CARNEGIElearning™
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Carnegie Learning's Cognitive Tutor™: Summary Research Results

The Cognitive Tutor™ program's heritage as a research project is reflected in the extensive work that has gone into evaluating its effectiveness. In this paper, we describe various evaluations that demonstrate the power of the Cognitive Tutor solution. Specifically, we make the following claims:

Compared to students in traditional mathematics classes:

- Students taking Cognitive Tutor Algebra I have been shown to perform 85% better on average on assessments of complex mathematical problem solving and thinking.
- Students taking Cognitive Tutor Algebra I have been shown to perform 14% better on average on standardized assessments of basic mathematical skills.
- Students completing the three-course Cognitive Tutor sequence (Algebra I, Geometry and Algebra II) have been shown to perform better on the TIMSS assessment (by 30%) and real-world problem solving assessments (by 227%).
- Students who enrolled in Cognitive Tutor Algebra I have been shown to be 69% more likely to pass traditional Geometry and 71% more likely to pass traditional Algebra II.
- The benefits of the Cognitive Tutor Algebra I approach have been shown to be equivalent for both Caucasian and African-American students.

The research supporting these claims is described below.

Compared to students in traditional algebra classes, students taking Cognitive Tutor Algebra I have been shown to perform 85% better on average on assessments of complex mathematical problem solving and thinking.

Two studies compared students using Cognitive Tutor programs at Pittsburgh public high schools to classes at comparable Pittsburgh public high schools who were not using the Cognitive Tutor programs. An additional study of the same design was performed with students in Milwaukee public schools. Students were assessed on their ability to solve real-world problems and to use multiple mathematical representations, as measured by instruments developed at Carnegie Mellon University.

The results, presented in Figure 1, show the dramatically superior performance of the Cognitive Tutor classes compared to the control groups.

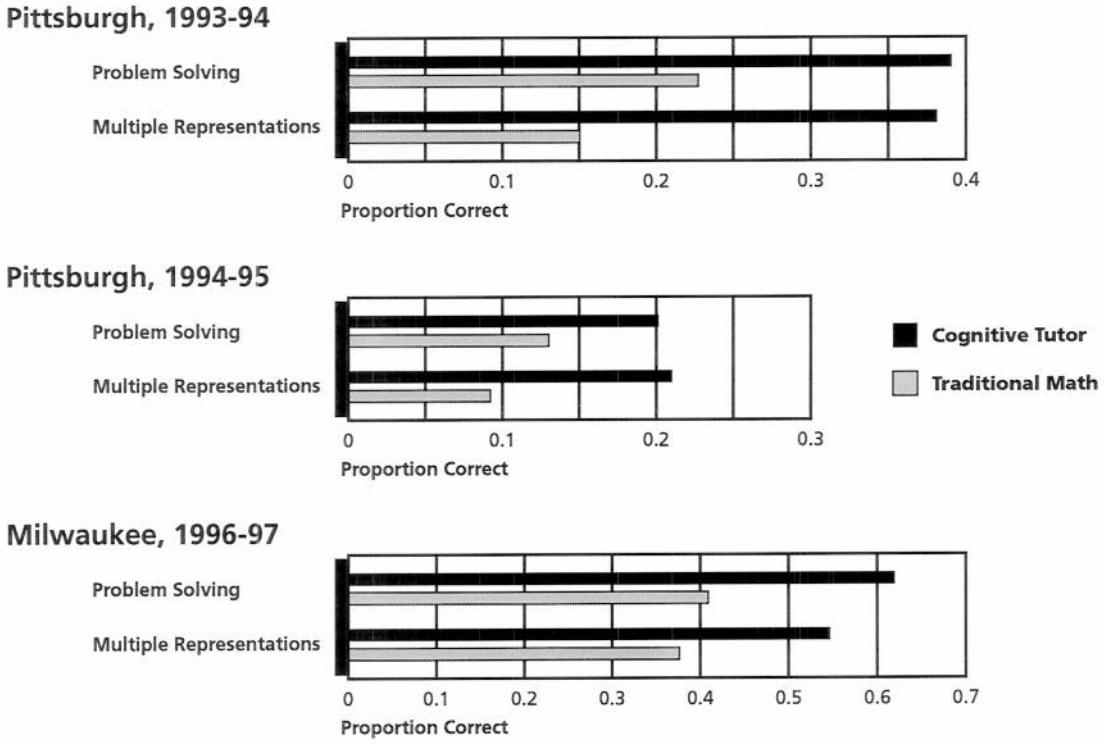

Figure 1: In all three studies, students taking Cognitive Tutor Algebra I performed better on problem solving and multiple representation assessments than compared to students in control classes.

Results from the 1993-94 Pittsburgh assessment were published in the *International Journal of Artificial Intelligence in Education* (Koedinger, Anderson, Hadley and Mark, 1997).

