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ABSTRACT

The dramatic and increasing availabilty of relatively cheap computer power has led people to tout microcomputers as the solution to education and training problems. However, such panaceas for educational problems fail because they do not address the real ingredients for successful instruction or the problems of large-scale implementation. Improvement in instruction, computer-based or not, will be a relatively slow, evolutionary process because: (1) attempts to improve instructional quality using systems approaches have shown how difficult it is to do and to manage; (2) use of computer-based instructional tools is in a rudimentary state of development; (3) improvements in instructional design technology depend on still-developing changes in the scientific base provided by the cognitive and computer sciences; and (4) any widespread use of computer-based instruction (CBI) requires the acquisition and standardization of programs, provision for their distribution, and their incorporation into schooling. Therefore, the prospects for attaining large increments in instructional effectiveness depend on understanding of instructional psychology and cognitive science, and on the ability to implement CBI on a large enough scale to make a difference. The potential for improvement in instructional quality is here, and progress will be made, but it will not be rapid or revolutionary. (Author/LMM)

# Computer-Based Instruction: Will It Improve Instructional Quality?

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## *ABSTRACT*

The dramatic and increasing availability of relatively cheap computer power has led people to tout microcomputers as the solution to the problems of education and training. We feel that this is misleading. This is another panacea for educational problems that is likely to follow earlier ones like teaching machines, programmed instruction, and main-frame CBI. The reason panaceas like these fail is that none of them address the real ingredients for successful instruction or the problems of large-scale implementation. Improvement in instruction, computer-based or not, will be a relatively slow, evolutionary process. Four reasons for this assertion are discussed in this paper. (1) Attempts to improve instructional quality using systems approaches have shown how difficult it is to do and to manage. (2) The use of computer-based instructional tools is in a rudimentary state of development. (3) Improvements in instructional design technology depend on still developing changes in the scientific base provided by the cognitive and computer sciences. (4) Any widespread use of computer-based instruction requires the acquisition and standardization of programs, provision for their distribution, and their incorporation into schooling. Therefore, the prospects for attaining large increments in instructional effectiveness, depend not on the availability of computing power or even computer programming *per se*, but on our understanding of instructional psychology and cognitive science, and on our ability to implement it on any scale big enough to make a difference. The potential for improvement in instructional quality is here. We are optimistic that progress will be made, but we do not expect it to be rapid or revolutionary.

# Computer-Based Instruction: Will It Improve Instructional Quality?

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## Introduction

The use of modern computer-based gadgets for instructional purposes is being advocated widely. The advocacy is based mostly on the assumption that computer-based instruction can solve many of the nation's educational problems. In newspapers, magazines, and on television, advertisements suggest that computer-based instruction is effective, fun, can answer concern for the "decline" in educational quality, and provide business, industry, and the military efficient and effective means of training personnel. Already, 50-60% of the nations schools reportedly use computers in classrooms (e.g., Newsweek, 1983). Although the use of this gadgetry will continue to increase simply because of its availability and declining costs, we are dubious about the assumption or hope that its presence will improve the quality of education and training, at least over the near term. It is not that CBI systems cannot be effective; they can be, and some are. Recent reviews thoroughly summarize many demonstrations of the effectiveness gains (Kearsley, 1983, Kearsley, Hunter & Seidel, 1983, Orlansky & String, 1980, 1981). But, while affordable hardware is a necessary ingredient for widespread effectiveness of CBI, it is not sufficient. Several other ingredients are necessary: good instructional design which uses computer power in appropriate ways, supportable and transportable software, and attention to the ongoing instructional systems into which CBI may be inserted.

In the rest of the paper we will present support for the thesis that improvement of instruction through CBI will be a relatively slow, evolutionary process. Reasons for this are that (1) instructional quality is difficult to achieve regardless of the method of delivery, (2) the use of computers as instructional tools is in a rudimentary state of development, (3) improvements in either instructional design or computer-based delivery will depend on fundamental changes in the scientific base, and (4) systematic planning for acquiring, standardizing and distributing proven instructional programs, and for incorporating them into schooling has not been done.

First, we review some attempts to improve quality through the development and implementation of systematic approaches to instructional design. These attempts have not been very successful, and their refinement will take time. Second, we briefly review some developments that have led to common forms of CBI and show that the advantage of using CBI is often unclear. Third, we then show that the problems with both instructional design and with traditional CBI are due largely to shortcomings in the underlying scientific base of the psychology of learning and instruction. Fourth, we describe developments in cognitive and instructional psychology and in computer science and artificial intelligence which provide *hope* that a better scientific base will develop, and we describe particular CBI systems which have been built on these developments. Finally, we discuss some things that can be done to provide a means for the widespread distribution and life-cycle support of CBI systems that have been found to be effective for specific purposes.

## Instructional Quality Occurs by Design

One fundamental belief we hold is that the adequacy of instruction (any instruction, not just CBI) depends on the amount and quality of the planning that goes into its design, development, implementation, and evaluation. Assuming that computers in the classroom will automatically improve instruction ignores the complexity and difficulty of making instruction effective in the first place. Effective instruction depends on determining what is to be learned, not just at some gross "top" level, but in sufficient detail so that intermediate learning requirements for the eventual development of expertise can be identified. Effective instruction also depends on being able to contrive situations and interchanges to promote student learning. Quality depends on how well the knowledge structures underlying performance can be described, the instructional theory used to guide the learning analysis, the design of lessons, the design of the instruction itself, and the planning for diagnosis and remediation. Only atter this design work should judgments be made about whether and how to incorporate computer aids for instructing, how many are needed, how to manage their introduction into the program, and so forth.

Traditional techniques for developing instructional programs depend on the expertise of the people doing the development. Intuition and artistry are important determiners of quality. Since intuitions about what and how to teach can and do vary widely, instruction may teach irrelevant things, or perhaps leave out things very important to a student's knowledge or performance. Most people's intuitions about how and what to teach depend on very naive implicit theories about the nature of learning and instruction. Analysis usually takes the form of "that's the way I learned it," and instruction is usually conceived as group-paced lecture with books for self-study. Further, people's artistry also varies. While one artist may design instruction that communicates very efficiently, another person may produce barely comprehensible "instruction." Thus, instability or variability is built into the instructional development process.

## Evolution of Instructional Systems Development Approaches

During the mid 1950s training developers recognizea the need to guarantee job relevance and to monitor inadequacies in learning systematically. Starting from a behavioristic framework, they began developing techniques to stabilize and structure the process of training development, to insure the relevance of training for peoples' jobs, and to make instruction efficient. This approach, adapted from those used in Operations Research and Systems Engineering (Churchman, 1968) for the development of veapon systems led to the development of systematic instructional design methods, currently called Instructional Systems D-sign (ISD).

The ISD procedures evolved from a conviction that the systems analysis approach, coupled with a behavioral view of learning and instruction, could simplify the complex task of developing programs of instruction. The method had been applied successfully to numerous problems whose complexity strained any one person's ability to comprehend and accomplish a task, such as, the project that put man on the moon (Carter, 1973). As applied to curriculum development, a group of experts in management, logistics, education/training, systems planning and other fields generated model procedures to simplify day-to-day tasks. For example, training experts might devise checklists or other outlines to remind them of steps in development that had to be carried out, and to record when they had done so. Such procedures help experts determine what to do next, but do not supplant the intelligence or knowledge needed to carry on the activity (Montemerlo & Tennyson, 1976; Montemerlo, 1979a; Andrews & Goodson, 1980).

