major universities, in the military and in a few large corporations. All of these efforts, however, were heavily dependent on federal funds. The Plato system at the University of Illinois, for example, utilized many millions of federal dollars. Plato has had limited commercial success despite these federal subsidies and, subsequently, a decade long and to date unprofitable investment by the Control Data Corporation, reportedly of about 900 million dollars. Plato’s development has been an unlikely scenario, made possible largely by the strong continued support of the chief operating officer of that corporation.

2) The second major problem during this early period was reliability. The delivery of CBI was totally and capriciously dependent on the effective functioning of large centralized computers. All too frequently these computers were down for maintenance or repairs, making it difficult and sometimes impossible to maintain a smoothly functioning instructional program.

3) Perhaps most important, too little was known about how to design effective instruction, which by its nature is highly dynamic and interactive. At that time, interactive instruction was considered primarily an art form to be mastered only in varying degrees by human practitioners.

Gradually, things began to change. The 1960’s and 1970’s saw considerable growth in instructional systems design. Increasingly, it became possible to design instructional systems by systematic means in a manner not unlike the way an engineer might plan a bridge, for example. Widespread use of the term “educational engineering” in this context is no accident. Then, beginning in the mid 1970’s, small, low cost, and reliable microcomputers were introduced. Today, barely seven years later, microcomputers constitute a multibillion dollar industry. Although educational uses have lagged behind those in recreation and business, widespread impact of computers in education seems assured.
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A vastly increased concern for improving scientific education. Initially these concerns were centered on mathematics. In a few years this concern spread to all sciences and science teaching. Moreover, by the early mid-1960's it became apparent that little was known about the educational process. It was becoming clear, for example, that the theories of Piaget, and their potential contribution to education, were first "rediscovered"—as it turns out 40 years after first announced. Consequently, federal support for educational research increased at a phenomenal rate. Although the emphasis, most research supported under the old Cooperative Research Act was concerned with such easily measured variables as the rate of instruction (e.g., discovery versus expository) and the effect of instruction versus non-use, TV, etc.

And at the risk of slight oversimplification, only two explanations come to mind (both with precursors in the past): 1) students were home doing (i.e., what they were taught) and 2) the methods of instruction do not matter much as long as it is taught well. Neither is good nor bad in and of itself. The results of research on what is being communicated and the care with which it is done can be traced from this period: 1) increased support for educational research; 2) educational research on practice, and 3) Title I and Title III programs aimed more directly at education. A substantial portion of these funds was for research. However, most of the money later was used at a few centers in computer-based instruction.

The second major development of concern involved the efficacy of large-scale curriculum development efforts supported by the Office of Education during the 1960's and 1970's. Much of this research had tapered off by the mid-late 1970's, so it is instructive to consider the extent to which those development efforts actually impacted on the educational system. Perhaps the best publicized early effort in this regard was the Individually Prescribed Instruction (IPI) project conducted by the Learning Research and Development Center at the University of Pittsburgh. This effort was a hasty contrived attempt to impose an incomplete behavioral philosophy on the actual operation of a school. Early on, the IPI curriculum consisted of cutting and pasting curriculum materials from a variety of commercial sources. Later, with considerable federal support, these materials were refined and tested at several levels both by the Center in Pittsburgh and by the Research for Better Schools Laboratory in Philadelphia.

One might expect that the results of such an effort would have been quickly adopted by schools and/or commercial publishers. As it turned out, with a few exceptions, very little of this curriculum material was thought to...
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Needed to say, federal support for secondary efforts of this sort is indefensible in these days of highly restricted budgets, especially under the preferentially biased subsidies provided for lab and center activities.

The problem has been put succinctly by Robert Tennyson of the University of Minnesota (personal communication), “Without a pipeline to Washington (e.g., in terms of former students or colleagues in the bureaucracy) there is little chance of funding.” He further postulated “a direct correlation between the number of former students in an agency and the amount of funding received.” One might add that it is doubtful that the preferentially funded labs and centers could have maintained themselves on merit were it not for strong political support.

III. INSTRUCTIONAL TECHNOLOGY: CURRENT STRENGTHS AND WEAKNESSES

Any consideration of current strengths and weaknesses in instructional technology must distinguish between what is currently known about instructional technology as a methodology (i.e., the strengths and weaknesses of current design and development methodologies) and the current state of educational technology in the sense of the use of technology for learning and instructional purposes.

