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ABSTRACT

This research assessed the academic impact of a computer-assisted instructional (CAI) software program to teach mathematics. The research hypothesis states that the use of the CAI program will produce superior academic achievement in mathematics for students who use the program compared to students instructed in mathematics without the program. The CAI program provided students with instruction in mathematics ranging from rudimentary concepts to high school algebra and geometry. This study involved elementary and middle grade students from a large urban North Carolina public school system with an enrollment of approximately 100,000. The study divided the students into two groups: a test or experimental group that used the CAI program, and a control group of students who were not exposed to the CAI program. It is concluded that students should benefit from the use of a CAI software program as a supplement to regular classroom instruction in basic mathematics and algebra. African-American students seem to benefit the most. If CAI is used appropriately, the gap between white and African-American students should begin to close. (Contains 27 references.) (ASK)

Computer Assisted Instruction in Mathematics Can Improve Students' Test Scores: A Study

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This research assessed the academic impact of computer-assisted instructional (CAI) software program to teach mathematics to elementary and middle grade students. The research hypothesis states that the use of CAI will produce superior academic achievement in mathematics for students who use the program compared to students instructed in mathematics without the program.

The use of computers for instruction is not new and was studied extensively in 1960s (Glaser. 1965). Skinner (1965:19) felt that the use of computers to teach could build "confidence in education" if they prove effective; and education is in "need of man's most powerful intellectual resources." Lumsdaine (1965:305), however, warned that in evaluating CAI, researchers should "indicate how many students started and completed the program, compute average completion time, compute average level of performance on pre and post program tests of achievement, and the variability of these measures." Evans (1965:383) reviewed studies on CAI programs in mathematics and found no controlled studies, which favored the computers over textbooks. The lack of controlled studies on CAI in mathematics in 1965 is still true today (Baker, 1999).

Today, we still are unable to find controlled studies on the use of CAI to teach mathematics to K-12 students (Johnson, 1996; and Kulik, 1994). A 1997 status report (Coley, Cradler, and Engel, 1977) on the use of technology in the classroom by the Educational Testing Service (ETS) drew a similar conclusion. Other status reports on the use of technology in schools by the Rand Corporation (Glennan and Melmed, 1996) and the American Institutes for Research (Birman, 1997) found similar results. Stories about the advantages of using technology in mathematics classes are common, but controlled research to judge their effectiveness is missing. The National Science Foundation (Hoffer, Moore, Wuin, and Suter 1996) and the U. S. Department of Education (Robinson, 1996) suggest potentially positive results from the use of technology in the classroom but cite no research to support their conclusions. Others (Morton, 1996; and Papert, 1993) suggest care in researching the use of technology in the classroom due to inequality in students' assignments by race, social economic class and the cultural context of teaching.

ETS (Wenglinsky, 1998) applied statistical modeling to survey data from the 1996 National Assessment for Educational Progress (NAEP) to assess the effectiveness of technology on achievement and found a modest correlation between classroom use, home use, teacher preparation and achievement. This was true for eighth graders but not for fourth graders. The study found that eighth grade Black students were less likely to be exposed to higher-order mathematics compared to white students. The same was true for poor, urban, and rural students. The researchers did not have available, the pre-test scores of students in the NAEP project.

The computer has the ability to teach children interactively, with the appropriate software (Weir, 1989:61-62). Students can receive feedback from the computer and the teacher. But, the teacher is key to this interaction. Given the current state of research on CAI in teaching mathematics this study appears appropriate and necessary at this time.

The Study

CAI Intervention

The CAI program provided students with instruction in mathematics ranging from rudimentary concepts to high school algebra and geometry. The program is flexible; users may return to sections previously reviewed or move forward to advanced topics. The program automatically randomly changes the numbers in problem sets each time you boot up the program, except for a few problems in geometry. It thereby creates a new and different problem set for each student each time they log on to the program. Teachers are encouraged to allow students to use the program daily or as they deem necessary.

This study involved elementary and middle grade students from a large urban North Carolina public school system with an enrollment of approximately 100,000. Overall 42% of the students in the school system are Black, 50% are White, and 8 % are from other racial and ethnic groups. The study divided the students into two groups: a test or experimental group that used the CAI program and a control group of students who were not exposed to the CAI program.