Compared to students in traditional algebra classes, students taking Cognitive Tutor Algebra I have been shown to perform 14% better on average on standardized assessments of basic mathematical skills.

The two Pittsburgh studies described previously included two additional assessments: a subset of the math SAT (selecting questions relevant for algebra students) and the Iowa Algebra Aptitude Test. The Milwaukee study included the math SAT subset but not the Iowa Algebra Aptitude Test. The results are shown in Figure 2.

These assessments show an advantage for the Cognitive Tutor students on standardized multiple-choice items measuring skill competency. This is a significant finding since students taking the Cognitive Tutor course are focusing more time on mathematical modeling and less time practicing skills than students in the control classes.

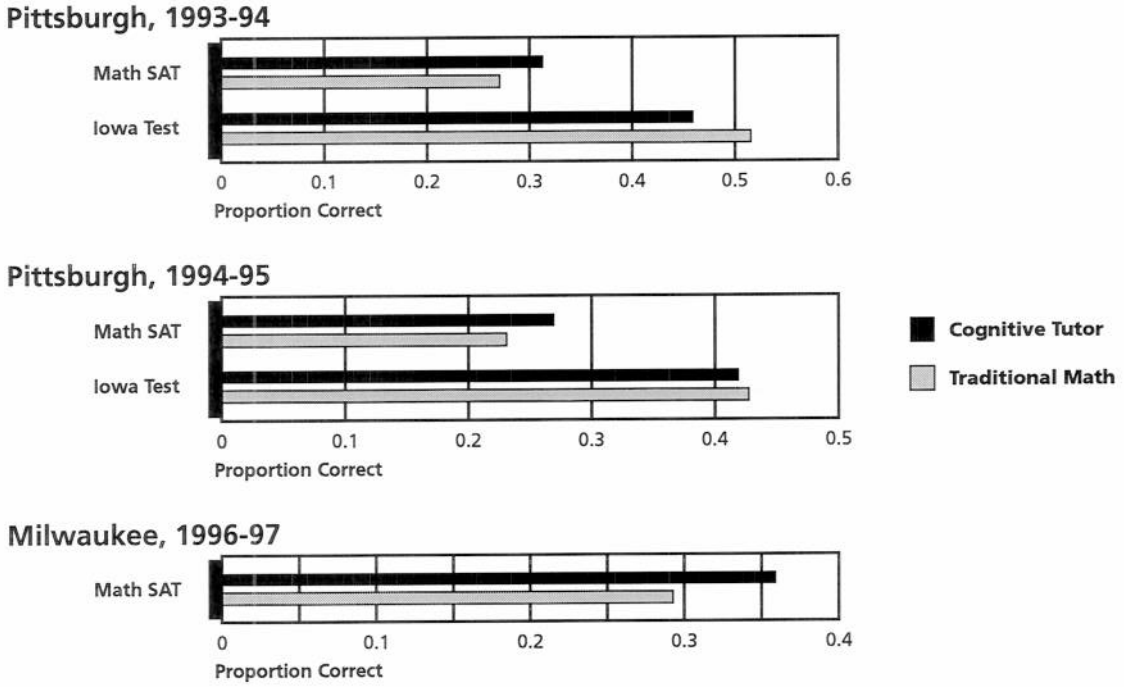

Figure 2: Overall, students taking Cognitive Tutor Algebra I performed better on standardized tests compared to students in control classes.

Compared to students in traditional mathematics classes, students completing the three-course Cognitive Tutor sequence (Algebra I, Geometry and Algebra II) have been shown to perform better on the TIMSS assessment (by 30%) and real-world problem solving assessments (by an average of 227%).

During the 1997-98 and 1998-99 school years, two groups of 11th grade students were compared: those at one Pittsburgh high school who had used Cognitive Tutor programs for Algebra I, Geometry and Algebra II, and students in a comparable Pittsburgh high school who had taken the same three courses using traditional instruction. Our comparisons included questions from the Third International Math and Science Study (TIMSS) and the math SAT. In addition, students were asked to use graphs, tables and equations to model and answer questions about three types of real-world problem situations, one based on linear functions, one represented by a quadratic function and one involving geometric areas.

The results, shown in Figure 3, indicate that Cognitive Tutor students performed 30% better on the TIMSS questions and performed an average of 227% better on the real-world problem solving assignment.

