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Close-Up #10

Computer-Assisted Instruction

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"There was a time when computers were a luxury item for American schools, but that time has clearly passed." --Bangert-Drowns, Kulik, and Kulik, 1985

INTRODUCTION

Not so long ago, the microcomputer was a rare and exotic sight in American classrooms. Then, during the 1970s, many schools began acquiring microcomputers and putting them to use for instruction, drill and practice, recordkeeping, and other applications.

The use of microcomputers expanded rapidly during the 1980s. Between 1981 and the end of the decade:

- American schools acquired over two million microcomputers.
- The number of schools owning computers increased from approximately 25 percent to virtually 100 percent.
- More than half the states began requiring--or at least recommending--preservice technology programs for all prospective teachers (Kinnaman 1990).

"The ‘information age' has clearly arrived," notes Kinnaman, "and in the '90s the educational use of computer technology will surely continue to grow." While this is no doubt an accurate prediction, many educators, legislators, parents, and researchers have expressed concern about the educational effectiveness of using microcomputers in schools. Because the acquisition of computer hardware and educational software programs involves a considerable monetary investment, these groups want assurance that computers in the schools are more than expensive and entertaining toys; they desire evidence that educational microcomputer use truly enhances learning in demonstrable ways.

Fortunately, a great deal of research has been conducted during the 1970s, 1980s, and early 1990s on the effects of computer use on student achievement, attitudes, and other variables, such as learning rate. This research covers a wide range of topics, from computerized learning activities which supplement conventional instruction, to computer programming, to computerized recordkeeping, to the development of databases, to writing using word processors, and other applications.

The main focus of this report is the most commonly used and most frequently researched kind of educational computer use--computer-assisted instruction (CAI). Findings about other educational computer applications are presented as they relate to this main focus.

DEFINITIONS

It will be helpful, before discussing the research findings, to offer some definitions of CAI and other kinds of learning activities involving computers. As Kulik, Kulik, and Bangert-Drowns point out in their 1985 research summary, "the terminology in the area is open to dispute" (p. 59). This is putting it mildly. Those seeking to make sense of the array of terms used by educators and researchers--computer-assisted instruction, computer-based education, computer-based instruction, computer-enriched instruction, computermanaged instruction--can easily become confused. The following definitions are a synthesis of those offered by Bangert-Drowns, et al. (1985), Batey (1987), Grimes (1977), Samson et al. (1986), and Stennett (1985), and represent commonly accepted (though certainly not the only) definitions of these terms:

- Computer-based education (CBE) and computer-based instruction (CBI) are the broadest terms and can refer to virtually any kind of computer use in educational settings, including drill and practice, tutorials, simulations, instructional management, supplementary exercises, programming, database development, writing using word processors, and other applications. These terms may refer either to stand-alone computer learning activities or to computer activities which reinforce material introduced and taught by teachers.
- Computer-assisted instruction (CAI) is a narrower term and most often refers to drill-and-practice, tutorial, or simulation activities offered either by themselves or as supplements to traditional, teacherdirected instruction.
- Computer-managed instruction (CMI) can refer either to the use of computers by school staff to organize student data and make instructional decisions or to activities in which the computer evaluates students' test performance, guides them to appropriate instructional resources, and keeps records of their progress.
- Computer-enriched instruction (CEI) is defined as learning activities in which computers (1) generate data at the students' request to illustrate relationships in models of social or physical reality, (2) execute programs developed by the students, or (3) provide general enrichment in relatively unstructured exercises designed to stimulate and motivate students.

THE CAI RESEARCH BASE

The findings offered in this summary emerge from an analysis of the 59 research reports cited in the Key References section of the annotated bibliography. Each of these reports documents some relationship(s) between computer-based learning and student outcomes. Twentyeight are research studies, 22 are reviews, and 9 are meta-analyses of research studies. Twelve of the documents focus on elementary students, 19 are concerned with secondary students, 7 cover the elementary-secondary range, 5 involve subjects spanning the elementary-postsecondary range, and the age/grade levels of subjects are not specified in 16 of the reports.

Most of the studies involved American students, but Israeli and Canadian subjects are also represented. Other specific populations serving as subjects in the documents include economically disadvantaged students (4), special education students (5), remedial students (2), and Hispanic students (2). The rest of the documents either concerned general student populations or did not specify characteristics of their subjects.

The 59 reports were concerned with the effects one or more of the following types of educational computer use on student outcomes: CAI (35), CBE in general (15), the use of word processors for written composition (5), computer-managed instruction (3), programming (2), and simulations (4).

The effects of computer use on a large number of outcome areas were examined, including academic achievement in general (30), in mathematics (13), in language arts (8), in reading (3), in science (2), in problem-solving skills (2), and in health and social studies (1 each). Studies also focused on students' attitudes toward the content of courses in which computers were used (21), toward computers themselves (19), toward school in general (6), toward the quality of instruction in courses with computer activities (4), and toward themselves as learners (4). Other outcome areas include learning rate (10), learning retention (9), locus of control and motivation, computer literacy, and cooperation/helping (4 each).

Beyond these outcome-focused reports, the General References section of the bibliography cites 18 additional reports on related topics, such as teacher training to conduct CAI effectively, cost-effectiveness of CAI, discussions of current and potential applications of computers in education, and examinations of students' favorable attitudes toward computer activities.

