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ABSTRACT

This study of the effects of computer-assisted instruction (CAI) on the academic achievement of educationally disadvantaged students in grades 2 through 8 in four urban schools tested three hypotheses: (1) supplementary CAI programs are significantly more effective than non-CAI supplementary instruction approaches for disadvantaged students; (2) school-based supplementary CAI programs are significantly more effective than district-based programs for this group; and (3) vendor-based programs are less effective than programs developed within the system by school personnel. The effects of three types of CAI programs are compared--a vendor supplied microcomputer system, a system-wide CAI program, and a school-based system--with both experimental and control groups for each program. The areas of study included reading comprehension; vocabulary; and mathematical concepts, problem-solving, computation, and composite skills. Analyses of the data failed to produce sufficient evidence to support the contention that disadvantaged students learned more when exposed to CAI, nor was there strong evidence that the impact of CAI varied with the system or the approach used. This report includes the purpose and objectives of the study; information on sample selection and procedures for data analysis and interpretation; study findings; and recommendations for future studies. Tables display data on the study sample by school, program, sex, and grade; pre- and posttest scores; and estimated posttest mean scores. Appendices provide a two-page reference list and analyses of the data on the six areas of study. (DJR)

DIFFERENTIAL EFFECTIVENESS OF THREE KINDS OF COMPUTER-ASSISTED INSTRUCTION

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ABSTRACT

This study investigates the effects of computer-assisted instruction (CAI) on academic achievement. Three types of CAI are compared, with control groups in each program to make achievement comparisons. Differences between types of CAI and effects of CAI are investigated.

Samples of subjects are drawn for each program with control subjects in each school to reduce school effects. An analysis of covariance using pretest scores adjusts for initial achievement differences between CAI program schools. Multiple comparisons are used to show differential effects of the various CAI programs.

The Problem

Computer-Assisted Instruction (CAI) is growing at a rapid rate with great diversity of approaches. An ever-increasing number of institutions or agencies, both public and private, seem to rely on this technological wonder as a means of accomplishing objectives. The literature is replete with evidence pointing to the extent to which CAI seems to be employed. In the private sector, for instance, CAI is used for a variety of projects ranging from training programs (Wehrenberg, 1985 and Mayer, 1983) to programs designed to change attitudes or alter the worker's sense of values (Billings, 1984). The armed forces, too, rely on CAI for training systems such as those in the Army (Bennik, 1980) and the remedial training programs operated for new recruits of the Navy (Wisher, 1981). State government and local government agencies also appear to have jumped on the bandwagon, using CAI for programs to improve employment opportunities for adults (Broussard, 1983, and Caldwell and others, 1984) or programs for changing behavior and improving the attitudes of those who have offended society (Florence V. Burden Foundation, 1984). But, perhaps the largest users of CAI are school systems, including colleges and universities.

The use of CAI at the elementary school, high school, or college level is so widespread that it would seem every aspect of the curriculum is covered. Evaluation reports indicate that some of the curriculum areas where some form of CAI is provided include: (a) programs for the improvement of writing and composition (Petersen, 1983); (b) bilingual instruction program (John Jay School Project, 1985); (c) supplemental or remedial instruction for low achieving students (Adams, 1983; Beck, 1983; and Wallace, 1984); (d) drills and tutorials (Becker, 1984); (e) summer school programs (Silfren, 1984); (f) improving attitudes, learner control, and transfer of learning (Clark, 1984); (g) special education (Smaldino, 1983); (h) simulations (Fisher, 1982); and (i) undergraduate instruction (Kulik, 1980; Baum, 1983; Brown, 1983; Goddard, 1983; and Stemmer, 1983).

The use of CAI is on the increase; nevertheless, very little is known about the effectiveness of the computer-based education. The extent of the impact of computer programs on learning is a question yet to be fully explored. Specifically, what needs to be determined, with the highest degree of certainty, is whether or not the use of CAI does boost achievement levels of students, particularly the educationally disadvantaged. Further, if CAI does indeed promote learning, then the factors associated with successful CAI programs must be identified so that administrators and teachers can choose wisely from the growing variety of computer-assisted instruction systems. Herein lies the need to continue studies of this important educational field.