Theory and Technique. – Among those who believe that instruction may be viewed at least partly as a science or technology, rather than just an art (e.g., Bork, Mager, Popham, Gage, Gagne, Glaser, Landa, Merrill, Pask, Reigeluth, Scandura and Tennyson), it is generally believed that instructional design involves specifying: (1) the goals or objectives of instruction in behavioral terms (i.e., in terms of what the learner is to be able to do after learning), (2) which of the specified objectives the learner has and has not met prior to instruction, and (3) techniques for assisting the learner to move from where he or she is toward the specified goals.

Unquestionably, the most widely used technique for specifying instructional goals involves behavioral objectives (e.g., Mager, 1968). Although variations exist, behavioral objectives essentially involve specifying educational goals in terms of observables.

It is also widely recognized that criterion referenced testing provides a sounder basis for planning instruction than does normative testing. In the latter, students are tested on broad samplings of tasks from at best vaguely defined domains (of tasks). This approach to testing is useful for comparing the generalized achievement levels of students (hence its widespread use in standardized testing). In general, however, normative testing does not pinpoint what individual students do and do not know in a way that lends itself to instructional decision making. Instructional purposes are better served via criterion referenced
testing because student capabilities are judged relative to predetermined standards (i.e., the goals of instruction).

Although most instructional designers believe that the above techniques can play an important role in developing instructional systems, there tends to be less agreement as to the sufficiency of these techniques or as to instructional methods. In general, the designer's perspective depends heavily on the role which cognitive processes, rather than just observable behavior, are assumed to play. At one extreme, are those committed to purely peripheral explanation, prediction, and behavioral control. In this camp, for example, are those who espouse such well known Skinnerian techniques as shaping (i.e., reinforcing student responses which tend toward desired goals), fading (providing progressively fewer clues as to what the learner is to do as learning progresses), and schedules of reinforcement. While the validity of these techniques has been demonstrated repeatedly in animal experimentation, most contemporary instruction designers recognize that much more is required for effective instruction. Schedules of reinforcement, for example, have more to do with motivation that learning per se (e.g., Scardua, 1973).

Recognition of the importance of task structure in designing human instruction led to the development of task analysis in the postwar years (e.g., Gagne, 1962). In task analysis, the criterion tasks (specified operationally in observable terms) constitute only a beginning. By repeatedly asking the question of what the learner must be able to do in order to do what is desired, the analyst constructs a hierarchy of tasks to be mastered with the criterion task at the apex. Those tasks immediately below are assumed to be necessary prerequisites for the former in the sense that they must be mastered before the criterion can be (mastered). Similarly, tasks below the prerequisites must be mastered before the prerequisites can -- and so on. At the bottom of the hierarchy are tasks that are so simple that they can be assumed available to everyone (in the targeted student population).

With the emergence of cognitive thinking during the late 1960's and early 1970's, two major limitations of behavioral objectives became apparent (e.g., Scardua, 1971). First, specifying behavioral objectives leaves unanswered the question of what (e.g., cognitive processes) must be learned in order to perform as desired. Knowing how an objective is to be achieved is not just an idle concern because any educational objective can be achieved in any number of ways. Thus, one can solve verbal problems in arithmetic, prove mathematical theorems or construct a paragraph by any number of methods. Moreover, even where each method achieves the same educational objective, the long-term value of particular methods (e.g., for subsequent learning) may differ dramatically. As a simple example, consider two students, one of whom has learned to pronounce words by "look and say" methods and one who has mastered phonetic analysis. The latter student would be far more likely to figure out for him or herself how to pronounce a new word than would the former.

The second major limitation is that behavioral objectives would not be sufficient -- even if one were to specify the corresponding cognitive processes. As stated by Scardua (1971)

"Because the characterizing (processes) are discrete, they can not account for behavior which goes beyond the given corpus, except in the most trivial sense. For example, suppose the characterizing only included (processes) for adding, subtracting, multiplying and dividing. In this case, the student would be unable to even generate the addition fact (e.g., 5 + 4 = 9) corresponding to a given subtraction fact (e.g., 9 - 4 = 5), although one might reasonably expect this type of behavior from a person who was well versed in arithmetic. One might counter, of course, that it would be a small thing to simply add a new objective or process to the original list (which relates the original ones). Indeed, this is precisely the sort of reply one might expect from a person of the operational objectives persuasion. When confronted with the criticism that their objectives do not constitute a ... viable curriculum, they would simply say we can add more objectives.

