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Effectiveness of Computer-based College Teaching: A Meta-analysis of Findings

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This review used Glass' (1976) meta-analytic techniques to integrate findings from 59 independent evaluations of computer-based college teaching. The meta-analysis showed that computer-based instruction made small but significant contributions to the course achievement of college students and also produced positive, but again small, effects on the attitudes of students toward instruction and toward the subject matter they were studying. Computer-assisted instruction also reduced substantially the amount of time needed for instruction. In general, the meta-analysis found little relationship between study findings and design features of the experiments, settings for the studies, or manner and date of publication of the findings.

The dream of a computer revolution in college teaching is now almost two decades old. Soon after the computer industry started using computers in personnel training in the late 1950's, farsighted educators began dreaming about a computer age in higher education. They envisioned college classrooms in which computers would serve as infinitely patient tutors, scrupulous examiners, and tireless schedulers of instruction. Teachers in these imagined classrooms would be free to work individually with their students. Students would be free to follow their own paths and schedules in learning.

Government agencies, private foundations, and commercial organizations have tried for more than a decade to make this vision become a reality. Since 1965, for example, the United States Office of Education and the National Science Foundation have funded hundreds of computer projects in education. The Exxon Foundation, the Sloan Foundation, and other private agencies also made awards to numerous colleges for development of computer-based approaches to teaching and learning. Finally, research and development units of computer corporations poured millions of dollars into the creation of hardware and software for computer-assisted instruction.

Not everyone shared the vision of a benign computer revolution, however. To some critics, computers were expensive gadgets that increased the cost and complexity of instruction without increasing its quality. Others worried that rigidly programmed machines might force all learners into the same mold and stifle idiosyncrasy. Finally, some educators feared that computer requirements would ultimately affect the choice

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of instructional content. Teachers using computers in instruction, they warned, might be tempted to teach only those things that could be taught easily by machine.

Systematic comparisons of outcomes of computer-based and conventional teaching were clearly needed to help guide educational policy, and in the late 1960's evaluations of computer-based teaching began appearing in print. In a typical evaluation study, a researcher divided a class of students into an experimental and a control group. Members of the experimental group received part of their instruction at computer terminals, whereas students in the control group received their instruction by conventional teaching methods. At the end of the experiment, the researcher compared responses of the two groups on a common examination or on a course evaluation form. Teachers and researchers carried out such studies many times and in many different settings.

Reviewers of these evaluation studies generally supported the effectiveness of computer-based teaching as a supplement to conventional instruction in elementary schools. Vinsonhaler and Bass (1972), for example, summarized results from 10 independent studies of computer-supported drill and practice, involving more than 30 separate experiments with about 10,000 subjects. Results indicated a substantial advantage for computer-augmented instruction. Elementary school children who received computer-assisted instruction generally showed performance gains of 1–8 months over children who received only traditional instruction. In a more recent review, Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) also concluded that normal instruction supplemented by computer-based teaching was more effective than normal instruction alone. Most of the studies that these authors reviewed were carried out in elementary schools, and results of some of these studies were, in the words of the authors, "quite remarkable." In their broad overview of effectiveness of instructional media, Jamison, Suppes, and Wells (1974) also concluded that computer-assisted instruction was effective as a supplement to regular instruction at the elementary school level. Finally, Hartley's (1977) research synthesis showed that computer-assisted instruction was one of the most effective ways of teaching mathematics at the elementary and secondary levels.

It has proved harder to show the educational advantage of computer-based instruction at higher levels of education. Jamison et al. (1974), for example, reviewed nearly a dozen small-scale studies of computer-based instruction in college classrooms. Most of these studies were carried out in courses operated as part of research and development projects in computer-assisted instruction. The results of the studies defied easy summary. At the college level, Jamison and his colleagues were therefore able to draw only the conservative conclusion that computer-assisted instruction was about as effective as traditional instruction when used as a replacement. Jamison and his colleagues pointed out that it is broadly correct to conclude that, at the college level, most alternative methods of instruction are equally effective.

In the late 1960's, the National Science Foundation began backing two systems of computer-assisted instruction on a scale sufficient to permit a realistic evaluation of the potential of the computer in college teaching. Ultimately, the National Science Foundation invested more than $14 million in the development of these systems, called PLATO (Programmed Logic for Automatic Teaching Operators) and TICCIT (Time-shared, Interactive, Computer-Controlled, Information Television). The PLATO system is a large educational and computing network based at the University of Illinois that supports nearly 1,000 terminals at dispersed locations and provides

each site with access to a central library of lessons (Bitzer & Skaperdas, 1971). The TICCIT system developed by the Mitre Corporation of Bedford, Massachusetts, supports small, local instructional computing facilities (Stetton, 1971). In the TICCIT system, lessons are displayed on a color-television screen connected to the student's keyboard and a local computer. One TICCIT system can serve 128 terminals.

