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ABSTRACT

Pecent reviews of computer-assisted instruction (CAI) in various journals suggest that the technological and economic barriers to its adoption and use may be overcome in the very near future, and that CAI will be feasible in a number of educational settings. Computer hardware costs have dropped dramatically in recent years, and a variety of programing languages are available to the user. Two major problems remain to be overcome. First, there are problems of instructional strategy including the lack of preservice and inservice teacher education on the use of CAI. In particular, there is a need for better training on the methodology of lesson development for CAI. Second, the variety of computer programing languages together with their technical intricacies presents a significant barrier to widespread use. In an effort to overcome the latter problem, Boeing Computer Services (BCS) has developed a series of computer routines to aid the instructor in the development and use of CAI lesson modules, SCHOLAR/TEACH. The software is currently in pilot testing and may be available for more general use in the near future. When available to the public, it will include a series of self-tutorial modules to assist teachers in the field with the use of the system for curriculum development. (DGC)

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LESS EQUALS MORE: COACHING/PROMPTING CAI
AS A TOOL TECHNOLOGY

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IMPORTANT NOTE:

SCHOLAR/TEACH is an experimental CAI software system developed by Boeing Computer Services, Inc.

The attached paper represents our current planning for the development of a production version. BCS is not yet committed to a firm schedule for development of SCHOLAR/TEACH III. When developed, S/T III will be a certified, Class 1 product, available through our nationwide sales organization.

We welcome any input that will assist us to produce a cost/effective instructional technology tool for education and training in academic and industrial environments.

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PREAMBLE

U. S. industry has achieved substantial success in meeting the production and distribution demands of a population of more than 200 million persons at a high level of comsumption of goods and services. That success is attributable in a large part to the employment of capital intensive tool technologies that maximize the cost efficiency of the labor force.

For example, the highly cost efficient production of Boeing commercial jet aircraft, at a high level of product reliability, depends on rapid and accurate processing of masses of information--from the design phase, through production, to maintenance of the aircraft in service throughout the world. Such a demand for information processing could not be met without the use of the tool technology of sophisticated computer systems.

Virtually all U. S. production and service industries rely heavily on computers. The major exception is education which, though information processing is its essential function, still relies in the main on traditional labor intensive means to accomplish its primary task--instruction. Yet the record of a decade and a half of experimentation with computer assisted instruction (CAI) indicates strongly that CAI is an effective tool technology for a wide range of instructional purposes.

SELECTIVE REVIEW OF THE LITERATURE

The objectives of education may be stated, for the purpose of this discussion, as, first, to achieve optimal learning by each person for effective participation in society; second, to maximize the equality of educational benefits among the population; and third, to attain these objectives at an acceptable cost. How has CAI performed with respect to these objectives?

Fletcher, Suppes, and Jamison (1972) cite a substantial record of achievement with respect to the learning objective. For example, in a Mississippi school mathematics program, in each of six grades, "the improvement in grade placement achieved by students randomly assigned to CAI was significantly greater ($p < .01$) than that achieved by control students." CAI students exceeded controls in grade placement gain by differences ranging from .41 to .88 (Suppes and Morningstar, 1969).

Studies of the relation of achievement to the amount of CAI provided show, for 150 ten-minute CAI session per year, grade placement gains of .58 to 1.26 years attributable to the CAI intervention (Jamison, Well, and Welchel, 1973; Suppes and others, 1973).

Fletcher and Atkinson (1972), evaluating an initial reading program, found statistically significant differences in favor of students receiving CAI instruction. In general, the reported experience supports the contention that learning gains can be maximized by the introduction of CAI to support a significant portion of the curriculum.

No claim is made here that CAI would equally well serve all students, at all ages, for all subjects. However, with respect to the objective of equalizing educational benefits among the population, Jamison and others (1973) and Fletcher and Jamison (1973) found that "CAI is inequality averting and that it provides roughly equivalent gains across all levels of student ability" (Fletcher, Suppes, and Jamison, 1972, p. 6).

During the 1970s, especially, the objective of achieving educational goals at an acceptable cost necessarily has received increasing attention. The traditional state and local sources of revenue for educational funding no longer are adequate to meet educational needs and to absorb spiraling costs. Again, experience supports the contention that CAI may be a cost effective tool, a means to resolve the conflict between educational need and the cost of satisfying it.

