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ABSTRACT

This paper contains summaries of the findings of research and meta analyses conducted on the effectiveness of computer-based instruction (CBI) on student achievement. Eight conclusions, based on the CBI research are then given: (1) when CBI and traditional instruction are compared, students receiving CBI demonstrate equal or better achievement; (2) equal or better achievement using CBI is obtained in less time; (3) the use of CBI improves student attitudes towards the use of computers in learning situations; (4) the positive effect on learning achievement occurs regardless of the type of CBI used, the type of computer system, or the age of the students; (5) teacher interaction proves to be effective in CBI situations; (6) there is little evidence to support the claim that learning to program will result in higher level cognitive skills and capabilities to learn; (7) tutorial and drill modes seem to be more effective for low-ability students than for middle- or high-ability students; and (8) the effect on learning achievement seems to be greatest for pre-college age learners. Research findings are also presented for social development factors and the cost effectiveness of CBI, and a summary statement and 27-item bibliography conclude the document. (JB)

Research on the Effectiveness of Computer-Based Instruction: A Review

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The technological revolution of the past two decades has created a number of new information technologies, these include televison, video recording devices, laser discs, and microcomputers. Clearly, microcomputers are the dominant technology in education today. The microcomputer is the most versatile of the technologies previoulsy listed. It has the distinction, when compared to other technologies, of being highly interactive. In this review, we will examine research on the effectiveness of computer-based instruction on student achievement.

Effectiveness of Computer-Based Instruction

Microcomputers are so new to the day-to-day aspects of education that a research base which provides some insight into the effectiveness of this new technology is limited. While we have a short history of using microcomputers in the classroom and very little empirical evidence to support our intuitions concerning how best to use this technology, there is a twenty-year history of experience with and research on the use of mainframe and mini-computers to instruct students. We will include here research on micro, mini, and main-frame computers. It seems resonable that much of what was learned in the past two decades from research on larger computers can be applied to today's microcomputers.

Evaluative Studies

Soon after the introduction of computer-based instruction (CBI), researchers began to design studies which attempted to determine the effectiveness of CBI when compared to traditional instruction. In one of the first large-scale evaluative studies, Suppes and Morningstar (1968), compared the Stanford Achievement Test scores of 925 students who were given an average of ten minutes daily of CBI math computation instruction with those of 1028 control students who received traditional instruction. In four California schools across all elementary grade levels, CBI produced equivalent or superior results when effects were corrected for time spent in instruction. Students across all grade levels in an elementary school in Mississippi who received CBI instruction showed significant increases in their test performances when compared with control students.

Atkinson (1968), conducted a similar comparison where 100 first graders received 20 minutes of daily computer based instruction in math. In this comparison, CBI was superior to the traditional instruction provided to a control group. In a later study of 50 matched pairs of male and female primary grade students, significant gains occurred only in the male group (Fletcher & Atkinson, 1972).

The Educational Testing Service (Alderman, 1978; Murphy & Rhea-Appel,

1977) evaluated the implementation of two major computer-based instructional systems in community colleges, PLATO (Programmed Logic for Automatic Teacher Operations) and TICCIT (Time-shared, Interactive, Computer-Controlled, Information Television). The two projects differ in several ways. PLATO is a large educational network supporting nearly 1000 terminals, each accessing content from a central library. Classroom teachers, coordinated by PLATO central staff, are involved in the preparation of the lessons. TICCIT, on the other hand, is a small, local computer-assisted instruction (CAI) facility using minicomputers and televison receivers. Teams of specialists, including teachers, produce the courseware. Both systems successfully produced advanced instructional systems capable of serving many students at one time. However, results of the evaluations are mixed.

The PLATO evaluation covered five fields: accounting, biology, chemistry, English, and mathematics. Computer use in these fields represented supplemental or replacement instruciton for regular classroom work; in no cases were the PLATO programs in lieu of entire courses. The findings indicated a significant positive achievement effect for PLATO versus traditional classroom procedures in the area of mathematics. However, no further significant achievement effects were found for any other subjects, either in favor of PLATO or in favor of the traditional instruction (Murphy and Rhea-Appel, 1977).

The TICCIT evaluation concerned both mathematics and English courses.

