

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED			1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY			3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.			
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE						
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NPRDC TR 84-54			5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION Navy Personnel Research and Development Center		6b. OFFICE SYMBOL (if applicable) 05	7a. NAME OF MONITORING ORGANIZATION			
6c. ADDRESS (City, State and ZIP Code) San Diego, California 92152			7b. ADDRESS (City, State and ZIP Code)			
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Chief of Naval Operations		8b. OFFICE SYMBOL (if applicable) OP-01	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State and ZIP Code) Washington, DC 20350			10. SOURCE OF FUNDING NUMBERS			
			PROGRAM ELEMENT NO. 63720N 62763N	PROJECT NO. Z1388 RF63-522- 801	TASK NO. PN.01 013	WORK UNIT NO. 03.04
11. TITLE (include Security Classification) Computer-based Instruction: Will It Improve Instructional Quality?						
12. PERSONAL AUTHOR(S) Montague, William E., and Wulfeck, Wallace H., II						
13a. TYPE OF REPORT Technical Report		13b. TIME COVERED FROM 1/83 TO 11/84		14. DATE OF REPORT (Year, Month, Day) August 1984		
15. PAGE COUNT 24						
16. SUPPLEMENTARY NOTATION Reprinted from <u>Training Technology Journal</u> , 1984, ^{WINTER} 1(2), 4-19.						
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)			
FIELD 05	GROUP 09	SUB-GROUP	Computer-based instruction Instructional systems design Instructional development			
19. ABSTRACT (Continue on reverse if necessary and identify by block number)						
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. Like earlier, acclaimed panaceas for educational problems, this solution does 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. Four reasons for this assertion are discussed in this paper: (1) Attempts to improve instructional quality using systems approaches have revealed major difficulties; (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; and (4) any widespread use of computer-based instruction requires the acquisition and standardization of programs, provision for their distribution, and incorporation of the programs into schooling. Therefore, the prospects for attaining large increments in instructional effectiveness depend not on the availability of computers and programs, but on the understanding of instructional psychology and cognitive science and on the ability to implement it on any scale big enough to make a difference. Progress will be made, but it will not be rapid or revolutionary.						
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED			
22a. NAME OF RESPONSIBLE INDIVIDUAL William E. Montague and Wallace H. Wulfeck, II			22b. TELEPHONE (include Area Code) (619) 225-6434		22c. OFFICE SYMBOL 05	

DD FORM 1473, 84 JAN

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NPRDC TR 84-54

AUGUST 1984

**COMPUTER-BASED INSTRUCTION:
WILL IT IMPROVE INSTRUCTIONAL QUALITY?**

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**NAVY PERSONNEL RESEARCH
AND
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**COMPUTER-BASED INSTRUCTION: WILL IT IMPROVE
INSTRUCTIONAL QUALITY?**

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FOREWORD

This paper, which was originally published in the Training Technology Journal, Winter 1984, is being reprinted by NPRDC to provide wider distribution. It was written at the request of the Commanding Officer and Technical Director for submission to the journal and was supported, in part, by work units Z1388-PN.01 (Low Cost Microcomputer Training Systems) and RF522-801-013-03.04 (Testing Strategies for Operational Computer-Based Training).

This study reviews the problems confronted in designing all instruction, computer-based or not, suggests that attempts to systematize instructional development have not succeeded in making training job-relevant and effective, presents suggestions for improving the process, and describes exemplary efforts. The results are intended for a general audience concerned with using computer-based training systems in military training.

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SUMMARY

Purpose and Background

Originally published in the Training Technology Journal,¹ this study was intended as contrast to popular views that tout microcomputers as a primary solution to the problems of education and training. Like earlier, acclaimed panaceas for educational problems, such as teaching machines, programmed instruction, and main-frame computer-based instruction (CBI), this solution does not address the real ingredients for successful instruction nor the problems of large-scale implementation. Improvement in instruction, computer-based or not, will be a relatively slow, evolutionary process. It will depend on current development of the scientific knowledge base, developments in computer programming, and changes in the instructional technology that synthesizes them.

Results and Discussion

1. Attempts to improve instructional quality using systems approaches have revealed major difficulties. Systems approaches to instructional design and development were devised to circumvent the problems of variable quality of instruction common in less controlled approaches. To overcome the inexperience of most curriculum developers, detailed procedural guidelines were developed. However, recent assessments have identified persistent problems: procedures that were not followed and materials that were mostly of poor quality. The quality of CBI is tied to the ability to manage the instructional development process.

2. The use of computer-based instructional tools is in a rudimentary state of development. Most existing CBI provides instruction as it could be provided without the computer: Text is presented for students to read, multiple-choice questions are asked, answers are chosen by the students, new materials are given if answers are correct, and review material is presented if answers are incorrect. In this form, CBI should not be expected to differ much from instructor-run versions of the same curriculum, and indeed, test comparisons show no learning benefits. The computer's capability to simulate tasks and provide interactive learning environments is rarely used.