A Chicago project, serving over 6,000 students in 32 elementary schools, provided daily practice in reading, language arts, and mathematics. The mean gain in reading level (1972-73) was 9.9 months in an eight month interim between pre- and post-test. The operational cost was approximately $40 per student per year in each curricular area (communication from H. Strassburg, Assistant Superintendent of Schools, Chicago, December 5, 1974).

The Melrose, Massachusetts, schools found that they could service their administrative computing needs, provide two CAI mathematics courses and four business data processing courses for 150 students, and support 40 students and teachers developing their own program, by installing an in-house computer system.

The in-house system cost $3,400 per year less than formerly was paid to service bureaus for administrative computing alone (Bachelder, 1974).

Ford, Slough, and Hurlock (1972) report a study by the Naval Personnel and Training Research Laboratory that shows both the learning effectiveness and learning efficiency potentials of CAI. The study compared CAI and conventional instruction on curriculum from the Basic Electricity/Electronics School. Students were randomly selected from the BE/E School to receive a segment of their training on CAI; 760 students received more than 10,000 terminal hours of instruction. The study shows that "CAI students scored higher than class instructed students on both the School Examinations and the Supplemental Tests. CAI required 39% to 54% less training time than class instruction." Further, students rated the CAI instruction highly, indicating they would prefer to have 70-80% of their instruction by CAI (p. iii).

Comparable results in technical training were attained at the Signal Corps Computer Assisted Instruction Center, Fort Monmouth, New Jersey (U. S. Army Signal Corps, 1973). And Bitzer and Boudreaux (1969) report a 40% reduction in instructional time, compared with conventional instruction, in a CAI course in maternity nursing.

SOME PROBLEMS AND A SOLUTION

Experience shows that CAI can achieve learning gain equal to or greater than that achieved by conventional instruction, with significant reduction of instructional time. Why, then, is CAI relatively little used in either public or private education and training? McLean (1973) suggests that "it is not yet time for CAI because of incompatible author languages, poor teaching strategies, and expensive, inadequate computer systems" (p. 21). The evolution of CAI in the past two years, we believe, has brought us to the threshold of a solution.

The Hardware Problem

The cost and efficiency of hardware, we think, is not now a significant problem. The variety of computers on the market virtually assures that most hardware requirements can be satisfied at acceptable costs. The trend in CAI applications, as represented in the literature, in conference presentations, and in conversations with colleagues, is to exploit the rapidly evolving mini- and micro-technology. This trend seems to have emerged, first, because instructional uses tend to lose in competition with administrative uses on large scale systems and, second, because the cost of high capability mini-hardware is decreasing.

For example, Digital Equipment Corporation's CLASSIC, announced in January, provides a 32K byte minicomputer, 512K byte dual floppy disk, and keyboard and CRT terminal and printer in 30 by 48 inches of floor space. This stand-alone unit can deliver CAI instruction at about one half the cost of conventional classroom instruction (see Cost Comparison, Appendix A). Mini-systems supporting multiple terminals can further optimize cost effectiveness. Basic Timesharing has announced a system that will support up to 256 terminals with a common data base and operating system without significant degradation of response time.

The rapid expansion and sophistication of micro-technology suggests that, in the near future, we may be able to produce self-contained CAI stations at or below the current price of terminals alone (see, e.g, Bowers, 1974).

With the hardware problem largely resolved, we now may address the problems of instructional strategy and language.

The Instructional Strategy Problem

The experience of the past decade clearly shows that effective CAI instructional strategies can be designed. The learning gains cited in the review of literature above are only a sampling of a substantial record of success. The problem, as we see it, is that instructors need explicit training in the strategies of programmed instruction for CAI. My own experience indicates that teacher candidates only rarely, at least until recently, received any such training.

Our experience at BCS in technical training indicates that a person competent in subject matter, though inexperienced in instruction, can learn relatively quickly to design course packages, operating with an explicit instructional design model. Thus, we believe, the instructional strategy problem can be resolved through pre-service or in-service training. And we believe the tool skills can be learned quickly and honed adequately with relatively short practice. Now the language problem remains to be addressed.