During the 1960's, there was a shift away from the reliance upon teams of experts, toward development of formal procedures, models, and design decision aids that would enable relatively inexperienced persons to design instruction. These procedures and aids were elaborate forms of the simple models and checklists used by the experts. The prospect of being able to use less experienced people to develop training appealed to managers of military instruction programs because experts were scarce--and still are--and job rotation restricts the buildup of expertise. Over 100 manuals were published telling how to design and develop programs of instruction (Montemerlo & Tennyson, 1976; Andrews & Goodson, 1980, Gustafson, 1978).

Although all these procedures differ in some details, they share a common approach. They analyze jobs to determine training objectives; they develop tests to assess whether trainees are progressing toward objectives; and they gear instruction toward specific learning goals that are tied to the objectives. In addition, they attempt to lay out how to decide upon the instructional presentations in detail sufficient to minimize the level of experience needed in instructional development and technology.

In summary, in instructional design technology there has been an attempt to circumvent the problems of intuition and artistry by introducing systematic management techniques for training analysis and design in behavioral terms. Further, attempts have been made to overcome the lack of expertise by proceduralizing the process with detailed guides. Unfortunately, people still don't seem to do training development very well.

**The Effectiveness of ISD Leaves Room for Improvement**

Some evidence of the lack of quality comes from a recent effort by Stern and Fredericks (1982) at our Center. They evaluated a module of a Navy course that had just been redone using ISD procedures. The lessons were to train people how to verify the correctness of messages typed on a form to be read by an optical character reader. Students were having problems learning from the lessons and instructors suggested that they needed revision. The main constituents of instruction, i.e., objectives, tests and learning materials, were found to be flawed even after revision according to ISD procedures. Some objectives were not related closely to the performance or knowledge required by the job. Testing did not always measure the performance or knowledge as specified in the objectives. Instruction was often not geared to the objectives or to the tests, and, as a result, was often confusing and otherwise inadequate.

An extensive review of the implementation of ISD methods by 33 groups that developed 57 different courses in all the military services noted a similar variety of problems. In this study, Vineberg and Joyner (1980) reported that the job-relevance was often ignored and that previously existing instruction was used as a starting point for course development. Instructional methods were selected not because they were effective and efficient, but because they existed. Similarly, tests to measure job-related learning were limitea to what could, rather than what should, be tested. Evaluation of training, according to Vineberg and Joyner, received little emphasis. Feedback systems from operational units concerning job competency of graduates were not well developed. As a result, training programs needed extensive tryouts and revision to make them effective.

These observations suggest that, at present, systematic methods for instructional design have not succeeded in attaining the goals of making training job-relevant, efficient, or cost-effective. There are several reasons for this, including the skill of the personnel, the adequacy of the procedures, and the state of the underlying scie.tific knowledge about how and why learning occurs from which to derive instructional prescriptions.

Current personnel who implement the ISD methods for military training are relatively untrained and inexperienced in teaching and training, and in the fundamental knowledge needed to determine the appropriate forms of instruction (Wetzel, Ellis, Wulfeck & Montague, 1982, cf., Montemerlo & Tennyson, 1976). In military organizations, training for instructors is brief and of questionable quality, turnover is high. Therefore, the development of instructional expertise is likely to be rare.

The procedures in recent guides for ISD are supposed to be prescriptive, and reduce the dependence on skill and knowledge about training design. However, the procedures specify "what to do" in detail, but not "how to do it," let alone "how to do it well." Although improvements can and are being made to the procedures to correct this problem (see e.g.; Montague and Wulfeck, 1982, Montague, Ellis & Wulfeck, 1983), it will take years to incorporate them into widespread use. Serious questions should be raised about what knowledge and skill is needed to follow instructional recipes.

Finally, the state of instructional and psychological science that provide the recipes or prescriptions for teaching does not suggest that their improvement will be rapid. Nor is it likely that artistry based on extensive training, knowledge and experience, can ever be eliminated completely. Most importantly, the scientific and theoretical foundation upon which instructional design and the development of instructional systems should be based is changing. We have moved from a psychology dominated by behaviorism, to one that emphasizes the importance of a person's cognition and knowledge in both learning and performing. This change ought to be reflected in both the techniques used for describing and analyzing tasks to be trained, and in the design prescriptions for instructional interactions. But, while these changes may provide improvements over the older science, it will take a long time for them to be absorbed into the technology. Some of this needed change in emphasis is described in the next sections.

## Using Computers for Instruction

From the earliest availability of computers, interest in using them to support instruction has been high. During the late 1950's and early 1960's, programmed textbooks had been developed, and even "teaching machines" were devised that used different varieties of programmed instruction. It seems only natural, that as computers became more available, they were used to present the programmed material. The form of material was traditional text broken into "frames" for study. Although programmed instruction originally required fill-in answers, early attempts at computerizing this instruction typically used multiple-choice questions because computers could more easily be programmed to score responses and branch students to segments of corrective feedback.

However, early computers were expensive to buy, to maintain, and to program. The high costs of preparing and maintaining computer systems led to a concern for large-scale implementations using many students to amortize the costs. From these efforts large scale systems such as PLATO and TICCIT were developed. During the later 1960's and into the 70's there was considerable hope that computer-based instruction would be widely adopted, and CBI was touted as a panacea that would revolutionize education. This led to a number of tests and evaluations of effectiveness, and to a growing concern with costs as related to gains in student learning, in learning time, or in reducing teacher load (increasing teacher effectiveness). Although substantial gains in performance were reported for CBI, it soon became apparent that these were obtained by the structuring and sequencing of the instruction, and tying it to better specified requirements, rather than to the use of computer-based presentations (Orlansky & String, 1980, 1981).

Then, in the late 1970s, microcomputers appeared, and again, CBI was proclaimed as the cure for the ills of training and education. These systems are much more affordable, so that many people could begin to use them for instructional purposes. However, the scientific base had not yet changed; the nodel for microcomputer-based instruction was large-machine CBI. There is a strong parallel to the ISD movement here: an implicit attempt has been made to shift the development responsibilities and costs for CBI to a broad base of "users." But, just as there is no "cookbook" for doing good instructional development, there are no cookbooks for doing good instructional delivery via computer. The result is that in most existing CBI, instruction is done as it could be done without the computer. Text is given for students to read, multiple-choice questions are then asked, answers chosen, then new materials are given if the answer is right, or review matter, if not. To be sure, newer CBI looks prettier: there is broad use of color, supposedly motivational tricks have been imported from video games, such as "lists of high scorers," or fancy graphic displays to provide reinforcement for correct responses, and systems that use menus seem to be "user-friendly." But the fundamental design of CBI has not changed; it is still heavily "programmed," heavily text based, and still relies on selected-response student interaction.

All of this is not to say that CBI cannot be effective. For certain kinds of instruction traditional CBI may be very appropriate. But there are at least three problems with the uncritical use of "modern" microcomputer-based instructional systems: First, the computer is often relatively superfluous, i.e., the materials and testing on the computer carry the major instructional function; the computer simply delivers them and keeps records. In this form we should not expect CBI to be much different from instructor-run versions of the same instruction, and test comparisons show no learning benefits (Orlansky & String, 1980), although management efficiencies may occur. Second, the computer's capability to simulate tasks and problems, and carry on an intelligent interactive dialog with a student is seldom seen. And third, the developers of micro-CBI have about as much training in the proper analysis, design, and development of instruction as other instructional developers today; that is, little or none. Therefore, the resulting CBI is not likely to be much better than other versions of the instruction. The reasons for this state of affairs lie in the way in which CBI was tied to the programmed instruction movement, in the lack of development of alternative instructional notions, in the difficulty in programming computer systems for simulation-like instruction, and again most importantly, in the lack of an appropriate scientific foundation for instructional development and delivery.