RESEARCH FINDINGS

MICROCOMPUTER USE AND STUDENT ACHIEVEMENT

The single best-supported finding in the research literature is that the use of CAI as a supplement to traditional, teacher-directed instruction produces achievement effects superior to those obtained with traditional instruction alone. Generally speaking, this finding holds true for students of different ages and abilities and for learning in different curricular areas. As

summarized in Stennett's 1985 review of reviews, "well-designed and implemented D&P [drill-andpractice] or tutorial CAI, used as a supplement to traditional instruction, produces an educationally significant improvement in students' final examination achievement" (p. 7).

(Research support: Bahr and Rieth 1989; Bangert-Drowns 1985; Bangert-Drowns, et al. 1985; Batey 1986; Bracey 1987; Burns and Bozeman 1981; Braun 1990; Capper and Copple 1985; Edwards, et al. 1975; Ehman and Glen 1987; Gore, et al. 1989; Grimes 1977; Hawley, Fletcher, and Piele 1986; Horton, Lovitt, and Slocum 1988; Kann 1987; Kulik, Kulik, and Bangert-Drowns 1985; Martin 1973; Mevarech and Rich 1985; Mokros and Tinker 1987; Office of Technology Assessment 1988; Okey 1985; Ragosta, Holland, and Jamison 1982; Rapaport and Savard 1980; Rupe 1986; Samson, et al. 1986; Stennett 1985; Way 1984; White 1983; Woodward, Carnine, and Gersten 1988.)

Some writers also reported on research which compared the effects of CAI alone with those produced by conventional instruction alone. Here, results are too mixed to permit any firm conclusion. Some inquires have found CAI superior, some have found conventional instruction superior, and still others have found no difference between them.

(Capper and Copple 1985; Edwards, et al. 1975; Rapaport and Savard 1980.)

Other researchers and reviewers compared the achievement effects produced by all forms of computerbased instruction (sometimes alone and sometimes as a supplement to traditional instruction) as compared with the effects of traditional instruction alone. While the research support is not as strong as that indicating the superiority of CAI, the evidence nevertheless indicates that CBE approaches as a whole produce higher achievement than traditional instruction by itself.

(Bangert-Drowns 1985; Bangert-Drowns, et al. 1985; Braun 1990; Hasselbring 1984; Kulik 1983, 1985; Kulik, Bangert, and Williams 1983; Kulik and Kulik 1987; Roblyer, et al. 1988; Swan, Guerrero, and Mitrani 1989.)

This group of findings supports the conclusion drawn by Dalton and Hannafin in their 1988 study to the effect that "while both traditional and computer-based delivery systems have valuable roles in supporting instruction, they are of greatest value when complementing one another" (p. 32).

Researchers concerned with student writing outcomes have determined that writing performance is superior when the teaching approach emphasizes "writing as a process," rather than focusing only on the end product- -the finished composition. The writing-as-a-process approach encourages students to engage in prewriting activities, followed by drafting, revising, editing, and final publication, with each step receiving considerable attention and often feedback from teachers or peer editors.

Word processing programs, with their capability to add, delete, and rearrange text, are seen as being far more congruent with the writing process than more laborious pencil-and-paper

approaches. And indeed, most research in this area indicates that the use of word processors in writing programs leads to better writing outcomes than the use of paper-and-pencil or conventional typewriters. Specific positive outcomes associated with the use of word processors in writing include:

- Longer written samples
- Greater variety of word usage
- More variety of sentence structure
- More accurate mechanics and spelling
- More substantial revision
- Greater responsiveness to teacher and peer feedback
- Better understanding of the writing process
- Better attitudes toward writing
- Freedom from the problem of illegible handwriting.

(Batey 1986; Bialo and Sivin 1990; Collins and Sommers 1984; Dickinson 1986; Kinnaman 1990; MacGregor 1986; Office of Technology Assessment 1988; Parson 1985; Rodriguez and Rodriguez 1986; Sommer and Collins 1984.)

Researchers are careful to point out that these desirable outcomes are obtained when computers are used as part of a holistic, writing-as-a-process approach. Only using computers for drill and practice on isolated subskills, such as grammar and mechanics, is not associated with improved writing achievement. As expressed by Sommers and Collins in their 1984 article on computers and writing, "microcomputers are counterproductive when used in a theoretical vacuum" (p. 7).

LEARNING RATE

As well as enabling students to achieve at higher levels, researchers have also found that CAI enhances learning rate. Student learning rate is faster with CAI than with conventional instruction. In some research studies, the students learned the same amount of material in less time than the traditionally instructed students; in others, they learned more material in the same time. While most researchers don't specify how much faster CAI students learn, the work of Capper and Copple (1985) led them to the conclusion that CAI users sometimes learn as much as 40 percent faster than those receiving traditional, teacher-directed instruction.

(Batey 1986; Capper and Copple 1985; Edwards, et al. 1975; Grimes 1977; Hasselbring 1984; Kulik 1983, 1985; Kulik, Bangert, and Williams 1983; Kulik and Kulik 1987; Rapaport and Savard 1980; Rupe 1986; Stennett 1985; White 1983.)