Purpose of the Study

The present study focuses on the following key questions: (1) For the educationally disadvantaged, does CAI improve achievement? (2) Is CAI significantly superior to conventional or non-CAI approaches to instruction? and (3) Does the effectiveness of CAI vary with program design or systems?

The literature, to date, sheds very little light on these questions. In the last several years, those who have investigated CAI programs seem to be divided in terms of their opinions regarding the effects of such programs. Some claim CAI is capable of helping learners become better readers, calculators, writers, and problem solvers. Others believe that computers may not yield unique learning benefits.

The research done by Kulik seems to serve as a cornerstone for much of the argument that views computers as valuable tools for teaching and learning. Specifically, Kulik claims that: (a) computer-based education is capable of producing positive effects on the achievement of elementary students (1984 and 1985); (b) CAI can produce substantial savings in instruction time (1983); (c) CAI fosters positive attitudes toward computers (1983); and (d) in general, computers can be used to help learners become better readers, calculators, writers, and problem solvers (1983). Kulik's conclusions on the effects of CAI seem to be supported by Smaldino (1983), whose study claimed that the benefits of CAI may be realized even in the area of special education. Smaldino's claim was based on a study that found that learning-impaired subjects made significantly fewer errors on problem-solving tasks when exposed to micro computer conditions.

Kulik's research findings and those of other investigators in his camp appear to contradict, directly, the conclusions reached by another group of researchers. Speaking for the latter, Clark (1984) does not seem to believe in the effectiveness of computers as a medium of instruction. Clark argues that existing evidence, including that derived via meta-analytical techniques, indicates computers do not yield learning benefits (1984). According to him, evidence to the contrary is subject to compelling rival hypotheses concerning novelty effects. Further, where achievement gains have been noted, he believes that it is not the media that influence performance but the instruction strategies used with the computers. In view of all this, Clark (1984) suggests that all research on the learning benefits of the instructional uses of computers should be halted until there is a plausible reason to expect that computers are instrumental in improving learning.

The fact that opinion is divided in the research community, compounded with the increase in demand for, or growing variety in, CAI systems, makes it imperative to continue research studies until sufficient evidence is available that refutes or supports, beyond the shadow of doubt, effectiveness of computer-based education. In addition, research studies carried out so far have yet to cover the wide range of school settings, each made unique by its own local situation factor. Thus, the present study is focused primarily on the use of CAI for disadvantaged students.

Objectives of the Study

From an educational point of view, perhaps the major differences among CAI systems arise from the decision-making process responsible for, and associated with, the implementation of each program. In a vendor supplied micro system, the decision to acquire and implement the program is generated at the school level, between the principal and his staff, and in consultation with a vendor. However, the control of the program's curriculum and the techniques used are fixed by the vendor. In a system-wide CAI program, the decision to acquire and implement the program emanates largely from the central office in consultation with a vendor. The role of schools and teachers is limited to the mechanics of implementation. In a school-based design, the teachers figure prominently in the decision-making process. In all probability, the decision to acquire the CAI program is shared between the principal and the classroom teacher responsible for implementation of the program.

With respect to the purposes for this study then, the following specific hypotheses are analyzed:

1. For the educationally disadvantaged students, supplementary CAI programs are significantly more effective than non-CAI supplementary instruction approaches.

2. For the educationally disadvantaged students, school-based supplementary CAI programs are significantly more effective than the district-based programs.

3. For the educationally disadvantaged students, vendor-based programs are less effective than programs developed within the system by school personnel.

Sample

A sample of educationally disadvantaged children enrolled in a variety of computer-based supplementary pull-out programs was required for this study. Six schools operating five distinct computer-based supplementary pull-out programs were found in the subdistrict of a large urban school system with the lowest general socioeconomic indicators. One thousand five (1,005) participating students, functioning below grade level according to teacher judgment, were identified. Of these, 47 were deleted from the analysis because they started in the program in midyear.

The system's computerized files of test data and student status were used to identify a group of students to serve as controls for the study. The control group was also limited to students functioning below grade level. In addition, to increase comparability, they were selected from the same homeroom classrooms as the program participants. Three hundred ninety-five (395) such students were identified.