## A Limited Scientific Foundation

In the 1950's and 60's behavioristic psychology was a predominant influence on instructional theory, and is still the predominant influence on derivative instructional technologies. This psychology was analytic, believing that complex tasks could be broken into their more basic observable components. Then, events could be programmed to teach the components using principles derived from "operant conditioning" (e.g., Taber, Glaser & Schaefer, 1965). The "laws of learning and instruction," such as sequencing instruction step-by-step, allowing students to proceed at their own pace, providing frequent reinforcement and feedback for responding to promote learning, were derived in part from animal conditioning studies, but also from verbal learning experiments with humans. Because the predominant form of instruction for the past several hundred years had been through books or verbal lectures, and because of the "verbal learning" emphasis in psychology, the resulting instructional delivery prescriptions tended to be concerned with presentation of textual information. And because nearly all of these studies involved the learning of simple procedures unconstrained by structural complexity, or the learning of verbal information intentionally designed to avoid structural relationships in the content to be learned, the resulting instructional design and delivery technologies did not include consideration of context, structure, or complexity. Both the bias toward text and the bias against contextual relationships and structure became an implicit foundation for both instructional design technology and CBI.

### The Bias toward Text in Instruction

Part of the influence which determined the form of instruction adopted by both ISD and traditional CBI was the bias toward the use of text for teaching (Olson, 1977). Instruction is done by written text because it is traditional to do so, and relatively easy to do in print or on computers, and not because of any analysis of requirements that suggests that it is the most appropriate means. Science textbooks have been criticized for many years as providing poor support for student learning of principles and concepts (Champagne, Klopfer & Gunstone, 1981). They describe results and abstractions as facts, or theoretical statements to be memorized. The content is decontextualized, and requires the student to provide much of the context from his/her own experience or imagination. Thus, text requires *extra* processing by the student to understand. It is often difficult to understand experiments, results, phenomena, and principles when they are described in text form. One has to imagine events, objects, processes, procedures that are often unfamiliar, or even invisible. Text may be inappropriate, or at least relatively ineffective, for teaching such knowledge. Yet is the primary way in which technical training and education is developed, delivered, and tested.

The traditional use of text creates a bias that seems to have limited our perspective of what instruction could orshould be like using the capabilities of modern computers. This perspective limits what has been done in CBI. If materials are in text form on a computer, they will not differ much from what they would be in text form in a book, and therefore one should not expect any gain in instructional effectiveness from computer presentation. The research literature shows this. As long as the instruction is text based, and teaching is to the same specifications, little or no difference is found (Orlansky & String, 1980).

### The Bias against Context and Structure

The lack of attention to performance context, content structure, conceptual interrelationships, and the role of metaphor and analogy in learning and memory, also led to inadequacies in ISD, particularly in the analytic phase of that process. As mentioned above, the emphasis from behaviorism was on bits of observable performance. The view was that since structural or contextual aspects of knowledge were not observable in task performance, they could not be reinforced, and therefore need not be considered during instructional programming. This led to a task analysis method which analyzed complicated performance into series of observable simpler sub-performances. In the hands of untrained ISD and CBI practitioners, this meant that more and more trivial but observable performances were identified as enabling prerequisites for complex skill. In general, the tendency was to identify observable step-by-step performances, rather than to try to figure out how to make the more important cognitive processes observable.

It is interesting to note that the text bias also places limitations on what is designed into any instruction. This point was made by Bunderson *et al*, (1981) recently. They suggested that the text bias, or "lexical bias" limits the approach to instructional design and development and the specification of performance objectives. The idea is that performance objectives described in words (in a particular format) lead naturally to testing in words in a paper and pencil format and lead to the derivation of similarly limited instruction. The implication is that this approach restricts the instructional methods used and can actually make it less like the actual tasks to be learned.

In general then, instructional technology today is based on a tradition of behaviorism, together with the implicit biases described. The lag in technology behind the scientific base should not be surprising. Applied well, current technology does represent an advance in developing instructional design and delivery tools. But improvement is needed, not uncritical application. There are areas of instruction where analysis may indicate that written text delivered by computer may be needed. If so, it should be done, but not because of tradition or bandwagon. The same is true of the scientific base. Many of the principles of learning and instruction derived from behavioral psychology are valid and robust. They must be integrated with more modern cognitive views, so that the scientific and theoretical base can grow and evolve.

## Hope for an Improved Scientific Foundation

Aside from the programmed instruction movement, there were developments in education that were of less importance to CBI initially, but are much more important today. Bruner (1964) in discussing the elements of instruction also talked of analysis, structuring and sequencing the materials and providing feedback to students. However, he emphasized the importance of the structure and form of knowledge, the (mental) representation of the knowledge the student learned, and the influence the representation had on the student's performance. This view has been expanded and is now an important part of cognitive science (Norman, 1980). It leads to alternate conceptions of the form that CBI should take, and is only now being implemented and systematically tested.

Until recently there was little understanding of cognitive processing and cognitive representations from which to derive design requirements for instructional presentations. We believe that situation is changing rapidly for two reasons. First, there is a growing body of research knowledge, theory, and techniques of analysis that focuses on people's representation of knowledge and procedures in carrying out or learning instructionally relevant tasks (Montague, Ellis & Wulfeck, 1981). Second, there have been developments in hardware, computer science, and artificial intelligence that allow models of human processes to be tested, and that lead to powerful computing environments so that sophisticated simulations of physical systems can be built. These have significant implication for CBI because we can better specify how to represent materials for students, we can better analyze cognitive processes, and we can better prepare interactive teaching environments because of developments in programming tools and hardware. In general, we can better analyze, model, display, and assess what was previously ignored as unobservable, but which we now know to be critical components of complex skill.

### Main Lines of Important Research

There are four main lines of cognitive research that illustrate the important developments. For example, considerable research has revealed the important role of organization and/or schemata in learning, reading, and comprehension. Structures in the learner's mind interact with the structure of the information to be learned (e.g., Anderson, 1977; Rumelhart & Ortony, 1977; Schank, 1980; Schank & Abelson, 1977; Chiesi, et al, 1979). Review of the literature on cognitive analysis indicates that the design of the instructional presentation must be concerned with the mapping between what the learner already understands and the structure of the task/material to be learned. This is needed to help the student apprehend the material, and probably will be dependent on the student's familiarity with the representational form. Since familiarity with the representational form is important, it seems likely that the representation appropriate at early stages in learning might have to be quite different from that appropriate at later stages.

Research on problem solving also reveals the importance of representation and structure. The quality of a person's representation of the problem determines the adequacy of the solution (e.g., Greeno, 1977, Hayes & Simon, 1976, Simon & Simon, 1978). Novices and experts differ in aspects of their approaches to problem solutions, primarily in the level of strategic knowledge applied (e.g., Chi, Feltovich & Glaser, 1981). It is suggested that some of this knowledge can be used to structure procedures to guide novices in problem solutions (Reif, 1979; Reif & Heller, 1982), and this has been shown to produce substantial improvements in performance (Heller & Reif, 1982). Thus, this research also seems likely to contribute to instructional techniques.