"The trouble with this sort of argument is that it misses the point entirely. Not only would such an approach be ad hoc ... but it would be completely infeasible where one is striving for completeness ... It is sufficient to note that a new (process) would have to be introduced for every conceivable interrelationship and that the number of such interrelationships is indefinitely large ..."

To allow for the unexpected (i.e., to provide for the possibility of building creativity into instruction), Scardua (e.g., 1971) introduced the idea of higher-order rules. Higher-order rules may be thought of as generalized strategies, together with networks of interrelated knowledge structures, by which new knowledge (i.e., new rules) may be derived as needed. Thus, for example, even if the creative student has not been taught explicitly how to solve a given class of problems, the possibility exists that he or she may have learned general strategies (i.e., higher-order rules) which allow one to derive solution methods where needed. Various kinds of higher-order rules have been demonstrated to be valid for this purpose, ranging from creation by analogy, to combining known information, to automating existing knowledge (as is necessary in achieving highly skilled performance). For present purposes, it is sufficient to simply note that many such higher-order capabilities exist and may be learned to good effect.

These and other advances in cognitive representation have led to increasing recognition that traditional task analysis per se is not in itself sufficient for purposes of instructional design. It is not sufficient to simply identify prerequisite tasks. For one thing, methods are needed to identify the cognitive processes (i.e., knowledge structures and processes) underlying such tasks. For this purpose, various methods of cognitive task analysis have been introduced independently by a number of investigators (e.g., P. F. Merrill, 1982; Pask, 1975; and Scardua, 1971). The methods introduced by Pask and Scardua explicitly provide for the identification of higher-order processes.

Work on these problems has continued throughout the 1970's and is still underway. No one has yet developed a method of cognitive task analysis which
both leads to behaviorally precise cognitive representations and is completely
general, systematic and objective; however, the method of structural analysis
(e.g., Scandura, 1982, 1983) appears to go further in this direction than others.

Although cognitive learning is highly relevant to instructional design, discussion
of this topic here would take us too far afield. It is sufficient for present pur-
poses to simply point out that introducing higher-order rules into cognitive
representations (including structures on which they operate), together with a
general purpose control mechanism which has been shown to be universally
available to school-age children, provides a highly efficient and generalized
means for explaining, predicting and, within the limits of behavioral science,
enhancing cognitive learning (e.g., see Scandura, 1971, 1973, 1974, 1977). Pask
(1975) also has developed an approach to explaining cognitive learning, albeit
one based on different although potentially compatible principles.

These advances in cognition have provided more exacting (i.e., precise and
reliable) bases for criterion referenced testing. Except when testing with respect
to the simplest behavioral objectives (e.g., being able to state the capital of
Virginia), the test items associated with any given criterion (e.g., the ability
to add numbers) are not necessarily equivalent. In general, students will perform
successfully on some of the items but not others. The question arises, therefore,
as to the kinds and number of test items needed for any given criterion.

Two basic approaches to this problem arose independently and more or less
simultaneously in the late 1960's and early 1970's (e.g., Hively, Paterson & Page,
(1968), for example, introduced the notion of item forms. The item forms
associated with any given criterion (in criterion referenced testing) are essentially
categories based on the visible forms of associated test items (e.g., as to whether
subtraction problems involve one-, two- or three-digit numbers). This method
proved useful in some cases in partitioning items into categories which were
relatively homogenous, in the sense that students tended to be either uniform-
ly successful or uniformly unsuccessful on items in any given category.
Where such homogeneity was achieved, criterion referenced tests could be con-
structed by simply sampling one or more items from each category (associated
with the corresponding criterion referenced objective).

Despite their potential utility, the basis for such categorization (via item
forms) remained obscure and the method itself seemed to work better with some
kinds of content (criteria) than others. In contrast, the methods proposed by
Landa (1974) and Scandura (1971, 1973) are based more directly on cognitive
processes. Items associated with a given criterion are partitioned into equiva-
 lent categories based on the actual processes required for solving them. This
approach to categorization yielded a method which was at once both more
precise and more generally applicable (than in the case of item forms).