To allow for both within-school and between-school analyses, it was required that for each CAI program at each school there exists a roughly equivalent-size control group. This requirement removed two schools and two programs from the final sample. Table 1 displays the final sample by school, program, sex, and grade. To jump ahead somewhat, it is clear upon inspection of the table that any joint analysis will be plagued by empty cells and nonorthogonality.

TABLE 1

SAMPLE

School	Program	Subject	Male	Female	GRADE 2	3	4	5	6	7	8
A	Vendor	Math	30	28	0	0	29	0	0	29	0
	Vendor	Reading/ Mathematics	24	32	0	0	0	37	19	0	0
	Control		34	51	0	0	28	2	28	27	0
B	District	Reading/ Mathematics	62	60	0	0	0	33	31	30	28
	Control		15	17	0	0	0	2	22	3	5
C	School	Reading/ Mathematics	24	23	19	28	0	0	0	0	0
	Control		46	53	36	63	0	0	0	0	0
D	District	Reading/ Mathematics	51	65	0	0	30	35	14	15	22
	Control		45	35	0	0	10	21	25	15	9
TOTAL			331	365	55	91	97	130	139	119	64

Table 2 displays the mean pre- and posttest NCE scores for the final sample. Several comments are in order. A few of the sampled students were missing on either the pre- or posttest. These students are omitted from analysis.

TABLE 2

SUMMARY OF PRE- AND POST-TEST NCE SCORES

School	Program	Statistic	Reading Comprehension Pre	Reading Comprehension Post	Reading Comprehension Gain	Math Composite Pre	Math Composite Post	Math Composite Gain
A	Vendor	Mean	31.3	31.5	-0.3	44.4	46.2	2.0
		S.D.	16.2	17.1	11.1	15.4	16.5	8.6
		N	54	55	54	112	113	112
	Control	Mean	46.6	39.5	-6.9	43.3	40.2	-2.9
		S.D.	10.7	12.1	9.9	14.6	13.8	10.0
		N	85	83	83	84	83	82
B	District	Mean	27.9	20.6	0.7	32.6	30.7	-1.8
		S.D.	10.0	13.2	12.2	13.6	14.7	11.6
		N	111	117	110	111	117	110
	Control	Mean	20.8	29.5	3.5	28.4	28.7	-1.0
		S.D.	11.3	15.8	14.2	15.6	18.2	12.3
		N	31	29	28	31	29	28
C	School	Mean	38.1	32.4	-5.9	37.4	35.3	-2.9
		S.D.	11.2	14.3	15.9	15.5	15.6	17.7
		N	34	46	33	35	46	34
	Control	Mean	46.2	40.0	-5.5	49.8	41.1	-8.0
		S.D.	14.8	14.8	13.2	18.3	17.5	16.7
		N	87	95	83	86	95	82
D	District	Mean	38.7	36.3	-2.4	43.1	40.3	-2.8
		S.D.	14.2	15.2	13.3	15.0	14.8	10.7
		N	114	114	114	113	114	113
	Control	Mean	30.2	28.8	-1.0	34.5	31.8	-1.9
		S.D.	16.5	16.8	13.9	16.6	17.7	13.1
		N	79	76	76	76	76	73

The difference between the pre- and posttests is negative in 12 of the 16 cells of Table 2, hardly what one could wish or would expect. However, the district instituted a policy of strict test security and uniform test administration between the pre- and the posttest. Scores citywide went down at all grade levels. Presumably, analysis of covariance could adjust for this pattern.

At most of the schools, the CAI students have higher pretest means than the control group. This suggests failure to control adequately for incoming differences. However, this pattern was not totally unexpected. It was deemed more appropriate to select control groups from the same educational environment (that is, from the same classrooms) as the CAI students than to vary environments in order to control entry characteristics. Again, it was assumed that covariation or blocking could be used to adjust for such differences.

On the other hand, at two schools for reading and one for mathematics, the CAI group had higher pretest scores. This was unexpected. Possibly, since students were selected to these programs on teacher judgment of need, it may be that the teachers understood that the pretest scores were sometimes biased. On the other hand, staff may have assigned students to the program on the basis of teacher expectations of students' ability to benefit, rather than strictly according to need. Whatever the reason, these facts raise doubt that covariance analysis can effectively adjust for preexisting differences in this sample.

