

The Effectiveness of Computer-Assisted Instruction in Developmental Mathematics

By Kathy Spradlin and Beth Ackerman

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ABSTRACT: *This quasiexperimental study compared academic performance of students enrolled in a developmental mathematics course using traditional instruction (i.e., lecture) and traditional instruction supplemented with computer-assisted instruction. In addition, gender differences in mathematical performance were also investigated. There was no statistically significant difference in the posttest scores of students receiving traditional instruction and traditional instruction supplemented with computer-assisted instruction. There was a significant difference in the posttest scores of females and males, with females outperforming males in both modes of instruction.*

A significant number of students start college underprepared for a college-level mathematics course (National Center for Educational Statistics, 2003). Without intervention only 10% will graduate, and with appropriate assistance up to 40% of those beginning college in developmental programs can earn a bachelor's degree (Brittenham et al., 2003). Success or failure in a mathematics course has a strong influence on students' choice of major and whether they graduate and qualify for meaningful jobs (Hall & Pontoon, 2005; McCabe, 2000). Some four-year colleges and universities and most community colleges offer courses equivalent to basic arithmetic and high school algebra in an attempt to prepare these students for courses such as college algebra and statistics (National Center for Educational Statistics, 2003).

Typically developmental mathematics courses have been taught via the traditional lecture method used for years in college-level courses (Armington, 2003; Kinney & Kinney, 2003; Maxwell, 1979). University educators across the country are concerned that the pass rate in developmental mathematics courses varies considerably, being as low as 24% at some colleges (Trenholm, 2006; Waycaster, 2001; Wright, Wright, & Lamb, 2002). Consequently, educators are implementing new programs designed to increase the number of students who stay in school, pass a college-level mathematics course, and graduate. Instructors are supplementing the traditional lecture with teaching strategies

that emphasize understanding of concepts, active learning, and relevant applications (Armington, 2003; Kinney, 2001; Perez, 1998). It is widely accepted that solely addressing the math skills of these students is not sufficient (Hall & Pontoon, 2005; Higbee & Thomas, 1999; Perez, 1998). Math anxiety, negative attitudes, poor study skills, and lack of responsibility for learning should also be addressed.

Increased availability of computers and students' increased interest in using computers for communication and socialization has led educators to explore ways to use computers as tools to enhance student learning (National Center for Educational Statistics, 2003; Madden & Jones, 2002). Standards developed by the American Mathematical Association of Two-Year Colleges (AMATYC, 1995) and also by the National Council of Teachers of Mathematics (NCTM, 2000) call for the use of technology to enhance student learning. In the Fall of 2000, 31% of the 3230 colleges surveyed by the National Center for Educational Statistics (2003) reported that computers were frequently used by students as an instructional tool for on-campus remedial mathematics, and 13% offered remedial courses through distance education, an increase from 3% in 1995. Many studies on the effects of computer-assisted instruction on the mathematical learning of students of various ages and ability levels suggest that computer-assisted instruction (CAI) as a supplement to traditional classroom instruction is more effective than traditional instruction alone (Brothen & Wambach, 2000; Butzin, 2000; McSweeney, 2003; Nguyen, 2002; Olusi, 2008). For example, a recent meta-analysis of 52 studies of 5000 subjects in Taiwan from first grade through college in English, physics, chemistry, statistics, mathematics, and business found that computer-assisted instruction had moderately positive effects on students' achievement over traditional instruction (Liao, 2007). The overall grand mean effect size was 0.552, the mean effect size for math was 0.291, and the mean effect size for college was 0.823.

However, existing research indicates mixed results regarding the effectiveness of CAI with mathematics; this may possibly be attributed to the choice of software used in the study, if it was

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used effectively, and if students were required to use the software. Stillson and Alsup (2003) studied the effectiveness of teaching Basic Algebra using the interactive learning system ALEKS to supplement traditional instruction. The students who took the time to use the software thought they learned more than they had in previous math courses, but a high number of students either dropped the course or received failing grades because they did not use the learning system. Higher test scores were associated with greater mastery and more time spent on ALEKS assignments. Interviews at the conclusion of the course indicated that students liked the immediate feedback, the repetition, and the convenience of working at their own pace. They did not like that ALEKS and the textbook did not correspond, making them feel like they were taking two math courses.

