Synthesis of Research on Computer-Based Instruction

JAMES A. KULIK

Programs for computer-based instruction (CBI) have come a long way in the last two decades. They are available today in a variety of sophisticated shapes and sizes, and show few traces of their origins in B. F. Skinner's modest, fill-in-the-blanks teaching machines. The programs tutor and drill students, diagnose learning difficulties, prescribe remedies for problems, keep records of student progress, and present material in print and diagram form.

Pioneers in CBI believed from the start that the computer would bring students great benefits, such as better, more comfortable, and faster learning; opportunities to work with vastly richer materials and more sophisticated problems; personalized tutoring; and automatic measurement of progress. Benefits for teachers were to include less drudgery and repetition, greater ease in updating instructional materials, more accurate appraisal and documentation of student progress, and more time for meaningful contact with learners.

Soon after its introduction, educational researchers started to design evaluation studies to determine whether CBI actually produced such benefits. Although these evaluation studies yielded potentially valuable information about the effects of computer-based teaching, the message from the studies was not immediately clear. One problem was that each evaluation report was published separately, making the total picture difficult to see. Another more serious problem was that studies were never exact replications of one another. They differed in experimental designs, settings, and in the types of computer applications they investigated.

The first systematic reviews designed to integrate findings from the various evaluation studies concluded that CBI is effective in raising student achievement, especially when it is used to supplement regular instruction in elementary schools. Vinsonhaler and Bass's review (1972), for example, reported that results from ten independent studies showed a substantial advantage for computer-augmented instruction. Elementary school children who received computer-supported drill and practice generally showed performance gains of one to eight months over children who received only traditional instruction. Edwards and others (1975) reviewed studies of CBI at various educational levels and in various subjects, and they also reached positive conclusions about its effectiveness in raising achievement test scores. These reviewers noted that CBI reduced the time it took students to learn.

Later reviewers have used meta-analysis to integrate evalution findings on CBI (Glass, McGaw, and Smith, 1981). Reviewers taking this approach apply quantitative methods to their work. They use objective procedures to locate studies, quantitative or quasi-quantitative techniques to describe study features and outcomes, and statistical methods to summarize overall findings and explore relationships between study features and outcomes.

Hartley (1977), who was the first to apply meta-analysis to findings on CBI, focused on mathematics education in elementary and secondary schools. She reported that the average effect of CBI was to raise student achievement by .41 standard deviations, or 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 the use of individual learning packets. Finally, Hartley found only small effects of study features on study outcomes.

Burns and Bozeman (1981), like Hartley, used meta-analysis to integrate findings on CBI in mathematics teaching in elementary and secondary schools. These reviewers 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. They found virtually no evidence of a relationship between experimental design features and study outcomes. Meta-analysis has also been used to reach conclusions about the effectiveness of computer-based college teaching (Kulik, Kulik, and Cohen, 1980). We found that CBI raised the examination scores of college students by approximately .25 standard deviations. It also had a moderate effect on the attitudes of students toward instruc-

James A. Kulik is Research Scientist, Center for Research on Learning and Teaching, University of Michigan, Ann Arbor.

The material in this article is based on work supported by the National Science Foundation under Grant No. SED 79-20742. A more detailed presentation of the findings appears in James A. Kulik, Robert L. Bangert, and George W. Williams, "Effects of Computer-Based Teaching on Secondary School Students," Journal of Educational Psychology 75 (1983): 19–26.

tion and the subject being studied. Finally, we found that CBI reduced substantially the amount of time needed for instruction.

The following describes findings from a meta-analysis on CBI effects that I recently completed with the help of my colleagues Robert Bangert and George Williams. Our analysis focused on applications of CBI in grades 6 through 12 and went beyond earlier efforts in at least two respects. First, it examined the most recent applications of CBI as well as early programs. Second, it examined a wider variety of instructional outcomes than did earlier meta-analyses.

Method

The data for the meta-analysis came from 51 objective, comparative studies of CBI located through computer searches of the educational literature. The studies covered five different types of applications of the computer in teaching: drill and practice, tutoring, computer-managed teaching, simulation, and programming the computer to solve problems. The studies also differed in experimental design, course setting, and publication history. Categorical variables, similar to those used in our previous meta-analyses (Kulik, Kulik, and Cohen, 1980), were used in classifying the studies according to their features.

The 51 studies also described educational outcomes in four different areas: learning, academic attitudes, attitudes toward the computer, and instructional time. To quantify effects of grouping in each of these areas, we used Glass's index of Effect Sizes *ES* (Glass, McGaw, and Smith, 1981). This index gives the number of standard deviations that separate the group averages that are being compared. For the present analysis, the index was defined as the difference between the mean of the class taught with CBI and the mean of the conventionally taught control class, divided by the standard deviation of the control class.

Learning Outcomes

Forty-eight of the 51 studies described effects of CBI on achievement test scores. In more than 80 percent of the studies, students from the CBI class received at least slightly better scores than did students from the control class. In more than 90 percent of the 25 studies reporting a statistically significant difference in results from the two teaching approaches, students from the CBI class received the higher scores. The average effect of CBI in the 48 studies was to raise student test scores by .32 standard deviations, or from the 50th to the 63rd percentile.

Although the effect of CBI was moderate in the typical study, the size of effect varied from study to study, ranging from highly positive to moderately negative. It seemed possible that this variation in study outcome might be systematic, and we therefore carried out further analyses to determine whether different types of studies were producing different results. These analyses, however, did not disclose any strong relationships between study features and achievement test results. Only two study features had effects on achievement scores that reached borderline levels of statistical significance. These features were year of publication and duration of the study. Effects on achievement scores tended to be somewhat higher in studies of CBI published during the last five years. Effects were also somewhat greater in studies of shorter duration.