Table 2 also appears to display limited variance. The expected value of the standard deviation of a distribution of NCE scores in a normal population is 21.06; the typical standard deviation in this sample is more on the order of 14 or 15. This fact would serve to attenuate any actual relationships.

<u>Procedure</u>

The basic model to be fitted to these data was to be built using analysis of covariance with one factor for CAI composed of four levels (vendor-based, district-based, school-based programs, and control groups), using the posttest as the dependent variable and the pretest as a covariate. However, as Tables 1 and 2 have made clear, between-school and between-grade effects could be expected to play a role. The modified model therefore contained three factors: school, grade, and treatment in a 4 x 7 x 4 design. Sequential decomposition of variance was used, with the school factor entered first and the treatment factor last.

This model was applied six times, one for each of the following subtests of the standardized achievement battery used by the system: reading comprehension, vocabulary, mathematics concepts, mathematics problem solving, mathematics computation, and the mathematics composite. All analyses were conducted in the NCE metric. (It has been argued that use of NCEs avoids the need to test for grade effects, since scores from all levels of a test battery are comparable in this metric. Such was not true here, however.)

First, full-rank models were estimated. If interaction effects were not present ($p<0.05$), they were removed from the model and the reduced-rank model employed to obtain estimates of the effect parameters. Significant interactions between the school and grade factors were assessed prior to the treatment factor.

Prior to the final model, the dependent variable and the covariate were tested for parallelism of the regression lines between cells. In addition, the homogeneity of the variance of these variables between cells was tested. For all subtests homogeneity of variance was not found. Given the number of cells (many empty) and the patterns observed in Table 2, this might have been expected, although it was not.

Where regression parallelism could not be demonstrated, the pretest was processed as an interval factor nested within the three other factors. Nesting in all three factors--school, grade, and treatment--was required in all cases, rather than nesting in fewer factors, which attests to the highly context-dependent nature of test results in these schools and for these programs.

Discussion

The ANOVA tables for all six analyses appear in the appendix. In no instance did the treatment factor, net of school, grade, and pretest effects, reach significance. The grade factor, net of school and pretest effects, was significant ($p<0.05$) in three trials and nearly significant in a fourth. The school factor, net of school and pretest effects reached significance in all trials except reading comprehension. These results confirm the initial reactions to Table 2: There is a great variety among these schools and grades, but little or none of this variation can be associated with CAI as a medium of instruction.

When this analysis was first considered, it was felt that the overall test of the treatment factor would display the effect of CAI as a medium of instruction and that the effects making up the factor (school-based vs. control, district-based vs. control, and vendor-based vs. control) would test the effectiveness of each type of CAI considered as the content of instruction.

With none of the treatment factor F-ratios approaching significance, a look at the significance of the parameters for the school vs. control, district vs. control, and vendor vs. control effects is hardly legitimate. Nevertheless, it is tempting to peek: Only 2 of the 18 effect coefficients in these six analyses produced a t-value associated with $p<0.10$. Clearly, this gives no support to any substantive effects related to differences in content of CAI as a mode of instruction.

TABLE 3

ESTIMATED POSTTEST MEANS

Test	District	School	Vendor	Control
Reading Comprehension	34.43	30.94	34.20	33.35
Vocabulary	29.24	28.62	26.83	31.39
Mathematics Concepts	34.89	34.18	45.53	32.69
Mathematics Problem Solving	34.59	41.09	39.92	34.99
Mathematics Computation	41.06	34.43	51.03	42.42
Mathematics Composite	35.33	34.99	44.39	34.43

Table 3 reports the adjusted means estimated by each model. These could be interpreted to suggest that the vendor-based program's content may be slightly more effective in mathematics, but that interpretation has no statistical foundation, as demonstrated above. In addition, analysis of variance models conducted within each school (these are not reported here) found no significant effects.