With support from the National Science Foundation, researchers at the Educational Testing Service recently carried out a major evaluation of these two systems (Alderman, 1978; Murphy & Appel, 1977). The evaluation was based on field tests of the TICCIT system in two community colleges in Arizona and Virginia and tests of the PLATO system in five community colleges in Illinois. The evaluators of PLATO reported that both students and teachers reacted favorably to this computer-teaching system, but that PLATO had no significant impact on student achievement. The evaluators of TICCIT reported that this system resulted in an improvement in student achievement, but students in TICCIT classes were more likely to drop out than those in conventionally taught classes. The evaluators concluded that neither PLATO nor TICCIT had reached the potential so long claimed for computer-based instruction.

The evaluation of PLATO and TICCIT gave educators an additional perspective on computer-based college teaching. The evaluation demonstrated that institutions of higher education would accept computer-based instruction as an additional resource for promoting student learning. But the conditions of the Educational Testing Service evaluation limited the settings to which its findings could be generalized. Although the evaluation was large in scale, it had many special characteristics. It was carried out in community colleges only. The evaluation focused on large-audience, lower level courses. Teachers involved in the study were recruited for participation; computer-based instruction was not an indigenous development at the colleges. Finally, PLATO and TICCIT were but two of many approaches to computer-based college teaching.

The purpose of this article is to provide an objective synthesis of findings from numerous studies of the effectiveness of computer-based teaching at the college level. The article is meant to integrate results from the PLATO and TICCIT evaluation and from more than 50 other independent studies of computer-based and conventional teaching. The approach used in this investigation has been called "meta-analysis," or the analysis of analyses. The term was first used by Glass (1976) to describe the statistical analysis of a large collection of results from individual studies for the purpose of integrating findings. Researchers carrying out a meta-analysis locate studies of an issue by clearly specified procedures. They characterize features of the studies and study outcomes in quantitative or semiquantitative ways. Finally, meta-analysts use multivariate techniques to describe findings and relate characteristics of the studies to outcomes.

This method was developed initially for handling the difficulties posed by the wealth and diversity of findings in the social sciences. When studies of an issue run into the hundreds, and findings are diverse, reviewers often see what they wish in the collected results. The use of quantitative methods and statistical tools somewhat constrains a reviewer's fancy. By applying to a collection of results the same objective methods that researchers use in analyzing results from an individual study, the meta-analyst is able to draw reliable, reproducible, and general conclusions. Meta-analysis is especially helpful in the social sciences when researchers are interested in formu-

lating ecological rather than individual generalizations—generalizations about the effectiveness of an approach in a population of settings rather than generalizations about effectiveness for a population of individuals in a single setting.

Methods

This section describes the procedures used in locating studies, coding study features, and quantifying outcomes of the studies.

Locating Studies

The first step in this meta-analysis was to collect a large number of studies that compared effects of computer-based instruction (CBI) and conventional teaching. The primary sources for these studies were eight library data bases computer-searched through Lockheed's DIALOG Online Information Service. The data bases included (a) *Compendex*, the machine-readable version of the *Engineering Index*; (b) *Comprehensive Dissertation Abstracts*; (c) *ERIC*, a data base on educational materials from the Educational Resources Information Center, consisting of the two files *Research in Education* and *Current Index to Journals in Education*; (d) *Inspec*, an on-line file corresponding to the printed *Physics Abstracts*, *Electric & Electronic Abstracts*, and *Computer and Control Abstracts*; (e) *NTIS*, the data base of the National Technical Information Service, consisting of reports on government-sponsored research, development, and engineering; (f) *Psychological Abstracts*; (g) *Scisearch*, a multidisciplinary index comprised of all the records published in *Science Citation Index*; and (h) *Social Scisearch*, a multidisciplinary data base containing the records published in the *Social Science Citation Index*. We developed a special set of key words for each computer search to take into account the distinctive features of the different data bases. The bibliographies in articles located through computer searches provided a second source of studies for meta-analysis.

In all, our bibliographic searches yielded over 500 titles. Most of the articles, however, failed in one way or another to meet the criteria established for the analysis. We reduced the initial pool of 500 titles to 180 potentially useful documents on the basis of information about the articles contained in titles or abstracts. We obtained copies of these 180 documents and read them in full. A total of 59 of the 180 reports contained data useful to the meta-analysis, and these 59 reports provided all the data used in our study.