Platforms such as Blackboard provide an instructional tool for educators to design an online component for developmental math courses in a mastery learning format (Boggs, Shore, & Shore, 2004). Multiple versions of tests can be created by random selection from a test bank, grading is automatic, feedback is immediate, teaching students working on different objectives is manageable, and multiple methods of communication between students and instructor are possible. The Allegheny College of Maryland reported a 66% success rate (using a sample of 40 students) for students using Blackboard compared to a 55% success rate (using a sample of 220 students) in classes not using Blackboard in a developmental math course. However, a study of the effect of a multimedia, interactive mathematics program on the mathematical achievement of students enrolled in intermediate algebra at a community college in Texas suggested that the program was not effective (Bump, 2004). The mean final exam score of students in lecture classes (20.65) was significantly higher than the mean final exam score (15.61) of students in the computer-assisted classes that met in a lab with no lecture. Bump (2004) acknowledged that there were numerous problems with the computer-assisted classes in his study, including slow servers, software flaws, confusing feedback, problems with the videos, and Internet problems, that may have influenced the outcome of the study.

In addition to computer assisted instruction, gender differences in mathematics are a concern of educators who are attempting to prepare all students for fulfilling careers. Stereotypes that females lack mathematical ability, perform poorly in math courses, and have limited experience with computers persist in society. There is evidence that, over the past several decades, the gender gap between men and women in mathematical performance has narrowed but may not

be eliminated. A recent analysis of state assessment test scores produced effect sizes for gender differences consistently less than 0.10, indicating no gender differences (Hyde, Lindberg, Linn, Ellis, & Williams, 2008).

To add to the literature base addressing these issues, this study investigates whether computer-assisted instruction enhances the learning of developmental mathematics or if traditional instruction is more effective for these students. Also, is there any difference in the mathematical performance of males and females in developmental mathematics courses? The specific null hypotheses follow: 1. There is no significant difference in the mathematics performance of students in a developmental mathematics course using the following instructional modes: (a) traditional lecture and (b) lecture with computer-assisted instruction. 2. There is no significant difference in the mathematical performance of developmental mathematics students by gender.

Results of this study may initiate changes

The difference was how students learned outside the classroom.

in the instructional modes in order to enhance mathematical achievement for all students. With information about the potential impact of computer-assisted instruction, institutions can invest their resources wisely. In addition, it may lead to investigation into what student characteristics are associated with the highest achievement in the various delivery formats.

Design of the Study

The nonrandomized control group pretest-posttest design was used for this quasi-experimental study. Intact groups of established classes were used. Students self-registered for the courses and could not be randomly assigned to the control or treatment groups without disrupting their schedules.

Participant and Institutional Demographics

In this study the subjects were the students enrolled in four sections of Intermediate Algebra at a large, private, eastern university. The Spring 2009 enrollment included 10,668 undergraduate students from 50 states and 80 countries. Regarding gender, 47% of the residential enrollment was male, and 53% was female. Ninety-five percent of the students were of traditional college age (≤ 23). Overall, 75% of the students were Caucasian, 14% were African American,

4% were Hispanic, and 7% were other ethnicities. International students represented 10% of the traditional and 12% of the traditional + CAI participants.

There were 17 computer labs on campus for student use, and 95% of the campus had wireless access. The university offered three developmental mathematics courses with Intermediate Algebra being the last in the sequence and the prerequisite for college algebra, statistics, and math for liberal arts.

