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Effectiveness of Computer-Based Instruction: An Updated Analysis

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Abstract — *A meta-analysis of findings from 254 controlled evaluation studies showed that computer-based instruction (CBI) usually produces positive effects on students. The studies covered learners of all age levels — from kindergarten pupils to adult students. CBI programs raised student examination scores by 0.30 standard deviations in the average study, a moderate but significant effect. Size of effect varied, however, as a function of study feature. Effects were larger in published rather than unpublished studies, in studies in which different teachers taught experimental and control classes, and in studies of short duration. CBI also produced small but positive changes in student attitudes toward teaching and computers, and it reduced substantially the amount of time needed for instruction.*

Since the early 1960s educational technologists have been developing programs of computer-based instruction (CBI) to drill, tutor, and test students and to manage instructional programs. In recent years these CBI programs have been used increasingly in schools to supplement or replace more conventional teaching methods. Many educational technologists believe that CBI will not only reduce educational costs in the long run but that it will also enhance educational effects. Some envision a day when computers will serve all children as personal tutors: a Socrates or Plato for every child of the 21st century.

Evaluators have conducted many studies to determine whether CBI programs can, in fact, produce such beneficial effects. They have divided classes of students into experimental and control groups and have taught experimental group students with computer assistance while teaching control students with conventional methods only. At the end of a study, the evaluator compares responses of experimental and control students on a common examination, on a course evaluation form, or on a log of time-on-task.

No individual outcome study, however, can show whether CBI is generally effective. To reach general conclusions reviewers must take into account the results from numerous studies carried out in different places, at different times, and

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under different conditions. It would be as pointless to judge all CBI programs by a single outcome study as it would be to judge all textbooks, lectures, or films by a single comparison.

Niemiec and Walberg (1987) have provided a comprehensive review of efforts to summarize evaluation results on CBI. They located a total of 16 reviews on the question. Three of these were traditional narrative reviews; two were box-score reviews, which presented tallies of negative and positive outcomes for CBI; and 11 reviews presented meta-analytic findings. Meta-analytic reviews express outcomes of all studies in standard deviation units and statistically investigate relationships between these outcomes and study features.

The conclusions from traditional reviews (Feldhusen & Szabo, 1969; Jamison, Suppes, & Wells, 1971; Thomas, 1979) have been basically positive. Feldhusen and Szabo (1969) and Jamison, Suppes, and Wells (19711) drew the conservative conclusion that CBI is at least as effective as live teaching, and it may also result in substantial savings of student time. A more recent traditional review by Thomas (1979) is even more positive. Thomas reported that achievement gains over other methods are the norm, that improved attitudes toward computers and subject matter were generally reported, and that many CBI students gained mastery status in a shortened period of time.

The box score reviews also reported positive results from CBI. Edwards, Norton, Taylor, Weiss, and Dusseldorp (1975) reported that most comparisons reported positive or at least mixed results, and Vinsonhaler and Bass (1972) reported that 94% of all comparisons favored CBI. Box score results reported in meta-analyses of CBI have reported similar splits. Niemiec and Walberg (1987). for example, reported a median box-score result of 92 percent of studies in favor of CBI.

Meta-analytic results give more information about the size of these CBI effects. The median of all effect sizes reported in the reviews of CBI was 0.42. The typical effect of CBI therefore was to place the average student using it at the 66th percentile of traditional groups — a substantial though not overwhelming advantage. Niemiec and Walberg (1987) mention that instructional effectiveness of CBI may be a function of instructional level, however. The average effect size for CBI in colleges was 0.26; in secondary schools, 0.32; in elementary schools, 0.46; and in special education settings, 0.56. Developers of CBI programs have been most successful so far in designing programs to teach elementary skills and information; they have apparently been less successful in teaching the higher order skills emphasized at higher educational levels.

Although reviews of CBI evaluations have shown remarkable consistency in their outcomes, they have some limitations. Even recent reviews (e.g., Bangert-Drowns, 1985; C. Kulik & Kulik, 1986; C. Kulik, Kulik, & Shwalb, 1986; J. Kulik, Kulik, & Bangert-Drowns, 1985a) cover no studies published after 1984, and studies carried out in 1984 usually report on research designed and executed years earlier. Extended periods of time are usually required for designing research studies, executing research plans, writing up results, and publishing reports.

