What Works Clearinghouse
IES Institute of Education Sciences
Curriculum-based interventions for increasing K-12 math achievement—middle school

Intervention report: Cognitive Tutor®

Updated December 1, 2004

Intervention

Cognitive Tutor®, a full-year course, covers organizing single variable data, simplifying linear expressions, mathematical modeling, solving systems with linear equations, problem-solving using proportional reasoning, and powers and exponents. Students work at their own pace to develop problem-solving skills. The duration of each lesson can vary, depending on the length of a school's class period. Generally, three periods a week are for classroom activities using the *Cognitive Tutor*® text, and two are spent in the computer lab using the *Cognitive Tutor*® software.

For

Middle school students.

Findings

In one randomized controlled trial, students in the *Cognitive Tutor*® group earned higher average scores on the Educational Testing Service Algebra I test and higher end of semester grades than did the comparison students in algebra classes that used *McDougal Littell's Heath Algebra I* curriculum.

Evidence base

1 randomized controlled trial meets evidence standards.

0 quasi-experimental design studies meet evidence standards with reservations.

5 studies do not meet evidence screens.

(see symbol key on page 6)

Evidence limits

The evidence base for *Cognitive Tutor*® is limited to one randomized controlled trial of 369 9th graders attending urban middle schools.

Scope of use

Cognitive Tutor® was first implemented in 1992. As of September 2004, it was used in about 1,500 schools by about 170,000 students.

Developer and contact

Carnegie Learning Inc., www.carnegielearning.com; email: info@carnegielearning.com; telephone: (888) 851-7094.

Profile

Cognitive Tutor®, developed by Carnegie Learning Inc., includes a set of curricula for Algebra I, Geometry, Algebra II, Integrated Math I, II & III, and Quantitative Literacy Through Algebra. This report focuses on one of its products used in middle schools: *Cognitive Tutor® Algebra I.*

Cognitive Tutor® is designed to help teach algebra with interactive computer software in personalized computer sessions. The goal of the curriculum is to improve students' understanding of basic foundational skills as well as high-order mathematical concepts. The curriculum covers the following eight topics:

- Organizing single variable data
- Simplifying linear expressions
- Finding linear equations from graphs
- Mathematical modeling
- Solving systems of linear equations algebraically and graphically
- Solving and graphing equations involving absolute values
- Problem-solving using proportional reasoning
- Powers and exponents

The developer states that these topics are designed to align with the National Council of Teachers of Mathematics (NCTM) *Curriculum and Evaluation Standards* (Corbett, Koedinger, & Hadley, 2001).

Cognitive Tutor® course materials for students include a textbook, software, and supplemental materials. Materials for the teachers consist of a teacher's edition of the textbook, student assignments with answers, assessments, a software manual, and a teacher's toolkit for student engagement activities.

Cognitive Tutor® is a full-year course with each lesson lasting the full class period.

Teaching

In the classroom, teachers facilitate small group problem-solving and whole classroom discussions. In the computer lab, teachers interact with students on a more individual basis, and *Cognitive Tutor*® acts as a classroom assistant to facilitate student progress.

Carnegie Learning provides a three-day preservice training. In-service professional development is also available during the year. Teacher training for all *Cognitive Tutor*® curricula provides educators the opportunity to understand the philosophy and application of these products. The training sessions are conducted by Certified Implementation Specialists, each a current or former mathematics teacher who has completed in-depth training from Carnegie Learning's staff of educators, technology specialists, and curriculum developers.

Typical lesson

Three class periods a week are organized around textbook materials and small group activities. In the other two class periods, students work at their own pace to develop their own problem-solving skills by working with the *Cognitive Tutor*® on the computer.

The software uses problem scenarios that pose multiple questions to the students. In some problems, the software presents a problem scenario for which the student must create a mathematical model, using equations, graphs, and tables. Students are expected to make connections between the symbolic, graphical, and tabular representations and the written problem—and provide justifications for the methods they use. In other units, students are expected to solve more abstract mathematics problems, such as linear equations, again justifying their approach and reasoning at each step. During this process students receive immediate feedback when they make errors.

Scope of use

Pilot implementation of the curriculum began in 1992 with 84 students in one school. As of 2004, it is in use in about 1,500 U.S. schools by about 170,000 students.

Cost

According to the 2004/05 pricing information, the price for *Cognitive Tutor*® ranges from $716 for a five-user lab pack to $12,500 for an annual site license for 400 or more users. Regional training is included in the site license, and schools buying lab packs can opt for onsite training for an additional $2,500.