RETENTION OF LEARNING

If students receiving CAI learn better and faster than students receiving conventional instruction alone, do they also retain their learning better? The answer, according to researchers who have conducted comparative studies of learning retention, is yes. In this research, student scores on delayed tests indicate that the retention of content learned using CAI is superior to retention following traditional instruction alone.

(Capper and Copple 1985; Grimes 1977; Kulik 1985; Kulik, Bangert, and Williams 1983; Kulik, Kulik, and Bangert-Drowns 1985; Rupe 1986; Stennett 1985; Woodward, Carnine, and Gersten 1988.)

ATTITUDES

Much of the research that examines the effects of CAI and other microcomputer applications on student learning outcomes also investigates effects upon student attitudes. This line of inquiry has brought most researchers to the conclusion that the use of CAI leads to more positive student attitudes than the use of conventional instruction. This general finding has emerged from studies of the effects of CAI on student attitudes toward:

- Computers and the use of computers in education (Batey 1986; Ehman and Glen 1987; Hasselbring 1984; Hess and Tenezakis 1971; Kulik 1983, 1985; Kulik, Bangert, and Williams 1983; Roblyer 1988; Way 1984)
- Course content/subject matter (Batey 1986; Braun 1990; Dalton and Hannafin 1988; Ehman and Glen 1987; Hounshell and Hill 1989; Rapaport and Savard 1980; Roblyer, et al. 1988; Rodriguez and Rodriguez 1986; Stennett 1985)
- Quality of instruction (Kulik, Bangert, and Williams 1983; Kulik and Kulik 1987; Rupe 1986; White 1983)
- School in general (Batey 1986; Bialo and Sivin 1990; Ehman and Glen 1987; Roblyer, et al. 1988)
- Self-as-learner (Bialo and Sivin 1990; Mevarech and Rich 1985; Robertson, et al. 1987; Rupe 1986).

OTHER BENEFICIAL EFFECTS

The effects of CAI on other student outcomes have not been as extensively researched as CAI's effects on achievement, learning rate, retention, and attitudes. Some researchers have, however, investigated CAI's influence on other variables and found it to confer benefits on:

- Locus of control. Capper and Copple (1985), Kinnaman (1990), and Louie (1985) found that CAI students have more of an internal locus of control/sense of self-efficacy than conventionally instructed students.
- Attendance. CAI students had better attendance in Capper and Copple's 1985 study, Rupe's 1986 review, and the 1990 ISTE study.
- Motivation/time-on-task. Bialo and Sivin (1990) and Capper and Copple (1985) found that CAI students had higher rates of time-on-task than traditionally instructed controls.
- Cooperation/collaboration. Cooperative, prosocial behavior was greater with CAI in the work of Dickinson (1986); Mevarech, Stern, and Levita (1987); and Rupe (1986).

CAI AND DIFFERENT STUDENT POPULATIONS

Is CAI more effective with some student populations than others? Many researchers have conducted comparative analyses to answer this question and have produced findings in several areas.

Younger versus older students. Most comparative studies have shown that CAI is more beneficial for younger students than for older ones. While research shows CAI to be beneficial to students in general, the degree of impact decreases from the elementary to secondary to postsecondary levels.

(Bangert-Drowns 1985; Bangert-Drowns, et al. 1985; Becker 1990; Bracey 1987; Ehman and Glen 1987; Hasselbring 1984; Kulik, Kulik, and Bangert-Drowns 1985; Okey 1985; Stennet 1985; Swan, Guerrero, and Mitrani 1989.)

Lower-achieving versus higher-achieving students. These comparisons show that CAI is more effective with lower-achieving students than with higher-achieving ones. Again, both lower- and higher-achieving students benefit from CAI. However, the comparatively greater benefits experienced by lower-achieving students, like those experienced by younger students, are largely due to the need these groups have for elements common to the majority of CAI programs--extensive drill and practice, privacy, and immediate feedback and reinforcement.

(Bangert-Drowns 1985; Bangert-Drowns, et al. 1985; Edwards, et al. 1975; Kinnaman 1990; Kulik, Kulik, and Bangert-Drowns 1985; Martin 1973; Okey 1985; Roblyer 1988.)

Economically disadvantaged versus higher-SES students. Researchers note that CAI confers greater benefits on economically disadvantaged students than those from more privileged backgrounds. Lower SES students, too, benefit greatly from opportunities to interact privately with CAI drill-and-practice and tutorial programs.

(Bangert-Drowns, et al. 1985; Becker 1990; Mevarech and Rich 1985; Ragosta, Holland, and Jamison 1982; Stennett 1985.)

Lower- versus higher-cognitive outcomes. Closely related to the above is the finding that CAI is more effective for teaching lower-cognitive material than higher-cognitive material. This research makes essentially the same point--that CAI is particularly effective for reinforcing the basic, fact-oriented learning most often engaged in by younger, lowerachieving, and/or lower SES students.

(Ehman and Glen 1987; Hasselbring 1984; Schmidt, et al. 1985-86.)

Handicapped learners. Research conducted with learning disabled, mentally retarded, hearing impaired, emotionally disturbed, and language disordered students indicates that their achievement levels are greater with CAI than with conventional instruction alone. In some of this research, handicapped CAI students even outperformed conventionally taught, nonhandicapped students.