The omission from most reviews of results from recent CBI applications is a serious problem for at least two reasons. First, computers have changed greatly during recent years. They have become smaller, less expensive, more reliable, and quicker in their operations. Communication with them has become easier, and their output has become more readable and attractive. Second, conceptions of the role that the computer can play in instruction have broadened. CBI designers no longer think of the computer simply as an efficient machine for drilling students. They think of it as a device that can be used in a variety of ways, in a variety of subjects, for a variety of goals.

Earlier reviews of CBI need to be updated therefore. We need to determine whether the record of effectiveness of CBI has changed with the development of new kinds of computers. The record of effectiveness of microcomputer-based instruction is an especially important issue that needs to be examined. We also need to know whether the record of effectiveness of CBI has changed with the development of new software in recent years. At least one earlier review (J. Kulik & Kulik, 1987) found evidence of a time trend in the record of effectiveness of CBI, and we need to know whether this trend has held up.

METHOD

The meta-analytic approach used in this review is the same as the approach used in our other meta-analyses. It requires a reviewer to: (a) locate studies of an issue through objective and replicable searches, (b) code the studies for salient features, (c) code study outcomes on a common scale, and (d) use statistical methods to relate study features to outcomes.

Data Sources

The studies considered for use in this meta-analysis came from three major sources. One large group of studies came from the references in our earlier meta-analytic reviews on CBI (Bangert-Drowns et al., 1985; C. Kulik & Kulik, 1986; C. Kulik et al., 1986; J. Kulik et al., 1985a). A second group of studies was located by computer-searching two library data bases using Lockheed's Dialog Online Information Services. The data bases searched in this way were: (a) Comprehensive Dissertation Abstracts, and (b) ERIC, a database on educational materials from the Educational Resources Information Center, consisting of the two files Research in Education and Current Index to Journals in Education. A third group of studies was retrieved by branching from bibliographies in the documents located through reviews and computer searches.

These search procedures yielded 55 new studies, in addition to the 199 studies included in our previous analyses. All studies met four basic criteria for inclusion in our data set. First, the studies had to take place in actual classrooms. They had to involve real teaching, not an analog of teaching. Second, the studies had to provide quantitative results on an outcome variable measured in the same way in both a computer-taught and a conventionally instructed class. Uncontrolled "experiments" and anecdotal reports were not acceptable. Third, the studies had to be free from such crippling methodological flaws as: (a) substantial differences in aptitude of treatment and control groups, (b) unfair "teaching" of the criterion test to one of the comparison groups, and (c) differential rates of subject attrition from the groups being compared. And fourth, the studies had to be retrievable from university or college libraries by interlibrary loan or from the Educational Resources Information Center, the National Technical Information Service, or University Microfilms International.

Outcome Measures

The instructional outcome measured most often in the 254 studies was student learning, as indicated on achievement examinations given at the end of the program of instruction. Other outcome variables measured in the studies were: (a) performance on a follow-up or retention examination given some time after the completion of the program of instruction, (b) attitude toward computers, (c) attitude toward instruction, (d) attitude toward school subjects, (e) course completion, and (f) amount of time needed for instruction.

For statistical analysis, outcomes had to be expressed on a common scale of measurement. The transformation used for this purpose was the one recommended by Glass, McGaw, and Smith (1981). Like Glass and his colleagues, we coded each outcome as an effect size (ES), defined as the difference between the mean scores of two groups divided by the standard deviation of the control group. For studies that reported means and standard deviations for both experimental and control groups, **ES** could be calculated directly from the measurements provided. For less fully reported studies, **ES** could usually be calculated from statistics such as t and F.

The application of the formulas given by Glass and his colleagues **was** straightforward in most cases. In some studies, however, more than one value was available for use in the numerator of the formula for **ES** and more than one value was available for the denominator. For example, some investigators reported raw-score differences between groups as well as covariance-adjusted differences, and some reported differences on a postmeasure as well as differences in prepost gains. In such cases, we used as the numerator of **ES** the difference that gave the most accurate estimate of the true treatment effect. That meant using covariance-adjusted differences rather than raw-score differences, and differences in gains rather than differences on posttests. In addition, some reports contained several measures of variation that might be considered for use as the denominator of **ES.** We used the measure that provided the best estimate of the unrestricted population variation in the criterion variable.