Scandura and his associates (e.g., Durnin & Scandura, 1973; Scandura, 1973,
1977; Scandura, Durnin, Ehrenprise & Wulfek, 1977) further demonstrated
that the categories of items associated with a wide variety of criterion referenced
tasks were not only highly homogenous but that they were hierarchically
related. This latter result provided a basis for highly efficient sequential testing.
Not only could one restrict testing to as few as one item per category, but one
could infer success or failure on untested categories on the basis of the prescrib-
ed hierarchical relationships among categories. Thus, as with traditional task
analysis, success on one category (task) would imply success on all prerequisite
categories (tasks), while failure would imply failure for all superordinate
categories (tasks).

Through the use of such inferencing, it often is possible to assess relatively
complex capabilities with as few as two or three carefully chosen test items.
Indeed, there is reason to believe that the inferencing potential inherent in such
a scheme effectively systematizes and is on a par with what skillful diagnosti-
cians (i.e., teachers) frequently do informally in the classroom.

Testing with respect to underlying processes has been shown to have the
additional advantage of providing an explicit basis for instruction (e.g., Durnin
& Scandura, 1973). Because particular categories of items are associated with
particular cognitive processes, it is possible to infer with considerable precision
which cognitive processes are known and which are not. This information,
together with prespecified relationships among the various processes, provides a
precise basis both for determining what any given student needs to learn and the
order in which it might best be taught.

Many of the ideas inherent in the above were adopted either formally or
otherwise in other areas of behavioral science, areas ranging from assessing stages
of child development (e.g., Seigler, 1979; Wulfek 1979) to the systematic detec-
tion of inadequacies in cognitive processes (called "bugs") by means of
computer (e.g., Brown & Burton, 1978). Recently, Scandura (1981) has
described how the more basic of these ideas might be implemented in a contem-
porary microcomputer environment. In the process, he described a general
purpose development system of this sort for creating commercially viable soft-
ware (e.g., Scandura, 1981.)

In earlier more basic research, Scandura (1977) had shown how similar ideas
could be extended to arbitrarily complex domains of tasks, involving indeter-
mately large numbers of different educational objectives. In brief, this was
accomplished by introducing and testing with respect to sets of underlying rules,
including higher-order rules. With the exception of a few advanced prototype
developments (e.g., Wulfek & Scandura, 1977), however, very little has yet
been done to capitalize on these ideas in more applied aspects of educational
technology.

To summarize, analysis of the available literature, and of major presentations
at national and international symposiums, leads this analyst to the conclusion
that a considerable amount of information has been accumulated which would be especially useful in the design of instruction for delivery by computer.

One should not infer, however, that everyone agrees we know as much as suggested about how to design instruction. As recently as 1983, for example, researchers at some of the more influential N.I.E. supported R & D centers have proposed that one of the major challenges of the 80's will be to determine how we can make use in designing instruction, of what has been learned in cognitive psychology (e.g., see Rensnick, 1981; Cordes, 1983). Similar proposals have been made with regard to the need to study cognitive learning during the 1980's. These calls for "new" research apparently stem from the facts that computer simulation studies in cognitive science during the 1960's and 1970's were almost exclusively concerned with cognitive "performance" and not "learning" (e.g., Newell & Simon, 1972) and that the individuals responsible either were not aware of earlier research on cognitive learning (e.g., Ausubel, 1968; Pask, 1975; Scandura, 1971, 1974) or, for whatever reason, did not recognize its relevance. Given this limited perspective, it is easy to see why they might think of cognitive learning as a new problem.

If nothing else, these illustrations show clearly how governmental support of only one line of basic research in an area over a period of time (in this case for over a decade) can lead to a "watering of the weeds" so to speak. Without serious competition in research, as in other walks of life, the country's knowledge edge lifeline suffers problems not unlike those attributable to other monopolies.

IV. USING INSTRUCTIONAL SYSTEMS DESIGN IN CBI DEVELOPMENT

Developing effective and efficient computer based instruction is not an easy or inexpensive task. At a minimum, it requires: considerable knowledge of computers, or at least knowledge of how to program; intimate familiarity with the subject matter involved; and methods for presenting the subject matter in ways that promote learning.