(Bahr and Rieth 1989; Bialo and Sivin 1990; Hall, McLoughlin, and Bialozor 1989; Horton, Lovitt, and Slocum 1988; Schmidt, et al. 1985-86; Woodward, Carnine, and Gersten 1988.)

Males versus females. This comparison was not addressed by enough researchers to draw firm conclusions. The 1988 meta-analysis of 82 studies of CBE conducted by Roblyer, et al. concluded that effect differences slightly favor boys over girls, with differences falling short of statistical significance.

CAI AND DIFFERENT CURRICULAR AREAS

A few researchers undertook to compare the effectiveness of CAI in different curricular areas. Their findings, though not conclusive, indicate that CAI activities are most effective in the areas of science and foreign languages, followed, in descending order of effectiveness, by activities in mathematics, reading, language arts, and English as a Second Language, with CAI activities in ESL found to be largely ineffective.

(Capper and Copple 1985; Kulik, Kulik, and BangertDrowns 1985, Roblyer, et al. 1988; Rodriguez and Rodriguez 1986.)

WHY STUDENTS LIKE CAI

An earlier section of this report offers research evidence showing that CAI enhances student attitudes toward several aspects of schooling. Some researchers took these investigations a step further by asking students what it is about CAI that they like. The following is a list of reasons given by students for liking CAI activities and/or favoring them over traditional learning. These student preferences also contribute to our understanding of why CAI enhances achievement.

Students say they like working with computers because computers:

- Are infinitely patient
- Never get tired
- Never get frustrated or angry
- Allow students to work privately
- Never forget to correct or praise
- Are fun and entertaining
- Individualize learning
- Are self-paced
- Do not embarrass students who make mistakes
- Make it possible to experiment with different options
- Give immediate feedback
- Are more objective than teachers
- Free teachers for more meaningful contact with students
- Are impartial to race or ethnicity
- Are great motivators
- Give a sense of control over learning
- Are excellent for drill and practice

- Call for using sight, hearing, and touch
- Teach in small increments
- Help students improve their spelling
- Build proficiency in computer use, which will be valuable later in life
- Eliminate the drudgery of doing certain learning activities by hand (e.g., drawing graphs)
- Work rapidly--closer to the rate of human thought.

(Bialo and Sivin 1990; Braun 1990; Lawton and Gerschner 1982; Mokros and Tinker 1987; Robertson, et al. 1987; Rupe 1986; Schmidt, et al. 1985-86; Wepner 1990.)

Many of these items point to students' appreciation of the immediate, objective, and positive feedback provided by computer learning activities by comparison with teacher-directed activities. As Robertson, et al. (1987) point out:

"This reduction in negative reinforcement allows the student to learn through trial and error at his or her own pace. Therefore, positive attitudes can be protected and enhanced" (p. 314).

COST-EFFECTIVENESS

While cost considerations are not a major focus of this report, it is worth noting that some of the research on effectiveness also addressed the cost-effectiveness of CAI and other computer applications. Ragosta, Holland, and Jamison (1982) concluded that equal amounts of time of CAI reinforcement and the more-expensive one-to-one tutoring produced equal achievement effects. Niemiec, Sikorski, and Walberg (1989) also found CAI activities significantly more cost-effective than tutoring and suggested that computers be used more extensively in schools. And in their 1986 study of costs, effects, and utility of CAI, Hawley, Fletcher, and Piele noted that the cost differences between CAI and traditional instruction were insignificant and concluded that "the microcomputer-assisted instruction was the costeffective alternative of choice" for both grades
addressed in the study (p. 22).

SUMMARY

The research base reviewed in preparation for this report indicates that:

- The use of CAI as a supplement to conventional instruction produces higher achievement than the use of conventional instruction alone.
- Research is inconclusive regarding the comparative effectiveness of conventional instruction alone and CAI alone.
- Computer-based education (CAI and other computer applications) produce higher achievement than conventional instruction alone.

- Student use of word processors to develop writing skills leads to higher-quality written work than other writing methods (paper and pencil, conventional typewriters).
- Students learn material faster with CAI than with conventional instruction alone.
- Students retain what they have learned better with CAI than with conventional instruction alone.
- The use of CAI leads to more positive attitudes toward computers, course content, quality of instruction, school in general, and self-as-learner than the use of conventional instruction alone.
- The use of CAI is associated with other beneficial outcomes, including greater internal locus of control, school attendance, motivation/time-on-task, and student-student cooperation and collaboration than the use of conventional instruction alone.
- CAI is more beneficial for younger students than older ones.
- CAI is more beneficial with lower-achieving students than with higher-achieving ones.
- Economically disadvantaged students benefit more from CAI than students from higher socioeconomic backgrounds.
- CAI is more effective for teaching lower-cognitive material than higher-cognitive material.
- Most handicapped students, including learning disabled, mentally retarded, hearing impaired, emotionally disturbed, and language disordered, achieve at higher levels with CAI than with conventional instruction alone.
- There are no significant differences in the effectiveness of CAI with male and female students.
- Students' fondness for CAI activities centers around the immediate, objective, and positive feedback provided by these activities.
- CAI activities appear to be at least as costeffective as--and sometimes more cost-effective than-- other instructional methods, such as teacher-directed instruction and tutoring.