For measurement of the size of CBI effects on course completion, we used the statistic h (Cohen, 1977). This statistic is appropriate for use when proportions are being compared. It is defined as the difference between the arcsine transformation of proportions associated with the experimental and control groups. To code CBI effects on instructional time, we used a ratio of two measurements: the instructional time required by the experimental group divided by the instructional time required by the control group.

Study Features

A total of nine variables were chosen from our previous list of variables to describe treatments, methodologies, settings, and publication histories of the studies (Table 1). These nine variables were chosen on the basis of evidence of relevance of these factors to the effectiveness of CBI in previous meta-analyses. Two coders independently coded each of the studies on each of the nine variables. The coders then jointly reviewed their coding forms and discussed any disagreements. They resolved these disagreements by jointly reexamining the studies whose coding was in dispute.

Unit of Statistical Analysis

Some studies reported more than one finding for a given outcome area. Such findings sometimes resulted from the use of more than one experimental or control group in a single study, and they sometimes resulted from the use of several sub-

Table 1. Categories Used to Describe Study Features

Type of application	
Computer-assisted instruction (CAI) — The computer provides (a) drill-and-practice exercises bu not new material, or (b) tutorial instruction that includes new material.	
Computer-managed instruction (CMI) — The computer evaluates student test performance, guides students to appropriate instructional resources, and keeps records of student progress	
Computer-enriched instruction (CEI) — The computer (a) serves as a problem-solving tool, (b) generates data at the student's request to illustrate relationships in models of social or physical reality, or (c) executes programs developed by the student.	
Duration of instruction	
Four weeks or less	
More than four weeks	
Type of computer interaction	
Off-line	
Terminal with mainframe	
Microcomputer	
Subject assignment	
Random — Subjects were randomly assigned to the experimental and control groups.	
Nonrandom — A quasi-experimental design was used.	
Control for instructor effects	
Same instructor — The same teacher or teachers taught both the experimental and control groups.	
Different instructors — Different teachers tuaght the two groups.	
Control for test-author bias	
Commercial — A standardized test was used as the criterion measure for student achievement	
Local — A locally developed test was used as the criterion.	
Course content	
Math	
Science	
Social science	
Reading and language	
Combined subjects	
Vocational training	
Others	
Year of the report	
Up to 1970	
1971 - 1975	
1976 - 1980	
After 1981	
Source of study	
Technical report — Clearinghouse document, paper presented at a convention, etc.	
Dissertation	
Professional journal — Journal article, scholarly book, etc.	

scales and subgroups to measure a single outcome. Using several ESs to represe results from one outcome area of one study seemed to be inappropriate to because the ESs were usually nonindependent. They often came from a singl group of subjects or from overlapping subject groups, and they almost alwa represented the effects of a single program implemented in a single setting. To rep resent a single outcome by several ESs would violate the assumption independence necessary for many statistical tests and would' also give undu weight to studies with multiple groups and multiple scales.

The procedure that we adopted, therefore, was to calculate only one ES for eac outcome area of each study. A single rule helped us to decide which ES best represented the study's findings. The rule was to use the ES from what would ordinarily be considered the most methodologically sound comparison when comparisons differed in methodological adequacy: (a) When results from both a true experimental comparison and a quasi-experiment were available from the same study, results of the true experiment were recorded; (b) When results from a long and short CBI implementation were available, results from the longer implementation were used; (c) When transfer effects of CBI were measured in addition to effects in the area of instruction, the direct effects were coded for the analysis; and (d) In all other cases, our procedure was to use total score and total group results rather than subscore and subgroup results in calculating ES.

RESULTS

Because most of the studies in the pool investigated effects of CBI on examination performance, we were able to carry out a complete statistical analysis of results in this area. The analysis covered both average effects and the relationship between effects and study features. We carried out less complete statistical analyses in other outcome areas because of the limited number of studies in these areas.

Examination Performance

A total of 248 of the 254 studies in our pool reported results from CBI and control groups on examinations given at the end of instruction. Of the 248 studies, 53 were new studies, not included in our previous meta-analyses on CBI. Major features and outcomes of these 53 studies are listed in Table 2. Comparable descriptive data on the remaining 196 studies appears in earlier reports on our work (Bangert-Drowns et al., 1985; C. Kulik & Kulik, 1986; C. Kulik et al., 1986; J. Kulik & Kulik, 1985).