To aid the process, considerable attention during the 1960's was given to the development of CBI-type programing languages such as COURSEWRITER, TUTOR, PILOT, etc. These languages are relatively easy to learn and have been designed to facilitate the selection and presentation of course and test materials. While designed to be general purpose and easy to learn, the available languages are nonetheless better suited to CBI development in some areas than in others. Moreover, the author is not only free but obliged to specify test and instructional sequences; most CBI programming languages provide little guidance in this respect. In effect, although high level CBI programming languages facilitate CBI authoring, the process still requires considerable familiarity with computer programming, with subject matter and with instructional design—a combination of knowledge and skills not easy to find in any one individual. This fact almost certainly has led as much as anything to the uneven quality of current CBI systems.

To help ameliorate the problem, a growing number of CBI specialists have argued in favor of developing authoring systems in combination with general purpose "drivers" (e.g., Scandura, 1981; Tennyson, 1981). Authoring systems allow authors to create course material using the English language and easily learned codes. This material is usually entered into authoring systems in response to specific prompts and is automatically coded. The driver program, in turn, operates on the coded material (as data), presenting it in a predetermined, but potentially conditional, sequence determined by the driver and the student inputs (e.g., student responses to questions).

In order for author/driver systems to function properly, various restrictions must be placed on the form of the course material. This is necessary, for example, to insure that the driver is able to locate the right information at the right time. These restrictions typically limit either the variety of subject matter that can be implemented successfully and/or the instructional effectiveness of the implementation. Thus, for example, while most subject matter can be "forced" into a given format the resulting instruction may be less than optimal.

In spite of the previously cited advances, few commercially available authoring systems make serious use of current knowledge concerning cognitive processes and/or instructional theory—knowledge that is increasingly available to the instructional design community but which has not yet become widely used in CBI development. (The Rule-Example oriented authoring system used in the TICCIT CBI effort was an early attempt to move in this direction.)

Indeed, it is well beyond the commercially viable "state of the art" to contemplate at this time the development of cognitively-based generative authoring systems that might be used with arbitrarily complex and interrelated content. There are, however, some kinds of content which are sufficiently well understood to provide considerable hope in this regard. As described previously, research over the previous two decades provides considerable insight not only into what has sometimes been called rule-based (or "algorithmic") knowledge, but also into effective and efficient techniques for assessing the knowledge of students and for providing remedial instruction. In this regard it should be emphasized that many topics traditionally taught in schools can be reduced to rule, or algorithmic, terms. The familiar arithmetic algorithms provide a standard but hardly exhaustive illustration. Most manipulations of concrete objects, as well as grammar (e.g., adding "ing" to words), for example, lend themselves readily to this type of analysis.

In spite of the relative complexity of cognitive-based development systems, the realization of such systems would have a number of important consequences. In contrast with fixed-content authoring systems, such as have been described above, content would be tied intimately to the underlying cognitive
processes needed for mastery. In this case, rather than having to prepare all instructions, questions, answers and feedback in advance, it is possible to envisage CBI systems in which directions, questions and other instructional content are generated by the computer on the “fly” so to speak, as it is needed by the student. In the same way, diagnostic testing and instructional remediation would follow naturally from analysis of the underlying cognitive requirements of the content in the manner outlined above.

The simplest examples of this type of CBI system undoubtedly involve simple drill and practice. Such systems currently are available from a number of commercial publishers.

A more general and ambitious CBI system of this sort is the general purpose RuleTutor (e.g., Scandura, 1982). This system takes as input a computer coded version of the rule or rules (i.e., cognitive processes) needed to solve the class of tasks at hand. When this code is combined with the general purpose RuleTutor code, the result is a rather sophisticated diagnostic and tutorial instructional system for teaching and testing the associated content. Given the rule code, the RuleTutor generates problems as needed, presents them to the student, grades them and automatically presents the needed information.

As it stands, the RuleTutor lacks one major requirement for a full fledged computerized authoring system. While the RuleTutor provides a significant degree of generalized instructional intelligence, it does not eliminate the need for programming. What is needed to achieve automation is the equivalent of a computerized technology (method) for structural (cognitive tasks) analysis. And, as noted above, while recent progress has been made in this direction, the level of research effort required to bring such technology to fruition at present largely precludes such development in a commercial context.