Conclusion

The purpose of the study was to determine whether CAI affects the achievement levels of educationally disadvantaged students. On the basis of the data analyzed for the study, the evidence is insufficient to support the contention of superiority of CAI. Specifically, our analyses did not indicate that disadvantaged students learned more when exposed to computer conditions. Nor was there strong evidence to suggest that the impact of CAI varied with the system used or the approach--it made no difference whether the students were enrolled in a school-based computer program, a vendor-based program, or a system-wide program.

The conclusion drawn with respect to the study should not, however, be taken to mean that computers are not valuable learning tools. We are not making that point. Similarly, we are also not suggesting that all computer programs were created equal. Indeed, during the course of our investigation, every teacher and every principal we talked to fervently supported not only CAI but also a particular brand of CAI. It may be that our study failed to uncover significant differences simply because of the design used and the sample available for investigation.

In view of the large sums of money being spent on computers, we recommend that CAI program developers test their own programs prior to packaging for distribution or sale to schools. At minimum, such tests should include adequately designed and statistically based evaluations of the outcomes of the programs in a real school setting. Following that, we also recommend that developers of CAI programs precisely specify the outcomes their programs are expected to bring about. All too often, researchers (including ourselves) assess programs on the basis of achievement test results because that is all that is available to us, even though these may not be the outcomes intended by the developers. Finally, we recommend that the study of CAI be continued to identify factors associated with effective programs (if any be found) for the benefit of all.

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APPENDIX

1. ANOVA for Reading Comprehension

Source of Variation	SS	DF	MS	F	P<
Within cells	77164.01	552	139.79		
Covariate regression	34237.29	1	34237.29	244.92	0.000
Constant	6553.07	1	6553.07	46.88	0.000
School	32.24	3	10.75	0.08	0.972
Grade	826.53	5	165.31	1.18	0.316
Treatment	638.21	3	212.74	1.52	0.208

2. ANOVA for Vocabulary

Source of Variation	SS	DF	MS	F	P<
Within + residual	60100.90	538	111.71		
Constant	565317.23	1	565317.23	5060.50	0.000
Pretest within factors	66210.81	28	2364.67	21.17	0.000
School	2075.18	3	691.73	6.19	0.000
Grade	1150.08	5	230.02	2.06	0.069
School by grade	1969.18	6	328.20	2.94	0.008
Treatment	594.46	3	198.15	1.77	0.151

3. ANOVA for Concepts

Source of Variation	SS	DF	MS	F	P<
Within + residual	83013.75	594	139.75		
Constant	892006.56	1	892006.56	6382.70	0.000
Pretest within factors	74152.77	30	2471.76	17.69	0.000
School	2905.85	3	968.62	6.93	0.000
Grade	1746.07	5	349.21	2.50	0.030
Treatment	639.35	3	213.12	1.52	0.207

4. ANOVA for Problem Solving

Source of Variation	SS	DF	MS	F	P<
Within + residual	98067.73	593	165.38		
Constant	908409.92	1	908409.92	5493.01	0.000
Pretest within factors	71699.12	30	2389.97	14.45	0.000
School	4312.35	3	1437.45	8.69	0.000
Grade	970.13	5	194.03	1.17	0.321
Treatment	323.62	3	107.87	0.65	0.582

APPENDIX (Continued)

5. ANOVA for Mathematical Computation

Source of Variation	SS	DF	MS	F	P<
Within + residual	92318.73	584	92318.73		
Constant	1216469.47	1	1216469.47	7695.28	0.000
Pretest within factor	112806.10	30	3760.20	23.79	0.000
School	2829.42	3	943.14	5.97	0.001
Grade	1937.26	5	387.45	2.45	0.033
School by grade	1814.85	6	302.47	1.91	0.077
Treatment	464.11	3	154.70	0.98	0.402

6. ANOVA for Mathematics Total

Source of Variation	SS	DF	MS	F	P<
Within + residual	70089.17	586	119.61		
Constant	924501.23	1	924501.23	7729.55	0.000
Pretest within factors	104807.52	30	3493.58	29.21	0.000
School	1379.03	3	459.68	3.84	0.010
Grade	2149.80	5	429.96	3.59	0.003
School by grade	1064.38	6	177.40	1.48	0.181
Treatment	27.24	3	9.08	0.08	0.973