The CAI program was evaluated by making statistical comparisons of students' mathematics achievement on the State's required end of grade and end of course test scores of students in the experimental group versus students in the control group. The school district collected and shared students' test scores with the researchers, along with demographic data by gender, race, grade level, and social economic information for students in both groups. The researchers did not interact directly with students. The study took place over two years. The first year, 1997-1998, involved elementary school mathematics. The second year, 1998-1999 involved algebra students in a middle school. The middle school asked for the delay until they could move into a new school with better computer equipment. The study involved students from three schools in 11 different classes.

The researchers agreed on a minimum of ten hours of CAI use for the school year for a student to qualify as a user of the CAI program. The classroom teachers provided the researchers with the estimated time of usage by students. The teachers also provided researchers with each student's: name, identification number, starting date, estimated number of times used per week and minutes of use per session. From this information it was possible to create the number of minutes used for each student. In addition, to the minimum hour requirement, students had to take a pretest and a posttest to qualify as a participant in the study. The pretest and posttest requirements were also applied to students in the control classes.

Each school had its own method of using the software. The approach of Elementary School A was the most innovative. The technology teacher in the computer lab guided students in the use of the software. ***The software was used before school began.*** Students came to the lab as soon as their parent or the bus dropped them off at school.

The primary use of the software occurred during pre-school time but some teachers allowed students use computer in the classroom as well.

The middle school arranged 18 computers on tables along the walls in one classroom. Then, the teacher in this classroom taught different classes of students. The students in this situation tended to use the software 2 or 3 times a week for 20 or 30 minutes a session depending upon their teacher's assessment of the needs of each child.

Although there was a computer lab with 50 computers at elementary school B, they were rarely used. Instead each teacher used the few computers in their classroom and shared each other's computers when they were idle. The manner and extent of computer use varied. Some teachers provided their students with only a minimally acceptable ten hours of computerized instruction. Others provided several times that amount.

The CAI program, *FUNdamentallyMATH* program was selected because it had received favorable reviews by independent evaluators in two journals published by the National Council of Teachers of Mathematics (Bailey, 1995; Alba, 1997), the local media (Gilster, 1999) and State's Home School Association. The software covers all K - 12 mathematics coursework except calculus and probability. Reviewers found the program easy to use and effective in explaining mathematics. The program was also selected because the program producer, Chips Publications of Chapel Hill, NC was assessable to the researcher.

Sample

The study involved 10 elementary school teachers: one from School A for grades levels 3-5; nine teachers in School B covering grades 3-5; and one teacher in School C covering grade 6. No special data or time logs were required of the teachers. The number of test subjects participating in the Study by school were School A (Elementary) - 29 students, School B (Elementary) 116, and School C (Middle) -69 students. School A - is a small elementary school located in an industrial blue-collar area near the airport? It probably has the least affluent students of the three schools. This may be ascertained from the relatively large percentage of students who were on free or reduced cost lunch -- an index of the economic status of its students. It is about evenly divided racially. School B - is a communications skills magnet elementary school located in a relatively affluent section of the city and has the smallest percentage of students receiving free or reduced cost lunches. White students are the majority racial group in this school. The reverse is true at School C - Middle. The latter forms a middle ground, economically and racially between the three schools. *All the schools and teachers volunteered to participate in the study.*

A group of students with similar academic and grade level characteristics were selected as a control group to be compared to the students who use the CAI program in mathematics. We collected pretest and posttest scores on the State end of grade examination for elementary students and similar test scores in algebra for the middle grade students.

Table 1
Percentage Students in Each School by Race and Economic Status

School	Percent White	Percent Black	Percent getting free lunch (economic status)
School A - Elementary	47	49	65
School B - Elementary	47	39	23
School C - Middle	41	50	49
School D - Middle	38	55	39

Methodology

Experimental and Control Groups. The students in the three elementary schools combined averaged 23 hours of computerized instruction per student for the school year. Only the scores on statewide end-of-grade examinations in mathematics were used to compare students who used the CAI program with a control group of students who did not use the program. Data was collected on the pre-test, the 1997 end of grade examination, and the 1998 end-of-grade examination (post-test) for students in grades 4 through 6. This was the pre-test and the end-of-grade examination in 1998 was the post-test. The statewide end-of-course examination is given in algebra.