"Most programs of computer-based instruction evaluated in the past," wrote Kulik and Kulik in 1987 "have produced positive effects on student learning and attitudes. Further programs for developing and implementing computer-based instruction should therefore be encouraged." Based on review of the research evidence published both before and after Kulik and Kulik's paper, the present report strongly supports this conclusion.

KEY REFERENCES

Bahr, C. M., and Rieth, H. J. "The Effects of Instructional Computer Games and Drill and Practice Software on Learning Disabled Students' Mathematics Achieve-ment." Computers in the Schools 6/3-4 (1989): 87-101.

Compares the effects of conventional instruction, computerized drill and practice, and computer games on the mathematics achievement of learning disabled junior and senior high school students. Students in the drill-and-practice condition outperformed other students to a modest degree.

Bangert-Drowns, R. L. Meta-Analysis of Findings on Computer-Based Education with Precollege Students. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL, MarchApril 1985. (ED 263 905)

Offers meta-analysis results of 74 studies on the use of computer-based education with elementary and secondary students. CBE was found to be beneficial overall, with elementary students reaping greater achievement benefits from CAI than secondary students, the reverse being true with CMI, and CEI being generally ineffective.

Bangert-Drowns, R. L.; Kulik, J. A.; and Kulik, C. C. "Effectiveness of Computer-Based Education in Secondary Schools." Journal of Computer-Based Instruction 12/3 (1985): 59-68.

Presents the results of a meta-analysis of 42 studies. Computer-assisted and computer-managed instruction had very beneficial effects on achievement, while computer-enriched instruction had only modest positive effects. All forms of CBE had positive effects on student attitudes toward computers and toward courses which included computer activities.

Batey, A. Building a Case for Computers in Elementary Classrooms: A Summary of What the Researchers and the Practition-ers Are Saying. Paper presented at the Second Leadership in Computer Education Seminar, Seattle, WA, December 1986.

Reviews research on computer-assisted instruction, the use of computers in language arts, computer games, and the use of computerized tools such as databases, spreadsheets, and science lab interfaces. Reports positive effects of all kinds of computer use with elementary students.

Becker, H. J. The Impact of Computer Use on Children's Learning: What Research Has Shown and What It Has Not. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC, 1987. (ED 287 458)

Examines findings from surveys and research studies to determine the effects of CAI and other computer applications on student achievement. Finds that most studies are too flawed to permit reliable conclusions and suggests new directions for future research.

Becker, H. J. When Powerful Tools Meet Conventional Beliefs and Institutional Constraints: National Survey Findings on Computer Use by American Teachers. Baltimore, MD: Center for Social Organization of Schools, Johns Hopkins University, September 1990.

Summarizes the author's own recent research and that of others to determine the nature, extent, and effectiveness of computer use in public schools. Cites disappointing results and attributes these to individual and institutional resistance to the kinds of changes that would lead to more productive use of computer technology.

Bialo, E., and Sivin, J. Report on the Effectiveness of Microcomputers in Schools. Washington, DC: Software Publishers Association, 1980.

Reviews research on the impact of educational microcomputer use on student achievement, motivation, and attitudes, as well as their effects on classroom social interaction and the learning environment. Results are generally favorable, with effects differing by subject area, student characteristics, software design, and other variables.

Bracey, G. W. "Computer-Assisted Instruction: What the Research Shows." Electronic Learning 7/3 (1987): 22-23.

Provides a brief summary of research conducted since the author's previous review on this topic, conducted in 1982. Main findings: 85-95 percent of studies show positive effects of CAI, and the effectiveness of CAI decreases from the elementary to secondary to postsecondary level.

Braun, L. Vision: TEST (Technologically Enriched Schools of Tomorrow) Final Report: Recommendations for American Educational Decision Makers. Eugene, OR: The International Society for Technology in Education, October 1990.

Reports the outcomes of a study of the potential that technology offers to education, including information on achievement effects, potential social and economic benefits, recommendations for educational decision makers, and suggestions for implementing those recommendations.

Burns, P. K., and Bozeman, W. C. "Computer-Assisted Instruction and Mathematics Achievement: Is There a Relationship?" Educational Technology 21/10 (1981): 32-39.

Presents the results of a meta-analysis of 40 studies to compare the effectiveness of traditional instruction alone with a combination of traditional instruction and computer-assisted instruction on students' mathematics achievement. The combined traditional-CAI approach was significantly more effective.

Campbell, D. L.; Peck, D. L.; Horn, C. J.; and Leigh, R. K. "Comparison of Computer-Assisted Instruction and Print Drill Performance: A Research Note." Educational Communication and Technology Journal 35/2 (1987): 95-103.

Compares the mathematics performance of third graders using a commercial computerized drill and practice program with that of similar students using a conventional print drill program. There were no statistically significant differences between groups.

Capper, J., and Copple, C. Computer Use in Education: Research Review and Instructional Implications. Washington, DC: Center for Research into Practice, 1985.

Discusses CAI and programming, the most common instructional uses of computers in school settings. Presents information on costs and equity issues, and offers implications for curriculum, instruction, and policy. Includes a summary of research reviews on the effects of CAI on student outcomes.