Control/Experimental Groups

The control group was two classes receiving instruction in the traditional lecture format with written homework. Students listened to lectures, took notes, observed the instructor working examples on the board, and asked and answered questions. At times, the students worked individually or in small groups as the instructor observed their work. Students turned in daily homework from the textbook, and it was graded and returned the following class. All quizzes, tests, and the final exam were taken in class on paper and graded by the instructor. Outside of class students could seek assistance from the instructor during office hours and from tutors in the developmental mathematics tutoring center, which offered free tutoring without an appointment.

The experimental group consisted of two classes receiving instruction by traditional lecture supplemented with computer-assisted instruction. The classroom instruction was the same as the control group. The difference was how students learned outside the classroom. Students used the computer learning system that accompanied the textbook and included homework and tutorials. Tutorials provided practice problems similar to homework problems, examples worked step by step with explanations, and links to the appropriate textbook pages. Tutorials were not graded. Each lesson had a computer homework assignment of 10 to 15 problems. Problems were free-response, multiple choice, and matching. Each question could be attempted three times during a session. The student received immediate grading of the problem by clicking "submit." Each assignment could be attempted 10 times. This encouraged students to immediately identify and correct their errors, attempting to earn a perfect score on each assignment. The management functions of the software allowed the instructor to see the number of attempts for each assignment, the grade, the time spent, and the answers to individual problems for each student. The computer learning system was available 24 hours a day from any computer with Internet access. Students could seek assistance from the instructor during of-

five hours or from tutors in the developmental mathematics tutoring center which was available five days a week.

All sections were taught by full-time instructors who had demonstrated competence in teaching developmental mathematics students and had experience teaching in both delivery formats. There were two instructors, each taught one class of each mode of instruction. Each class had 25 to 30 students enrolled. Students did not know they were participating in a research study so that they would not deliberately or subtly influence the outcome of the study.

Instrumentation

The questionnaire asked for the student’s gender, age, ethnicity, international student status, how many years since last math class, how many semesters the student had been in college, number of credit hours he or she was taking the current semester, how the student had used computers in the past, and attitude toward mathematics and computers. The construct of mathematics achievement was operationally defined as scores on the Intermediate Algebra final exam, which was the posttest. This was a departmental final exam given to all students in Intermediate Algebra. Validity of the exam was the extent to which it measured mathematics achievement. The exam was a collection of test items created by the developmental mathematics faculty and matched to the Intermediate Algebra course objectives in proportion to the emphasis given to each topic during the semester. This provided face validity. The test questions were critiqued by a team of Department of Mathematics faculty members. This provided content validity. Reliability of the final exam is the extent to which scores were free of random error, that is, the extent to which the exam yielded consistent results. Ideally, the reliability coefficient should be close to one. Cronbach’s Alpha, or coefficient alpha, for the final exam was 0.915 as calculated using The Statistical Package for the Social Sciences (SPSS), based on scores from a sample of 80 final exams from eight instructors from a previous semester. The pretest consisted of five questions from the final exam, representing five major course objectives of Intermediate Algebra. Cronbach’s alpha for the pretest was calculated and found to be 0.714, compared to 0.915 for the posttest. Shorter tests generally have lower reliability than longer tests.

Data Collection

The first class meeting of the semester, all students completed a questionnaire to provide descriptive data of the classes and to determine similarity of the two groups. A pretest was given the first week of class consisting of five questions from the final exam; the final was the posttest.

Classes from both groups completed all three instruments on paper. Instructors graded the pretest and posttest. Instructors assigned a sequential number to each student for the purpose of matching the questionnaire to pretest and posttest scores and then removed the students’ names from the questionnaire, pretest score, and posttest score before submitting them to the researcher. The researcher recorded the number, responses to the questionnaire, pretest score, posttest score, and instructional method in SPSS.

Data Analysis

SPSS was used to run descriptive statistics on the data. The sample size, mean, and standard deviation were tabulated by method of instruction and gender. Scores were omitted for students who did not complete either the pretest or posttest and for a single outlier.

One hundred thirteen students took the pretest (58 from the traditional and 55 from the tra-

The mere presence of computers does not improve student learning.

ditional + CAI). Of these 113 students, 99 took the posttest with 51 enrolled in traditional and 48 in traditional + CAI. Table 1 shows the distribution of the 99 participants among the methods of instruction and gender.