The control groups were selected using end-of-grade and end-of-course examinations. Every effort was made to keep the selection of control subjects unbiased. The first step was to compile a list of students who were not exposed to the software. Students on that list were not permitted to be a control group subject. The 1997 end-of-grade score (pre-test) was recorded for each test subject. Fourteen students in the test group moved into the school district after the pre-test was given. Since no pre-test data were available for these students, they were dropped from the study. This left 200 students who used the software and a similar control group of 200 students. The control group had to mirror the test group. Every control subject needed to have the similar grade, same gender, and same race as his or her counterpart test subject. A control subject was also required to have a raw score on the pre-test within two points of that of its corresponding test subject. At this point the number of control subjects equaled the number of test subjects. However, each group would soon be reduced further. Control group subjects were selected based upon their pre-test scores in mathematics. Now the 1998 scores were accessed. One test subject left the school district. The test group was reduced to 199. A large number, 37, of the control subjects did not take the post-test. Presumably this was due to their leaving the district. The control group was reduced to 163.

Data Analyses. The CAI program was evaluated by making statistical comparisons of students' mathematics achievement on end-of-grade tests for elementary students and end-of-course tests in algebra for students in the experimental group versus students in the control group. The *two-tailed T-statistics* was the major statistics utilized to compare the academic advancements between the groups. The school district collected and shared students' test scores with the researchers, along with demographic data by gender, race, grade level, and social economic information for students in both groups. The researchers did not interact directly with students.

Results

Elementary Students. Test data between the experimental group and the control group were analyzed using T-tests. The two groups were first examined against each other. The information was separated by grade for comparing the test group versus the control group by race. Black students in the experimental group were compared with that of white experimental students. Black test students were also compared to the Black students in the control group. Only two comparisons met the proof required at the .05 level of probability or the 95% confidence level. Both addressed the performance of African-American students who use the CAI program:

> Black fourth graders who used the CAI program made greater progress than Black fourth graders in the control group who did not use the program. Both groups started the school year with similar test scores in mathematics. T-tests revealed that the difference in the 1998 scores was statistically significant at the .01 levels or at the 90 percent level of confidence that the program produced these results. There is only a 9.9 percent probability that these results did not come their use of the CAI program.

It is very possible that multiplication, a basic fourth grade topic, is learned more easily at the computer than in traditional ways. The computer's capacity to instantly provide graphic illustrations of a multiplication sequence as well as drill the student with infinite patience make it an ideal teaching tool for this mathematical operations. The data for Black students in grades 3, 4, 5, and 6 is provided below.

Table 2
T-Test Statistics for Blacks Test and Control Groups: 1998 Test Scores

Grade	Type	N	Mean	SD	SE	df	t	p
3	Control	18	140.44	10.49	2.47	33	0.074	0.941
	Test	17	140.18	10.89	2.64			
4	Control	8	143.38	11.43	4.04	19	-1.735*	0.099
	Test	13	151.92	10.68	2.96			
5	Control	17	156.94	9.85	2.39	42	0.171	0.865
	Test	27	156.44	9.09	1.75			
6	Control	23	154.09	7.74	1.61	46	-0.764	0.449
	Test	25	156.24	11.30	2.26			

The ability of CAI to teach fourth grade mathematical topics is greater when we examine differences between pre-test and post-test scores. The test group of fourth grade Black

students had a mean score of almost one-half point lower on the 1997 pre-test (the starting level) than Black fourth graders in the control group. As shown in table 3, the variability of the test group's 1998 performance was smaller than that for the control group. ***When viewed in terms of their relative improvements, the T-test revealed that of the Black fourth grade students who used the CAI program enhanced their performance significantly (at the 99.9% confidence level).***

Table 3
T statistics for 1997-1998 School Year, Black Students Only: Number, Mean Gain Scores, Standard Deviation and Standard Error

