Christopher H. Tienken
Michael J. Wilson

Planning and Changing
Vol. 38, No. 3&4, 2007, pp. 181–190

THE IMPACT OF COMPUTER ASSISTED INSTRUCTION ON SEVENTH-GRADE STUDENTS' MATHEMATICS ACHIEVEMENT

Introduction

The perceived problem of low mathematics achievement is a concern to education leaders at all levels of PK–16 education. Reflecting this problem, the Third International Mathematics and Science Study–Repeat (TIMSS-R) showed the weaknesses of mathematics in the U.S. compared to other industrialized countries when eighth grade U.S. students performed lower than those from 14 of the 38 participating nations (NCES, 2000). In addition, 15-year-olds from the U.S. ranked between 16th and 23rd out of 31 countries that participated in the 2000 administration of the Programme for International Student Assessment (PISA) (OECD, 2004). On the national level, the 2005 administration of the National Assessment of Education Progress (NAEP) mathematics test indicated only 36% of Grade 4 students scored "at or above proficient" and only 30% of Grade 8 students scored "at or above proficient" (NCES, 2005). These results raise concerns about the mathematics learning of U.S. middle school students.

Education leaders search for interventions to address issues related to improving mathematics achievement. This article presents findings from a middle school mathematics intervention implemented to improve students' mathematics performance. The purpose of this empirical study was to determine if there was a measurable difference in achievement on the mathematics section of the TerraNova Full Battery standardized test by a sample of seventh-grade students whose teachers taught them to use mathematics websites and presentation software as tools to practice basic mathematics skills (e.g., recall, comprehension, and application; Bloom, 1956) related to their curriculum compared to students whose teachers did not teach the use of such tools.

Literature Review

Computer Assisted Instruction (CAI) provides one possible avenue for education leaders to overcome or address the problem of low achievement in mathematics. The following review of literature presents an overview of the influence and impact of CAI on mathematics achievement based on empirical studies and meta-analyses conducted during the past 20 years.

Positive Results of Computer Assisted Instruction

A number of studies have suggested that the computer provides an

effective vehicle for improving student achievement (Bahr & Rieth, 1989; Bangert-Drowns, 1985; Capper & Copple, 1985). Hawley, Fletcher, and Piele (1986) observed that the overall mathematics achievement of third and fifth grade students who used CAI was higher than their peers who did not use computers to practice mathematics. Bahr and Rieth (1989) identified CAI as a factor for improved mathematics achievement of disabled junior- and senior-high students. Additional meta-analyses conducted during the 1990s found positive influences for some aspects of CAI, such as drill and practice of mathematical processes (Christmann & Badgett, 1997; Sivin-Kachala, 1998). Waxman, Connell, and Gray (2002) conducted a meta-analysis of 13 quantitative CAI studies published in peer-reviewed journals between 1997–2002 and found a positive average effect size (d) (Cohen, 1988) for CAI of .42. Social scientists consider an effect size of .2 small, while sizes in the range of $.2 < d < .8$ are considered moderate, and those greater than .8 are considered large. Traynor (2003) found CAI improved mathematics achievement of regular education, special education, and limited English proficient middle school students ($n = 161$) on mathematics pretest-posttest when compared to traditional, teacher-directed practice techniques. The students he studied comprised intact groups based on the ways that the middle school scheduled students into exploratory classes.

Mixed Results of Computer Assisted Instruction

While some studies during the past 20 years have suggested positive results from CAI, other studies have raised questions about its efficacy. The results of CAI remain mixed. Levin (1986) cautioned against an irrational exuberance toward the influence of CAI on achievement and stated that education leaders should not accept, uncritically, the claims of efficiency and effectiveness. Campbell, Peck, Horn, and Leigh (1987) found no significant difference in the mathematics achievement of third grade students who used CAI drill and practice activities compared to students who used only printed drill and practice materials. Kelman (1989) found drill and practice CAI activities to be dominated by monotonous isolated lessons, convergent questions, and narrow behaviorist activities. Griswold (1984) stated that CAI activities failed to foster positive student attitudes toward school or mathematics. Rosenberg (1991) issued a negative review of the influence of computers on instruction and achievement. He stated that the computer failed to deliver on the promises of increased efficiency and effectiveness. The structure of the CAI drill and practice activities he found ranged from laissez-faire to heavily programmed, the latter featuring "teacher-proof" lessons, intense control of student behavior, and a myopic focus on monitoring student performance. Baker, Gersten, and Lee (2002) conducted a synthesis of studies on the influence of CAI on mathematics achievement of low-achieving students. They found the low-achievers did not perform significantly better, and they observed