An analysis of covariance (ANCOVA) was conducted to determine if there were significant differences in mathematical performance between the two methods of instruction. The dependent variable was the posttest. An ANCOVA was also conducted to determine if there was a significant difference in mathematics performance by gender. The covariate was the pretest, the independent variable was gender, and the dependent variable was the posttest. The interaction of method and gender was analyzed by including method as an independent variable.

Data from the questionnaire were tabulated by group, listing frequency and percent for gender, ethnicity, age, part-time or full-time status, semesters in college, years since last math course, math attitude, computer attitude, international students, and how students use computers.

Results

For Hypothesis 1, the independent variable was the method of instruction. The dependent variable was mathematics performance defined as scores on the posttest. Mathematics performance before treatment was defined as scores on the pretest, which served as the covariate in the analysis of covariance. After ANCOVA adjusted the mean posttest score for any initial differences among the groups on the pretest, the posttest scores were used to compare mathematics performance by the methods of instruction (see Table 2).

After verifying that the four assumptions of analysis of covariance were met, an ANCOVA was conducted to determine if the difference in the posttest scores, after controlling for pretest scores, was statistically significant and did not occur by chance alone. Ninety-nine students completed the pretest and posttest, 51 in the traditional group and 48 in the traditional + CAI group. The independent variable was the method of instruction, the dependent variable was the mathematics performance as measured by the posttest, and the covariate was the pretest. SPSS was used for the analysis with an alpha = .05 level of significance. The results, as reported in Table 3 (p. 16), indicated there was

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Table 1
Distribution of Sample

	Male	Female	Total
Traditional	21	30	51
Traditional + CAI	23	25	48
Total	44	53	99

Table 2
Descriptive Statistics by Method of Instruction

Method		Pretest		Posttest	
		Mean	SD	Mean	SD
Traditional	(n=51)	29.44	15.00	73.88	14.83
Traditional + CAI	(n=48)	32.31	14.44	78.23	13.81
Total	(N=99)	30.69	14.75	75.99	14.43

no statistically significant difference for method of instruction, $F(1,94)=2.35, p=.128$. Therefore, Null Hypothesis 1 was not rejected. There was no statistically significant difference in mathematics performance as measured by the posttest of Intermediate Algebra students receiving traditional instruction and those receiving traditional instruction supplemented with computer-assisted instruction. The posttest mean for traditional + CAI was higher, but not significantly higher, than the posttest mean for traditional instruction. In addition, the covariate of pretest significantly influenced the dependent variable of posttest, $F(1, 99)=10.52, p=.002$. Results reveal the adjusted posttest mean scores after accounting for differences using the pretest scores are not significantly different for traditional (73.51) and traditional + CAI (77.59) methods, with standard errors of 1.862 and 1.888 respectively.

To address Hypothesis 2, data from 44 males and 55 females who completed both the pretest and posttest was analyzed. Table 4 presents the descriptive statistics for performance on pre- and posttest by gender

The ANCOVA results for Hypothesis 2 are reported in Table 3 with gender being the independent variable, posttest the dependent variable, and pretest the covariate. The results indicate a significant difference for gender, $F(1,94)=10.45, p=.002$. Therefore, Null Hypothesis 2 was rejected. There was a statistically significant difference in posttest mean scores of male and female Intermediate Algebra students, when adjusting for the effect of pretest scores. Results reveal that females ($M=79.84; SE= 1.768$) scored higher on the posttest than males ($M=71.26; SE=1.972$).

The ANCOVA summary in Table 3 indicates no significant interaction between method and gender, $F(1,94)=.07, p=.792$. Table 5 shows that females outperformed males in both traditional instruction and traditional instruction supplemented with computer-assisted instruction.