Considerable research has studied the role of spatial representations and imagery in learning, memory and performance. For example, when told to imagine visual scenes or places, subjects learn arbitrary lists of words faster (Bower, 1970, Paivio, 1972). The "vividness" of stories enhance learning (Montague & Carter, 1974). The research suggests that imagery is powerful for learning and remembering arbitrary materials, but little systematic work has been done with more complicated subject matter or tasks. It seems unlikely that visualization will play the same role in learning complicated tasks. However, when it is important to know a special environment, experience with it, or with one similar to it, may be important (Attneave, 1974). Graphical representations of such environments may be important ways to assist in instruction.

Recent research on analogical representations shows promise for assisting instructional design. It is common practice to introduce a new topic by analogy to a familiar domain. The real question is how to choose an appropriate or good analogy. Should we rely on tradition or experts for their derivation or must we structure them appropriately for the limited understanding of novices? Analogies that elicit erroneous inferences can interfere with learning (Gentner, 1980; Gentner & Gentner, 1982; Riley, 1981, 1982). Animated visual analogies have been suggested as important in teaching invisible processes, or in understanding complex sequences of events in science (Rigney & Lutz, 1974). By providing an interactive, visual representation that can direct the student's attention to particular aspects of the process as it occurs provides a means of conveying dynamic changes in events that would otherwise be very difficult to convey (Forbus, 1981).

A representation may be described as a set of propositions about the subject matter, stated in visual terms, not verbal. It is a pictorial abstraction which visually symbolizes the critical, relevant attributes of the processes or concepts being communicated to the learner (Rigney and Lutz, 1974,). To be useful or effective a representation of this type must possess these characteristics: (1) correct representation of relevant aspects of objects or relations, (2) recognizable or understandable by the learner, (3) unambiguous, and (4) provide the basis for straightforward transfer to the later task (Arnheim, 1969; Riley, 1981).

**Translating this Foundation into a Technology.**

All of this recent work suggests that guidance can be found to structure instructional information and interactions to promote learning. How well this can be developed into a technology is uncertain, but a considerable advance is possible. What needs to be done is to describe task conditions and performance requirements in sufficient detail for adequate mental representation, and to contrive appropriate forms of instructional representation to promote effective learning and understanding. Interactive computer-based instruction systems must provide the cues, the opportunities for students to respond, make and correct errors, and observe the consequences of their actions. This arrangement allows students to develop appropriate mental representations of a system and/or content to be learned. It provides a phenomenological basis for developing experience. With such presentations, students can learn to operate a system, learn its principles of operation, exercise required vocabulary and procedures, correct errors, etc.. In order to accomplish this, the representation needs to show what changes occur because of certain actions by the student. It should allow frequent and rapid practice of procedures to be learned, actively diagnose reasons for performance failure, and provide corrective feedback for errors not so that the errors can be reduced in frequency, but so that underlying misconceptions can be eliminated.

It may also be true that systems intended for training novices and those intended to provide extensive practice or retraining for moderately competent people may need to be be designed quite differently. The need for extensive corrective feedback is substantially different for these groups. Novices need extensive guidance, and precise corrective explanation of their errors and the reasons for them, while already trained individuals may need refreshment, or may need to broaden their knowledge base for situations or of signals or events that may be encountered. Novices need relatively simplified examples of problems to facilitate learning. Normally invisible events or processes may need to be made visible in order to support understanding. The more experienced individual, on the other hand, needs to refine his skill. This may require more realistic representation of critical aspects of the task. Systematic development of these ideas is needed.

A primary idea is that CBI needs *instructional* task fidelity (Semple, et al, 1981). This requires that the form of the presentation be understandable to the learner, that conditions be provided which support student learning, and that misunderstandings be detectable by testing.

Instructional task fidelity requires both the design of the appropriate representation(s) for learning, and the inclusion of the necessary learning principles that support acquisition. A major difficulty is that such design is based on learning/cognition task analysis procedures which are not yet well developed, especially for complicated tasks involving decision making and problem analysis. Bunderson, et al (1981) suggest that the derivation of "Work Models" which are simulations of the terminal task(s) to be learned provide a means of improving the specification of performance objectives. Such an approach calls for designing an interactive setting where the student can converse in newly learned vocabulary, use the appropriate concepts, perform the appropriate procedures, make predictions and solve representative problems. But to do this, systematic development of prescriptive techniques is needed. The final skills to be learned need to be specified in terms of task performance, the performance conditions, and performance standards. Also, the steps involved in apprehending the skill need to be identified. This would include the representation(s) appropriate for the learner's competency level. Then these can be implemented into interactive CBI systems utilizing the powerful tools being developed in computer and cognitive science.

It seems likely that these general categories represent the major conditions needed for designing interactive instruction. What is uncertain is whether a prescriptive design technology will develop quickly from this general perspective. Much basic information is needed, and recommendations need to be tested to provide a better knowledge base for a technology. What seems apparent is that by focusing design considerations on work or task representations, learning situations are likely to be more effective than otherwise. It is also apparent that to do this is difficult and labor intensive. It requires considerable task knowledge and attention to the analysis of students' cognitive processes. It requires knowledge and skill in computer science to build and use tools for implementing interactive representations. This will require a team, each member of which is skilled in appropriate areas of computer science, cognitive science and instructional science.

## Examples of Interactive CBI and Design Aids

It seems likely that the knowledge about student representations and problem solving will be combined with the capabilities in hardware and software to develop more simulation-like interactions for CBI. The use of such simulations is increasing rapidly, partly because of cost reductions, and partly because of the face validity of the simulations themselves. There are two developments in recent cognitive science and computer technologies that are examples to show how interactive CBI can be designed, and provide tools to help: (a) "Generative" or "Intelligent" CBI, and (b) computing aids or tools for instructional design and development. Each of these will be discussed briefly.

### Examples of Generative and Intelligent CBI

Generative CBI represents a departure from the bulk of instructional interactions currently available on computer systems familiar to most people. The idea is that the instruction is generated through interaction between some content or knowledge base, and programs that incorporate teaching methods, e.g., an instruction manager, and a monitor of the student's progress with the material to be learned. The subject matter and the instructional methods are, therefore, separate programs. The interactions are not prestructured combinations of material and instructional strategy in the usual Programmed Instruction sense.

The difference between generative and intelligent CBI resides primarily in how extensive the programs are that support instruction. Intelligent CBI contains (a) a "content model" or "model of the expert" which allows the computer to predict problem solutions that can be compared with a student's for comment, (b) a "tutor model" which provides for interactive questioning or demonstration as appropriate, and (c) a "student model" provides a way for the program to compare particular students' interactions with those expected and monitor student progress through the content. Intelligent CBI has the goal of making the instruction resemble the interactions between a tutor and a pupil. In the examples to be discussed, techniques for representing the content ~~or tasks~~ to be learned are separated from techniques that represent the "theory" of teaching. The advantages are that both systems can be refined independently and the system can be responsive to student idiosyncracies(see, e.g., Brown & Sleeman, 1981, and Clancey, 1981 for more extensive discussion).

### Generative CBI

An example of generative CBI has been developed at the Navy Personnel Research and Development Center under the direction of Dr. James Hollan (Crawford & Hollan, 1983). The particular content is factual information about Naval ships: their characteristics, their capabilities, and their weaponry. This knowledge base is important fundamental knowledge for certain officers aboard ship. Experience with using semantic networks as representations of declarative knowledge, plus the development of programming methods that allow structuring such networks in computer memory led to the development of ways of putting the content into a microcomputer. Then, management programs were constructed to search through the knowledge base for related items. Using these programs, a tutorial interface to the student was developed which uses a variety of games like "Twenty Questions" or "Jeopardy" or "Flash-card" (McCandless, 1981). The modularity of this approach allows the retrieval management programs and the game interfaces to be independent of the particular content. Other content can be (and has been) substituted.