More generally, in spite of these positive uses of instructional systems design, both real and potential, considerably more attention in future basic research must be given to the dynamic, and highly interactive nature of CBI systems. The fundamental nature of such interaction, and its relationships to cognitive learning, need to be better understood if we are to realize the full potential of instructional systems design in CBI development.

V. THE USE OF TECHNOLOGY IN INSTRUCTION

The technologies used to promote learning in schools range from the printed page, blackboards, overhead projectors, etc., on the one hand, and, on the other, to television and other electronic forms of communications and computers. The main thing all of these technologies have in common is that they can be used either well or badly. Their effectiveness in promoting learning depends far more on the viability of the content and on the way the technologies are used, in most cases, than on the technologies themselves. This fact has been demonstrated numerous times in educational research by the lack of reliable effects attributable to particular technologies (or to instructional methods per se, e.g., Scandura, 1964).

The present analysis is concerned exclusively with the advantages and limitations of interactive technologies in education. Of special concern are technologies which involve two-way communication, as is the case with “live” instruction (and instruction by means of tele-communications). Until the advent of computers, with the exception of outmoded mechanical teaching machines, essentially all nonhuman uses of technology for instructional purposes involved one-way communication. Indeed, this limitation is perhaps the primary reason that television has never achieved the educational impact that was once forecast.

At the present time, the computer has three major but quite distinctive roles to play in instruction: (a) as an object to be understood both in relationship to the circumstances and society in which we live and as useful means (when combined with appropriate software) for getting things done more efficiently, (b) as an object of study in its own right, as knowledge and skills to be mastered and (c) as a means of assisting the learning process.

Regarding the first role, computers are certain to have progressive and far reaching effects on future society. Developments have reached the point where every child must achieve some degree of computer literacy, if nothing else but to understand what is happening in the world around him or her. Since most educators feel this need personally, considerable attention is being devoted to this problem and little more will be said here.

The second major role for computers in education is sometimes equated with the first but is sufficiently different to warrant separate consideration. The emphasis in this case is on the computer itself. This includes learning how computers operate and developing the knowledge and skills necessary for getting computers to do what one wants (e.g., learning to program). Just as students should become as verbally and mathematically literate as possible, few educators would deny the need for today’s youth to get as much training in these areas as they can reasonably absorb.

Some proponents of computer training, however, go considerably beyond these admirable goals. This view seems to be especially widespread among proponents of the LOGO programming language (e.g., Papert, 1980). In general, these individuals view learning in a manner analogous to the long discredited “mental discipline” view that dominated educational thinking around the turn of the century. To wit: By learning to program, a person develops such skills as learning how to learn and how to create. As it has been put, they “learn how to control the computer instead of being controlled by it.” It is undoubtedly true that students who learn how to program may learn (in varying degrees) general higher level skills in the process. But, learning to program is hardly unique in this
practice CBI, a fact which has not gone unnoticed by educational publishers.

As the label implies, tutorial CBI systems are designed to teach new information as well as to exercise previously available knowledge. Building on the previous illustration, for example, a tutorial CBI system in arithmetic might explicitly introduce a student to the computational algorithms, rather than just exercise previously acquired algorithms.

Tutorial systems can be envisaged in almost every conceivable area, ranging from teaching basic concepts and principles (e.g., rules) to teaching complex, highly interrelated bodies of content. Generally speaking, to be classified as a tutorial system, the information taught must involve more than simply learning new facts (e.g., as in learning new vocabulary). The latter generally can be learned by simple drill and practice.

The simulation and educational modelling category is less well defined because the available CBI systems, which might be so classified, range from serious education to pure amusement. One could argue that every well designed CBI system has some educational value — even PACMAN probably has some redeeming features. The relevant educational question, as always, is the value of what is learned when judged in terms of the time spent, and particularly whether all or some of that time might be better spent on other activities.

Unlike tutorials, which tend (but need not) emphasize instruction by verbal means, simulations emphasize instruction by illustration. In the simplest cases, for example, a simulation might consist of little more than an animated visual illustration showing, say, how an internal combustion engine operates.

This type of simulation, of course, might just as well be accomplished by film or a mechanical modelling devise. As with all CBI applications, simulations must be interactive if they are to fully utilize the capabilities of the computer.

