CAI: THE BOTTOM LINE

PREPARED FOR

NATIONAL AUDIO-VISUAL ASSOCIATION/
INTERNATIONAL COMMUNICATION INDUSTRIES ASSOCIATION
3150 SPRING STREET
FAIRFAX, VIRGINIA 22031

EDUCATION TURNKEY SYSTEMS inc

256 NORTH WASHINGTON STREET
FALLS CHURCH, VIRGINIA 22046

NOVEMBER 1984

TABLE OF CONTENTS

Preface

"CAI: The Bottom Line" was prepared at the request of NAVA/ICIA by Education TURNKEY Systems, Inc., a firm which has provided education technology research, development, and planning services to the U. S. Department of Education, over 1,000 local education agencies, and virtually all state education agencies over the last 15 years. The principle authors of the paper are Charles L. Blaschke, President and veteran of the computer-based education movement for over two decades, and Patricia Abrams, Research Associate and doctoral student at the Virginia Polytechnic Institute. TURNKEY recently completed Project SLATE, which assisted over 600 policy makers, including legislators and governors, in 20 states plan for the use of technology. At present, TURNKEY is developing scenarios on computer use in schools over the next decade for the National Commission for Employment Policy. TURNKEY also provides market research services -- especially in "thin" markets such as bilingual, special, and vocational education -- to private firms.

A. INTRODUCTION

In 1976, the National Science Foundation commissioned a study of computing activities in public schools; the word "microcomputer" did not appear in that report (Karotkin, 1977). Less than ten years later, approximately 630,000 microcomputers have been purchased by public schools, with a projected inventory base of 1.1 million units by 1985 (TALMIS, 1984). Approximately 98 percent of school districts with enrollments greater than 600 now have one or more microcomputers (QED, 1984). This rapid growth of microcomputers in education can be attributed to a number of factors: (a) a dramatic reduction in hardware costs relative to microprocessor speed and capacity over the last decade; (b) a grassroots movement which emerged during the late 1970s led by "computer buff" teachers; (c) external pressures upon the schools by parents with home microcomputers; and (d) school staff perceptions that microcomputers would increase their control of their work environment. In the recent past, and in the foreseeable future, microcomputer usage will be further bolstered by: (a) state-level policy initiatives and financial support (TURNKEY, 1984); (b) Federal initiatives, particularly grants consolidations which allow Federal funds for hardware and software purchases (e.g., Chapter II) and the recent passage of the Education for Economic Security Act (P.L. 98-377); and (c) greater availability of quality educational courseware sold at increasingly competitive prices.

Microcomputers are being used by schools for four basic purposes. First, computer-assisted instruction (CAI) allows the student to interact directly with the computer, either for large segments of a curriculum or, most prevalently, for supplemental or enrichment instruction. While most education courseware packages were drill-and-practice during the early 1980s, simulation and tutorial offerings are now increasing. Second, microcomputers can be used, particularly by teachers, for managing the instructional process. Computer-managed instruction (CMI) applications include capabilities for: (a) monitoring student progress; (b) diagnosing learning needs and prescribing learning activities; (c) test scoring and analysis; (d) lesson planning; and (e) curriculum management. Third, microcomputers can be used for a number of administrative purposes ranging from school attendance to complex areas such as administrative processing, student tracking and reporting, and developing IEPs for special education students. And last, the computer can be the object of instruction in computer literacy or "information technology" courses in separate laboratories or integrated into regular subject area curriculum. Over the next five years, the use of microcomputers as the object of instruction will most likely decline relative to increased use for administrative, CMI, and CAI purposes.

While administrative applications (both mainframe and microcomputers) have been justified on the basis of reduced paper work, staff time, and cost, the expansion of CAI will largely be dependent upon the demonstrated effectiveness of CAI in increasing student performance. School districts which jumped on the CAI "bandwagon" three or four years ago are now, because of the above reasons, demanding evidence of the effectiveness of CAI from courseware developers, publishers, and education dealers.