In 202 (81%) of the 248 studies, the students in the CBI class had the higher examination average; in 46 (19%) of the studies, the students in the conventionally taught class had the higher average. The difference in examination performance of CBI and control students was reported to be significant in 100 studies. In 94 of the 100 cases, the significant difference favored the CBI class, whereas only six studies favored conventional teaching. Overall, these box-score results favor CBI.

The index ES provides a more exact picture of the degree of benefit from CBI in the typical study. The average ES in the 248 studies was 0.30; its standard error was 0.029. This average ES means that in the typical study, the performance of CBI students was 0.30 standard deviations higher than the performance of the control students. ESs can also be expressed in terms of percentile scores. Approximately 62% of the area of the standard normal curve falls below a z-score of 0.30. We conclude, therefore, that the typical student in an average CBI class would perform at the 62nd percentile on an achievement examination, whereas the typical student in a conventionally taught class would perform at the 50th percentile on the same examination. Put in another way, the average student from the CBI class would outperform 62% of the students from the conventional classes.

Examination Performance and Study Features

Although the increase in examination performance attributable to the computer was moderate in the typical study, effects varied in magnitude from study to study. The

... Studies of Computer Based Instruction

Study	Place	Grade	Content**	Use	Duration in weeks	Effect size
Elementary school studies						
Adams, Ingebo, Leitner Miller, Mollanen, & Peters, 1983	Oregon	2 - 8	Reading & math	Managing	32	0.18
Alberta Department of Education, 1983	Canada	3	Reading	D & P	20	0.76
Al-Hareky, 1983	Saudi Arabia	4	Math	Tutoring	4	0.56
Anderson, 1984	Nebraska	3 & 4	Keyboard skills	Tutoring	4	0.38
Ash, 1986	Alabama	5	Math	D & P	36	0.48
Chamberlain, Beck,& Johnson, 1983	Ohio	4 - 8	Reading	Tutoring	25	-0.15
Clements, 1986	Ohio	1 & 3	Reading & math	D & P	22	0.29
Coomes, 1986	Texas	4	Reading	D & P	36	-0.14
Cooperman, 1985	Delaware	2 - 4	Reading	D & P	36	-0.06
Diamond, 1986	Utah	K	Keyboard skills	Tutoring	8	-0.07
Ferrell, 1985	Texas	6	Math	Tutoring	36	0.39
Larrea-Peterson, 1985	Utah	2 - 6	Reading & math	Tutoring	24	0.60
Levy, 1985	New York	5	Reading & math	D & P	36	0.22
Melnik, 1986	Illinois	5	Problem solving	D & P	10	0.30
Todd, 1986	Texas	4	Reading & math	D & P	28	0.25
Turner, 1986	Arizona	3 & 4	Math	D & P	13	0.26
Secondary school studies						
Beck & Chamberlain, 1983	Ohio	9	Reading	Tutoring	28	0.16
Bostrom, Cole, Hartley, Lovell, & Tait, 1982	England	8	Math	Tutoring	3	0.16
Feldhausen, 1986	Nebraska	9 - 12	History	D & P	2	0.10
Henderson, 1983	California	9 - 12	Math	Tutoring	12	0.88
Krull, 1980	Missouri	7	Math	Programming	10	0.68
Mandelbaum, 1973	Pennsylvania	11	Math	Programming	10	0.05
Porinchak, 1984	New York	9 - 12	Reading	Tutoring	28	0.19
Wainwright, 1985	Minnesota	9 - 12	Chemistry	D & P	3	-0.42
Way, 1984	Kansas	8 - 9	Math	D & P	24	0.08

(continued)