In reducing the initial pool of 500 titles to a final group of 59, we used a set of explicit guidelines. To be included in our final sample, studies had to satisfy three criteria. First, the studies had to take place in actual college classrooms. We did not include in our analysis studies carried out at the elementary or secondary levels, nor did we include studies describing laboratory analogues of college teaching. Second, studies had to report on quantitatively measured outcomes in both computer-based and conventional classes. We excluded studies without control groups and studies with anecdotal reports of outcomes from our analysis. Third, studies had to be free from crippling methodological flaws. Our analysis did not include data from studies in which treatment and control groups were clearly different in aptitude. Nor did it include data from studies in which a criterion test was unfairly "taught" to one of the comparison groups.

In addition, we established guidelines to ensure that each comparison was counted only once in our analysis. When several papers reported the same comparison, we used the most complete report for our analysis. When the same comparison was carried out in the same course at the same institution for two or more terms, we used the data from the most recent term. When an instructional outcome was measured on several instruments in a single paper, we pooled the results from the instruments to obtain a composite measure. Finally, when a single paper reported on a number of courses, we pooled results from the various courses to obtain a composite result. These guidelines maximized independence among comparisons and prevented a few major research efforts from having an undue influence on overall results.

Describing Characteristics of Studies

The 59 studies located for use in the meta-analysis described four major types of applications of the computer to instruction: tutoring, computer-managed teaching, simulation, and programming the computer to solve problems. In tutoring studies, the computer presented instruction directly to students. In studies of computer-managed teaching, the computer evaluated student performance, diagnosed weaknesses, and guided students to appropriate instructional resources. In simulation studies, students explored relationships among variables in models simulating aspects of social or physical reality. Finally, in the programming studies, students programmed the computer to solve problems in the academic field they were studying.

The 59 applications of the computer to instruction also varied along two other dimensions. In some studies, the computer substituted for conventional teaching, replacing lectures, recitation sections, conventional readings, or problem assignments or some combination of these. In other studies, the computer supplemented regular instruction. Instead of replacing regular course elements, the computer simply served as an additional resource for students. Finally, in some studies the computer was used for instruction for the full duration of a course, whereas in other studies the computer was used only for a unit of instruction, usually for a week or two during a course. Table I lists 57 of the 59 studies according to type of computer application, use as a substitute or a supplement in teaching, and use in a unit or a full term of teaching. The two studies not listed in the table (Culp, 1971; Tsai & Pohl, 1977) contained data from two or more different applications of the computer to teaching, and these studies could not be placed into single cells of the table.

Studies differed not only in their use of the computer but also in other features. To describe these features, we defined 13 additional variables. Table II lists these variables, the coding categories for each, and the number of comparisons in each category. The first five variables in the table describe aspects of the experimental design of the studies (Bracht & Glass, 1968; Campbell & Stanley, 1963). The next six variables describe features of the course setting, including class level, field of the course, and level of the institution in which the course was offered. Classification of fields was based on Biglan (1973), and categorization of institutional level was based on the Carnegie taxonomy of institutions of higher education (Carnegie Commission on Higher Education, 1976). The last two variables describe publication features of the studies.

The purpose of coding the studies in this fashion was twofold. First, the classification helped us to determine areas in which computer-based instruction was studied extensively and areas in which it was relatively unstudied. Second, the classification

TABLE I

Comparative Effectiveness Studies on Computer-based Instruction

Type of use	Substitute		Supplement	
	Unit	Full	Unit	Full
Tutorial	Ibrahim (1970) Meyer & Beaton (1974) Proctor (1968) Ward & Ballew (1972)	Alderman (1978) Arsenty & Kieffer (1971) Axeen (1967) Broh (1975) Cartwright, Cartwright, & Robine (1972) Castleberry, Culp, & Lagowski (1973) Culp, Stotter, & Gilbert (1973) Emery & Enger (1972) Hamm (1975) Homeyer (1970) LeCuyer (1977) Lee (1973) Lorber (1970) Montanelli (1977) Morrison & Adams (1968) Murphy & Appel (1977) Ozarowski (1973) Paden, Dalgaard, & Barr (1977) Romaniuk (1978) Skavaril (1974) Suppes & Morningstar (1969) Vaughn (1978)	None	Byers (1973) Castleberry & Lagowski (1970) Grandey (1970) Liu (1975) Skavaril, Birky, Duhrkopf, & Knight (1976)
Managed	Cunningham & Fuller (1973)	Gallagher (1970) Kromhout, Edwards, & Schwarz (1969) Lawler (1971) Roll & Pasen (1977) Torop (1975) Weiss (1971) Wood (1976)	None	Anderson, Anderson, Dalgaard, Paden, Biddle, Surber, & Alessi (1975) Henry & Ramsett (1978) Jones & Sorlie (1976) Kelley (1972) Smith (1976)
Simulation	Coombs (1976) Green & Mink (1973) Roe & Aiken (1976)	Cox (1974) Hsiao (1973) Mancuso (1975) Steinkamp (1977)	None	Dudley, Elledge, & Mukherjee (1974)
Programming	None	Bell (1970) Deloatch (1977) Fiedler (1969)	None	DeBoer (1973) Holoien (1970)