These applications represented entire courses, although the English TICCIT program included much more personal interaction between students and faculty than did the mathematics course. The results of the mathematics evaluation comparing the TICCIT courses to the traditional instruction indicated a significant achievement effect of TICCIT over the regular classroom, although fewer TICCIT students completed the course within the semester than did those of the regular classroom. Additionally, more students had favorable attitudes toward the lecture classes than towards the computer approach.

The results of the English evaluation also indicated a significant achievement effect in favor of the TICCIT approach, and the completion rate for TICCIT students was the same as traditional instruction students. Additionally, there were not significant attitude differences in favor of either approach (Alderman, 1978).

While the early evaluation studies produced some valuable information on the effects of computer-based instruction, the results from the studies were inconsistent and the conclusions drawn by the investigators were often unclear. In an attempt to gain a better understanding of the effect of CBI on achievement, reviews were written to bring the separately published studies together to reveal the common findings. These early reviews used a "box-score" technique for integrating the results. These box-score reviews generally reported the proportion of studies which were favorable and unfavorable toward CBI, as well as, narrative comments on the studies.

Box-Score Reviews

In one of the first box-score reviews, Vinsonhaler and Bass (1972) summarized the results of ten major studies conducted from 1967 to 1970 involving CBI drill and practice with more than 10,000 elementary school children from different sections of the country. The investigators concluded that children who received computerized drill and practice generally showed performance gains of 1 to 8 months over control children who received only traditional instruction.

The Vinsonhaler and Bass conclusions were supported in a later review by Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) who evaluated the effects of drill and practice, problem-solving, simulation, and tutorial computer instruction programs for producing achievement gains in school children. Based upon results from six studies, they concluded that CBI plus traditional instruction was more effective than traditional instruction alone. CBI as a substitute for traditional instruction produced positive effects in nine studies and no difference compared with traditional instruction in eight others. Two studies in this review indicated that CBI drill and practice programs were more effective for low-ability students than for children functioning in the average range. These reviewers noted that CBI reduced the time it took students to learn, in addition, they concluded that CBI produced better results than did traditional instruction on end-of-course examinations, but not on retention examinations.

Jamison, Suppes, and Wells (1974) concluded that when CBI was used as a supplement to traditional instruction at the elementary level, achievement scores were improved, especially for disadvantaged students. At the secondary and college level, the investigators concluded that CBI was at least as effective as traditional instruction, and in some cases, CBI resulted in a substantial savings in student time.

While the box-score reviews provided additional insight into the fundamental questions regarding the effectiveness of CBI, this type of review has certain limitations. For example, the box-score reviews do not say how much better one method is than another, they simply report how often the method comes out on top. Further, they do not use statistics to find the characteristics that distinguish studies with positive results from those with negative findings. In an attempt to overcome the limitations of box-score reviews, researchers have employed a more sophisticated method called meta-analysis. Meta-analysis, most simply, is an analyis of a large collection of results from individual studies for the purpose of integrating the findings.

Meta-Analyses

Hartley (1977) was the first to apply meta-analysis to findings on CBI. She focused her analysis on math education in elementary and secondary schools. Hartley reported that the average effect of CBI was to raise student achievement from the 50th to the 66th percentile. Hartley also reported that the effects produced by CBI were not so large as those produced by programs of peer and cross-age tutoring, but they were far larger than effects produced by programmed instruction or individual learning packets.

Burns and Bozeman (1981) also used meta-analysis to integrate findings on CBI in mathematics teaching in elementary and secondary schools. They found that computer-based tutorials raised achievement test results by .45 standard deviations and that computer-based drill and practice raised test scores by .34 standard deviations. In a summary of their analysis, the reviewers wrote, "While no ultimate final answers related to CAI effectiveness or guarantors of success can be presented, <u>the analysis and synthesis of many studies do point to a significant enhancement of learning in instructional environments supplemented by CAI, at least in one curricular area - mathematics" (p. 37).</u>

Kulik, Kulik, and Cohen's (1980) review of research on CBI at the college level indicated that CBI had a modest positive effect for advanced learners. Their meta-analysis of 59 studies indicated that CBI produced gains of approximately .25 standard deviation units on content mastery exams for college-level courses, an effect that was found uniformly across student ability level. Moreover, students tended to have a more positive attitude toward courses that included computer instruction. More importantly, in every study in which computer-based instruction was substituted for traditional teaching, the computer group completed the instruction in about two-thirds or less of the time required by traditional teaching methods.