The purpose of this paper is to summarize the effectiveness and effects of CAI and, to a lesser extent, CMI and the conditions under which they work best. In developing this summary of CAI effects and effectiveness, we have relied heavily on over 15 studies conducted over the last decade which have focused upon the effectiveness of CAI and upon observations of individuals directly involved in implementing CAI programs in the schools. Because over 90 percent of the studies conducted over the last decade focus primarily upon the use of mainframe or minicomputer programs, we have also attempted to isolate those effects associated primarily with the use of stand-alone microcomputers.

B. CURRENT RESEARCH FINDINGS ON COMPUTER-ASSISTED INSTRUCTION

Results from CAI evaluations conducted over the past ten years have clearly yielded positive effects in several areas. As early as 1968 computers have been linked with student time savings and associated effectiveness and/or cost-effectiveness in education and training.

1. <u>Reduced Student Learning Time</u>

Six reviews of CAI effectiveness studies report major findings of time savings for students using computer-based instruction. A review by Blaschke et al. (1977) highlighted a 1968 study which compared a simulated application of CAI in Army electronics training with a similar type of CAI in secondary education. A reduction in student time spent in electronics training of approximately ten percent justified the expenditure and conversion of a large portion of the existing electronics curriculum to CAI. In her review, Dence (1983) listed several studies conducted at the postsecondary level which suggest that students using CAI take less time to learn as much or more than do students receiving traditional instruction.

Findings from investigations at both the elementary and secondary levels reach similar conclusions. Fisher (1983) reported that students complete material faster on computer than off -- occasionally as much as 40 percent. In meta-analyses conducted by Kulik and associates (1983), two studies were identified that reported findings of substantial time savings of students using CAI. Studies conducted with secondary students revealed 39 percent (Hughes, 1973 -- as cited by Kulik) and 88 percent (Lunetta, 1972 -- as cited by Kulik) savings in student learning time. Investigations with college students revealed statistically significant differences favoring computer instruction (e.g., 3.5 hours of instructional time per week for conventional classes and 2.25 hours for computer-based instruction).

Reporting on extensive computer-based training conducted in the military services, Orlansky (1983) indicated that the major benefit of CAI, compared to conventional instruction, is that is saves student time in attaining required minimum levels of knowledge and skills without loss of student achievement.

If no other positive effects were indicated with CAI, reduced learning time offers the potential for cost savings or opportunities for greater student advancement than does conventional instruction. In one study, a cost benefit analysis concluded that the costs of CAI were equivalent to the benefits that might accrue from equal amounts of tutoring (Ragosta, 1982). A recent study by

Levin et al. (1984), which reported that cross-age tutoring was more cost-effective than CAI, did not impute a cost for tutors and analyzed a program operated on a costly minicomputer in the mid-1970s as the cost comparison for CAI.

Positive effects of CAI, however, have been found in other more pervasive areas than merely time savings. Students' achievement, attitudes, and social relations have been positively affected by computer-assisted instruction.

2. Student Achievement

Over 20 studies conducted between the years 1968 to 1978 lead to four conclusions drawn by Fisher (1983), as follows:

- student performance is highest in science and foreign language, followed by mathematics, and lastly reading and language arts;
- CAI appears effective when aimed at specific student body groups (e.g., high and low achieving students and students with learning difficulties);
- when CAI is fully integrated into the curriculum, it is more effective; and
- positive effects increase when the proper settings and scheduling are established.

More recent reviews substantiate the findings of past studies. In particular, Kulik et al. (1980, 1983, 1984) have used a meta-analysis technique to more stringently measure the effects of CAI on both achievement and attitudes. Meta-analysis performed at all three levels -- college, secondary, and elementary -- yield positive effects. Most impressive is Kulik's finding that CAI seems most effective for student achievement at the elementary level. In 20 of the studies analyzed, Kulik reported that 68 percent of CAI classes outperformed the average student from the control classes on standardized achievement tests. Achievement results analyzed from approximately 30 studies conducted at the secondary level revealed that students from CAI classes performed at the 63rd percentile on their examinations, compared to students not using CAI who performed at the 50th percentile on the same examination.