TABLE II

Categories for Describing Studies and Number of Studies in Each Category

Coding categories	Number
Methodological features	
Random assignment of comparison groups	
No	41
Yes	18
Control for instructor effect	
Different instructors	15
Same instructor	35
Control for historical effect	
Different semesters	3
Same semester	54
Control for scoring bias in criterion	
Nonobjective test	8
Objective test	35
Control for author bias in criterion	
Instructor-developed test	29
Commercial standardized test	9
Ecological conditions	
Duration of treatment	
Fraction of semester	20
Whole semester	38
Course level	
Introductory	42
Other	17
Content emphasis on "hard" discipline	
Soft	26
Hard	31
Content emphasis on "pure" knowledge	
Applied	20
Pure	38
Content emphasis on "life" studies	
Nonlife	40
Life	18
University setting	
Comprehensive, liberal arts, or community college	15
Doctorate-granting institution	41
Publication features	
Source of study	
Unpublished	30
Published	29
Study year	
1967–69	6
1970–72	17
1973–75	18
1976–78	18

helped us to determine how properties of studies affected the principal findings. With carefully described studies, we were able to answer such questions as: "Is computer-based teaching as effective in 2- and 4-year colleges as it is in research universities?" and "Do studies using true experimental designs and studies using quasi-experimental designs produce the same results?"

Quantifying Outcomes

The outcomes described in the 59 studies were of five major types: student achievement, correlation between aptitude and achievement, course completion, student attitudes, and instructional time. First, we described the effect of CBI on achievement as measured on a unit or a final examination. As our basic index of achievement effect, we used *d*, defined as the difference between the means of two groups divided by the standard deviation common to the two populations (Cohen, 1977). For studies that reported means and standard deviations for both experimental and control groups, we calculated *d* from the means and the pooled standard deviation, using standard formulas for the pooled standard deviation. For less fully reported studies, we calculated *d* from statistics such as *t* and *F*, using procedures described by McGaw and Glass (in press). To add to the interpretability of our results, we also expressed differences between CBI and conventional classes in concrete terms. We calculated the difference in percentage scores on examinations by subtracting the average examination score (expressed as a percentage) in the conventional class from the average in the CBI class.

Second, we examined the effect of CBI on the correlation between student aptitude and achievement in college courses. A number of researchers have suggested that the aptitude-achievement correlation will be higher in conventional classes than in computer-based classes. In conventional classes in which all students receive the same amount and kind of instruction, aptitude plays a strong role in determining achievement. But in computer-based, individualized classes, students should receive the amount and kind of instruction they need, and aptitude should play less of a role in determining performance. Student aptitude can be measured in various ways: standardized aptitude measures, instructor prepared pretests, or student grade-point average on entry to a course. To quantify CBI effect on the aptitude-achievement correlation, we calculated *q* (Cohen, 1977) by transforming correlations using Fisher's *Z* transformation and then subtracting *Z* for the conventional class from the *Z* for the CBI class.

Third, we measured the effect of CBI on course completion. We first calculated withdrawal rates for CBI and conventional classes, where withdrawal rate was defined as the proportion of students initially enrolled who failed to complete a course in a term. We then used Cohen's (1977) procedures for determining *h*, the index of effect size when proportions are being compared. Calculation of *h* involved arcsine transformation of proportions and then subtraction of the transformed value for the conventional group from the transformed value for the CBI group.

Fourth, we quantified CBI effects on student attitudes. Quantifying effects in this domain presented some special difficulties. To measure student attitudes, most researchers examined the degree of endorsement of items on questionnaires. Different investigators, however, used different rating scales to measure attitudes. We had to decide when differently phrased items should be considered equivalent. We first

developed two lists of model-rating items to cover two major attitudes: overall attitude toward the course that the students were taking and their attitude toward the general subject that they were studying. We included in our analysis results on any item that appeared in one of our lists. Our basic index of effect size was *d*, calculated from the difference in average scale scores of CBI and conventional groups on items in our lists. To add to interpretability of our results on attitudes, we also converted rating results to scores on a 5-point scale (where 5 represented the most favorable attitude and 1 the least favorable attitude) and calculated the difference between ratings for CBI and conventional classes.