an average effect size of .01 (Cohen, 1988). Plano (2004) found that CAI activities for algebra had a non-significant predictive influence on student achievement overall but had a slightly significant influence on the Algebra achievement of English language learners. Cole and Griffin (1987) stated that isolated CAI activities violate communication theory because students do not interact with each other nor with the teacher and the activities actually impede learning because of their convergent nature.

Active Learning

Like CAI, active learning is designed to improve student achievement. Cooperstein and Kocevar-Weidinger (2004) noted that active learning occurs when (a) the learner can construct his or her own meaning; (b) current learning is developed on previous learning; (c) the learner is involved in meaningful social interaction; and (d) the learning is built through the use of authentic involvement with the learning materials.

A number of studies demonstrated that active learning is an effective method of enhancing students' learning in a variety of areas. Hetland (2000) concluded that students' active involvement in music had an effect on the development of their spatial thinking. Wilson, Flanagan, Gurkewitz, and Skrip (2006) found that students' active involvement in origami resulted in increased problem-solving ability. Cerezo (2004) discovered that active involvement in problem solving enhanced the learning of mathematics. Huffaker and Calvert (2004) determined that active learning was particularly useful when used in problem solving with computers.

The Problem

Although some controversy exists about the effective use of CAI, particularly with respect to the drill and practice forms associated with simple knowledge development, the studies reviewed confirm a fairly positive effect for active learning. The effect on learning occurred primarily with more complex kinds of learning, such as open-ended, divergent problem solving. From the research reviewed, it is not clear, however, whether using active learning with simpler processes, such as those associated with computation-based drill and practice computer software and programs, will also have a positive impact on student achievement. Finally, most other computer related active learning studies use fairly complex components in their investigation, such as CAI combined with a problem-based learning approach used by the teacher. In this study, we examined the effect of a drill and practice CAI in combination with a less complex active learning follow-up exercise—namely, direct instruction of how to use computer presentation software to communicate understanding of the drill and practice exercises—on student achievement of mathematics skills and knowledge.

Methodology

We used a pretest/posttest quasi-experimental design because students comprised intact groups and thus random assignment of students was not possible. We assigned teachers randomly to experimental and control groups.

Hypothesis

The null hypothesis: There will be no difference in achievement on the mathematics section of the Terra Nova Full Battery standardized test between students taught to use websites and presentation software as tools to practice basic mathematics skills and students who did not receive such instruction.

Sample

This 2004/05 study utilized a sample of seventh-grade students and teachers from a population of four middle school classrooms from a school in central New Jersey. The treatment (X) group consisted of n = 126 and the control (O) group of n = 141 students. Only students who took the Terra Nova (CTB-McGraw Hill, 2003) mathematics test the previous year (in sixth grade) were eligible to be included in the groups. The final sample included all students who met the following criteria: (a) received a valid score on the mathematics section of the TerraNova test in the sixth and seventh grades, (b) were enrolled in the school for the entire sixth- and seventh-grade years, (c) were enrolled in the regular education program during the sixth- and seventh-grade years.

The final sample included students from various ethnic groups. The demographic characteristics of the groups were relatively balanced in terms of percent of Caucasian and non-Caucasian students (see Table 1).

Table 1

Ethnic Characteristics (n & %) of the Seventh Grade Regular Education Students in the X and O Groups

Ethnic/racial group	O (control)	X (treatment)
Caucasian	74 (58.7%)	74 (52.4%)
Black/African American	30 (23.8%)	48 (34.0%)
Hispanic/Latino	19 (15.0%)	15 (10.6%)
Asian/Pacific	3 (2.3%)	4 (2.8%)
Total	126 (99.8%)[a]	141 (99.8%)[a]

Note. Sample includes students receiving basic skills instruction.
[a]Totals do not add up to 100% due to rounding off.