Kulik's findings also revealed positive effects on students' attitudes. First, in eight out of ten studies reporting results on attitudes toward subject matter, attitudes were more positive in classrooms using CAI. Second, all four studies that measured how students viewed the technology reported that attitudes toward computers were more positive in the CAI classes than in classes taught by conventional instruction.

Four large-scale programs using CAI were evaluated by the Educational Testing Service (ETS): (a) the TICCIT project; (b) the PLATO demonstration; (c) the LAUSD study; and (d) IBM's Writing to Read program. Anastasio et al. (1984) report positive effects of CAI across grade levels.

In the Time-Shared Interactive Computer Controlled Information Television project (TICCIT), community college students were taught mathematics and English using CAI. Positive achievement results indicated ten percent improvement over conventional lecture sections for math and five percent for English. Attitudes toward subject matter were also affected positively, especially where the instructor's role took the form of explaining the subject matter, reviewing written work, and conducting small group discussions.

Community colleges and elementary grades were the targets of the Programmed Logic for Automated Teaching Operations (PLATO) demonstrations. For the community college sample, four out of five analyses yielded significant positive differences between PLATO and control classes in course completion. Positive achievement effects appeared in mathematics, chemistry, and biology. Further, the attitude items revealed a favorable impact of the PLATO demonstration on the attitudes of both students and instructors.

The PLATO demonstration conducted at the elementary level involved 300 students in math, and approximately 700 students who received reading lessons through CAI. In math, significant positive treatment effects were found at all grade levels (4, 5, and 6). Treatment effects were greatest for topics emphasized by both PLATO and the teacher. Attitudes toward subject matter tended to be more positive in the PLATO group than in the group that received conventional instruction. Positive attitudes were higher for math than for English.

The third study evaluated by ETS was a four-year longitudinal study conducted with elementary students involved in compensatory education, Title I classes in the Los Angeles Unified School District (LAUSD). Computer labs for the study were equipped with terminals controlled by a minicomputer using drill-and-practice courseware in math, reading, and language arts. Findings of the LAUSD study included positive effects of CAI in achievement and attitudes. For example, with exposure times averaging ten minutes per day in math, CAI students showed significant positive effects in computational skills compared with control students. With 20 minutes per day, computational skills were doubled. Additionally, longitudinal data revealed continued and increasing gains in computational skills. In the reading and language arts areas, smaller but consistently positive results were obtained. A major finding of the LAUSD study involved effects on attitudes. Attitudes toward reading, and feelings of internal responsibility for success, were significantly higher among students who received CAI than among students who did not.

Overall the results from this study extend the knowledge gained from other research on CAI. Anastasio and Wilder suggest that the success of CAI in this study may be related to the successful practices associated with other instructional effectiveness studies:

- mastery learning;
- high academic learning time with a high probability of success in responding;
- direct instruction;
- adaptability and consistenty of instruction;
- direct instruction with expectation of success in basic skills; and
- use of drill with equal opportunity for responses from all students.

The last study by ETS was large in scope, covering more than 10,000 kindergarten and grade one students in 21 sites and, in the second year, it concentrated on a core sample of 3,210 students using IBM's microcomputer-based Writing to Read program and 2,379 comparison students in classes not using the program. Results of the study indicated the following.

- For writing achievement, eight out of 13 sites reported statistically significant improvement for the kindergarten sample. Kindergarten Writing to Read students averaged 15 percentile points higher on achievement tests. By the end of the program, 72 percent of the students had progressed beyond word level writing to the production of phrases and sentences. Positive results were also reported for first graders in Writing to Read classes.
- For reading achievement, seven of 11 sites reported positive results for Writing to Read students; the remaining four sites reported results equal to the non-Writing to Read students.
- Teachers' responses indicated additional positive effects of the students in the CAI group.
- Fifteen percent more parents reported greater progress in their children as compared to parents of the non-Writing to Read students.