Grade	Type	N	Mean	SD	SE	df	t	p
3	Control	18	3.6	6.3998	1.5084	33	-0.33	0.744
	Test	17	4.4	7.922	1.9214			
4	Control	8	2.0	7.329	2.5912	19	-3.785*	0.001
	Test	13	11.0	3.6056	1.0000			
5	Control	17	8.2	5.379	1.3048	42	0.008	0.993
	Test	27	8.2	4.7744	0.9188			
6	Control	23	3.2	6.3886	1.3321	46	-0.711	0.481
	Test	25	4.5	6.29	1.2585			

If one were to characterize by grade level the major difficulty most students' experience with mathematics by grade and problem might be as follows: multiplication in grade four, long division in the fifth grade and the transition to middle school combined with poor fundamental skills in 6th grade. Most difficulties with long division come from a lack of knowledge of multiplication algorithm and/or the multiplication tables. Based upon positive results with the fourth graders who used the CAI program, we believe a longitudinal study is needed.

A comparison of Black students with White students in test groups across all grades revealed a negative relationship between the groups. There was a significant difference in test scores among students in the control group who did not use the CAI software between White and Black students. Improvement in the post-test scores was much lower among Blacks (statistically significant at the 99.8% level of confidence). On the other hand, in the test group, improvement in scores among Black students was greater than test scores among White students (but not statistically significant).

Table 4
T-Tests by Race by Group Status: Mean Improvement, Standard Deviation, and Standard Error of the Mean.

Type	Race	N	Mean	SD	SE	df	t	p
Control	Black	66	4.4697	6.5309	0.8039	146	-3.079*	0.002
	White	82	7.6585	6.0394	0.6669			
Test	Black	82	6.7439	6.2988	0.6956	180	0.626	0.532
	White	100	6.1800	5.8316	0.5832			

*Significant at the 0.05 levels.

The average performance of African-American students in the control group who did not use the CAI program was worse when one considers the distribution of skill levels of students. The end-of-grade examinations to classify students into 4 skill levels: Level 1-below grade, Level 2-modestly below grade, Level 3-at grade level, Level 4-above grade level. There were few Level 1 students in the study. The chart below combines students in Levels 1 and 2 into one "below grade" category.

One would normally expect students in the "below grade" group to demonstrate a larger improvement than those in the above grade group. It is more difficult for a student ranked at the 96th percentile, for example, to demonstrate considerable advancement, compared with the opportunity for students at the 35th percentile to make a major advancement. These results revealed that CAI could improve the rate in which Black students learn mathematics; we need more studies with CAI programs to further the findings of this study.

Table 5
Students' Achievement Levels by Race and Group

Group by Race	Below Grade	At Grade	Above Grade	Total*
Control				
Black	27	27	12	66
White	10	22	50	82
Test				
Black	30	32	20	82
White	2	40	58	100

*Note: the test group also included 10 Asian students, 6 Hispanic students, and 1 American Indian.

The table below lists pretest and posttest scores of Black fourth graders in the experimental group demonstrated improvement in mathematics.

Table 6
Test Scores, Percentiles, and Beginning Math Skill Level by Year of Successful Black Fourth Graders

Minutes Used	Home Use	School	Gender	1998 Score	1998 Percentile	1997 Score	1997 Percentile	Math Level
1170		B	M	140	28	132	25	2
810		B	F	141	31	127	14	2
2160		A	F	137	21	131	22	2
1620		A	F	140	28	134	29	2
750	Yes	B	M	154	75	145	64	3
2160		A	F	147	51	136	35	3
1620		A	F	148	54	139	44	3
2925	Yes	B	F	152	69	141	50	3
1560		B	F	162	94	144	61	4
750		B	F	161	93	148	75	4
1170		B	F	163	96	147	71	4
2160	Yes	B	M	170	99	158	96	4
2160		A	F	160	91	150	81	4

The students in table 6 are equally divided between the three grade categories. Judging from their percentile ranks three of the four students classified as below grade maintained approximately the same fourth grade percentile rank while one made a substantial improvement. Other students made substantial improvement (including improvement from 96th percentile to 99th, which is substantial for students starting at level 4).