Table 2. Continued

Study	Place	Grade	Content**	Use	Duration in weeks	Effect size
			College studies			
Austin, 1983	Florida	College	Math	Tutoring	1	0.48
Benedict & Butts, 1981	Virginia	College	Psychology	Simulation	4	0.56
Bray, 1981	Kentucky	College	Psychology	Managing	16	0.51
Curtis, 1986	Texas	College	Food biology	Simulation	1	0.86
Evans, Michelson, & Smith, 1984	Canada	College	Basic composition	Tutoring	1	-0.21*
Fawson, 1985	Hawaii	College	Library science	Tutoring	1	1.41
Friedman, 1981	California	College	Accounting	D & P	15	0.33
Groomer, 1981	Indiana	College	Accounting	Tutoring	16	0.42
Harris, 1984	Texas	College	Industrial arts	Tutoring	4	0.74
Hong, 1972	New York	College	Math	D & P	16	0.30
Hythecker, Rocklin, Dansereau, Lambiotte, Larson, & O'Donnell, 1985	Texas	College	Learning strategy	Tutoring	1	0.32
Jim, Gee, Hyneck, Shannon, Fox, & Fillbeck, 1984	Michigan	College	Applied therapeutics	Tutoring	2	-0.11
McKeown, 1976	Illinois	College	Accounting	Tutoring	16	0.51
Miller, 1986	Florida	College	Biology	Simulation	1	0.22
Perreault, 1984	Oklahoma	College	Keyboard skills	Tutoring	15	0.59
Schurdak, 1967	Connecticut	College	Programming	Tutoring	1	0.79
Spangler, 1986	Iowa	College	Welding	Simulation	8	0.45
Strickland, 1985	New York	College	Writing	Tutoring	15	-0.24
Tamaccio, 1984	Mass	College	Electrocardiography	Tutorign	6	0.90
Taylor, 1984	Ohio	College	Reading	Tutoring	7	0.97

Boldovici & Scott, 1984	Virginia	TT	Technical math	D & P	6	0.23*
Broughton, 1986	Texas	TT	Life insurance	Tutoring	1	0.14
Bruce, 1984	Florida	TT	Radar operation	Simulation	2	1.02
Bruce, 1986	Minnesota & North Dakota	TT	Medical quality control lab	Tutoring	2	-0.14
National Training Anal Evaluation Group, 1983	Florida	TT	Airman apprentice training	Tutoring	1	0.21
Trede, Russell, & Miller, 1985	Iowa	TT	Farm management & marketing	Tutoring	1	0.29
Wiggins, 1984	S. Carolina	TT	Home economics	Tutoring	1	0.01

*Estimated effect size.
**TT = Technical training.

strongest positive result reported was an effect of 2.17 standard deviations (Cartwright, Cartwright, & Robine, 1972); the strongest negative result was an effect of -1.20 standard deviations (Diem, 1982). In our previous syntheses, further analyses were conducted to determine whether different types of studies were in fact producing different results. This procedure was repeated once more for this updated sample of 248 studies. Three study features proved to be significantly related to achievement ES (Table 3). Average ES differed in: (a) studies from different publication sources, (b) studies with and without controls for teacher effects, and (c) studies of different durations.

Publication source. The average ES in studies found in professional journals was significantly higher than was the average effect in studies found in dissertations and technical documents, F (2,245) = 5.55, $p < .005$. The average ES in the 76 journal studies was 0.44 ($SE = .06$); it was 0.23 (SE = 0.04) in the 117 dissertation studies; and it was 0.27 ($SE = 0.14$) in the 55 technical reports. The difference between results found in dissertation studies and those found in technical documents was too small to be considered statistically significant, but the difference in results from journals and from other sources was significant. Publication source was significantly related to study result in both precollege and postsecondary studies.

Duration of treatment. The average effect size in studies of short duration — four weeks or less — was significantly higher than the average effect size in longer studies, F (1,246) = 6.77, $p < .01$. The average **ES** in the. 68 studies of short duration was 0.42 (SE = 0.07); it was 0.26 ($SE = 0.03$) in 180 longer studies. **The** difference in effectiveness for long and short studies was significant at both precollege and postsecondary levels of teaching.

Controlfor instructor effects. The average **ES** of studies without a control for instructor effects was significantly higher than was the average effect in studies with such a control, F (1,234) = 5.2, $p < .03$. The average **ES** in 110 studies without a control was 0.39 (SE = 0.04); it was 0.25 (ES = 0.04) in 124 studies with such control.

Follow-up Examinations

Twenty studies examined the performance on follow-up examinations of CBI and conventionally taught classes. The follow-up interval in these studies varied from two to 10 weeks. The 20 studies were not completely representative of the total pool of studies. Whereas the average **ES** on course examinations was 0.30 for all 242 studies, the average **ES** on final examinations **for** these 20 studies was 0.21. The average retention ES in the 20 studies was 0.17 ($E = 0.04$).