The responses to the questionnaire revealed some interesting attributes in the students. From the study sample, 35% of the traditional students and 28% of the traditional + CAI students reported having a negative or very negative attitude toward math. Nearly all students (95 of 99) used computers for both academic purposes and other reasons, such as email, social networking, and shopping. Very few students had a negative attitude toward using the computer for educational purposes; 71% of the traditional students and 59% of the traditional + CAI students reported feeling positive or very positive toward using computers for educational purposes.

Discussion

The literature and the findings of the current study reveal several interesting observations concerning developmental mathematics and computer-assisted instruction. The results of this study indicate that developmental mathematics students learn equally well with or without computer-assisted instruction. The mere presence of computers does not improve student learning. Computers have the potential to be useful tools to improve learning; however, it is the responsibility of the faculty to choose software that meets the needs of the course and the students, to use it effectively, and to require its use. As supported by questionnaire responses, students have an interest in using technology for a variety of purposes including academics. Educators can tap into this interest by using technology to deliver instruction and assess learning. Computer learning systems provide educators the opportunity to create courses in a variety of alternative formats to the traditional lecture in order to address the different learning styles and preferences of students. Quality is essential in any mode of instruction. The current study also suggests that females may learn more than males in a developmental mathematics course.

Limitations

This study was conducted at a large university, using Intermediate Algebra courses delivered by two modes of instruction: traditional classroom instruction and traditional instruction supplemented with computer-assisted instruction. The results may not generalize to other developmental mathematics courses, such as pre-algebra or beginning algebra. In addition, the results may not apply to a course that uses computer-assisted instruction in a different way, such as a

Table 3
Method of Instruction ANCOVA Summary

Source	df	MS	F	p
Between treatments	4	1114.79	6.57	<.001
Pretest	1	1785.29	10.52*	.002
Method	1	399.66	2.35	.128
Gender	1	1773.55	10.45*	.002
Method X Gender	1	11.84	0.07	.792
Error	94	169.76		
Total	99			

* $p < .05$

Table 4
Descriptive Statistics by Gender

Gender		Pretest		Posttest	
		Mean	SD	Mean	SD
Male	($n=44$)	29.20	16.24	70.93	14.89
Female	($n=55$)	31.89	13.48	80.04	12.81
Total	($N=99$)	30.70	14.75	75.99	14.43

Table 5
Adjusted Posttest Means by Method and Gender

Method	Male		Female	
	M	SE	M	SE
Traditional	68.87	2.869	78.15	2.379
Traditional + CAI	73.65	2.718	81.53	2.613

laboratory setting or hybrid course. Of the seven full-time instructors at the university, only two were teaching the course sections used in this study because they were the only ones teaching in both modes of instruction being investigated. The number of students in this study was limited to those enrolled in Intermediate Algebra for the Spring 2009 semester in the sections taught by the two instructors. The computer software was limited to the system that the developmental math program had already adopted, CengageNOW.

Implications for Practice and Future Research

Several sources indicate that colleges and universities should offer developmental mathematics courses with computer-assisted instruction. Standards developed by the American Mathematical Association of Two-Year Colleges

(1995) and the National Council of Teachers of Mathematics (2000) call for the use of technology in the classroom to improve student learning. Technological advances have made computers more powerful and less expensive, which has resulted in more students having access to computers. Most college students, including this study's sample, are inclined to use them for academic purposes in addition to communication and social uses. Eighty-five percent of college students in the Pew Internet and American Life Project (Madden & Jones, 2002) had their own computer and 79% said the computer had a positive impact on their college academic experience.

Faculty and advisors should improve the course selection process so that students choose the instructional model that best matches their learning style. Students could complete a questionnaire about learning styles and preferences that would provide feedback on which instructional model is likely to provide a successful experience. This questionnaire could be available online, in advising sessions, from math instructors, and in the learning center. In an online course, before the course begins, the professor should inform students how much time and computer skill will be required to successfully complete the course.