Middle School

The 1998-99 school year involved an examination of the ability of the CAI software to improve the algebra skills of eighth grade pupils in middle school. The school enrolled 1045 students and is a Workplace Magnet School. The school is located on a large tract of land with an elementary school and a high school in close proximity to enable a student to remain on the same campus from kindergarten through high school. One-third of its students come from families who are employed nearby, one-third must live in the area, and one-third come from satellite areas to attract minority students. The school located in a relatively affluent section of the city. The racial balance at all of the four schools participating in the study is shown in Table 1.

Methodology. The two algebra teachers who participated in the study allowed their classes to work with the CAI software one day a week for 45 minutes at a time. Occasionally some students would work on the software in small groups during other class periods. These small groups would be sent to the computer lab to work on material covered in class. Typically there would be a student question, an explanation from the teacher, and then further reinforcement of the explanation by sending small groups of

students to use specific sections of the software. Students were exposed to the CAI software, their textbook, and teacher. Students in both classes follow a similar curriculum.

End-of-grade (7th) examination mathematics scores were used to select control subjects. This was the test all algebra students took before entering the course. The control subjects were similar to test subjects. The difference between test subjects and control subjects on pre-test scores was kept as small as possible, usually zero or one point. The post-test was the end-of-course algebra examination. The test group consisted of 54 students. Seven (7) students in the test group moved into the district after the pre-test examination in mathematics was given. Roughly 40 percent of all students involved were ranked "on-grade" (level 3) and the remainder "above grade" (level 4) in mathematics.

Results. Gains in mathematics scores from pre-test scores to post-test scores for students who used the CAI software were significant (at the 0.05 levels). The T-statistic is 2.839, significant at the 99.5% confidence level. There was a 17 percent jump in algebra percentile scores for students using our CAI software program. This improvement is impressive when we view statewide results. Percentile rankings in this report are statewide figures. The number of students taking this examination in May of 1998, the last date for which data is presently published, was 83,124. One is forced to conclude that a jump of 17 percentile ranks is an enormous improvement vis-à-vis other students.

Table 7
T-statistics by Group Status: Algebra 1998-1999 Post-Test

Group Status	N	Mean	Percentile	SD	SE	df	t*	p
Test	54	58.70	62	7.89	1.07	99	-2.839	.005
Control	47	53.53	45	10.38	1.51			

*two-tailed test

These data reveals a significant improvement in performance when the test group is compared to the control group. We also looked for differences between the test group and the control group by race and gender. The results were significant at the 95% confidence level for Black females.

Table 8
T-Test 1999 Algebra Score Blacks Students Only

Group	N	Mean	SD	SE	df	t	p
Control	15	51.27	10.39	2.68	29	-2.560*	.016
Test	16	59.06	6.17	1.54			

*Significant at the 0.05 levels.

Black students who did not use the CAI program performed the worst and Black students who used the CAI program made the most improvement.

Table 9

All CAI Algebra Users v. Non Users by Group Status, Race, Mean, and Percentile

Group Status	Number	Mean	Percentile
Test Group			
Black	16	59.06	64.19
White	31	58.45	61.19
Control Group			
Black	15	51.27	39.27
White	29	54.59	47.87

Females represented another group that demonstrated a significant improvement from the use of the CAI program. Even though female students in the test group continue to lag behind males in the test group, their enhanced performance from the program helped them to outperform male students in the control group.

Table 10

T-Test: 1999 CAI Female Users v. Female Non -Users, Only

Type	N	Mean	SD	SE	df	t*	p
Control	25	52.96	10.26	2.05	55	-2.089	.041
Test	32	57.81	7.27	1.29			

Table 11

Male v. Female CAI Users v. Non Users in Algebra by Group Status

Gender by Group	N	Mean	Percentile
Females - Test Group	32	57.81	58.97
Males - Control Group	22	54.18	49.68
Males - Test Group	22	60.00	67.09

The results of comparing males in the test group versus males in the control group were significant (0.055 level or, the 95% confidence when rounded to the nearest whole number). One benefit from using the CAI software was the improvement in the African-American test subjects' knowledge of mathematics.