In a more recent meta-analysis, Kulik, Bangert, and Williams, (1983) analyzed 51 independent experimental studies which used CBI in grades six through twelve. Kulik et al. found that when CBI was used in instruction, student scores on final examinations were raised from the 50th to the 63rd percentile which represented a .32 standard deviation increase. In addition, Kulik and his colleagues reported that student attitudes toward the subject being learned and student ratings of the quality of instruction are slightly more favorable with CBI. Further, student's attitudes toward computers are significantly more positive as a result of CBI.

Wise and Okey (1983) conducted a meta-analysis on twelve CBI studies which used microcomputers for the delivery of instruction. Eight of the twelve studies were done at the college level, two at the high school level, one in middle school and one at the pre-school level. Of some interest in these studies is the number of microcomputers available for the research. In nine of the twelve studies, one computer was available. In the remaining three studies, two, four, and ten microcomputers were made available for the studies. These investigators reported that the mean effect size of .82 standard deviation units on ten student outcomes was in favor of students receiving CBI. Unfortunately, the investigators did not describe the student outcome measures which made up the large effect size.

A Longitudinal Study of CBI Effectiveness

While the effectiveness of CBI has been demonstrated in a number of studies, few of these investigations have been conducted over long periods of time. For example, Wise and Okey (1983) report that in three of the studies they reviewed, the students had only one encounter with a computer and the greatest number of encounters for any study was only eleven. Thus, many of the findings being reported are based on brief encounters with CBI by the students. There is, however, one notable exception. The Educational Testing Service (ETS), in conjunction with the Los Angeles Unified School District (LAUSD) recently conducted a four-year study on the effectiveness of CBI for compensatory education students (Ragosta, Holland, & Jamison, 1982). The study was designed to answer questions about the effectiveness of three CBI curriculums -- mathematics, reading, and language arts -- when used for one year and over several years.

Four elementary schools were each equipped with CBI labs using terminals and printers operated by a minicomputer. Half of the students in each school attended the CBI lab for 10 to 20 minutes a day over four years. Each of the curriculums was designed to reinforce skills which students had already been taught in the classroom. The computer program adapted its delivery of each skill strand of the CBI curriculum to the performance level of each student and moved the student along at his/her own rate or progress.

In this study, the learning effects were translated into equivalent percentile scores which allows comparison between CBI and traditional instruction; the fiftieth percentile being the average for the control students. On the curriculum specific tests designed for this study, the math CBI students showed significant and indisputable progress. They performed at the 79th percentile of their within-class groups at the end of only one year, at the 82nd percentile by the end of two years, and at the 89th percentile at the end of three years.

While student gains using the reading and language arts CBI curriculums did not show the pattern of increasing performance over time that was evident with the mathematics curriculum, substantial gains (15 percentiles in reading and 26 percentiles in language arts) made during the first year were maintained over the three-year period. After the initial improvement, however, the gains were not substantial.

Overall, each of the CBI curriculums demonstrated the capacity for improving the test scores of students requiring compensatory education as well as students performing at grade level (Ragosta, Holland, & Jamison, 1982). The results from this study are consistent with other CBI studies. Dence (1980), and Gershman & Sakamoto (1981) have reported that low aptitude students profit more from the use of CBI than either average or high aptitude students. This seems to be especially true when the type of computer-based instruction is of the drill and practice or tutorial type. Further, many reluctant learners become active and interested learners when involved in computer supported programs.

Conclusions

Based upon the twenty years of CBI research, it seems clear that several conclusions can be drawn with regard to the effectiveness of CBI on student achievement:

1. When CBI and traditional instruction are compared, students receiving CBI demonstrate equal or better achievement.

2. When CBI and traditional instruction are compared, equal or better achievement using CBI is obtained in less time.

3. The use of CBI improves student attitudes toward the use of computers in the learning situation.

4. The positive effect on learning achievement occurs regardless of the type of CBI used, the type of computer system used, or the age range of students.