In this same vein, educational modelling may range from the trivial to highly interactive models with a serious educational message. In the latter category, for example, Howe (1982) and his associates at Edinburg and Bork and his associates at Irvine (1982) have developed a number of ingenious CBI systems which model significant segments of science (e.g., mechanics). These systems are highly interactive and are designed so that the student learns (or discovers) scientific laws governing the domains in question as he or she interacts with the systems.

To summarize, all three kinds of application have a valuable role to play in instruction. Drill and practice is best where students need a high level of skill in a well defined area. Tutorial systems are best where what must be learned is clearly defined and where learning should be as efficient as possible. Simulations and educational modeling are best where the desired learning is more diffuse and/or less clearly defined. In this type of situation, one wants to introduce students to a wide variety of related situations as is feasible in the hope that they will acquire a significant portion of what might be known.
VI. CONCLUSIONS AND RECOMMENDATIONS

Unlike many other countries where the federal government determines educational policy, state and local governments in the United States traditionally have been responsible for the implementation of school curricula. Indeed, the rate at which educational technology, particularly in the form of microcomputers, is being introduced into schools across the country attests to local wisdom in this respect.

As regards the federal role in instructional technology, the above analysis clearly demonstrates the following: (a) Technology and particularly low cost microcomputers have a very definite role to play in education during the 1980's and beyond. These roles range from incorporating the study of technology into school curricula to the use of technology to improve instruction in other areas. (b) Although CBI systems have been of variable quality, the last couple of years has witnessed rapid growth in the quality of educational software. (c) While much remains to be done, we have learned a good deal about cognitive learning and instructional processes during the past 20 years. (d) Very little of the software, which presently is available commercially, makes significant use of this knowledge base.

The foregoing analysis also shows that past patterns of federal involvement in educational research generally, and educational technology in particular, have been less than optimal in their effectiveness. Specifically, the concentration of resources at a small number of R & D centers and laboratories has greatly diminished research competition and effectively robbed the nation of badly needed intellectual resources. Moreover, recent planning documents released by the N.I.E. suggest that, while serious questions are being raised about the lack of research competition, the concept of R & D centers per se could still be sanc-scrutinized. If so, this could be a serious mistake. Given rapidly increasing international competition from Japan and elsewhere, as well as very real constraints on the federal budget, it seems imperative that the role of the federal government in educational technology be reevaluated without preconditions.

These observations lead to the following recommendations:

(1) Experience shows that commercial viable, large-scale development efforts in educational technology may far more efficiently be handled by the private sector. In the present view, government at all levels, specifically including the N.I.E. labs and centers, should gradually withdraw from such efforts almost completely. Whatever savings accrue at the federal level from such changes in emphasis should be reallocated to basic research in instructional technology and to the development of advanced prototypes. The results of such efforts should provide the “seed corn” from which the private sector in the U.S.A. might draw.

(2) Although the long-term payoff of basic research has been proven time and time again (as described herein in the case of educational technology), the results typically obtained are sufficiently general and the immediate payoffs are so unpredictable in any specific case, that it would be infeasible, and rarely cost effective, to expect significant direct support for this type of effort from the private sector or from states and local governments.

The federal government, therefore, should concentrate its efforts in educational technology on those things that can only or most efficiently be done at a national level. In general, this means an emphasis on basic research, including relevant instructional theory, instructional systems design, and the development of advanced technological prototypes and general informational services not otherwise attainable.

(3) Since the value of basic research is primarily contingent on the worth of ideas rather than simply magnitude of effort, federal support should be directed toward those individuals who propose the most promising programmatic efforts and who have demonstrated the ability to carry such efforts to fruition.

Specifically, whenever feasible, a variety of approaches should be funded. As this analysis clearly shows, putting all of one’s eggs in one basket is a serious mistake when it comes to research and advanced development. A variety of smaller programmatic efforts over a period of time has time and time again proven its worth over the cyclic fadism which too frequently has characterized behavioral research.

(4) In this regard, because of the time and often unproductive effort involved in preparing proposals, federal officials should give more attention both to minimizing such efforts (and correspondingly placing more emphasis on “end products”) and to cost-benefit analysis of the likely benefits of holding “open” competitions when less than, for example, 25% of the proposals can be funded.