3. Effects and Effectiveness of CMI

Many of the positive effects of computer-assisted instruction which have been observed or reported also reflect the use of computer-managed instruction systems. Indeed, many of the CAI studies reported earlier were supplemented by CMI applications, such as monitoring student progress and reporting; and, when moderate to high student achievement gains occur in CMI programs, the hardware costs are usually substantially less than those associated with CAI classrooms. On the other hand, the implementation of CMI systems has to be preceded by extensive and in-depth training on the part of all instructional staff, principals, and key administrators, particularly in the areas of individualized instruction. Well-implemented CMI programs have produced significant gains at moderate costs (Hofmeister, 1983; Hartley, 1980). Over the next two to three years, one might reasonably expect heightened interest in CMI systems, especially those which are single product line independent as: (a) school staff see CMI as a means to assist in integrating appropriate supplemental courseware into existing curriculum; (b) state departments of education take a greater leadership role in attempting to ensure effective use of technology at the local level; and (c) more and more high quality comprehensive CMI and curriculum management packages become commercially available.

4. Additional Positive Effects

Other positive effects of computer-assisted instruction recur in several studies:

- Teachers' attitudes toward using microcomputer technology in the classroom are improving (Ragosta, 1982; Becker, 1983; Ingersoll et al., 1984).

- Teachers report that students appear to cooperate more with each other and with teachers during academic tasks when using computers (Ragosta, 1982; Becker, 1983, 1984; Sheingold, 1983).

- Students feel they have more control over their learning when using CAI than students not using computers (Ragosta, 1982; Bracey, 1984; Anastasio, 1984; Becker, 1984). This appears to be particularly true when microcomputers are used rather than terminals/mainframes.

- The social organization of learning is improved considerably when microcomputers are used -- increased student enthusiasm and independent student learning (Becker, 1984).

Policy makers, educators, and developers are eager to know why computer technology appears to enhance learning in students, regardless of age. Obviously, it is not the hardware itself that raises student achievement and fosters positive attitudes toward subject matter. The bottom line must be drawn between the computer itself and other variables known to have an impact on learning -- namely, courseware and the conditions which ensure effective implementation and use.

C. QUALITY COURSEWARE AND CONDITIONS

The use of quality courseware is a necessary condition for improving student performance; however, by itself it is not sufficient. Below we summarize the characteristics of successful quality courseware which have been identified by researchers and successful computer-using teachers. Specific conditions for successful implementation and use are then summarized.

1. Characteristics of Quality Courseware

All or most of the following characteristics can be found in courseware which improves student achievement:

- provides opportunities for students to control (or perceive they control) the learning process (Crandall, 1977; Ryba et al., 1983);
- provides interaction, feedback, and often rewards (Hartley et al., 1980; Kulhavy, 1976; Rankin et al., 1978);
- allows students and/or teachers to establish and implement goals and provides for self-evaluation (Ryba et al., 1983; Shavelson et al., 1984);
- allows diagnosis of conceptual difficulties with materials and prescriptive branching (Magidson, 1978; Coulson et al., 1970);
- uses the full range of hardward capabilities such as graphics, sound and color, etc. (Shavelson et al., 1984);
- includes important concepts, if curricular in nature, as well as facts related to subject matter (Ryba, 1984; Shavelson et al., 1984);
- allows for easy integration, if supplemental, into curriculum (Shavelson et al., 1984; Fisher, 1983);
- includes, at a minimum, student record keeping capabilities, if curricular in nature, and monitors student progress (Shavelson et al., 1984); and
- allows for easy operation, accompanied by clear documentation, and can be modified by teachers (Shavelson et al., 1984; Gold, 1984).

2. Conditions for Successful Use

If one uses courseware with most of the above characteristics <u>and</u> most or all of the following conditions are met, the probability of improved student performance is enhanced considerably.