The Language Problem

We agree with McLean (1973) that a standard CAI authoring language is not likely to emerge. Computer programming will remain multi-lingual. The competition among instructional strategies will not abate, and we would argue should not. Thus CAI will remain a field of competing languages and strategies. We are neither surprised nor disturbed. Twenty-six years ago E. C. Tolman urged that "there are really a number of different kinds of learning" (Tolman, 1949, p. 144). On that grounds, N. L. Gage (1963) suggested that no single approach "will embrace all the phenomena that go under the single name of teaching" (p. 2). Thus, we suggest, no single approach to instructional technology is likely to suffice.

We see the language problem as a matter, not of incompatibility among languages, but, first, of the ease with which an instructor can acquire an authoring language and, second, of the ease with which he can employ it. In other words, how much time is required to bring an instructor to production speed in the language? And how much preparation time is required per hour of instructional material produced in the language?

A Solution

Between 1968 and 1972 BCS Technology developed SCHOLAR/TEACH, a CAI software system. The primary design objectives of our developers were to eliminate dependence on a programming language and, by means of a coaching/prompting technique, to assure the logical integrity of lesson structure. The SCHOLAR/TEACH Basic

System comprises two main subsystems: SCHOLAR, the lesson presentation subsystem, interactively presents instructional material to the student and maintains a record of the student's performance. TEACH, the lesson writing system, interacts with the courseware author to build instructional material. TEACH EDITOR, a subset of TEACH, provides rapid, flexible editing capability for courseware correction and updating.

SCHOLAR/TEACH converses with the user in ordinary English. Lesson coding, transparent to the user, is accomplished by the software. The only special language demand on the user comprises the logon/logoff procedure and less than two dozen editing commands. The command language can be learned in one session. Of course, the courseware author is required to be competent in instructional design--a demand of all CAI systems.

The SCHOLAR/TEACH author prepares his lesson on paper. We have designed planning forms, but they are a convenience rather than a necessity, since program coding is not required. The instructor plans text, questions, anticipated responses and comments, exercises or problems, and branching as a continuous dialogue between student and system. The instructor then enters the lesson material via a terminal,* using the TEACH subsystem. TEACH converses with the author, coaching and prompting him in the construction of variable length text block and other lesson elements.

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*Batch entry capability is designed and will be implemented in SCHOLAR/TEACH III.

TEACH allows the use of four student response evaluation modes: FREE, UNORDERED, ORDERED, and IDENTICAL. The FREE mode allows unordered responses and evaluates on one or more key words; extra words are permitted. The UNORDERED mode requires that all anticipated response words be given, but not in a specified order; extra words are not permitted. The ORDERED mode requires the return of specified words in specified order; extra words are permitted. The IDENTICAL mode requires the return of all specified words in specified order; extra words are not permitted. Response modes may be intermixed in a lesson.

TEACH monitors branching in the lesson. Branching may be forced by the instructor through program instruction or placed under student control. Branching control is accomplished by specifying a criterion--e.g. if less than two acceptable responses in the first six, branch to review material; if more than four acceptable responses in the first six, branch to challenge material. TEACH keeps track of the branching, and will not allow loose ends; every branch must conclude with a return instruction.

When the lesson entry is completed, TEACH asks whether the instructor wishes to test the lesson. If so, SCHOLAP is called to present the lesson. With or without test run, the instructor may file the lesson for future use, or may reenter TEACH to edit the lesson. A lesson may be recalled to TEACH at any time to be edited or updated.

Experimental Tests

The ease with which an instructor can begin to use SCHOLAR/TEACH is illustrated in two experimental tests of the system. "In the first test, two high school teachers developed lessons using SCHOLAR/TEACH II. The teachers were given a user's manual that introduced them to the coaching/prompting approach to lesson preparation, but were given no other instructions on how to prepare CAI lessons or how to use the system. They preplanned their lessons and then entered, edited, and tested them. After the lessons were prepared, selected students were invited to take the lesson to test their validity. The students scored well, and no errors were found in the lesson structure. The total effort involved in developing these lessons ranged from 15.8 to 23.4 hours per hour of instructional material" (Simonsen and Renshaw, 1974).

In the second test, a lesson segment of about two minutes was developed by experienced and inexperienced users of SCHOLAR/TEACH and another CAI language. The results are shown in the table following:

	Lesson Preparation Time	
User	SCHOLAR/TEACH	Other System
Experienced	16 min.	48 min.
Inexperienced	36 min.	90 min.