The fifth outcome that we described was time required for instruction. A number of reviewers have suggested that CBI reduces the amount of time needed to teach students. We therefore paid close attention to the studies that compared the number of hours per week spent in instruction in CBI and conventional classes. We again used *d* as our index of CBI effect on instructional time. As an aid in interpretation, we also calculated the average number of hours per week spent in instruction in CBI and conventional classes.

To make our study more similar to traditional reviews, we also examined the direction and significance of differences in outcomes of computer-based and conventional teaching. On the basis of results, we classified each outcome on the following 4-point scale: 1 = difference favored conventional instruction and statistically significant; 2 = difference favored conventional instruction but not statistically significant; 3 = difference favored CBI but not statistically significant; and 4 = difference favored CBI and statistically significant.

In our previous meta-analyses of research on programmed and audiotutorial instruction (Kulik, Kulik, & Cohen, 1979b; Kulik, Cohen, & Ebeling, in press), we reported that different effect-size measures agreed remarkably well when applied to the same data set. This also turned out to be the case in the present analysis. For 30 of the studies with data on achievement outcome, for example, we were able to calculate both *d* and examination differences in percentage points. The correlation between the two indexes was .94. The correlation between effect sizes as measured by *d* and by scores on the 4-point scale reflecting direction and significance of differences was .77. Because these correlations were so high, we were able to write regression equations for "plugging" missing data on specific effect-size measures. If, for example, a study did not report final examination averages in percentage terms but did report data from which *d* could be calculated, we were able to use *d* to predict the number of percentage points separating experimental and control groups on the examination.

In our previous research, we also reported negligible correlations between effect sizes for different types of outcomes. In our meta-analyses of research on programmed and audiotutorial instruction, for example, correlations between effect sizes on achievement, course withdrawal, and student satisfaction were nonsignificant. Most of the studies collected for this article reported only a single outcome. In the few studies that reported multiple outcomes, there was no indication of predictability from one type of effect to another. The correlation between the effect on achievement and on course completion was small and insignificant, for example, as was the correlation between effect on achievement and on student attitudes.

Results

In this section we describe results of statistical analyses comparing effects of computer-based and conventional teaching. We describe the findings in five areas: (a) achievement, (b) aptitude-achievement correlation, (c) course completion, (d) student ratings, and (e) instructional time.

Student Achievement

A total of 54 of the 59 studies located for this meta-analysis looked at examination performance of students in CBI and conventional classes. In 37 of the 54 studies, CBI examination performance was superior to examination performance in a conventional class; 17 studies favored conventional instruction. Fourteen of the 54 comparisons reported statistically significant differences between teaching methods. Results of 13 of these studies favored CBI, and results of one study favored conventional instruction. If no overall generalization about the effect of CBI was possible, one would expect about half the cases to favor CBI and half to favor conventional teaching. Instead, a clear majority of studies favored CBI. We were therefore able to reject the null hypothesis of no effect of CBI on student achievement.

Continuous measures of effect size permit a more exact description of the influence of CBI on examination performance. The average examination score was 60.6 percent in the typical CBI class; the average was 57.6 percent in the typical conventional class. Examinations from computer-based and conventional classes therefore differed by 3.0 percentage points; the standard deviation of this difference was 6.5. It is statistically very unlikely ($p < .01$) that a difference of this size would occur if there were no overall difference in effectiveness of computer-based and conventional teaching.

The average d in the 54 studies was .25. Thus, the effect of CBI in a typical class was to raise student achievement by about one-quarter of a standard deviation unit. This implies that a typical student in a CBI class was performing at the 60th percentile on examinations, whereas the typical control student performed at the 50th percentile. Cohen (1977) described effects of this magnitude as small. With $d = .2$, for example, treatment-group membership accounts for only 1 percent of the variance in a trait, and treatment effects are ordinarily too small to be observed without special measuring procedures. When group averages are separated by a half standard deviation ($d = .5$), the effect is said to be medium in size. When $d = .8$, effects are large.

Although the effect of CBI in the typical study was small, effect sizes varied from study to study. Figure 1 presents a distribution of effect sizes for the 54 studies. The figure shows that nearly one-quarter of the studies reported a medium or large effect in favor of CBI, nearly three-quarters of the studies found small or trivial effects, and very few studies (less than 5 percent) reported moderate or large effects favoring conventional instruction.