- School/Classroom Environment:

  - flexible scheduling of students and individual student self-pacing (Ragosta et al., 1982; Fisher, 1983);

  - opportunities for integrating use of hardware and software in a classroom setting, rather than a pull-out laboratory; and

  - active support of computer use by the principal, who also perceives his/her role as instructional as opposed to an administrative leader (Hofmeister, 1984; Ragosta et al., 1982).

- Decision Making:

  - selection of specific courseware and, to a lesser extent, hardware in a participatory process involving key individuals (teachers) in the implementation process (Becker, 1983; TURNKEY, 1976-77; Shavelson, 1984); and

  - decentralized and flexible decision making during implementation, especially at the classroom level.

- Training/Support:

  - teachers are trained in the use of specific courseware packages and/or applications prior to actual use in the classroom (TURNKEY, 1983; Shavelson, 1984);

  - for CMI programs, teachers are trained, where necessary, in the functions related to instructional management and individualized instruction (Hofmeister, 1984; Blaschke et al., 1977);

  - in-service training and follow-up support is available on a timely basis to instructional staff (Shavelson, 1984; Blaschke, 1984);

  - training is provided by persons who are or have been in similar teaching situations (Shavelson, 1984; Wagner, 1984); and

  - incentives, such as released time, are provided to teachers for training (Shavelson, 1984; TURNKEY, 1983).

And last, when appropriate courseware is targeted upon specific content areas and students, higher achievement can be expected. For example, drill-and-practice courseware could be targeted upon lower achieving students; adjustable or modifiable courseware for students with specific learning disabilities (e.g., special education); simulations and creative applications with gifted and talented students and high achievers.

D. CLOSING COMMENT

Clearly the current research findings indicate that computer-assisted instruction can increase student achievement in certain areas when quality courseware is used, and when the programs are planned and implemented in an effective manner by school staff. Findings in studies which report that CAI is not as effective as conventional instruction usually also report that the conditions for effective implementation were inadequate or nonexistent. While electronic learning courseware developers and publishers, working with teachers and school staff, can improve the quality of courseware, the effective implementation of programs can be enhanced considerably by training, support, and other assistance on the part of education dealers who are knowledgeable in the use of CAI in operational settings. The future of computer-assisted instruction in education is largely dependent upon the degree to which it meets the bottom line in education -- namely, improving student achievement and performance. Herein lie the challenges and responsibilities which are jointly shared by developers, publishers, dealers, and computer-using school staff.

References

1. Anastasio, Ernest J., and Wilder, Gita Z., "Is Computer-Based Instruction Ready to Move Into the Home?" Paper Presented at Computers in the Home -- New Opportunities and Challenges for Education, National Institute of Education, Washington, D. C., June 1984.

2. Becker, Henry, "School Uses of Microcomputers: Reports From a National Survey," Issues No. 1,2,4,5; 1983, 1984. (Available from Center for Social Organization of Schools, The Johns Hopkins University, Baltimore, Maryland).

3. Blaschke, Charles L., "The Special Ed Market for Computer Products," Educational Dealer, Vol. 8, No. 1, January 1983, pp. 18-20.

4. Blaschke, Charles, and Sweeney, John, "Implementing Effective Educational Technology: Some Reflections," Educational Technology, Vol. 17, January 1977, pp. 13-18.

5. Bracey, Gerald W., "Issues and Problems in Devising a Research Agenda for Special Education and Technology," Paper Presented at Special Education Technology Research and Development Symposium, Sponsored by U. S. Department of Education, Washington, D. C., June 1984.

6. Coulson, J. E. et al., "Effects of Branching in Computer-Controlled Auto-Instructional Devices," Journal of Applied Psychology, Vol. 54, 1970, pp. 384-392.

7. Crandall, N. D., "Computer Assisted Instruction: How it Raises Childrens' Achievement Scores," Internal Report, Los Nietos School District, California, 1977.

8. Dence, Marie, "Toward Defining the Role of CAI: A Review," Educational Technology, Vol. 20, November 1980, pp. 50-54.

9. Education TURNKEY Systems, Inc., "State Leadership Assistance for Technology in Education (Project SLATE), Final Report," Prepared for the U. S. Department of Education, Contrct No. 300-82-0179 (Falls Church, Virginia: Education TURNKEY Systems, Inc., September 1984).