Collins, J. L., and Sommers, E. A. (eds.). Writing OnLine: Using Computers in the Teaching of Writing. Montclair, NJ: Boynton/Cook, 1984.

Summarizes research on the use of computers in teaching composition and presents methods for integrating computer use into the writing curriculum. Supports the use of computerized word processing programs as part of a holistic writing program; does not support the use of drill-and-practice programs for teaching isolated subskills.

Dalton, D. W., and Hannafin, M. J. "The Effects of Computer-Assisted and Traditional Mastery Methods on Computation Accuracy and Attitudes." Journal of Educational Research 82/1 (1988): 27-33.

Compares the effects of five different instructional approaches involving the use of mastery and nonmastery methods and computerized or teacher-directed instruction. The subjects, eighth grade math students, performed best with mastery treatments and when remedial instruction varied from initial instruction. There were no differences between CAI students and those receiving teacher-directed instruction.

Dickinson, D. K. "Cooperation, Collaboration and a Computer: Integrating a Computer into a First-Second Grade Writing Program." Research in the Teaching of English 20/4 (1986): 357-378.

Presents a review of research on the use of microcomputers in writing programs, followed by the report of a study conducted with primary-age children. The use of the microcomputer for teaching writing fostered cooperation and collaboration among students.

Edwards, J.; Norton, S.; Taylor, S.; Weiss, M.; and Dusseldorp, R. "How Effective is CAI? A Review of the Research." Educational Leadership 33/2 (1975): 147- 153.

Reviews research on the effects of CAI on achievement, retention, and learning rate and its effects on students of different ability levels. CAI as a supplement to traditional, teacher-directed instruction was found to be very beneficial.

Ehman, L. H., and Glen, A. D. Computer-Based Education in the Social Studies. Bloomington, IN: Indiana University, 1987.

Discusses the types of computer software available to supplement social studies instruction, teacher training needs, research findings on the different kinds of CAI used with social studies curricula, cost considerations, and other topics.

Gore, D. A.; Morrison, G. N.; Maas, M. L.; and Anderson. E. A. "A Study of Teaching Reading Skills to the Young Child Using Microcomputer-Assisted Instruction." Journal of Educational Computing Research 5/2 (1989): 179-185.

Investigates the effectiveness of reinforcing basic reading skills and teaching computer literacy skills to five-year-old children through use of a drill-andpractice software program. Results indicated that the CAI program was effective in developing both kinds of skills in subjects.

Grimes, D. M. Computers for Learning: The Uses of Computer Assisted Instruction (CAI) in California Public Schools. Sacramento, CA: California State Department of Education, 1977.

Discusses several aspects of the use of CAI in California schools, including findings regarding its effectiveness, obstacles to its use, cost factors, instructional potential, and sources of additional information.

Hall, E. R.; McLaughlin, T. F.; and Bialozor, R. C. "The Effects of Computer-Assisted Drill and Practice on Spelling Performance with Mildly Handicapped Students." Reading Improvement 26/1 (1989): 43-49.

Reports the results of a study in which computerassisted instruction was used with mildly handicapped elementary students. The spelling achievement scores of CAI participants was significantly greater than the scores of conventionally instructed students, and half the CAI students had scores equal to those of their nonhandicapped peers.

Hasselbring, T. Research on the Effectiveness of Computer-Based Instruction: A Review. Technical Report No. 84.1.3. Nashville, TN: George Peabody College for Teachers, Learning Technology Center, 1984. (ED 262 754)

Summarizes results of research studies and metaanalyses on the effects of computer-based instruction on student achievement and attitudes. Results favor the use of CBI over traditional instruction.

Hawley, D. E.; Fletcher, J. D.; and Piele, P. K. Costs, Effects, and Utility of Microcomputer-Assisted Instruction. Eugene, OR: University of Oregon, 1986.

Reports results of a study that involved implementing computer-assisted instruction with Canadian third and fifth graders. Although subtest results were mixed, the "total mathematics" posttests of CAI students were significantly higher than those of students receiving traditional instruction only.

Hess, R. D., and Tenezakis, M. D. Selected Findings from "The Computer as a Socializing Agent: Some Socioaffective Outcomes of CAI." Stanford, CA: Stanford University School of Education, 1971.

Compares attitudes of junior high school CAI participants with those of nonparticipants toward teachers, computers, and other sources of information. Both groups had a more favorable view of computers than teachers, textbooks or television news.

Horton, S. V.; Lovitt, T. C.; and Slocum, T. "Teaching Geography to High School Students with Academic Deficits: Effects of a Computerized Map Tutorial." Learning Disability Quarterly 11/4 (1988): 371-379.

Compares the achievement of ninth grade learning disabled and remedial geography students, who used an atlas and work map to learn the location of Asian cities, with the achievement of similar students, who learned via a computerized map tutorial. The computerized map tutorial produced significantly higher performance.

Hounshell, P. B., and Hill, S. R., Jr. "The Microcomputer and Achievement and Attitudes in High School Biology." Journal of Research in Science Teaching 26/6 (1989): 543-549.

Compares the achievement and attitudes of students participating in a "computer-loaded" biology course with those participating in traditional biology instruction. Students using the computer simulations had significantly better achievement and attitudes than those in the conventional setting.