### Intelligent tutoring

Intelligent CBI adds considerably to the capabilities available in generative CBI. It builds upon the knowledge acquired about computer modeling and graphics to build running models of systems or other complicated knowledge bases. It includes models of experts to test or evaluate student answers, models of tutoring to provide interactive response to student queries and answers, and interactively builds a representation of a student to allow shaping the topics covered by the tutor to those appropriate for the student.

This approach leads to a qualitatively different form of training. Dr. Hollan and his group have undertaken to develop "STEAMER" as a prototype. This effort represents the state of the art in Intelligent CBI (Holla1, Williams & Stevens, 1980). The system consists of a graphical interface to a simulation of a shipboard steam propulsion system. The "content" in the system is represented in the form of an executable mathematical model of the eutire steam plan. A graphical interface to the mathematical model provides students with an easy and natural means of inspecting and manipulating the plant simulation. Another display helps the student to select the particular aspect of the simulation he/she wants to view and enables selection of various states. The simulation is displayed as animated diagrams that can be manipulated by the student. Components such as valves, switches, and pumps can be operated and the effects can be observed on plant parameters such as changes in pressures, temperatures, and flows. The tutorial part of STEAMER is being developed piece by piece into the intelligent tutor desired. It currently includes an explanation generator to demonstrate how components work, one for teaching basic physics principles, and one to provide guidance on plant operating procedures. The mathematical model (simulation) was translated into LISP and the other components have been developed in that language. The interface is a color graphics terminal that dynamically shows the functioning of the steam plant and an alphanumeric terminal to allow students/instructors to select material to be shown. It runs currently on a stand-alone computer running the LISP programming language.

This work combines several technological developments and areas of research. First are the computer and numerical modeling techniques needed to build a portable simulation system. Important contributions come from developments in student modeling, knowledge representation systems, and qualitative reasoning (Williams, Hollan and Stevens, 1983). Student modeling techniques make it possible to do more than just correct errors. By using accumulated evidence about student misconceptions the system will provide tutorial assistance to help him/her understand the nature of the error. Knowledge representation techniques make it possible for STEAMER to teach the student about generic systems and procedures, and show how they apply to the specific systems he/she must operate (Stevens & Roberts, 1983). Recent formalization of qualitative reasoning enables the development of modeling techniques to represent the conceptual relationships that form the basis of an expert's knowledge of the operation of complex systems. These techniques make it possible for STEAMER to generate and communicate to the learner the causal relations between changing events in the propulsion plant (Stevens, Roberts, Stead, Forbus, Steinberg, & Smith, 1982). It should be noted that the interactive nature of generic or intelligent CBI systems require a powerful, dedicated computer system rather than one shared by a number of users.

**Aids for the Design of Interactive Instruction:**

On the basis of the research literature and theorizing about how students reoresent materials, processes, procedures to themselves, it seems apparent that we can predict generally that computer-based interactive, graphical systems will importantly advance instructional effectiveness. Considerable work is needed to develop and refine the analytic techniques that serve as a basis for designing representations, but the basis is there. Another line of development is needed before it will be possible to implement such representations in interactive computer systems. These are user, or author or teacher "tools." They allow the author to develop computer-run representations of tasks that permit diagnostic assessment of student interactions, and permit revision with relative ease.

There are two primary kinds of developments taking place that exemplify such tools. First, there are aids to instructional design and development that include advisors or critics to assist developers in their work. The model for these are developments like the "Programmer's Workbench" or "Writer's Workbench" both developed at Bell Laboratories, or modern LISP programming environments. These tools or environments include task managers, programming aids, editors optimized for particular programming languages, help facilities, program debuggers, interactive text analyzers and spelling correctors, document preparation tools, and drivers for high-quality printers and phototypesetters. A similar set of tools should be provided for designers and developers of instruction.

Second, there are byproducts of the work in developments like STEAMER that provide powerful ways for less experienced persons (in computer programming) to develop interactive, graphical representations for teaching. One of the powerful facilities developed in the STEAMER project is a graphics editor which enables instructional programmers and subject matter specialists to build and try out new representations for instruction with a fraction of the effort needed heretofore. In this editor a number of objects (e.g. gauges, controls) is shown in a menu form. The instructor can select an object from the menu, and can indicate wnere he wants it put on the color graphics screen. He or she can select a number of objects for a new representation, connected by appropriate pipes and valves. More importantly, the user also has access to "taps," which are links to the values in the mathematical model that are translated into the appropriate value or representation to be shown, e.g., a dial reading, state (on-off), or flow-rate. The instructor is not creating static pages to be displayed to a student, but instead, dynamic representations of the state of a working system. With this tool, entirely new displays can be designed in a very short time. By providing general tools for the generation of computer-based interactive instruction considerable amounts of time and labor can be saved and lavished on the instructional interactions and error detection. Discussion of other tools for generating graphics are contained in Freeman (1980), and Bork (1981) includes a discussion of interactive instruction by means of computer systems as well as aids for authoring.

It is clear that research on mental representations and the analytic procedures developed in that research have important ideas for instructional design and for the implementation of interactive CBI. Concentration on the design of interactive representations, and the utilization of powerful computer programming tools will help break the text bias of CBI. This should result in gains in instructional effectiveness. By designing appropriate representations that are task simulations, learning can be more rapid and long lasting. Although these conclusions are hopeful, it is apparent that procedures will have to be developed to guide the design of interactive simulations as well as systematic evaluation of the underlying principles.. Therefore, more formal development of the principles is needed. In order to accomplish this, an intensive research effort is required.

## Providing Widespread Distribution

If CBI programs for microcomputers are to be incorporated into instructional programs the decision to use them needs to be guided by knowledge and analysis of how and why they were developed, whether their objectives meet current needs, and evidence of their effectiveness. Because programs or courseware purchased off-the-shelf often lack information about their purpose and effectiveness, their introduction may actually interfere with or reduce the quality of instructional programs. In our view, the major problem with the implementation of traditional CBI is that prospective users are unaware of the limitations of current techniques or programs. The tendency is to buy a particular program usually on the basis of its supposed manageability, its publicity, or its cosmetics, then apply it uncritically.

Even if requirements for instruction are carefully identified, and instruction has been well designed, CBI may or may not be the best or only method to deliver it. There may be perfectly good reasons to use a computer to replace a proctor, to deliver pencil and paper tests, to present written text; to guide students through a workbook, to provide extra practice, etc. But decisions to use a computer for any instructional purpose should be based on careful requirements analysis coupled with good prescriptive guidelines about what interventions are likely or unlikely to achieve improvement in instruction. At present, there is still little substantive evidence to guide the selection and implementation of traditional CBI systems let alone developing ones. Alternative means of presenting instruction are possible, can be as effective, and any choice needs to be based on costs of developing, implementing, and running the different forms, balanced against their expected outcomes.

For constructing new instructional programs, the primary problem is in controlling the quality of the ISD process. And here, computer use makes things more complicated, because additional attention must be given during the analysis and development phases to instructional logic (which the teacher normally does), to planning the student-computer interaction and interface, to the types of student response data required, to the schoolhouse utilization and maintainability of the hardware and software, and to a variety of other issues. In addition, teachers need to be able to modify programs, and must learn to use systems if they develop instruction or even to use canned programs. All of this provides a substantial training problem, both in computer use, and in programming instruction.