Attitudes

Nineteen studies examined students' attitudes toward computers. Contact with the computer in many of the studies produced positive changes in students' attitudes, and 15 of the 19 studies reported more favorable attitudes for students in the CBI class. The average **ES** in the 19 studies was 0.34 (SE = 0.10).

Twenty-two studies examined student ratings of the quality of instruction. Sixteen of the 22 studies found more positive attitudes in the CBI class; two studies

Table 3. Means and Standard Errors of Effects Sizes (ES) for 248 CBI Studies Classified by Study Feature

Category				Postsecondary			Total		
								ES	
								M	SE
								.31	0.04
								.37	0.07
								.26	0.05
								.42	0.07***
								.26	0.03
								.26	0.05
								.32	0.04
								.25	0.08
								.31	0.06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.30	0.03
Instructors									
Same	35	0.23	0.06	91	0.26	0.05*	126	0.25	0.04**
Different	61	0.36	0.04	49	0.42	0.08	110	0.39	0.04
Test author bias									
Local test	25	0.27	0.10	116	0.30	0.05	141	0.29	0.04
Local & commercial	12	0.28	0.10	9	0.33	0.08	21	0.30	0.07
Commercial test	62	0.32	0.04	24	0.33	0.10	86	0.32	0.04
Content									
Mathematics	50	0.37	0.05	41	0.14	0.06	91	0.26	0.04
Science	13	0.10	0.11	29	0.23	0.08	42	0.19	0.07
Social science	2	0.16	0.06	32	0.39	0.10	34	0.38	0.09
Reading & language	18	0.25	0.07	11	0.45	0.19	29	0.35	0.08
Combined	12	0.26	0.05	7	0.25	0.09	19	0.26	0.04
Vocational training	3	0.46	0.18	23	0.45	0.11	26	0.45	0.10
Other	1	0.98	—	6	0.58	0.37	7	0.64	0.31
Source of publication									
Unpublished	28	0.34	0.06*	27	0.19	0.08*	55	0.27	0.05***
Dissertation	54	0.24	0.05	63	0.22	0.06	117	0.22	0.04
Published	17	0.46	0.08	59	0.44	0.07	76	0.44	0.06

(continued)

Table 3. Continued

Category	Precollege			Postsecondary			Total		
		ES			ES			ES	
	N	M	SE	N	M	SE	N	M	SE

Table 4. Effects in Other Outcome Areas

y	Grade level	Instructional time (Ratio of X:c)	Retention at follow-up	Attitude toward computer	Attitude toward instruction	Attitude toward subject
[illegible], 1986	College	0.35				
Bruce, 1986						
D'Souza, 1984		1.02			-0.14	-0.06
Fawson, 1985					0.37	
Hythecker, Rocklin, Dansereau, Lambiotte, Larson, & O'Donnell, 19[illegible]5				0.53	0.51	
Mandelbaum, 1973	11					0.42
Miller, 1986	College		0.16			
Rushinek, 1981	College			0.21	[illegible]	
Schurdak, 1967	College	[illegible]90				
Todd, 1986	4					0.[illegible]7
Turner, 1986	3 - 4					0.[illegible]0
Wainwright, 1985	9 - 12		[illegible]6	[illegible]7		-0.[illegible]3
Wiggin, 1984	Adult	1.1[illegible]				

found no difference in attitudes for CBI and conventionally taught classes; and four studies found more negative attitudes in the CBI class. The average **ES** in the 22 studies was 0.28 ($SE = 0.08$).

Thirty-four studies examined the effects of CBI on student attitudes toward the subject matter that they were being taught. Twenty of the 32 studies reported that student attitudes in CBI classes were more positive than in conventional classes; 14 studies found negative effects. The average **ES** for student attitudes toward subject was 0.05 ($SE = 0.06$), a very small positive effect.

Course Completion

Twenty-three studies compared the numbers of students completing CBI and conventional classes. All of these studies were carried out at the postsecondary level. Ten of the 23 studies found higher completion rates in the CBI class; and 13 studies found higher completion rates in the control class. The average h for attrition for the 23 studies was -0.06 ($SE = 0.056$), a very small effect favoring the control class.