(Simonsen and Renshaw, 1974)

Experience with SCHOLAR/TEACH indicates that an experienced user can construct CAI lesson material averaging 15-20 hours of preparation time per hour of instructional material produced. Comparing the achieved SCHOLAR/ TEACH preparation ratio of, conservatively, 20:1 to the reported industry average of 100:1, we believe we have overcome a major inhibition on the generalization of CAI.

The Status of SCHOLAR/TEACH

SCHOLAR/TEACH II, a development and demonstration vehicle, is resident on BCS's timesharing service, MAINSTREAM-CTS, at our McLean, Virginia, Data Center. The Basic System is fully operational with respect to the authoring and instructional functions, with limited student performance recording capability. This developmental system will serve as the model for design of a production version with significantly enhanced capabilities.

SCHOLAR/TEACH III will comprise an optimized and enhanced Basic System, including batch off-line input and printout capability and a simulated calculator subroutine, and four optional modules. The modular design will permit considerable flexibility in configuring the software system to satisfy users' needs and budgetary constraints. The optional modules include:

Computer Managed Instruction (CMI) module. The CMI module is designed to provide automated management of student progress through a prescribed course of study, and automated administrative capability for programmed curricula.

Student Data Base (SDB) module. The SDB module will support student records, providing statistical analysis and reporting capability for both individual and group performance histories.

Audio-visual Control (AVC) module. The AVC module will allow interface under program control with peripheral audio-visual equipment, such as slide/tape units. The feasibility of interfacing with a voice simulator unit is under examination.

Graphic Control (GC) module. The GC module will provide graphic representation capability through both alphanumeric presentation on the user's terminal and interface with plotter equipment.

SCHOLAR/TEACH III will be supported with two user training packages. Introduction to Teach, a CAI course, will provide interactive training in the use of the Basic System. SCHOLAR/TEACH Instructors' Workshop, a five day classroom course, will comprise Introduction to Teach and intensive instruction and practice in writing effective CAI lesson material. The software, its implementation, and its use will be supported by BCS's Education & Training Division, supplemented by our Consulting Division if needed.

SCHOLAR/TEACH III will be packaged for IBM's VM operating system to provide development, demonstration, and in-house training capability, and a short term testing capability for customers, on our MAINSTREAM-CTS service. This packaging will make S/T III also available to other VM users.

In keeping with the market trend, S/T III also will be packaged for minicomputers, making the software available to users of a wide range of economical hardware. And included in our longer range planning is research and development effort to explore the possibilities of the burgeoning micro-technology, which soon may permit the design of self-contained CAI units at or below the present cost of intelligent terminals.

THE TIME FOR CAI IS NOW

We believe that developments in hardware and software, in the two years since McLean (1973) cautiously assessed the case for CAI, justify the contention that the time for CAI is now. Moderate cost hardware and a software system such as SCHOLAR/ TEACH III can increase significantly the cost/efficiency of instructional individualization at an acceptable cost. CAI is capital intensive; it permits a teacher to serve a student population several times greater than with conventional instruction.

The individualization of instruction possible with CAI provides automatic adjustment to variations in students' learning rates, reduces the number of students who fail to achieve minimum mastery, and equalizes the relative educational benefit among a student population with heterogeneous abilities. And provision of instruction by means of CAI frees teacher time to provide the diagnostic and personal support that can be achieved only by person-to-person interaction. A machine can teach mathematics; it cannot provide a perceptive, sympathetic ear or hold a hand.

Further, the combination of skilled instructor/authors and CAI can assure the development, delivery, and maintenance of consistently high quality instruction. Well managed CAI, with effective quality control on lesson material, virtually can assure the effectiveness of instruction, free from the variations of instructors' abilities and moods that are almost inescapable in conventional instruction.

Finally, the decrease of learning time and increase of learning gain consistently shown in experimental CAI applications suggest the possibility of achieving greater breadth and depth of learning within present schooling or training periods, or significant savings in training costs. In a working world of constant change in job skill requirements, and frequent changes of job by workers, the acceleration of learning is virtually a necessity.

In the late 1970s and into the 1980s, we see only three barriers to the generalization of CAI: first, lack of widespread recognition of the benefits of the technology; second, lack of knowledge about the present state-of-the-technology; and third, following from the first two, hesitance to employ the technology. We believe that a concerted educational effort by CAI vendors and developers can override these barriers. Our inherent resistance to changing our habits of behavior likely will have to be overcome by attrition.

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