Academic Attitudes

Computer-based teaching had only small effects on the academic attitudes of students. Ten studies, for example, reported results on students' attitudes toward the subject matter being taught. In eight of these studies, attitudes were more positive in the classroom using CBI. The average size of effect, however, was only .12 standard deviations. Another four studies reported on student ratings of the quality of instruction in CBI and conventional classes. In each of the studies, the students from the CBI class gave the more favorable ratings, but none of the differences between classes was statistically significant. The average size of effect in the studies was .19 standard deviations, again a small effect.

Attitudes Toward Computers

The effect of CBI on attitudes toward computers was strikingly different from its effect on academic attitudes. Four studies reported results in this area. In each of these studies, student attitudes toward computers were more positive in the CBI class, and in three of the studies, attitudes were significantly more positive among students who used CBI. The average size of effect was .61, a moderate to large effect.

Instructional Time

Only two studies contained comparative data on the amount of time students



Anne B. Adamson

"The average effect of CBI in the 48 studies was to raise student test scores . . . from the 50th to the 63rd percentile."

took to learn. In one of the studies, students spent 220 minutes on instruction and study when taught in a conventional manner and 135 minutes when taught with computers, for a 39 percent savings in time. In the other study, students spent 745 minutes on instruction and study when taught conventionally and 90 minutes when taught with computers, for an 88 percent savings in time. These effects are obviously large enough to be of practical importance.

Discussion and Conclusions

The findings of this meta-analysis are consistent for the most part with findings of earlier reviews. Other reviews have also reported moderate-size effects on achievement test scores from computer-based teaching, and other reviews have also stressed the potential importance of the computer in saving instructional time. Our findings on attitudinal effects should seem less familiar. Most reviews do not examine effects of CBI in the attitudinal domain. The attitudinal findings, however, are potentially important. CBI appears to have an important positive effect on student attitudes toward computers and also appears to have a smaller positive effect on student school attitudes.

Like other meta-analysts working in this area, we found that features of studies were not strongly related to study outcomes. None of the relationships between study features and outcomes that we investigated, in fact, could be considered clearly statistically significant with the number of studies available to us. Nonetheless, the few small correlations of borderline significance that we found were interesting because they confirmed findings from earlier meta-analyses.

The tendency for more recent studies to produce stronger results, for example, has been noted several times in the past in meta-analyses on instructional technology. Hartley (1977) noted this tendency in studies of programmed instruction at the elementary and secondary levels, and Kulik (1981) noted the same effect in two separate meta-analyses of findings on programmed instruction at the secondary and college levels. It seems unlikely that the stronger effects reported in more recent studies can be attributed to a switch in recent years to better research designs. None of the meta-analyses showed great improvements in research methodology over time, and they all reported little relationship between research design features and study outcomes. It seems more likely that instructional technology has simply been used more appropriately in recent years.

Other meta-analyses on instructional technology have also found an inverse relationship between study length and strength of effects. Cohen, Kulik, and Kulik (1982), for example, reported a similar result for programs of cross-age and peer tutoring in elementary and secondary schools. Although the smaller effects reported in longer studies may actually show that experimental effects decrease in potency with extended use—too much of a good thing—it is also possible that shorter studies are better controlled and more likely to estimate true effects.

One final point should be kept in mind by readers forming an overall impression of computer-based teaching on the basis of this or other meta-analyses. It concerns the very nature of the method. Meta-analysis provides a way of determining the major themes in research studies that have already been carried out. It thus provides a picture of the past. It does not necessarily give us a good view of the future. Developments in computer technology have been occurring so swiftly that no one can predict with confidence what the next few years will bring in computer-based teaching.□

References

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

Cohen, P. A.; Kulik, J. A.; and Kulik, C.-L. C. "Educational Outcomes of Tutoring: A Meta-Analysis of Findings." *American Educational Research Journal* 19 (1982): 237.

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

Glass, G. V.; McGaw, B.; and Smith, M. L. *Meta-Analysis in Social Research*. Beverly Hills: Sage Publications, 1981.

Hartley, S. S. "Meta-Analysis of the Effects of Individually Paced Instruction in Mathematics." Doctoral dissertation, University of Colorado, 1977.

Kulik, J. A. "Integrating Findings From Different Levels of Instruction." Paper presented at the American Educational Research Association, Los Angeles, April 1981.

Kulik, J. A.; Kulik, C.-L. C.; and Cohen, P. A. "Effectiveness of Computer-Based College Teaching: A Meta-Analysis of Findings." *Review of Educational Research* 50 (1980): 525–544.

Vinsonhaler, J. F., and Bass, R. K. "A Summary of Ten Major Studies on CAI Drill and Practice." *Educational Technology* 12 (1972): 29–32.



Highlights from Research on Computer-Based Instruction

A meta-analysis of 51 studies of computer-based instruction shows that:

- **CBI can improve student learning. The average effect is to raise student test scores from the 50th to the 63rd percentile.**
- **Student attitudes toward the subject being learned and student ratings of the quality of instruction are slightly more favorable with CBI.**
- **In contrast, students' attitudes toward computers are strikingly more positive as a result of CBI.**
- **Finally, CBI has been reported as saving anywhere from 39 percent to 88 percent of student learning time.**
- **Because of the rapid change in computer technology and classroom use of computers, these findings do not necessarily predict future results.**

Resource Information Service (RIS) provides ASCD members access to research and sources of information on selected topics. The information is available through RIS-sponsored research syntheses, the RIS column in *Update*, and the quarterly publication of *Curriculum Update*.

Copyright © 1983 by the Association for Supervision and Curriculum Development. All rights reserved.