Study findings

Randomized controlled trial

In the single study on the *Cognitive Tutor*® that meets evidence standards, students in the *Cognitive Tutor*® group earned significantly higher mean scores on the Educational Testing Service Algebra I test and on their end-of-semester grades than did the students in the comparison group.

Strength of the evidence base

The WWC collected more than 800 studies for the Middle School Math Curriculum review. Five studies looked at *Cognitive Tutor*®. Four failed to meet WWC evidence screens. All four of the studies were quasi-experimental design studies that did not account for pre-existing differences between groups with matching or equating.

Studies were rated according to the strength of their causal evidence. Studies that placed students into the intervention and comparison groups randomly (randomized controlled trials) without notable design or implementation flaws are classified as meeting evidence standards (✓✓[a]). Other studies that use comparison groups (quasi-experimental designs) and randomized controlled trials with notable flaws are classified as meeting evidence standards with reservations (✓[a]).

One study on *Cognitive Tutor*® meets WWC evidence standards. WWC focused on the part of this study that randomly assigned students to groups.

Studies are further rated for intervention fidelity, outcome measures, breadth of evidence, reporting on subgroups, analysis, and statistical reporting. That information is provided in study reports, but does not affect the overall rating.

The intervention in this study is well defined and has no noted implementation problems. The primary outcome measures, ETS Algebra I Test and end of semester grades, appear to be valid and aligned with the intervention. Appropriate methods were used to estimate average effects of the intervention. The study looked at and reported findings for only 9th-grade students in an urban Oklahoma district.

Table A2 describes the one outcome study of *Cognitive Tutor*® that meets WWC evidence standards. For a more detailed description of the study, see the *Detailed Study Report* or *Brief Study Report*.

a See symbol key on page 6.

References

✓✓ Morgan, P., & Ritter, S. (2002). *An experimental study of the effects of Cognitive Tutor Algebra I on student knowledge and attitude.* (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)

Anderson, J. R., & Lebiere, C. (1998). *The atomic components of thought.* Mahwah, NJ: Lawrence Erlbaum.

✗ Corbett, A. T. (2001). *Cognitive Tutor® results report.* (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)

✗ Corbett, A. T. (2003). *Cognitive Tutor® results report: 8th grade*. (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)

Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User modeling and user-adapted interaction*, 4: 253–278.

Corbett, A. T., Koedinger, K. R., & Hadley, H. S. (2001). Cognitive tutors: From the research classrooms to all classrooms. In P. Goodman (Ed.), *Technology enhanced learning: Opportunities for change* (pp. 235–263). Mahwah, NJ: Erlbaum.

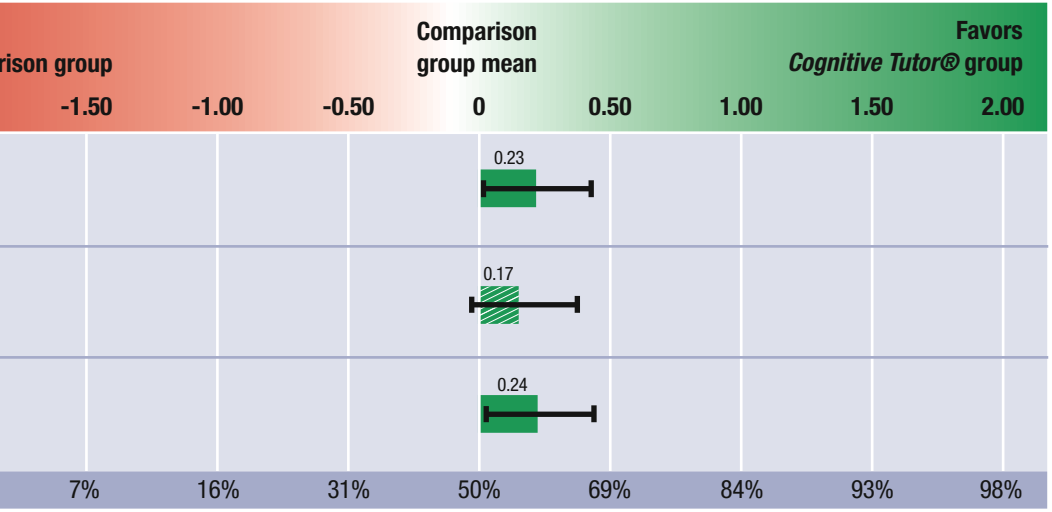
✗ Koedinger, K. R. (2001). *Cognitive Tutor® results report PA-01-01.* (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)

✗ Koedinger, K. R. (2002). *Cognitive Tutor® results report PA-01-02: Cognitive Tutor 6th grade math.* (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)

✗ Nathan, M. J., Stephens, A. C., Masarik, K., Alibali, M. W., & Koedinger, K. R. (2002). Representational fluency in middle school: A classroom study. In D. S. Mewborn, P. Sztajn, D. Y. White, H. G. Wiegel, R. L. Bryant, & K. Nooney (Eds.), *Proceedings of the annual meeting of the North American chapter of the International Group for the Psychology of Mathematics Education* (pp. 463-472). Columbus, OH: International Group for the Psychology of Mathematics Education.