10. Education TURNKEY Systems, Inc., "Assisting LEAs to Adopt New Technology," Prepared for the for U. S. Department of Education, Contract No. 300-81-0337 (Falls Church, Virginia: Education TURNKEY Systems, Inc., March, 1983).

11. Education TURNKEY Systems, Inc., "Development of a Cost-Effective Model for Michigan Compensatory Education Programs," Project Conducted for the Michigan State Department of Education (Falls Church, Virginia: Education TURNKEY Systems, Inc., 1975).

12. Fisher, Glenn, "Where CAI is Effective: A Summary of the Research," Electronic Learning, Vol. 3, Nov/Dec. 1983, pp. 82, 84.

13. Gold, Patricia C., "Educational Software: New Guidelines for Development," AEDS Journal, Vol. 18, No. 1, Fall 1984, pp. 41-50.

14. Hartley, J. R., "Computer Assisted Learning," Human Interactions, ed. H. T. Smith and T. R. G. Green (London: Academic Press, 1980).

15. Ingersoll, Gary M., and Smith, Carl B., "Availability and Growth of Microcomputers in American Schools," T.H.E. Journal, Vol. 12, No. 1, August 1984, pp. 84-87.

16. Kulhavy, W. K., "Feedback and Response Confidence," Journal of Educational Psychology, Vol. 68, No. 5, 1976, pp. 522-528.

17. Kulik, James A., Bangert, Robert L., and Williams, George W., "Effects of Computer-Based Teaching on Secondary School Students," Journal of Educational Psychology, Vol. 75, 1983, pp. 19-26.

18. Kulik, James A., Kulik, Chen-Lin C., and Bangert, Robert L., "Effects of Computer-Based Education on Elementary School Pupils," Paper Presented at the Annual Meeting of the American Educational Research Association, New Orleans, Louisiana, April 1984.

19. Kulik, James A., Kulik, Chen-Lin C., and Cohen, Peter A., "Effectiveness of Computer-Based College Teaching: A Meta-Analysis of Findings," Review of Educational Research, Vol. 50, No. 4, Winter 1980, pp. 525-544.

20. Levin, Henry M., Glass, Gene V., and Merster, Gail R., "Cost-Effectiveness of Four Educational Interventions," Paper Prepared for the National Institute of Education, Contract No. NIE-G-83-0003, Washington, D. C. 1984.

21. Magidson, E. M., "Trends in Computer-Assisted Instruction," Educational Technology, Vol. 18, No. 4, 1978, pp. 5-63.

22. Orlansky, Jesse, "Effectiveness of CAI: A Different Finding," Electronic Learning, Vol. 3, September 1983, pp. 58, 60.

23. Quality Education Data (QED), Report on Computer Usage, (Denver, Colorado: Quality Education Data, 1984).

24. Ragosta, Marjorie, Holland, Paul W., and Jamison, Dean T., "Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study (Executive Summary and Policy Implications)," National Institute of Education, Contract No. 0400-78-0065 (Princeton, New Jersey: Educational Testing Service, 1982).

25. Rankin, R. J., and Trepper, T., "Retention and Delay of Feedback in a Computer-Assisted Instructional Task," Journal of Experimental Education, Vol. 46, No. 4, 1978, pp. 67-70.

26. Ryba, Kenneth A., and Chapman, James W., "Toward Improving Learning Strategies and Personal Adjustment with Computers," The Computing Teacher, Vol. 11, August 1983, pp. 48-53.

27. Shavelson, Richard J. et al., "Teaching Mathematics and Science: Patterns of Microcomputer Use," Prepared for the National Institute of Education (Santa Monica, California: Rand Corporation, 1984).

28. TURNKEY. See Education TURNKEY Systems, Inc.

29. Wagner, W., "Technical Assistance: Nuturing the Computer Education Movement," (San Jose, California: Santa Clara Office of Education, 1984).