The percentage of students eligible to receive free or reduced lunch was similar in the X and O groups. The X group contained fewer students who were eligible for basic skills instruction in mathematics and/or language arts (see Table 2).

Table 2

Socio-Economic and Academic Descriptive Statistics as Number and Percent of Total Population for the Seventh Grade Regular Education Students in the X and O Groups

Characteristic	O (control) (n = 141)	X (treatment) (n = 126)
Free/reduced lunch	44 (31.2%)	35 (27.7%)
Basic skills/math	42 (29.8%)	22 (17.4%)
Basic skills/reading	46 (32.6%)	18 (14.3%)

Pre-intervention mathematics achievement of X-group students on the sixth-grade, full battery TerraNova mathematics test was significantly ($p < .05$) lower than the achievement of O-group students. In short, the previous achievement of groups was not similar (see Table 3).

Table 3

Pre-Intervention Achievement Comparison of NCE Means for Seventh Grade Regular Education Students (N = 267)

Group	n	Mean NCE	SD	p value	t-score
O	126	64.57	15.96	.000	6.12
X	141	53.73	12.94		

Note. Sample includes students receiving basic skills instruction. O = control group; X = experimental group.

Treatment

We randomly assigned teachers to X (n = 2) and O (n = 2) groups prior to the start of the study. The teachers in the X group used mathematics drill and practice websites and slide presentation software with students. The teachers in the control group used neither the websites nor the presentation software. The purpose of the CAI used by X teachers with X students was to provide practice with basic math skills related to the grade-level curriculum. After students became familiar with the CAI, the teachers taught them to use slide presentation software to create a digital "book-report" in which they were assigned to explain one aspect of mathematics they learned via the CAI. Each student used the software to construct an explanation of the material he/she learned in the drill and practice

CAI. Upon completion of their report, students presented the information to their classmates. The students used the technology two-times per week for 20 weeks.

The mathematics websites focused on drill and practice of computation in operations, fractions, geometry, data analysis, and algebra based on the New Jersey Core Curriculum Content Standards and school's seventh-grade mathematics curriculum. A site facilitator (district mathematics supervisor) observed instruction to monitor fidelity of implementation. The site facilitator ensured that the mathematical content was consistent for all teachers and that those in the X group were the only ones using the mathematics websites in their presentations. The site facilitator conducted weekly classroom observations of the X and O teachers and reviewed lesson plans weekly. Teachers in the X group facilitated student creation of slide shows so students could demonstrate their understanding of mathematics concepts such as adding and subtracting fractions with unlike denominators.

Instrument

The CTB/McGraw Hill TerraNova is a commercially prepared, norm-referenced, standardized achievement test for K–12 schools. The test is available in all 50 states and 275,000 students nationwide took part in the last norming process. More districts in New Jersey use the TerraNova to measure student achievement than other available standardized tests. The seventh-grade TerraNova mathematics portion contains content that addresses number sense and number relationships, computation and numerical estimation, operation concepts, measurement, geometry and spatial sense, data analysis, statistics, probability, patterns, functions, algebra, problem solving and reasoning, and communication. The reported internal consistency (Cronbach alpha) reliability coefficient for the mathematics portion is .92 for the seventh-grade Form 16.

We used students' Normal Curve Equivalent (NCE) scores from the full mathematics battery TerraNova, Form 16. We used the NCE scores because the school district did not make scale scores available. Students' sixth-grade TerraNova mathematics NCE scores were used as a covariate and seventh-grade NCE scores were analyzed for differences between the treatment and control group students.

Analysis and Findings

A two-way ANCOVA was used to analyze the two group data (see Table 4). We used this statistic to control for both the pretest differences and a possible interaction due to socio-economic status (SES). Each student's free/reduced lunch status was used as a measure of SES. Prior to the analysis an alpha level criteria was established at $p < .05$.