So far, the message has been pessimistic. Because we don't seem to be able to control instructional quality on a large scale, the mere availability of computers or computer-based lessons won't rapidly bring about significant advancement, and will probably complicate and increase the expense of instructional development.

**What Needs to be Done to Obtain Quality Improvement?**

We have repeatedly made the point that computers and CBI software should not be bought with the expectation that they will solve today's instructional problems. Instead, CBI programs must be built explicitly to teach, and this means that some form of ISD must be performed. That is why this paper includes both ISD and CBI as topics; for quality, they can't be separated. Moreover, if the quality of ISD is not improved, then CBI will only improve through sporadic artistry. Therefore, in our view, two developments are necessary· automated aids for ISD, and a coherent software distribution and maintenance system.

**Automated Aids for Instructional Design and Development.**

The continued lack of progress with ISD implementaton seems due to the variable quality of those doing the implementation, and the lack of "how to do it" procedures in usable forms. Since added proceduralization is unlikely to be useful (Montague and Wulfeck, 1982), it is necessary to provide job aids. In paper form job aids can help, but too much still depends on learning by the developers and there is little time or resources for this. Computer based aids to authoring instruction can make substantial differences in the quality of instruction whether it is on-line or off-line, and of course in the efficiency of ISD.

The earlier description of the ISD process gave no indication of record-keeping requirements, although formidable record-keeping problems exist. A typical military training program has hundreds or sometimes even thousands of learning objectives, which must be developed, cross-referenced, tested, and taught. For example, about 7,000 learning objectives are contained in the training program for P-3 aircraft crews (Daubek, et al, 1980).

Records also cover a wide variety of other ISD activities such as generating test items, choosing alternative training media and strategies, evaluating graduates, and revising courses.

More importantly, computerized ISD aiding systems can not only assist with these record-keeping problems, they can facilitate the development process itself by providing guidance for test and instructional development and similar tasks. Moreover, computer-based systems can insure that guidance is followed by monitoring and evaluating developers' performance, especially by forcing attention to the delivery options available and the trade-offs among them, and by assisting developers as they proceed. Computer systems can also provide training for instructional developers, who can fit it into their work schedules. Finally these systems are essential for aiding implementation and utilization of CBI. Today, most CBI users such as teachers, school boards, military training activities, and businesses want the ability to customize and adapt instructional software. They cannot do this unless tools are available for modification and refinement of CBI programs.

The most desirable reason for using computer tools, however, is that the modern design and development tools described earlier in this paper, such as an "Instructional Developer's Workbench" or the STEAMER graphics editor, can be incorporated into the ISD process. This provides the only mechanism whereby developing science can improve day-to-day practice. Computer-based author aids, then, must be developed to support both ISD for CBI and utilization of CBI.

**Improved Distribution and Maintenance of CBI Programs.**

The transfer of software is a problem. There are attempts to catalog programs and annotate them (e.g. CONDUIT at the University of Iowa, the Minnesota Educational Computing

Consortium). While these efforts serve to acquaint people with the range of programs available, several major problems remain. First, many schools, businesses, and military activities are buying computers. Unfortunately, these are often not compatible, so common software packages cannot be developed and shared without substantial recoding and duplication of effort. A second problem is the tremendous repetitive nature of the programming efforts. One program or another develops programs that present questions and require selected answers or fill in answers, present text descriptions,etc. All of these require functionally the same code. Computer software companies have recognized the same sort of repetitiveness in computer programs and are developing ways to use code already developed in new programs. This speeds up the development process and reduces errors by a large factor. A third problem is that most current CBI programs are not supported by appropriate authoring support and instructional management aids.

We believe that a solution to these problems is to develop families of CBI software to support computer-based instruction in a wide variety of education applications. This can be done by developing *libraries of computer-based instructional programs*, sufficiently flexible to support development, delivery, and management to meet many instructional requirements. The library should also be concerned with demonstration of and specifications for generic hardware systems capable of executing library software, and with planning for and assisting institutionalization of CBI programs. By providing transportable, carefully tested CBI software and development tools, compatibility and supportability problems are solved, user requirements are more efficiently addressed, implementation and life-cycle costs are reduced, standard data on student performance and CBI cost/effectiveness can be obtained for budget justification, and acquisition costs of training can be reduced. And again most important, institutional software libraries can achieve a "critical mass" so that evolutionary improvements through application of new technologies like authoring aids can be achieved.

The Department of Defense is currently developing such a library called TRIADS. The intent is to synthesize efforts in all the services related to CBI technology. Initial programs in the TRIADS library are those which have already received rigorous test and evaluation within the developing service. Later programs will be accepted in the library only after such analyses have been conducted, and only if they interface with existing authoring and management support aids, or include new ones. The purpose of this effort is to develop software quality standards and instructional quality standards for programs to be included in the system library, adapt and enhance existing programs for this system library, demonstrate the programs, and develop user training. This effort involves the following work:

A quality assurance process including software-engineering standards and instructional quality standards that computer-based educational applications programs should be required to meet for acceptance into the system library is being prepared.

Another major task is to design, develop, and write "authoring" support programs which enable instructional-content specialists who are not computer programmers to enter instructional content to the appropriate database for each of the software programs developed. These authoring programs will take the form of "authoring environments" which provide support for users for database construction and entry. The authoring programs will meet the following design goals:

*Uniformity of User Interaction:* The programs will be designed so that commands, file naming conventions, initiation, file saving or archiving, etc. are the same for all tasks. The same editor will be used for all database construction, entry, and maintenance tasks, although there may be some task-specific commands.

*On-Line Documentation:* On-line documentation, helps, command prompts, etc. will be available. On-line (and hard-copy) examples will be provided.

*Archive and Back-Up Facilities:* Easy-to-use archive and back-up methods will be provided.

*On-Line Input Checking:* The programs will include on-line facilities for checking the form and syntax of user entries.

*Debugging Tools:* Easy-to-use facilities for checking the correctness of user-entered databases will be provided. These may take the form of facilities for simulating student inputs during program operation, and displaying the results to the author.

*Videodisc Preparation:* Methods to assist in videodisc preparation, such as frame-number recordkeeping, simulating videodisc displays with videotape, assistance in frame sequencing to minimize disc access time, etc., will be provided.

A fourth task is to design, develop, and write instructional management programs for each of the instructional programs in the library. These programs will allow instructors who are not computer programmers to track student progress through the instructional programs, and to obtain data concerning student performance.

Finally, the effort involves developing a user training course to instruct users who are not computer programmers in the operation of all software developed. Training materials will include operations aids and manuals for all software, and a decision aid to assist users in determining which of the CBI systems is most appropriate for their particular instructional needs. This development will include validation of the training materials by providing training to a selected number of users in the operation of the system, including database construction.

In general, efforts like TRIADS are essential if CBI is to be widely implemented, and again, provide a more straightforward vehicle for evolution of the scientific base into practice.

## Conclusion

History shows that educational innovations in this century go through a peculiar three-stage life cycle (Montemerlo & Tennyson, 1976; Campbell, 1971). In the first stage, advocates of an innovation proclaim its usefulness and its success. In stage two, many people are attracted to the innovation, and begin using it. Then, widespread implementation is attempted, often without sufficient planning for use, or training for intended users. The final stage, however, is one of growing skepticism and criticism of the innovation's adequacy as its shortcomings are discovered through experience. Because this criticism comes late in the process, it does not help improve the technique, but rather hastens its abandonment in favor of yet another innovation. The process then begins anew.