Table 1
Effects

Study	Measure	Favors comparison group / Comparison group mean / Favors *Cognitive Tutor®* group
Morgan & Ritter 2002	Educational Testing Service Algebra Test (N=360 students)	0.23
	Semester 1 grade (N=369 students)	0.17
	Semester 2 grade (N=364 students)	0.24
Approximate percentile ranking		2% 7% 16% 31% 50% 69% 84% 93% 98%



How to read this table: The wide, shaded bar indicates both the direction and estimated size of the effect of the intervention. The estimated effects reported here are standardized differences in the mean values between the intervention and comparison groups. Bars extending to the right of zero denote estimated effects that favor the intervention group, and those extending to the left of zero denote estimated effects that favor the comparison group. The solid line through the shaded bar marks the 95% confidence interval of the estimated effect; when there is no solid line, the study did not provide data to correctly compute the confidence interval. When the line does not cross zero, the estimate is statistically significant. The bar is striped if the effect is not statistically significant or if significance could not be accurately computed. The scale at the bottom of the chart indicates the approximate percentile distribution of students in the comparison group. The percentile ranking at the end of the shaded bar can be used to interpret the standardized mean difference in the outcome. For example, an effect of 0.5 is roughly equivalent to an increase in the mean value from that of the average student in the comparison group (50th percentile) to that of the average student in the 69th percentile.

Appendix

Table A1 **Summary characteristics and findings from randomized controlled trials on *Cognitive Tutor®***

Study	Study sample	Measure	Sample size			Mean outcome		Standard deviation[a]		Estimated impact[b]	
			Intervention group	Comparison group	Total	Intervention group	Comparison group	Intervention group	Comparison group	Mean difference	Standardized mean difference
Morgan & Ritter 2002	9th-grade, regular education students	Educational Testing Service Algebra Test[c]	222	138	360 students	16.7	15.4	5.7	5.6	1.3	0.23 (±0.21)
		Semester 1 grade	190	179	369 students	2.9	2.7	1.1	1.2	0.2	0.17 (±0.20)
		Semester 2 grade	187	177	364 students	2.7	2.4	1.2	1.3	0.3	0.24 (±0.21)

a Shows how dispersed the participants' outcomes are. A small standard deviation would suggest that participants had similar outcomes.

b The WWC estimated impact based on statistics reported by the study author.

c This is not a state or nationally normed standardized test, but it appears to be valid and aligned with the intervention.

Table A2 **Characteristics of interventions in reviewed studies on *Cognitive Tutor®:* Morgan & Ritter 2002**

Evidence base rating	Characteristic	Description
✓✓	Study citation	Morgan, P., & Ritter, S. (2002). *An experimental study of the effects of Cognitive Tutor Algebra I on student knowledge and attitude.* (Available from Carnegie Learning, Inc., 1200 Penn Avenue, Suite 150, Pittsburgh, PA 15222)
	Participants	369 9th-grade students in the part of the study that used random assignment. About two-thirds of the students in the study were white, with the other third Asian, black, Hispanic, Native American, and other. None of the students was in special education.
	Setting	Four urban junior high schools in the Moore Independent School District in Oklahoma (in the part of the study that used random assignment). Six teachers in three of four intervention schools taught both the intervention and the control curricula.
	Intervention	The intervention group was taught Algebra I using the *Cognitive Tutor® Algebra I.* The intervention is designed to be a full-year course. Students in this group spent three class periods each week in group activities and classroom discussions and two developing their own problem-solving skills at their own pace by working with the *Cognitive Tutor®*.
	Comparison	The comparison group was taught Algebra I using the *McDougal Littell's Heath Algebra I*, a traditional, teacher-directed curriculum. The study does not provide further information on this curriculum.
	Primary outcomes and measurement	ETS Algebra I End-of-Course Assessment, developed by ETS, consisting of 25 multiple-choice and 15 constructed-response questions. The other two outcomes were semester 1 grades and semester 2 grades.

Symbol key for evidence base rating

✓✓ Study meets evidence standards (randomized controlled trial without notable flaws).

✓ Study meets evidence standards with reservations (randomized controlled trial with notable flaws or quasi-experimental design study without notable flaws).

✗ Study does not meet evidence screens.