We also wanted to know whether the studies that reported large effects differed systematically from those reporting small effects. We therefore examined the relation between achievement-effect sizes and study characteristics. Table III presents the correlation between study characteristics and achievement-effect size. The table shows that only one variable—use of a control for instructor effect—was significantly related to effect size. The average effect size d was .13 for those studies in which a

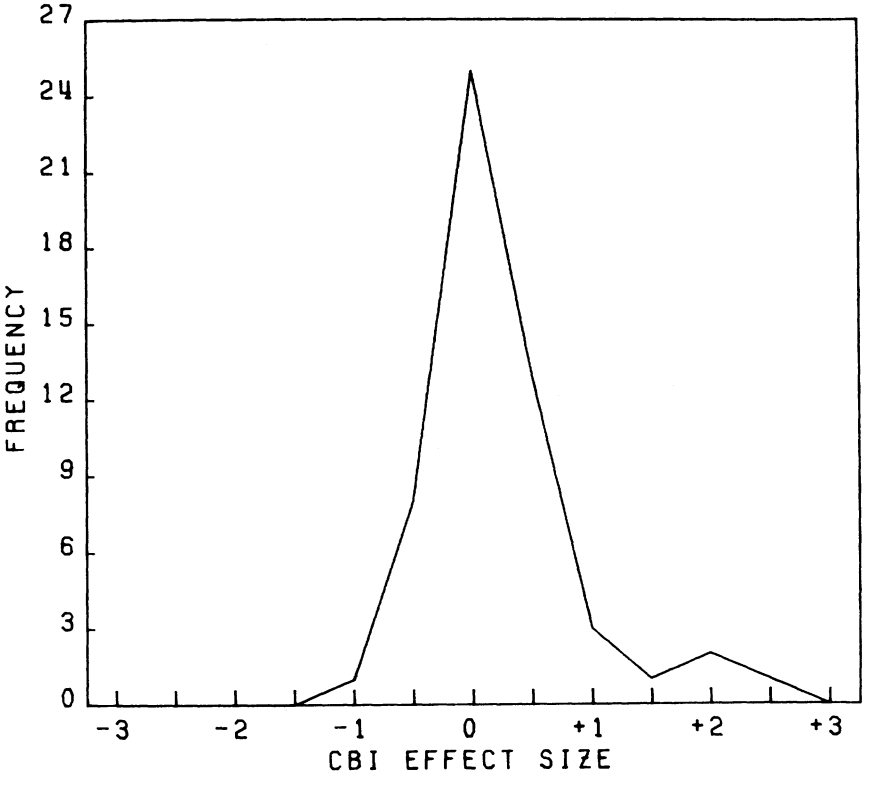

FIGURE 1. Distribution of achievement effect sizes for 54 studies.

single teacher gave both computer-based and conventional sections of a course. Effects were larger when different teachers gave the two sections. The average effect size was .51 when different teachers gave computer-based and conventional sections of a course.

Other study features were less highly related to effect size. Correlations between effect size and the remaining variables were low in magnitude, and none could be considered significantly different from zero. To investigate the possibility that a combination of variables might predict effect sizes more accurately than a single predictor, we also carried out a stepwise multiple regression analysis with generous limits for inclusion of predictor variables. Results of this analysis were clear-cut. Once instructor control was taken into account, none of the variables was significantly related to effect size.

Aptitude-Achievement Correlation

Seven studies reported aptitude-achievement correlations separately for CBI and conventional classes. We first examined the direction and significance of differences

TABLE III

Correlations of Study Characteristics with CBI Effect on Achievement

Study characteristic	Correlation with effect size
Use of computer for managing	.04
Use of computer for tutoring	.17
Use of computer for simulation	−.18
Use of computer for programming	−.14
Extent of use	.15
Implementation	−.10
Random assignment of comparison groups	.08
Control for instructor effect	−.27*
Control for historical effect	.02
Control for scoring bias in criterion	.11
Control for author bias in criterion	.12
Duration of treatment	−.08
Course level	.07
Content emphasis on "hard" discipline	−.18
Content emphasis on "pure" knowledge	.09
Content emphasis on "life" studies	.16
University setting	.01
Source of study	−.05
Study year	−.12

* $p < .05$.

in aptitude-achievement correlations in these studies. For three of the studies, the correlation between aptitude and achievement was higher in the CBI section; for the other four studies, the correlation was higher in the conventional section. Only one study reported a significant difference in the aptitude-achievement correlations found in CBI and conventional classes, and in that study the correlation was higher in the conventional class. Second, we examined the average aptitude-achievement correlation in the two kinds of classes. The average correlation coefficient in the CBI classes was .41, and the average correlation in the conventional classes was .51. Finally, we determined the average q, the index of size of difference in correlation coefficients. The average q was .12, a small value. It seems safe to conclude that CBI has at best a small effect on the correlation between aptitude and achievement in college courses.