3. Improvements in instructional design technology are likely, but depend on ongoing changes in the scientific base provided by the cognitive and computer sciences. Since the 1950s, behaviorist psychology has dominated instructional theory; it still dominates the derivative instructional technology. Recent research and theory focus on the importance, ignored by earlier approaches, of cognitive processes in learning and performing. For example, misinformation that students have at the outset must be challenged and corrected. An improvement in instruction could be made by the use of "work models," in which an interactive setting allows each student to converse in newly learned vocabulary, use the appropriate concepts, perform the appropriate procedures, make predictions, and solve representative problems. These processes can be implemented into interactive CBI systems that use the powerful tools being developed in computer and cognitive science. However, these capabilities will take years to develop.

¹Montague, W. E., & Wulfeck, W. H., II. (Winter 1984). Computer-based instruction: Will it improve instructional quality? Training Technology Journal, 1(2), 4-19.

4. Widespread use of CBI requires acquiring and standardizing programs, providing distribution, and incorporating them into instruction. Families of CBI software for a variety of instructional functions need to be collected and distributed, possibly by developing libraries of computer-based instructional programs. These programs could support development, delivery, and management in meeting many instructional requirements. The libraries could also provide demonstrations and descriptions of generic hardware systems capable of executing the programs, as well as assistance in planning and implementation of CBI programs.

Conclusions and Recommendations

1. Prospects for attaining large increments in instructional quality by using CBI do not depend primarily on the availability of computing hardware. Rather, they depend first on understanding the instructional process, influenced by evolving cognitive science research, and then on the use of powerful programming facilities to provide interactive instruction suggested by the research. Even so, the impact will depend on large-scale implementation and will not be attainable until methods are developed and people trained for carrying out the necessary design, development, implementation, and quality assurance. Meanwhile, systematic application of what is already known should be used appropriately to help solve current problems.

2. The search for a simple cure-all for education and training problems should be abandoned. Trainers must recognize the limits of 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.

3. Technologies like CBI should be used where they provide demonstrable gains. To do so, systematic planning and a library of appropriate tools are needed.

4. Further research should be conducted to develop the scientific knowledge base that supports the CBI technologies.

CONTENTS

Introduction	1
Instructional Quality Occurs by Design	2
Evolution of Instructional Systems Development Approaches	2
The Effectiveness of ISD Leaves Room for Improvement	3
Using Computers for Instruction	4
A Limited Scientific Foundation	5
The Bias Toward Text in Instruction	5
The Bias Against Context and Structure	5
Hope for an Improved Scientific Foundation	6
Main Lines of Important Research	6
Translating this Foundation into a Technology	7
Providing Widespread Distribution	8
What Needs to be Done to Obtain Quality Improvement?	9
Examples of Interactive CBI and Design Aids	9
Automated Aids for Instructional Design and Development	10
Improved Distribution and Maintenance of CBI Programs	12
Conclusion	14
References	15
Distribution List	17

Computer-Based Instruction: Will It Improve Instructional Quality?¹

By William E. Montague and Wallace H. Wulfek II

Introduction

The use of modern computer-based gadgets for instructional purposes is being advocated widely. This 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 percent of the nation's schools reportedly use computers in classrooms (e.g., Newsweek, 1983). Although 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.

The rest of this paper 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) computers, as instructional tools are 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 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.

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.

Requests for reprints should be sent to either author, Code 05, NPRDC, San Diego, CA 92152.

Instructional Quality Occurs by Design

ISD 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 after 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 recognized the need to guarantee job relevance and to monitor inadequacies in learning systematically. Starting from a behavioristic frame-

work, they began developing techniques to stabilize and structure the process of training development, to ensure 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 weapon systems led to the development of systematic instructional design methods, presently called Instructional Systems Design (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 1960s, 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 presentation in sufficient detail 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 the Navy Personnel Research and Development 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 limited 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 scientific 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 provides 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 instruc-

tional 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 1950s and early 1960s, 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, maintain, and 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 1960s and into the 70s there was considerable hope that computer-based instruction would be widely adopted, and CBI was considered a panacea that would revolutionize education. This led to numerous 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 model 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 1950s and 60s 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 it 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 or should 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 less important 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 rep-

resentation 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 implications 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 proce-

dures 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 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.. 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 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.

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 also guided by 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 soft-

ware, 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: auto-

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, sep-

arate programs. The interactions are not pre-structured 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" which 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).

mated 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 implementation 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

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 micro-computer. 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 (Hollan, 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 entire 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

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 ensure 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

principles, and one to provide guidance on plant operating procedures. The mathematical model (simulation) was translated into LISP (a programming language) 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.

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 represent 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 are 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

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

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 where 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 rep-

resentations 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. To accomplish this, an intensive research effort is required. □

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 codes 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 any 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, to 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 opera-

tions 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 construction 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.

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. □

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DR. WALLACE H. WULFECK II and **DR. WILLIAM E. 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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