Performance on TIMSS assessments and Problem Solving

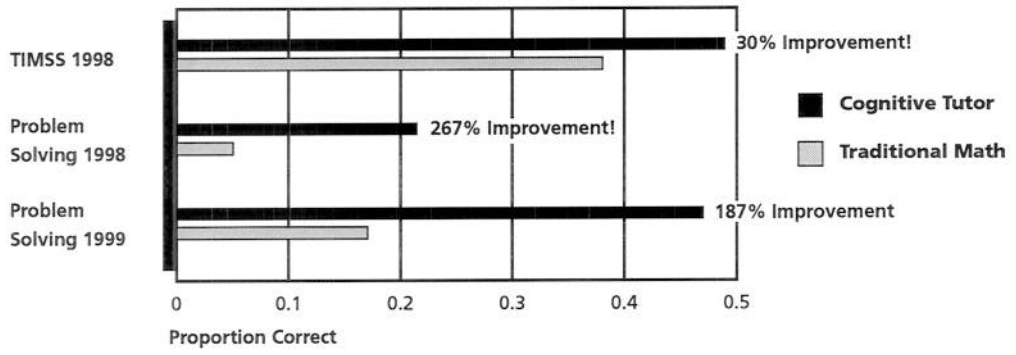

Figure 3: The results shown above show that Carnegie Learning's Cognitive Tutor students performed 30% better on the TIMSS questions and performed an average of 227% better on the real-world problem solving assessments.

Compared to students in traditional algebra classes, students who enrolled in Cognitive Tutor Algebra I have been shown to be 69% more likely to pass traditional Geometry and 71% more likely to pass traditional Algebra II.

In the first year that the Cognitive Tutor Algebra I course was used at Langley High School (1992-93) some students were still taking a traditional algebra course. Since the Cognitive Tutor Geometry and Cognitive Tutor Algebra II courses were not yet developed, students in both groups who continued in mathematics took the same traditional Geometry and Algebra II courses. In this study, the progress of students who took Carnegie Learning Algebra I was compared to students who took a traditional Algebra I course as they went through the same subsequent traditional mathematics courses.

	COGNITIVE TUTOR ALGEBRA I		TRADITIONAL ALGEBRA I	
	Enrolled Students	Students passing course	Enrolled Students	Students passing course
9TH GRADE ALGEBRA I	**84**	**57**	30	13
10TH GRADE TRADITIONAL GEOMETRY	**58**	**38**	15	8
11TH GRADE TRADITIONAL ALGEBRA II	**38**	**24**	5	5

Table 1: Students on the right were enrolled a traditional Algebra I course and those on the left were enrolled in Cognitive Tutor Algebra I. All students took the same traditional Geometry and Algebra II courses. However, significantly more students who had been enrolled in Cognitive Tutor Algebra I later enrolled in, and passed, subsequent math courses.

As shown in Table 1, students were more likely to pass the Cognitive Tutor Algebra I course than the traditional Algebra I course (68% vs. 43%). In fact, 66% (38 out of 58) of the Cognitive Tutor Algebra I students who took traditional Geometry passed that course, as opposed to only 53% (8 of 15) of students who had taken traditional Algebra I and were enrolled in the same Geometry course. The effects were still strong two years after the Cognitive Tutor course. When these students were ready for Algebra II, 29% (24 of 84) of the students who had taken Cognitive Tutor Algebra I passed the traditional Algebra II course. This compares to only 17% (5 of 30) of the students who had taken the traditional Algebra I course.

The benefits of the Cognitive Tutor Algebra I approach have been shown to be equivalent for both Caucasian and African-American students.

	COGNITIVE TUTOR ALGEBRA I		TRADITIONAL ALGEBRA I	
	Caucasian	African American	Caucasian	African American
INCOMING MATH BACKGROUND	33	**18**	**38**	22
END-OF COURSE ASSESSMENTS				
Problem Solving	43	**22**	**19**	6
Standardized Tests	49	**37**	**44**	37

Table 2: Percent correct on various measures, divided by race. Although African-American students entered the Cognitive Tutor course disadvantaged relative to Caucasian students (as evidenced by prior-year CAT scores), their scores upon leaving the course were comparable to those of Caucasian students in a traditional course, as measured both by standardized tests and problem-solving measures.

Further analysis of the studies reported here show that the effects apply fairly equally to all students. In the Pittsburgh high schools we studied, African-American students came to high school with poorer math skills than Caucasian students. Looking at eighth-grade standardized math test (CAT) scores, African-American students scored 19% as compared to 35% among Caucasian students.

Despite entering the Cognitive Tutor Algebra I course with weaker math skills, African-American students left the course demonstrating the same mathematics skill level as the Caucasian students who had taken a traditional algebra course. With respect to the problem solving test, African American students taking the Cognitive Tutor course scored 22%, as opposed to 19% for Caucasian students in the traditional course. On the standardized tests, African American students taking the Cognitive Tutor course scored 37%, as compared to 44% for Caucasian students in the traditional course. Neither of these differences are statistically significant.

Summary

The studies described in this paper confirm the significant advantages that Cognitive Tutor curricula offer over more traditional approaches to mathematics instruction. Student in Cognitive Tutor classrooms perform better on both applied and traditional assessments, and they succeed when placed in subsequent traditional mathematics courses. Benefits were significant to students of all races and backgrounds and the advantages of the Cognitive Tutor approach appear in study after study.

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