Whatever the causes of the cycle--and some theorists believe they are political and social (e.g., Montemerlo, 1979b)--the effect is that when an educational innovation is introduced, its proponents suppress constructive criticism as they nurture and protect their "brain child." The danger is that ISD and CBI--which have enjoyed their days of advocacy and are now somewhere between phase two of widespread use, and phase three of growing skepticism--may share the fate of so many other innovations.

As ISD moves into the criticism phase of its life cycle, it still retains much of its early promise. ISD has made progress in developing techniques to make training more job-relevant. As we saw however, problems exist in successfully implementing these techniques. The process of designing any instruction including CBI depends on the expertise of the persons designing and developing the system. A large part of this expertise depends on their skill in analyzing tasks, knowledge in the cognitive science background for instructional psychology, and how CBI can be integrated into instructional programs. In addition, in cases where new material is not being developed but purchased, evaluation of its quality is essential. Although there is general agreement that systematic methods for instructional design and development are a good idea, they have not yet been successful in improving training on a large scale. This failure stems from a less-than-adequate state of knowledge about human learning and instruction, as well as our inability to provide recipes for training development that untrained people can follow.

The availability of relatively cheap computer power and its frequent purchase by schools have led people to tout microcomputers as the solution to the problems of quality in education and training. We feel that this is misleading. Microcomputer CBI use is "another" panacea for educational problems that is likely to follow earlier ones. Panaceas like this often fail because they don't address the real ingredients for successful instruction or the problems of large-scale implementation. The quality of instruction depends on a combination of factors: the analysis of the need for the instruction and the specification of what students are to learn from it, the care taken in the design of instructional interactions, their ability to support learning, and the capability of the computer-based system to incorporate the characteristics needed for instruction. Additionally, quality is often dependent on how the CBI is integrated into the instructional program.

Therefore, the prospects for attaining large increments in instructional effectiveness, depend not on the availability of computing power or even computer programming, but on our understanding of instructional psychology and cognitive science, on the use of programming strategies developing in computer science which will lead to more powerful forms of instruction heretofore impossible, and on our ability to implement their prescriptions on any scale large enough to make a difference. These, however, will not be widely applicable for some time to come. Methods and trained people for carrying out the necessary design, development, implementation, and quality assurance will take time to develop.

In order to break this cycle of panaceas, we must recognize the scientific and theoretical base underlying learning and instruction, and, as in the rest of the sciences, adopt a longer-term evolutionary view. Progress comes very rarely from an overnight revolution. Instead scientific and technical progress comes from incremental additions to the knowledge base, and incremental applications of technology.

The potential for improving the quality of instruction is here. But interest in the issues that we raise, and support for the research, development, management and implementation of modern instructional design and CBI must be developed. We are optimistic that progress will be made, but we do not expect it to be rapid or revolutionary.

## Footnote

[1] The views, opinions and/or findings contained in this paper are those of the authors and should not be construed as an official Department of the Navy or Department of Defense position, policy or decision, unless so documented by other official documentation.

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Drs. Wulfeck and Montague are researchers in the Training Research Laboratory at NPRDC. For several years they have been involved with improvements of instructional design methods and computer uses in training. Much of this work has been involved in developing prescriptive methods based on research knowledge for instructional design and ways of improving internal quality assurance for the instructional program development process. Primary efforts were the development of the Instructional Quality Inventory (IQI), a Navy test development manual, and test/evaluation of the use of microcomputer systems in instructing and in instructional program development. Montague was trained as an experimental psychologist at the University of Virginia, did research in human factors for the Navy Electronics Laboratory, taught psychology and educational psychology at the University of Illinois, and moved to NPRDC in 1972 as a project leader. Wulfeck taught secondary school mathematics, did graduate training in education and psychology receiving his Ph.D. from the University of Pennsylvania, and moved to NPRDC in 1976.

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# REFERENCES

Anderson, R. C. (1977). The notion of scemata and the educational enterprise: General discussion of the conference. In Anderson, R. C., Spiro, R. J. & Montague, W. E. (Eds.) *Schooling and the acquisition of knowledge*. Hillsdale, NJ: Erlbaum Assoc., pp.415-431.

Andrews, D. H. & Goodson, L. A. (1980). A comparative analysis of models of instructional design. *Journal of Instructional Development*, 3(4), 2-16.

Arnheim. R. (1969). *Visual thinking*. Berkeley, CA: University of California Press.

Attneave, F. (1974). How do you know? *American Psychologist*, 29, 493-499.

Bork, A. (1981). *Learning with computers*. Bedford, MA: Digital Equipment Corp.

Bower, G. H. (1970). Organizational factors in memory. *Cognitive Psychology*, 1, 18-46.

Brown, J. S. & Sleeman, D. (1981). *Intelligent tutoring systems*. London: Academic Press.

Bruner, J. S. (1964). Some theorems on instruction illustrated with reference to mathematics. In E. R. Hilgard (Ed.) *Theories of learning and instruction: The sixty-third yearbook of the National Society for the Study of Education (Part I)*. Chicago, IL: NSSE.

Bunderson, C. V., Gibbons, A. S., Olsen, J. B., & Kearsley, G. P. (1981). Work models: Beyond instructional objectives. *Instructional Science*, 10, 205-215.

Campbell, J. P. (1971). Personnel training and development. *Annual Review of Psychology,*

Carter, L. F. (1973). The systems approach to education: Mystique and reality. *Introduction to the systems approach.* (Educational Technology Review Series No. 3) Englewood-Cliffs, NJ: Educational Technology Publications.

Champagne, A. B., Klopfer, L. E. & Gunstone, R. F. (1981). *Cognitive research and the design of science instruction.* Pittsburgh, PA: University of Pittsburgh, Learning Research and Development Center.

Chi, M. T. H., Feltovich, P., & Glaser, R. (1981). Categorization and representation of physics problems by experts and novices. *Cognitive Science, 5*, 121-152.

Chiesi, H., Spilich, G. J., & Voss, J. F. (1979). Acquisition of domain-related information in relation to high and low domain knowledge. *Journal of Verbal Learning and Verbal Behavior*, 18, 257-273.

Churchman, C. W. (1968). *The system approach.* New York: Bell.

Clancey, W. J. (1981) *Methodology for building an intelligent tutoring system.* Stanford, CA: Department of Computer Science, Stanford University, Report No. STAN-CS-81-894.

Crawford, A. & Hollan, J. (1983) *Development of a computer-based tactical training system.* San Diego, CA: Navy Personnel Research and Development Center, NPRDC SR 83-13.

Daubek, K., Freedman, C., Walker, R. A., & Thode, W. F. (1980). *Instructional systems development for P-3 aircrew training*. (NPRDC Technical Report). San Diego, CA: Navy Personnel Research and Development Center.

Forbus, K. D. (1981). *Project STEAMER: IV. A primer on Conlan--A constraint-based language for describing the operation of complex physical devices*. (NPRDC TN 81-26). San Diego: Navy Per.onnel Research and Development Center.

Freeman, H. (Ed.) (1980). *Tutorial and selected readings in interactive computer graphics*. New York: IEEE, Inc.

Gentner, D. (1980). The structure of analogical models in science. Technical Report No. 4451, Cambridge, MA: Bolt Beranek and Newman.