Kann, L. K. "Effects of Computer-assisted Instruction on Selected Interaction Skills Related to Responsible Sexuality." Journal of School Health 57/7 (1987): 282-287.

Compares the effects of CAI, regular classroom instruction, and no instruction on the knowledge, attitudes, and behavior of secondary students in three areas related to responsible sexuality--decision making, assertiveness, and interpersonal communication. CAI students significantly outperformed other groups on most measures.

Kinnaman, D. E. "What's the Research Telling Us?" Classroom Computer Learning 10/6 (1990): 31-35; 38-39.

Provides summaries of research studies and projects concerning computers in education. Topics include effects of CAI on student achievement, computer coordinators as change agents, using "guided inquiry" rather than recitation in classrooms, software evaluation, networking, and different types of reinforcement provided by educational software.

Kinzie, M. B.; Sullivan, H. J.; and Berdel, R. L. "Learner Control and Achievement in Science ComputerAssisted Instruction." Journal of Educational
Psychology 80/3 (1988): 299-303.

Compares the test performance of eighth grade science students who engaged in a learner-controlled CAI lesson with those who participated in a program-controlled lesson. Those in the learner-controlled condition significantly outperformed program-controlled subjects.

Kulik, J. Consistencies in Findings on Computer-Based Education. Paper presented at the Annual Meeting of the American Educational Research Association, April 1985. (ED 263 880)

Reports the results of three meta-analyses of research on computer-based education at the elementary, secondary, and postsecondary levels. Found CBE superior to traditional instruction

in its effects on achievement, retention, learning rate, and attitudes toward computers and courses.

Kulik, J. A. "Synthesis of Research on Computer-Based Instruction." Educational Leadership 41/1 (1983): 19- 21.

Provides the results of a meta-analysis of 48 comparative studies of the effects of computer-based instruction. CBI was found to be moderately better than traditional methods in promoting achievement, had moderately positive effects on academic attitudes, and very positive effects on attitudes toward computers.

Kulik, J. A.; Bangert, R. L.; and Williams, G. W. "Effects of Computer-Based Teaching on Secondary School Students." Journal of Educational Psychology 75/1 (1983): 19-26.

Presents the results of a meta-analysis of 51 studies on the effects of computer-based teaching on students in grades 6-12. In general, computer-based instruction was favored over conventional instruction to a moderate degree.

Kulik, J. A., and Kulik, C. C. Computer-Based Instruction: What 200 Evaluations Say. Paper presented at the Annual Convention of the Association for Educational Communications and Technology, Atlanta, GA, February-March 1987. (ED 285 521)

Presents results from an examination of 199 studies of computer-based instruction at the elementary, secondary, university, and adult education levels. Reports favorable results for student achievement on standardized tests, learning time, attitude toward instruction and toward computers. Attitude toward subject matter was unaffected.

Kulik, J. A.; Kulik, C. C.; and Bangert-Drowns, R. L. "Effectiveness of Computer-Based Education in Elementary Schools." Computers in Human Behavior 1/1 (1985): 59-74.

Offers findings of a meta-analysis of 32 studies of the comparative effects of computer-based instruction (CBI) and non-computer-based instruction. Computerassisted instruction (CAI) had a significant, positive effect on achievement. Computer-managed instruction (CMI) had only a small, nonsignificant effect.

Lawton, J., and Gerschner, V. T. "A Review of the Literature on Attitudes Towards Computers and Computerized Instruction." Journal of Research and Development in Education 16/1 (1982): 50-55.

Reviews research and other literature on students' responses to CAI. Findings are mixed due to diversity in computer software and learning programs, confusion over computer-related terminology, different study methodologies, and computer phobias on the part of many teachers. Most studies concerned students use of computers for drill-and-practice activities.

Lopez, C. L., and Harper, M. "The Relationship Between Learner Control of CAI and Locus of Control Among Hispanic Students." Educational Technology Research and Development 37/4 (1989): 19-28.

Examines the connection between degree of control of CAI lessons, locus of control (LOC), and achievement of Hispanic junior high students. Although it was expected that internal LOC students would outperform external LOC students in the maximum-control situation, this was not the case.

Louie, S. Locus of Control Among Computer-Using School Children. A Report of a Pilot Study. Tucson, AZ: National Advisory Council for Computer Implementation in Schools, 1985. (ED 260 692)

Reports the results of a study undertaken to determine the effects of microcomputer learning activities on the locus of control of students 9-15 years old. Children 12 and younger exhibited a shift toward internal locus of control, presumably because of the empowering effects of the computer activities.

MacGregor, S. K. "Computer-Assisted Writing Environments for Elementary Students." Proceedings NECC ‘86 (Proceedings of the National Educational Computing Conference). Eugene, OR: International Council for Computers in Education, 1986.

Examines the effects of using a word processor on the language arts achievement of sixth graders. Participants outperformed paper-and-pencil-using controls on measures of writing mechanics, spelling accuracy, word usage and narrative length.

Martin, G. R. TIES Research Project Report: The 1972- 73 Drill and Practice Study. St. Paul, MN: Minnesota School District Data Processing Joint Board, 1973.