Table 12

T-Test 1999 End of 8th Grade Score of Blacks CAI Users v. Non Users, Only

Type	N	Mean	SD	SE	df	t	p
Control	15	174.07	7.89	2.04	30	-2.313*	.028
Test	17	179.82	6.18	1.50			

*Significant at the 0.05 levels.

African-American test subjects' knowledge in mathematics appears to have been improved by their use of CAI software program. White test subjects did not show significant improvements in mathematics from their use of the CAI program. However, caution should be taken in using these findings about White students, since more Whites when compared to Blacks were in the higher skills levels where improvement was least expected.

Table 13

Algebra End of 8th Grade Examination Mean, Number, and Gain of CAI Users v. Non Users: Summary Table

Group	N pre-test	Pre-test Mean	N post-test	Post-test Mean	Gain*
Black - control	15	172.73	15	174.07	1.34
Black - test subjects	15	173.53	17	179.82	6.29
White - control	29	175.31	29	179.28	3.97
White - test subjects	29	175.66	31	178.97	3.33

*A gain score is the difference between the pre-test mean score and the post-test mean score.

Improvement within the control group is inverted from what was expected. The White students in the control group showed higher test scores on the pre-test examination and greater gains on the posttest examination than the Black students in the control group. Difference in improvement, the 1999 end of grade score minus the 1998 end of grade score, is close to being significant at the 95% confidence level. The T-statistic is at the 94.3% level of confidence, which is close to the 95% level (a standard measure for most statistical studies).

Conclusions

The CAI software appears more beneficial to the African-American algebra students than to the African-American elementary students, except for fourth graders. Black students mathematical skill still lagged behind that of the white students, but in general they showed the most improvement. In algebra, the Black test subjects outperformed all

groups in improving their skills in mathematics. The Black test subjects out performed Black students in the control group and gained on their white classmates in both groups.

Students should benefit from the use of a CAI software program as a supplement to regular classroom instruction in basic mathematics and algebra. African-American students seem to benefit the most. If CAI is used appropriately, the gap between White and African American students should begin to close.

Lessons Learned

1. Comparisons between the experimental and control groups were limited by the composition of the students who volunteered to participate in the study. Even though we selected a control groups that mirrored the experimental groups, we were confined by the membership in the experimental groups. In general, the White and Black students who volunteered did not have the same important characteristics such a economic status and achievement levels. However, it was valid to compare Black students in the experimental groups who used the CAI program with Black students in the control groups who did not use the program; and White students against White students in the two groups. The different starting levels may explain the difference in the growth in mathematics between African American and White students who used the CAI program. In general, the White students began the program at higher levels than the African American, leaving less potential for growth for white students and greater potential for growth among African American students. But, the important measure was the growth for African American students who used the CAI program versus those who did not use the program. African Americans who used the program made greater progress in mathematics than those who did not use the program.

2. The ability to conduct controlled research on the use of CAI programs is not easy. First, it was easy to get initial interest in the software among teachers and principals, but difficult to get them to commit to participate in a study. Second, after getting a school system's permission to allow schools to participate on a voluntary basis, only a few schools volunteered to participate. Third, even though participation in the study was voluntary, it required signed agreements of participation by the district, the

principal, teachers, students, and parents of students. Fourth, the school district agreed to supply pretest and posttest scores of students, but we were low priority on their list of things to do and these data came much later than expected. Finally, we conducted workshops for teachers on how to operate the CAI program at our expense (including pay for substitute teachers), we had no control or influence over how the program was integrated into the curriculum.

3. We found the available of annual State mandated tests for all students to be a great advantage in conducting this study. These tests made it easy for the research team to gain assess to students test scores (without names). The study would have more difficult or impossible with these data.

4. This research gives strong support for the use of quality CAI software programs to supplement classroom instruction to improve the acquisition of mathematics by elementary and middle grade algebra students (Davis, 1997; and Friske, 1988). Specifically, the African American students who ranked below their white classmates in mathematics achievement levels gained the most from use the CAI software. Minority students, in general, rank below their white classmates in mathematics achievement (Payne and Biddle, 1999; Peat. 1996; Peng, Wright and Hill, 1995; and Singham, 1998) Therefore, we strongly recommend that teachers supplement their instruction with quality CAI programs.

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