Instructional Time

Thirty-two studies compared the instructional time for students in the CBI and conventional classrooms. **All** 32 studies are at the postsecondary level. The ratio of instructional time for CBI students to instructional time for students studying conventionally was 0.70 in the average study. In other words, CBI students required about two-thirds as much instructional time as did students who were taught conventionally. The range of ratios varied from .16 to 1.15. In only three cases did a CBI class require more instructional time than a conventionally taught class.

DISCUSSION

This meta-analysis examined results of 254 studies that compared student learning in classes taught with and without CBI. Overall results were consistent with findings in earlier literature reviews in this area. CBI raised final examination scores in a typical study by 0.30 standard deviations, or from the 50th to the 62nd percentile. This figure is very close to the average effect size of 0.31 reported in our earlier meta-analysis of findings from 199 studies of CBI (J. Kulik & Kulik, 1987).

Results of this and our earlier analysis not only agreed overall, but they also agreed in detail. In our earlier analyses, for example, we had reported a relationship between achievement outcomes of studies and: (a) study duration, (b) control for instructor effects, and (c) publication source. This updated analysis confirmed the significance of relationships between achievement outcomes and each of these factors.

The treatment feature most strongly related to effect size in this analysis was length of treatment. CBI was especially effective when the duration of treatment was limited to four weeks or less. The average effect of CBI in such studies was to raise performance by 0.42 standard deviations. In studies where the treatment was continued for several months, a semester, or a whole year, treatment effects were less clear. The average effect of CBI in such studies was to raise examination performance by 0.26 standard deviations. A similar relationship between treatment duration and study outcome has been reported in other areas of educational research (J. Kulik, Kulik, & Bangert-Drowns, 1988).

Some have argued that the relationship between treatment duration and study outcome found in such meta-analyses is the opposite of what it should be. With brief programs, the argument goes, one should expect small effect sizes. With prolonged exposure to a treatment in a long program, effects should be larger. This argument would be correct if both long and short programs used the same measure of achievement — say, an overall achievement test like the Stanford Achievement Test. With a month of improved instruction, experimental group students might be able to surpass control group students in educational age by a few days, or a week at most. With a year-long exposure to a superior teaching method, gains of a few months would be possible, and such gains would translate into larger effect sizes. But short-term studies do not use the same tests that long term studies do. They use tests that cover small content areas in great detail. Long studies use overall tests. With tests tailored to the amount covered in an instructional period, there is no reason to expect effect sizes, which are measured in standard deviation units, to be larger in long studies.

It is unclear, however, why effects are significantly smaller in long studies. A novelty effect, or Hawthorne effect, could certainly explain the finding. A novelty effect occurs when learners are stimulated to greater efforts simply because of the novelty of the treatment. As the treatment grows familiar, it loses its potency. But it is also possible that shorter experiments produce stronger results because short experiments are more tightly controlled experiments. In short experiments, it is usually possible to use precisely focused criterion tests, to keep control group subjects from being exposed to the experimental treatment, and so on. There is little empirical evidence available that allows us to choose between these explanations for the difference in findings of long and short experiments.

Like our earlier meta-analyses, this one produced evidence that the use of a control for instructor effects influences the outcome of evaluations of CBI. Effects were larger when different instructors taught experimental and control classes: effects were smaller when the same instructor taught both CBI and conventional classes. A similar relationship between control for instructor effects and study outcomes has also been reported in meta-analyses in other areas (e.g., J. Kulik & Kulik, 1987).

produced by selective assignment of experimental and control teachers. If stronger teachers are usually assigned to CBI classes and weaker teachers to conventional classes, two-teacher experiments would be expected to produce stronger effects than one-teacher experiments. Another possible explanation for the effect is treatment contamination. If teaching an experimental class has generally beneficial effects on a teacher's performance, two-teacher experiments would also be expected to produce stronger effects than do one-teacher experiments because the control group in the one-teacher experiments gets some of the benefits of the treatment.

The final feature that was significantly related to study outcome was publication source. Results found in journal articles were clearly more positive than were results from dissertations and technical documents. The difference in effects from these different sources was not only highly significant, but it was also highly predictable. A difference between journal and dissertation results has been reported in numerous quantitative syntheses of research and evaluation findings

(Bangert-Drowns et al., 1984; Glass et al., 1981, pp. 64-68). The relationship is one of the best documented findings in the meta-analytic literature.