Investigates the effects of a computerized drill-andpractice program on the achievement and attitudes of third and fourth grade students of different ability levels. Participants outperformed controls, and lowability students gained more than middle- or highability students. No attitude differences were noted.

Mevarech, A. R., and Rich, Y. "Effects of ComputerAssisted Mathematics Instruction on Disadvantaged Pupils' Cognitive and Affective Development." Journal of Educational Research 79/1 (1985): 5-11.

Compares the effects of CAI and traditional instruction on the mathematics achievement and attitudes of disadvantaged Israeli students in grades 3, 4, and 5. The achievement of CAI participants was higher, and their attitudes toward school and toward themselves as math learners were more positive.

Mevarech, Z. R.; Stern, D.; and Levita, I. "To Cooperate or Not to Cooperate in CAI: That Is the Question." Journal of Educational Research 80/3 (1987): 164-167.

Compares the achievement, attitudes, and level of prosocial orientation of students engaging in CAI language arts lessons in pairs with those who participated individually. Paired students outperformed individual learners on all measures.

Mikkelsen, V. P.; Gerlach, G.; and Robinson, L. "Can Elementary School Students Be Taught Touchtyping in Unsupervised Environments?" Reading Improvement 26/1 (1989): 58-63.

Compares the effectiveness of a supervised and an unsupervised microcomputer tutorial program for teaching keyboarding skills to students in grades 3-6. The program was found to increase keyboarding speed and accuracy and to be equally effective for both conditions, all grade levels, both sexes, and for students with and without previous keyboarding experience.

Mokros, J. R., and Tinker, R. F. "The Impact of Microcomputer-Based Labs on Children's Ability to Interpret Graphs." Journal of Research in Science Teaching 24/4 (1987): 369-383.

Presents the results of three studies designed to determine the effects of microcomputer laboratory activities on the graphing skills of middle school students. Participants' skill increases were significantly higher following lab activities.

Okey, J. R. The Effectiveness of Computer-Based Education: A Review. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, April 1985. (ED 257 677)

Reviews nine reviews and meta-analyses on the effectives of computer-based education. Major finding: CBE is effective in promoting learning, particularly when used to supplement traditional, teacher-directed instruction.

Ragosta, M.; Holland, P. W.; and Jamison, D. T. Computer-Assisted Instruction and Compensatory Education: The ETS/LAUSD Study. The Executive Summary and Policy Implications. Princeton, NJ: Educational Testing Service, 1982.

Presents the results of a four-year study conducted in four Los Angeles elementary schools on the use of CAI for compensatory education. Participants engaged in drill-and-practice activities in reading, mathematics, and language arts.

Rapaport, P., and Savard, W. G. Computer-Assisted Instruction. Topic Summary Report. Portland, OR: Northwest Regional Educational Laboratory, 1980. (ED 214 707)

Reviews and synthesizes research on the effects of CAI on student achievement, attitudes, and learning rate. Found traditional instruction supplemented by CAI superior to either method alone, and found CAI to be beneficial to student attitudes and learning rates.

Robertson, E. B.; Ladewig, B. H.; Strickland, M. P.; and Boschung, M. D. "Enhancement of Self-Esteem Through the Use of Computer-Assisted Instruction." Journal of Educational Research 80/5 (1987): 314-316.

Reviews research on the self-esteem effects of CAI, then compares the self-esteem scores of eighth and ninth grade students receiving only traditional instruction with the scores of students whose instruction was supplemented with CAI activities. CAI participants had significantly higher self-esteem ratings than control students.

Roblyer, M. D. "The Effectiveness of Microcomputers in Education: A Review of the Research from 1980-1987." Technological Horizons in Education Journal 16/2 (1988): 85-89.

Summarizes a meta-analysis described in detail in Roblyer, et al. 1988 (see entry below).

Roblyer, M. D. The Impact of Microcomputer-Based Instruction on Teaching and Learning: A Review of Recent Research. Syracuse, NY: ERIC Clearinghouse on Information Resources, 1989. (ED 315 063)

Offers a summary of the Roblyer, et al. (1988) metaanalysis cited below.

Roblyer, M. D.; Castine, W. H.; and King, F. J. Assessing the Impact of Computer-Based Instruction: A Review of Recent Research. New York: Haworth Press, 1988.

Describes the methodology and findings from a metaanalysis of 82 studies and dissertations on the use of microcomputers in education from the elementary through college and other adult levels. Research generally indicates favorable achievement effects, but with some notable exceptions, such as ESL.

Rodriguez, D., and Rodriguez, J. J. Teaching Writing with a Word Processor, Grades 7-13. Urbana, IL: ERIC Clearinghouse on Reading and Communication Skills and National Council of Teachers of English, 1986.

Presents research findings and implementation guidelines regarding the use of word processing programs in composition instruction. A series of lesson ideas is appended.

Rupe, V. S. A Study of Computer-Assisted Instruction: Its Uses, Effects, Advantages, and Limitations. South Bend, IN: Indiana University, 1986. (ED 282 513)

Reviews research on the effects of CAI, as well as reviewing literature on other aspects of computer use in education. Reports favorable results regarding CAI and achievement, attitudes, learning time requirements, learning retention, social development, and selfesteem.