Course Completion

Only 13 of the 59 studies in our collection examined the effect of CBI on course completion. In seven studies withdrawal rate was higher in the CBI section, and in six studies withdrawal rate was higher in the conventional section. The difference in withdrawal rates was statistically significant in only three studies. In one of these cases, withdrawal rate was significantly higher in the CBI class, and in two cases it was significantly higher in the conventional class. Under a null hypothesis of no overall effect of CBI on course completion, one would expect withdrawal rates to be higher in CBI classes about half the time. The results obtained do not differ significantly from this expectation.

We were able to perform a more sensitive test of the effect of CBI on course withdrawal by treating withdrawal rate as a continuous variable. Even with this procedure, however, we could not reject the hypothesis of no difference in course withdrawals as a function of teaching method. The average CBI withdrawal rate was 26.9 percent; the average rate in the conventional classes was 27.6 percent. Finally, we also expressed the average effect size as *h* (Cohen's measure of size of effect for comparisons of proportions). For these withdrawal data, average *h* equaled .005, a trivial value.

Student Attitudes

Only 11 of the 59 studies contained results from quantitative comparisons of student attitudes toward instruction in computer-based and conventional classes. CBI ratings were higher than conventional ratings in eight of the studies, and conventional ratings were higher in the remaining three studies. Four studies showed a statistically reliable difference in favor of computer-based teaching, and one study showed a statistically reliable difference in favor of conventional teaching. On a 5-point scale from 1 (the lowest rating) to 5 (the highest rating), the average rating of course quality was 3.77 in the CBI classes and 3.50 in the conventional classes. This difference in ratings is probably best considered a small one. It corresponded to a *d* of .24.

Computer-based teaching also had a small effect on student attitudes toward the subject matter in these courses. Seven of the studies in our collection examined effects on student attitudes toward subject matter. In five studies the CBI classes had more favorable attitudes, and in two studies the conventional classes expressed more favorable attitudes toward the subject matter. In two studies there was a statistically reliable difference between CBI and conventional students in their attitude toward subject matter, and both of these studies reported more favorable attitudes on the part of the CBI students. In general, however, CBI effects on subject matter attitudes were small. The average *d* for the seven studies with relevant data was .18.

Instructional Time

Eight investigators collected data on the amount of time spent in instruction of students in CBI and conventional classes. Each of the eight investigators found that the computer produced a substantial saving in instructional time. In all of the cases in which investigators performed statistical tests, the differences in instructional time between CBI and conventional classes were statistically significant. On the average the conventional approach required 3.5 hours of instructional time per week, and the computer-based approach required about 2.25 hours. This is a substantial and highly significant difference between methods. There appears to be little doubt that students can be taught with computers in less time than with conventional methods of college teaching.

Discussion

This meta-analysis showed that for the most part the computer has made a small but significant contribution to the effectiveness of college teaching. In the typical implementation, computer-based instruction raised examination scores by about 3 percentage points, or about one-quarter standard deviation. Thus, the typical student

in a computer-based class scored at the 60th percentile on an achievement examination over course material, whereas the typical student in a conventional class scored at the 50th percentile. The boost that computer-based teaching gave to student achievement was about as noticeable in high- and low-aptitude students as it was in average students; computer-based instruction did not seriously reduce the expected correlation (about .5) between aptitude and achievement in college classrooms. Computer-based teaching also had small and positive effects on attitudes of college students toward instruction and toward the subject matter that they were taught. College students tended to like their courses somewhat more and become more interested in the subject of these courses when instruction was computer based.

In individual studies, there were notable exceptions to the general rule of small effects of the computer on student performance and attitudes. In a few applications, the introduction of computer-based instruction into a college classroom dramatically influenced student examination performance; class averages on final examinations rose by 15–20 percentage points in these cases. In a few cases, the computer also had strong positive effects on student attitudes. Studies like those by Cartwright, Cartwright, and Robine (1972), Grandey (1970), and Roll and Pasen (1977) are potentially important because these investigators reported unusually strong, positive effects of computer-based instruction.