The factors that produce this difference, however, are not completely understood. A number of writers have attributed the difference in journal and dissertation findings to publication bias (e.g., Clark, 1985). This is the purported tendency of researchers, reviewers, and editors to screen reports for publication on the basis of size and statistical significance of effects, rather than on the basis of study quality. Such publication bias would make journals an unreliable source for information about the effectiveness of experimental treatments. Other writers have noted that journal studies and other studies are carried out by different persons working under different conditions (e.g., J. Kulik, Kulik, & Bangert-Drowns, 1985b). The typical author of a journal article, for example, differs from the typical dissertation writer in research experience; resources, professional status, and in many other respects. If the weakness of dissertation results is attributable to the inexperience of dissertation writers, then dissertations would be a poor source for information on the effectiveness of treatments.

Our analysis also found a small and inconsistent relationship between type of computer use and effect on student learning. At the postsecondary level, in fact, there were no significant differences in effectiveness of different types of computer use. Programs of computer-assisted instruction (CAI), computer-managed instruction (CMI), and computer-enriched instruction (CEI) all made moderate positive contributions to student learning. At the precollege level, however, CAI, CMI, and CEI programs produced somewhat different effects. CAI and CMI programs were moderately effective, whereas CEI programs contributed little to student achievement. CEI programs may be too unfocussed to produce clear effects on examinations, or they may produce effects that are not measured well by conventional tests of achievement.

Earlier meta-analyses had suggested that evaluation results might change as microcomputer implementations became more common. Niemiec and Walberg (1987) reported, for example, an average effect size of 1.12 for microcomputer-based instruction and an average effect size of 0.38 for studies of CBI delivered through mainframes. They suggested that this difference might be a sign of the special effectiveness of microcomputers. The difference was based on only 7 studies of microcomputers, however. The present meta-analysis covered 34 studies of microcomputer-delivered instruction, and it provided no evidence to suggest unique effects from microcomputers.

Kulik and Kulik (1987) reported suggestive evidence that effectiveness of CBI was increasing with time, presumably as a function of the growing sophistication of computer software and hardware. In the Kulik and Kulik meta-analysis, studies from 1966 to 1974 had an average effect size of 0.24; studies from 1974 to 1984 had an average effect size of 0.36. The current meta-analyses covered a larger pool of recent studies and showed that the earlier indications of greater gains from CBI in recent years were misleading. Recent contributions from CBI are no different from earlier ones.

In our earlier meta-analyses we emphasized that contributions from CBI were not restricted to the cognitive domain. This analysis, like earlier ones, showed that there are reductions in instructional time associated with CBI. In 29 of the 32 studies that reported results on instructional time, the computer did its job quickly — on the average in about two-thirds the time required by conventional teaching methods. It is clear therefore that the computer can teach satisfactorily while reducing time spent in instruction. In addition, CBI had small and positive effects on attitudes of students toward instruction. Students tended to like their courses somewhat more when instruction was computer-based. Finally, CBI had a positive effect on student attitudes toward the computer.

Although CBI produced only modest effects in the typical evaluation study, some individual studies reported large effects. Included among the studies that reported unusually strong, positive effects are several in education and psychology: Cartwright, Cartwright, and Robine (1972); Green and Mink (1973); Lorber (1970); and Roll and Pasen (1977). Other studies that reported strong positive effects come from the area of music education: Humphries (1980) and Vaughn (1977). Researchers may wish to scrutinize results of these atypical studies very carefully. The programs evaluated in these studies may point the way to better uses of the computer in teaching in the years ahead.

Finally, this meta-analysis produced no evidence on what is certainly one of the most important questions of all about CBI: Is it cost effective? An early analysis by Levin, Destner, & Meister (1986) had suggested that the costs of CBI were too great, given its record of effectiveness. Levin et al. suggested that nontechnological innovations, such as tutoring, produced results that were just as good at a lower cost. Later reanalyses, such as those by Blackwell, Niemiec, and Walberg (1986), have suggested that computer-based instruction is not only a cost-effective alternative to traditional instruction but that it is far more cost-effective than such nontechnological innovations as tutoring. Further work is needed on this important variable in instruction.

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