Table 4

Post-Treatment Results Using Two-Way ANCOVA

Source	*SS*	*df*	*MS*	*F*	Sig.
Pretest	63,763.267	1	63,763.267	658.188	.000
Treatment	285.948	1	285.948	2.952	.086
Free lunch	13.042	2	6.521	.067	.935
Treatment X free-lunch[a]	163.090	2	81.545	.842	.432

[a]Interaction effect between SES and treatment.

The initial two-way ANCOVA suggests there was no statistically significant interaction between the SES level and the treatment. Because of the lack of interaction, it was felt that the variance from the interaction could be pooled in the error term and a one-way ANCOVA could be used to examine the effect of the treatment across the two groups.

The subsequent one-way ANCOVA using the pooled variance for low and high SES showed the treatment to be statistically significant at the $p < .05$ level (see Table 5).

Table 5

Results of One-Way ANCOVA Using Pooled Variance

Source	*SS*	*df*	*MS*	*F*	Sig.
Pretest	64,686.683	1	64,686.683	670.084	.000
Treatment	764.543	1	764.543	7.920	.005

A Cohen's *d* (Cohen, 1988) was calculated to examine the effect size. The result showed an effect size of $d = .12$, which suggested that, although significant, the effect size was small using Cohen's interpretation scheme.

Conclusions

The data suggest that the treatment of CAI with an active learning component had a positive, although slight, effect on the X group students' learning of basic mathematics skills (i.e., knowledge, comprehension, and application; Bloom, 1956) as tested by the TerraNova standardized mathematics test. These data imply that the learning of basic computational skills can be somewhat enhanced through the use of web-based drill and practice exercises when students subsequently become involved in a presentation process in which they are required to actively restate and explain what they learned. The small but significant effect also argues for more careful study of the impact of this treatment.

While the results are statistically significant and positive, the findings raise the question of whether time spent on CAI drill and practice will enhance overall mathematics achievement in educationally significant ways. For example, given that half of the possible points on the New Jersey eighth-grade mathematics test come from questions that require open-ended problem solving, middle level educators in the state, and in states with similar tests, may consider whether CAI drill and practice activities deserve the amount of time given by the school in this study.

The results of this study may prompt middle level leaders nationwide to examine the amount of time students and teachers spend on CAI drill and practice activities in their schools compared to the amount of class time spent on problem-solving activities. In the end, leaders need to determine if CAI drill and practice are worth it.

Future Research and Limitations

Future research needs to be conducted to examine the effect of different aspects of computer and web-based learning experiences and active learning experiences. The effect size is partially a function of the standard error of measure associated with large scale tests as well as the differences (achievement and SES) between the treatment and control groups. Controls, like those provided by random assignment of students as well as teachers, might have shown a larger effect size. Better controls would allow future researchers to establish comparability in advance instead of relying on the use of a residualized covariate.

Because these results were a function of the domain of regular classroom practice, there is also always the concern that treatment experiences may have not been consistent across all classes or the control groups were not entirely separate from the treatment group. Although we took steps to minimize this possibility through the use of a site facilitator to provide oversight, there is a constant need for replication to ensure an externally valid result.

References

Bahr, C. M., & Rieth, H. J. (1989). The effects of instructional computer games and drill and practice software on learning disabled students' mathematics achievement. *Computers in the Schools, 6*(3/4), 87–101.

Baker, S., Gersten, R., & Lee, D. (2002). A synthesis of empirical research on teaching mathematics to low-achieving students. *Elementary School Journal, 103*(1), 51–73.

Bangert-Drowns, R. L. (1985, March). *Meta-analysis of findings on computer-based education with precollege students.* Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Bloom, B. S. (Ed.). (1956). *Taxonomy of educational objectives: The classification of educational goals* (Handbook I: Cognitive Domain). New York: McKay.

Campbell, D. L., Peck, D. L., Horn, C. J., & Leigh, R. K. (1987). Comparison of computer-assisted instruction and print drill performance: A research note. *Educational Communication and Technology Journal, 35*(2), 95–103.

Capper, J., & Copple, C. (1985). *Computer use in education: Research review and instructional implications.* Washington, DC: Center for Research into Practice.