The most dramatic finding in this meta-analysis, however, is related to instructional time. In every study in which computer-based instruction substituted for conventional teaching, the computer did its job quickly—on the average in about two-thirds the time required by conventional teaching methods. It is clear that the computer can function satisfactorily in college courses and at the same time reduce time spent in instruction.

Overall, however, the accomplishments of computer-based instruction at the college level must still be considered modest. The present results, for example, are not so impressive as those for computer-supplemented instruction in elementary schools. The studies reviewed by Edwards et al. (1975) and by Vinsonhaler and Bass (1972) were unanimous about the effectiveness of supplemental computer-assisted instruction at the elementary level, and Hartley's (1977) meta-analysis also reported differences at the elementary school level of at least one-half standard deviation between students whose classes received supplemental CBI and students who did not receive computer-supplemented instruction. Nor are the results of computer-based teaching as impressive as results for other applications of instructional technology at the college level. Keller's Personalized System of Instruction, for example, has produced much more dramatic results in college classrooms (Kulik, Kulik, & Cohen, 1979a). Numerous studies have reported that Keller's teaching method makes a substantial contribution to examination performance and also contributes dramatically to ratings of instruction. The effects of computer-based teaching were smaller and comparable in size to those reported in studies of programmed instruction (Kulik et al., in press) or of Postlethwait's audiotutorial approach to teaching (Kulik et al., 1979b).

In general, we found little relationship between design features of experiments and experimental outcomes. For the most part, design features of experiments did not influence outcomes. Quasi-experimental studies and true experiments produced similar results. Experiments with controls for historical effects yielded the same results as experiments without historical controls. Nor did settings influence findings

in any substantial way. Findings were similar in "hard" and "soft" disciplines, in pure and applied areas, and in life studies and other content areas. Findings were also the same for courses at different levels.

We were especially surprised to find no relationship between publication features and findings reported in the studies. In our meta-analysis of research on Postlethwait's audiotutorial approach (Kulik et al., 1979b), we reported that findings in published studies were stronger than those in unpublished studies and dissertations—a relationship reported in a number of meta-analyses (Peterson, 1979; Rosenthal, 1976). In our meta-analysis of research on programmed instruction (Kulik et al., in press), we reported that study year was related to size of effect; more recent studies produced results more favorable to programmed instruction. Other meta-analysts have also reported time trends in results (Hall, 1978). For computer-based teaching, however, neither variable—nature of publication or study year—was significantly related to study outcome.

Only one variable predicted study outcome in our meta-analysis, and that was use of a design that controlled for instructor effects. In studies in which different teachers taught computer-based and conventional sections of a course, examination differences were more clear-cut and favored computer-based teaching. In studies in which a single teacher taught both experimental and control classes, differences were less pronounced. We found a similar relationship between this research design feature and experimental outcomes in our meta-analysis of research on Keller's Personalized System of Instruction (Kulik et al., 1979a). It seems possible that involvement of teachers in innovative approaches to instruction may have a general effect on the quality of their teaching. Outlining objectives, constructing lessons, and preparing evaluation materials (requirements in both computer-based and personalized instruction) may help teachers do a good job in their conventional teaching assignments.

Two points should be kept in mind by readers forming an overall evaluation of computer-based college teaching on the basis of our meta-analysis. The first point concerns the weighting that we gave to different studies in the analysis. Our meta-analysis gave equal weight to each independent study that we located, where "study" was defined as a set of results described in a single report or publication. If we had weighted studies according to the number of students, classes, or comparisons described in them, our results would have been different. The findings from the ETS evaluation of PLATO and TICCIT (Alderman, 1978; Murphy & Appel, 1977) would have carried as much weight as the results of all the other investigators combined, and the unique ETS findings—elevated withdrawal rates and neutral-to-negative student attitudes to computer-based courses—would have had a far greater influence in our findings.

The other point concerns the very nature of meta-analysis. This method provides a way of determining major themes in reported research findings. In this meta-analysis, we looked at student outcomes that were frequently studied: student learning, student attitudes, student course completion, instructional time, and the correlation between aptitude and achievement. We did not examine less direct, more subtle, or even unique outcomes of computer-based teaching. We do not know, therefore, whether computer-based teaching helped students develop a sense of confidence with computers, whether it contributed to faculty development, or whether it provided the groundwork for future innovations far more effective than anything now imagined. Furthermore, the effectiveness research that we examined was con-

ducted during the time period 1967 through 1978. The picture we drew is of the past, not the future. Developments in computer technology have been occurring so swiftly that no one can predict with confidence what the next year, much less the next decade, will bring in computer-based college teaching.

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