5. "Primary CBI", where no teacher interaction occurs during the learning

process, is much less effective than "adjunct CBI" where teacher interaction is a critical part of the instruction.

6. While advocates of teaching computer programming claim that programming will result in higher level cognitive skills and capabilities to learn, there is little evidence on this matter, one way or the other.

7. Tutorial and drill modes seem to be more effective for low-ability students than for middle or high-ability students.

8. The effect on learning achievement seems to be greatest for pre-college age learners.

Social Development Factors

Much has been written speculating on the effect that the microcomputer will have on the social development of students. The microcomputer is viewed by many as a machine which invites individual and sometimes asocial activity. To date, there is very little evidence which describes how this new technology will effect the social climate of classrooms. However, what little evidence there is suggests that microcomputers provide opportunities for interaction and collaboration among students in classrooms. Several recent research reports state that children often work together and teach their peers over microcomputers (Papert, Watt, diSessa, & Weir, 1979; Sheingold, Kane, Endreweit, & Billings, 1981).

Hawkins, Sheingold, Gearhart, and Berger (1982) examined the type and amount of social interaction that took place during regular classroom activities and around computers. The investigators observed the type and frequency of peer interactions that occurred in classroom work before and after computers were placed in the classroom. The findings indicate that more task-related interaction occurred among children when they were working with computers than when they were engaged in other non-teacher-directed classroom tasks (e.g., math and language activities). In addition, the results suggest that the computer may provide a context in classrooms where children recognize each other as helping resources. Thus, it would seem that the personal computer may actually enhance the social development of youngsters in the classroom rather than inhibit social development as some have suggested.

The Cost of CBI

Computer-Based Instruction research generally has shown that the use of the computer for delivering instruction results in positive student gains. Unfortunately, the cost of this delivery has been quite high. It is anticipated that the declining cost of today's microcomputer will bring the cost of CBI delivery within reasonable limits. This, however, remains to be seen.

Cost estimates for CBI are highly variable and difficult to establish with any degree of accuracy, particularly as CBI can be delivered on a variety of computer systems. However, in an attempt to provide prospective microcomputer users with some cost estimates, Pressman & Rosenbloom (1984) presented an example in which 15 microcomputers would be used in a school of 750 to 1000 students. Costs were broken down into hardware and software and spread over a seven year period. While, seven years does not represent the maximum life of a microcomputer, this time period was chosen for illustrative purposes for estimating yearly costs. With an initial investment of $98,550, over seven years the adjusted average yearly costs would be about $17,360. When this figure is adjusted for yearly student use, Pressman and Rosenbloom estimate the average cost per student hour to be $1.32.

In another cost projection, Melmed (1982) provides a detailed breakdown on the cost, in 1980 dollars, of equipping the nation's schools with enough microcomputers by 1990 so that each elementary and secondary school student could average 30 minutes per day at a computer. Melmed concludes,

> "For about $30 per student per year (including the costs of equipment, maintenance, courseware, and materials other than courseware), each student in the elementary and secondary education system could enjoy a computer-enriched instructional program averaging 30 minutes a day. This figure represents 1.2 percent of the projected annual instructional budget of $2500 per student in 1990 (projected by the National Center for Education Statistics). If the cost of equipment were to be provided through a separate (capital) budget, the remaining annual operating cost of $5 would represent only 0.2 percent of the projected annual instructional budget spent for each student. This compares with about 0.8 percent of the instructional budget spent for all instructional materials in 1980. (p. 310)"

Summary

Having reviewed a cross section of CBI research conducted over the past two decades, one can ask, what do we know about the effectiveness of computer-based instruction in education? First, there is evidence that computers can be used to effect positive student gains in all curricular areas, but especially in math. It also seems that CBI is especially powerful for disadvantaged and students with learning difficulties. It is clear that computers do not stifle the creative process, are not dehumanizing, and do not foster antisocial behavior or development. However, none of the potential benefits of CBI are inherent. On the contrary, the greatest gains from the use of the computer seem to occur when it is integrated thoughtfully into the on-going curriculum and not used as a replacement for existing courses. While CBI has reduced the dependence of instruction upon the quality of human effort to some extent, human effort and quality instructional materials still remain the major factor in the successful or unsuccessful use of computers in education.

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