Experience at other (non-educational) research agencies suggest that it is far more efficient, both for agencies and proposers, for the agencies to make preliminary judgments based on brief letter proposals — if necessary with expert opinion from outside the agency. More complete proposals in such cases are only requested where there is a reasonably high possibility of funding. To insure that competitive ideas are fairly evaluated, reviewers at all levels should both be compensated for their time and held accountable for inaccuracies or bias in their reviews. (Minimizing bias, for example, might be accomplished by making reviewers known to proposers; this practice also might provide a useful mechanism for clarifying misconceptions.) Societal needs in instructional technology are too important to allow form to stand in the way of substance.

(5) Recommendations (3) and (4) implicitly assume that the Congress will recognize both the very real needs in instructional technology and the problems which have arisen as a result of noncompetitive funding of the N.I.E. centers and laboratories. It also assumes that the Congress will reallocate moneys currently mandated to centers and laboratories, making them available for free and open competition. (In this regard, it must be emphasized that the total amount of
federal money allocated for research in educational technology is distressingly small when compared with that provided by the Japanese and many European governments. It is apparent both to this reviewer and to everyone who has reviewed or otherwise reacted to this report that research funds should be increased to the extent that budgetary conditions will allow. There are few areas that could have more bearing on the future competitiveness of American society in a technological world."

In the absence of Congressional reallocation (of the mandated center and laboratory funds), the definition of what constitutes a center or laboratory should be modified so as to place the emphasis on small, competitive programmatic efforts by independent researchers and their associates. In this context, for example, it could be a serious mistake to start one new center or laboratory in educational technology, not because more programmatic efforts in this area are not (badly) needed. It could be a mistake because such a center would inevitably end up dominated by one or at most two or three themes to the exclusion of otherwise equally competitive ideas.

A better way would be to fund a variety of smaller, competing programmatic efforts by leading investigators under center or laboratory auspices. These leading investigators would normally be scattered at various locations throughout the country. Rarely are the best people at one institution.

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**Footnotes**

1. This analysis was commissioned and supported in part by the National Institute of Education, Office of the Assistant Secretary. This support, however, does not imply N.I.E. or U.S.O.E. endorsement. While accepting full responsibility for the views expressed, the author is deeply indebted to John H. Durnin, Frank F. Farley, M. David Merrill, Paul Merrill, Joseph D. Novak, Harry O'Neil, Ellis E. Page, Charles Reigeluth and Robert Tennyson for many helpful suggestions concerning both a draft of this manuscript and an invited symposium presentation on the substance of the paper at the American Educational Research Association meeting in Montreal on April 14, 1983.

2. Whereas the methods proposed by Landa and Scandura can be shown to be mathematically equivalent (e.g., Chang & Lee, 1977), Landa was more immediately concerned with applications while Scandura was primarily concerned with broader theoretical implications.

3. In the absence of Congressional reallocation (of the mandated center and laboratory funds), the definition of what constitutes a center or laboratory should be modified so as to place the emphasis on small, competitive programmatic efforts by independent researchers and their associates. In this context, for example, it could be a serious mistake to start one new center or laboratory in educational technology, not because more programmatic efforts in this area are not (badly) needed. It could be a mistake because such a center would inevitably end up dominated by one or at most two or three themes to the exclusion of otherwise equally competitive ideas.

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**Annotated References**


Cordes, C. Search goes on for 'best' ways to learn science. APA Monitor, April, 1983. Refers to purportedly new problems and scientific advances.


An early discussion of the relationship between the psychology of learning and instruction.


Self descriptive.


Discusses relationships between programming concepts and the structural learning approach to diagnostic testing.


Describes a long-term effort in the computer simulation of human thought process.


Describes a conceptual approach to instruction.


A criticism of NIE priorities.


Describes the LOGO programming language and hypothesized relationships to children’s learning.


Describes “conversation theory,” a systems perspective on human interaction.


Based on behavioral objectives.


Reviews research in instructional psychology, much of it conducted at or in conjunction with the LRDC in Pittsburgh. Also proposes that developing instructional implications of cognitive psychology is a major “new” problem for the 1980’s.


A series of studies demonstrating that minor within method differences may have a greater effect on learning than differences between methods themselves.


Text on mathematics and methods for teachers.


Basic introduction to the structural learning theory and research methodology.


Technical and more complete source on structural learning.


Experimental demonstrations of the role of higher-order rules.


A wide variety of contributions, emphasizing structural/process theories of learning and instruction.