Cerezo, N. (2004). Problem-based learning in the middle school: A research case study of the perceptions of at-risk females. *Research in Middle Level Education Online, 27*(1). Retrieved on June 1, 2007, from http://www.nmsa.org/portals/0/pdf/publications/RMLE/rmle_vol27_no1_article4.pdf

Christmann, E., & Badgett, J. (1997). Progressive comparison of the effects of computer-assisted instruction on the academic achievement of secondary students. *Journal of Research on Computing in Education, 29*(4), 325–337.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cole, M., & Griffin, P. (1987). *Contextual factors in education: Improving science and mathematics education for minorities and women.* Madison: Wisconsin Center for Education Research.

Cooperstein, S. E., & Kocevar-Weidinger, E. (2004). Beyond active learning: A constructivist approach to learning. *Reference Services Review, 32*(2), 141–148.

CTB-McGraw Hill. (2003). *Glossary of Assessment Terms.* Retrieved on June 1, 2007, from http://www.nmsa.org/portals/0/pdf/publications/RMLE/rmle_vol27_no1_ article4.pdf

Griswold, P. (1984). Elementary students' attitudes during two years of computer-assisted learning. *American Educational Research Journal, 21*(4), 737–754.

Hawley, D. E., Fletcher, J. D., & Piele, P. K. (1986). *Costs, effects, and utility of microcomputer-assisted instruction.* Eugene, OR: University of Oregon.

Hetland, L. (2000). Learning to make music enhances spatial reasoning. *Journal of Aesthetic Education, 34*(3/4), 179–238.

Huffaker, D. A., & Calvert, S. L. (2004). The new science of learning: Active learning, metacognition, and transfer of knowledge in e-learning applications. *Journal of Educational Computing Research, 29*(3), 325–334.

Kelman, P. (1989, June). *Alternatives to integrated instructional systems.* Paper presented at the annual meeting of the National Educational Computing Conference, Nashville, TN.

Levin, H. M. (1986). The economics of computer-assisted instruction. *Peabody Journal of Education, 64*(1), 52–66.

National Center for Education Statistics (NCES). (2000). *Highlights from the Third International Mathematics and Science Study—Repeat.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement. Retrieved May 3, 2007, from http://nces.ed.gov/pubs2001/2001027.pdf

National Center for Education Statistics (NCES). (2005). *The nation's reportcard.* Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement. Retrieved May 3, 2007, from http://nces.ed.gov/nationsreportcard/pdf/main2005/2006453.pdf

Organization for Economic Co-operation and Development (OECD). (2004). *Learning for tomorrow's world: First results from PISA 2003.* Retrieved May 3, 2007, from: http://www.oecd.org/document/55/0,2340,en_32252351_32236173_33917303_1_1_1_1,00.html

Plano, G. (2004). *The effects of the cognitive tutor algebra on student attitudes and achievement in a 9th grade algebra course.* Unpublished doctoral dissertation, Seton Hall University, South Orange, NJ.

Rosenberg, R. (1991). Debunking computer literacy. *Technology Review, 94*(1), 58–64.

Sivin-Kachala, J. (1998). *Report on the effectiveness of technology in schools, 1990–1997.* Washington, DC: Software Publishers Association.

Traynor, P. (2003). Effects of computer-assisted-instruction on different learners. *Journal of Instructional Psychology, 30*(2), 137–151.

Waxman, H. C., Connell, M. L., & Gray, J. (2002). *A quantitative synthesis of recent research on the effects of teaching and learning with technology on student outcomes.* Retrieved November 6, 2006, from http://www.ncrel.org/tech/effects/effects.pdf

Wilson, M., Flanagan, R., Gurkewitz, R., & Skrip, L. (2006, November). Understanding the effect of origami practice, cognition and language on spatial reasoning. Paper presented at the fourth annual Science, Origami, Mathematics, and Education Conference, California Institute of Technology, Pasadena, CA.

Christopher H. Tienken is an Assistant Superintendent for the Monroe Township School District in Middlesex County, New Jersey, and an Adjunct Instructor at Rutgers University, New Brunswick, New Jersey.

Michael J. Wilson is an Assistant Professor in the Department of Education and Educational Psychology at Western Connecticut State University, Danbury, Connecticut.