It is important that developmental educators learn how to use technology effectively to improve student learning. One of the factors identified as critical to success in an online developmental mathematics course was professional development for faculty (Perez & Foshay, 2002). A report based on 176 literature reviews and individual studies found that the achievement of students using computer-based instruction was significantly related to the amount of technology-related training the teachers had received and whether the technology was being used appropriately (Bialo & Sivin-Kachala, 1996). Caverly and MacDonald have proposed standards and resources for professional development in technology integration for developmental educators (2004).

Faculty should constantly evaluate computer software because new products continue to be developed and old ones changed. Some software is designed to supplement classroom instruction and some is designed to deliver instruction (Kinney & Robertson, 2003). Instructors need time to evaluate and select software appropriate to the course design. They need to know how to use the technology and how to integrate it in the curriculum in a way that enhances student learning. Since developmental students often lack study skills, organizational skills, and

motivation (Armington, 2003), courses should include lessons and discussion boards on learning strategies (Kinney & Robertson, 2003; Trenholm, 2006; Wadsworth, Husman, Duggan, & Pennington, 2007).

This study indicates similar learning gains for developmental mathematics students in traditional and traditional + CAI classrooms. Although lecture alone has, at times, been ineffective with developmental mathematics students, there is evidence in the literature that enhancing the lecture with such techniques as group work (Wright, Wright, & Lamb, 2002), cooperative learning (Kinney, 2001), class discussions (Perez, 1998), real-world examples (MacDonald et al., 2002), and peer tutoring (Kinney, 2001) has positive results. Educators using the traditional lecture should examine their teaching practice and find ways to enhance it with active learning and relevant examples that will motivate students to learn. Courses could be redesigned with classes meeting four or five days a week (Way-

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caster, 2001); two or three days could be lecture with the remaining days used for students to work problems and take quizzes.

Professional development should also be provided to help developmental educators understand the needs of developmental students (Boylan, 2002). This professional development can be attending developmental education conferences, reading current research, and participating in departmental workshops on relevant topics. Often colleges and universities hire instructors with high school teaching experience or use professors in the traditional mathematics department to teach developmental courses. However, they must learn how developmental students differ from high school students and how they differ from those ready for college-level work. Instructors must be committed to continually improving their instructional practice in order to provide a high-quality education for all students, no matter what method of instruction is being used.

Developmental educators should strive to give all students, whether male or female, equal

opportunities to receive a quality education. Instructors should examine whether they treat males and females differently in any way, including asking and answering questions from one gender more than the other, and then make necessary corrections. A peer or supervisor could conduct a classroom observation in which the number and types of interactions are recorded by gender.

Colleges and universities should offer developmental mathematics courses in a variety of modes of instruction to meet the diverse learning needs of developmental students. Recommendations for further study include replicating the study with a larger sample and in other developmental mathematics courses, investigating math anxiety levels of students in various modes of instruction, and examining performance of students based on faculty gender and student gender.

Conclusion

Computer-assisted instruction offers students an opportunity to be actively engaged in the learning process, to receive instruction through a variety of multimedia, to choose when and where they learn, to work at their own pace, and to receive immediate and accurate feedback (Brown, 2003; Cotton, 1991; Hannafin & Foshay, 2008; Kinney & Robertson, 2003). Also, students in the current study and several others (Bump, 2004; Ford & Klicka, 1998; Kinney & Robertson, 2003) reported choosing a math class based on what fit their schedule, not whether the class used a computer.

Concern for the low pass rates in developmental mathematics courses has led educators to explore alternatives to the traditional lecture that has been used for many years in college classrooms. Computers make possible new methods of delivering instruction with the potential to improve learning by providing an active learning environment. This study compared the mathematical performance of students receiving two different modes of instruction in developmental mathematics. Findings from the study support that students perform equally well when receiving traditional classroom instruction and traditional classroom instruction supplemented with computer-assisted instruction. In addition, females outperformed males in both instructional modes. Faculty must improve the curriculum and their instructional practice so that all students in every instructional setting have an opportunity to improve their learning, to pass a developmental mathematics course, and to achieve their educational and career goals.

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