Gentner, D. & Gentner, D. R. (1980). Flowing waters or teeming crowds: Mental models of electricity. In Gentner, D. & Stevens, A. (Eds.) *Mental models*. Hillsdale, NJ: Erlbaum Assoc.

Greeno, J. G. (1977). Process of understanding in problem solving. In N. J. Castellan, D. B. Pison, & G. R. Potts (Eds.), *Cognitive theory* (Vol. 2). Hillsdale, NJ: Erlbaum Assoc.

Gustafson, K. L. (1978). *Survey of instructional development models*. Washington, DC: U. S. Department of Education, National Institute of Education, ERIC: ED211097.

Hayes, J. R., & Simon, H. A. (1976). The understanding process: Problem isomorphs. *Cognitive Psychology*, 8, 165-190.

Heller, J. I. & Reif, F. (1982). *Cognitive mechanisms facilitating human problem solving in physics: Empirical validation of a prescriptive model.* Berkeley, CA: University of California, Physics Department and Group in Science and Mathematics Education, Working paper ES-14b.

Hollan, J., Stevens, A. & Williams, M. (1980) *STEAMER: An advanced computer-assisted instruction system for propulsion engineering.* Paper presented at Summer Simulation Conference, Seattle, WA, August.

Kearsley, G. (1983). *Computer-based training.* Reading, MA: Addison-Wesley, 1983.

Kearsley, G., Hunter, B. & Seidel, R. J. (1983). Two decades of computer-based instruction projects: What have we learned? *T.H.E. Journal.*

McCandless, T. (1981). *Computer-based tactical memorization system.* San Diego, CA: Navy Personnel Research & Development Center, Technical Note 81-8.

Montague, W. E. & Carter, J. F. (1974). Vividness of imagery in recalling connected discourse. *Journal of Educational Psychology*, 64(1), 72-75.

Montague, W. E., Ellis, J. A. & Wulfeck, W. H. (1981). *After years of instructional research do we know more than grandma did about how to teach people.* Invited Address, Div. C, Sect. 4, American Educational Research Association, Session 23.02. ERIC Document

Montague, W. E., Ellis, J. A. & Wulfeck II, W. H. (1983) Instructional Quality Inventory: A formative evaluation tool for instructional development. *Performance and Instruction*

*Journal.1983, 22,* 11-14.

Montague, W. E. & Wulfeck II, W. H. (1982) Improving the quality of Navy training: The role of R&D in support of instructional systems design. San Diego, CA: Navy Personnel Research and Development Center, Special Report 82-19, March.

Montemerlo, M. D. (1979a). *The instructional systems development model: Tool or tyrant?* Paper presented at the American Psychological Association Annual Convention, New York.

Montemerlo, M. D. (1979b). *Politics: The human factor in instructional innovation.* Paper presented at the American Psychological Association Annual Convention, New York.

Montemerlo, M. D. & Tennysen, M. E. (1976). *Instructional systems development: Conceptual analysis and comprehensive bibliography.* Orlando, FL: Naval Training Equipment Center, NAVTRAEQUIPCEN Technical Report IH-257.

Newsweek Magazine. (1983). *Can the schools be saved?* May 9, 19[illegible].

Norman, D. (1980). Twelve issues for cognitive science. *Cognitive Science,* 4, 1-32.

Olson, D. (1977). The languages of instruction: On the literate bias of schooling. In Anderson, R. C., Spiro, R. J. & Montague, W. E. *Schooling and the acquisition of knowledge.* Hillsdale, NJ: Erlbaum, Assoc., pp. 65-90.

Orlansky, J. & String, J. (1980). *Cost effectiveness of computer-based instruction in military training.* Arlington, VA: Institute for Defense Analysis, IDA Paper P-1375.

Orlansky, J. & String, J. (1981). Computer-based instruction for military training. *Defense Management Journal*, 46-54.

Paivio, A. (1971). *Imagery and verbal processes.* New York: Holt, Rinehart & Winston.

Reif, F. (1979). *Cognitive mechanisms facilitating human problem solving in a* realistic domain: The example of physics. Berkeley, CA: University of California, Manuscript submitted for publication.

Reif, F. & Heller, J. I. (1982). *Cognitive mechanisms facilitating human problem solving in physics:* Formulation and assessment of a prescriptive model. Berkeley, CA: University of California, Physics Department and Group in Science and Mathematics Education, Working paper.

Rigney, J. W. & Lutz, K. A. (1974). CAI and imagery: Interactive computer graphics for teaching about invisible processes. Los Angeles, CA: Department of Psychology, University of Southern California, Technical Report No. 74.

Riley, M. S. (1981). *Representations and the acquisition of problem-solving skill in basic electricity/electronics.* Pittsburgh, PA: University of Pittsburgh, Learning Research and Development Center. Also presented as a paper at American Educational Research Assoc. Annual Meeting, Session 23.02, 15 April 1981. ERIC Document

Riley, M. S. (1982). Representations and the acquisition of problem solving skill. Paper presented at Annual Meeting, American Educational Research Assoc., Session 55.21.

Rumelhart, D. E., & Ortony, A. (1977). The representation of knowledge in memory. In R. C. Anderson, R. J. Spiro, & W. E. Montague (Eds.), *Schooling and the acquisition of knowledge*. Hillsdale, NJ: Erlbaum Assoc.

Schank, R. C. (1980). Language and memory. *Cognitive Science*. 4(3), 243-284.

Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals, and understanding: An inquiry into human knowledge*. Hillsdale, NJ: Erlbaum Assoc.

Semple, C. A., Hennesey, R. T., Sanders, M. S., Cross, B. K., Beith, B. H., & McCauley, M. E. (1981). *Aircrew training devices: Fidelity features* Wright-Patterson Air Force Base, OH: Air Force Human Resources Laboratory Logistics and Training Division, (AFHRL-TR-80-36).

Simon, D. P., & Simon, H. A. (1978). Individual differences in solving physics problems. In R. Siegler (Ed.), *Children's thinking: What develops?* Hillsdale, NJ: Erlbaum.

Stern, H. W. & Fredericks, P. (1982) *Instructional Quality Inventory: Usability of Procedures*. San Diego, CA: Navy Personnel Research and Development Center, TR 82-46, June. (DTIC No. AD A117681).

Stevens, A., & Roberts, B. (1983). Quantitative and qualitative simulation in computer based training. *Journal of Computer Based Instruction*, 10, 16-19.

Stevens, A., Roberts, B., Stead, L., Forbus, K., Steinberg, C. & Smith, B. (1982). *Project Steamer: VI. Advanced computer-aided instruction in propulsion engineering--An interim* *report*. San Diego, CA: Navy Personnel Research & Development Center, Technical Report 82-28.

Taber, J., Glaser, R., & Schaefer, H. H. (1965). *Learning and programmed instruction*. Reading, MA: Addison-Wesley.

Vineberg, R., & Joyner, J. N. (1980) *Instructional System Development (ISD) in the armed services: Methodology and application*. (TR 80-1) Alexandria, VA: Human Resources Research Organization, January.

Wetzel, S. K., Ellis, J. A. Wulfeck, W. H. & Montague, W. E. (1982) *The status of suthoring aids for instructional systems development: An analysis of needs and availability*. San Diego, CA: Navy Personnel Research and Development Center, Special Report 82-37, August.

Williams, M., Hollan, J., & Stevens, A. (1983). Human reasoning about a simple physical system. In D. Gentner & A. Stevens (Ed.), *Mental Models*. Hillsdale, NJ: Erlbaum.