What Works Clearinghouse

Cognitive Tutor® Algebra I

Program Description[2]

The *Cognitive Tutor® Algebra I* curriculum, published by Carnegie Learning, is an approach that combines algebra textbooks with interactive software. The software is developed around an artificial intelligence model that identifies strengths and weaknesses in each individual student's mastery of mathematical concepts. It then customizes prompts to focus on areas where the student is struggling and sends the student to new problems that address those specific concepts.

Research[3]

One study of *Cognitive Tutor® Algebra I* meets What Works Clearinghouse (WWC) evidence standards. The study included 255 ninth-grade students from three junior high schools in Oklahoma.[4]

Based on this study, the WWC considers the extent of evidence for *Cognitive Tutor® Algebra I* to be small for math achievement.

Effectiveness

Cognitive Tutor® Algebra I was found to have potentially positive effects on math achievement.

	Math achievement
Rating of effectiveness	Potentially positive effects
Improvement index[5]	Average: +15 percentile points

1. This report has been updated to include reviews of 11 studies that have been released since 2005. A complete list and disposition of all studies reviewed is provided in the references. Additionally, one study that met standards with reservations in the previous version (Shneyderman, 2001) will now be eligible for review as part of the WWC high school math area. (The protocol for the middle school math area was revised to narrow the scope from examining any students in grades 6 to 9 to examining only those students who are attending middle schools or junior high schools. Studies examining students in grade 9 who are attending high school are included in the high school math area.)
2. The descriptive information for this program was obtained from a publicly available source: the program's website (http://www.carnegielearning.com, downloaded September 2008). The WWC requests developers to review the program description sections for accuracy from their perspective. Further verification of the accuracy of the descriptive information for this program is beyond the scope of this review.
3. The studies in this report were reviewed using WWC Evidence Standards, Version 1.0 (see the WWC Standards).
4. The evidence presented in this report is based on available research. Findings and conclusions may change as new research becomes available.
5. This number shows the average student-level improvement index for all findings across the study.

Absence of conflict of interest

The studies Dynarski et. al. (2007) and Campuzano et. al. (2009), cited in the references section below, were prepared, in whole or in part, by staff of Mathematica Policy Research, Inc. (MPR).

However, because the *Cognitive Tutor® Algebra I* study samples fell outside the scope of the review, the studies were not eligible for review under the Middle School Math topic area.

Additional program information

Developer and contact

Cognitive Tutor® Algebra I was developed by and is distributed by Carnegie Learning, Inc. Address: Frick Building, 20th Floor, 437 Grant Street, Pittsburgh, PA 15219. Email: info@carnegielearning.com. Web: http://www.carnegielearning.com/software_features.cfm. Telephone: (888) 851-7094.

Scope of use

Pilot implementation of the curriculum began in 1992 with 84 students in one school. As of August 2008, *Cognitive Tutor®* curricula, which include Bridge to Algebra, Algebra I, Algebra II, Geometry, and Integrated Math, have been used by more than 500,000 students in approximately 2,600 urban, rural, and suburban school districts across the United States. The number of students solely using *Cognitive Tutor® Algebra I* is not available.

Teaching

Cognitive Tutor® Algebra I addresses both mathematical content and process standards. Generally, three periods a week are spent using the *Cognitive Tutor® Algebra I* text for classroom activities, and two periods are spent in the computer lab using the *Cognitive Tutor® Algebra I* software. The textbook aims to foster a collaborative classroom environment where students develop skills to work cooperatively to solve problems, participate in investigations, and propose and compare solutions. Students learn with the adaptive software at their own pace. The math problems are designed to emphasize connections between verbal, numeric, graphic, and algebraic representations.

Cost

Curricula can be purchased as a full license for software and text or as a software-only license. *Cognitive Tutor® Algebra I* as a blended model is available as a set of software and textbooks for a price of approximately $67.70 per student; a teacher text set of materials costs $85. Volume and term discounts are available, as well as site license models for schools purchasing the software only; contact the publisher for a price quote.

Research

Fourteen studies reviewed by the WWC investigated the effects of *Cognitive Tutor® Algebra I*. One study (Ritter, Kulikowich, Lei, McGuire, & Morgan, 2007) is a randomized controlled trial that meets WWC evidence standards. The remaining 13 studies do not meet either WWC evidence standards or eligibility screens.

Meets evidence standards

Ritter, Kulikowich, Lei, McGuire, & Morgan (2007) randomly assigned algebra course sections to the intervention or control curriculum to assess the impact of *Cognitive Tutor® Algebra I* on the math achievement of ninth-grade students in three suburban junior high schools in Oklahoma. During the 2000–01 school year, ten *Cognitive Tutor® Algebra I* classrooms were compared with nine classrooms using McDougal-Littell's Heath Algebra I, a traditional, teacher-directed curriculum. The analysis sample for the end-of-course algebra assessment included ten *Cognitive Tutor® Algebra I* classrooms (153 students) and six traditional classrooms (102 students).[6] Each of six study teachers taught both *Cognitive Tutor® Algebra I* and traditional classrooms.

6. In order to save on the cost of the end-of-course algebra assessment, the study authors randomly selected one control classroom for each teacher to take the exam.

Research *(continued)*

Meets evidence standards with reservations

No studies meet evidence standards with reservations.

Extent of evidence

The WWC categorizes the extent of evidence in each domain as small or medium to large (see the WWC Procedures and Standards Handbook, Appendix G). The extent of evidence takes into account the number of studies and the total sample size across the studies that meet WWC evidence standards with or without reservations.[7]

The WWC considers the extent of evidence for *Cognitive Tutor® Algebra I* to be small for math achievement.

Effectiveness

Findings

The WWC review of interventions for Middle School Math addresses student outcomes in the math achievement domain. The findings below present the authors' estimates and WWC-calculated estimates of the size and the statistical significance of the effects of *Cognitive Tutor® Algebra I* on students.[8]

Math achievement

Ritter, Kulikowich, Lei, McGuire, & Morgan (2007) reported a positive but not statistically significant effect of *Cognitive Tutor® Algebra I* on the Educational Testing Service (ETS) Algebra End-of-Course Assessment. The effect size was large enough to be considered substantively important according to WWC standards (that is, at least 0.25).

In sum, one study showed a substantively important positive effect in the math achievement domain.

Rating of effectiveness

The WWC rates the effects of an intervention in a given outcome domain as positive, potentially positive, mixed, no discernible effects, potentially negative, or negative. The rating of effectiveness takes into account four factors: the quality of the research design, the statistical significance of the findings, the size of the difference between participants in the intervention and the comparison conditions, and the consistency in findings across studies (see the WWC Procedures and Standards Handbook, Appendix E).

The WWC found *Cognitive Tutor® Algebra I* to have potentially positive effects for math achievement

Improvement index

The WWC computes an improvement index for each individual finding. In addition, within each outcome domain, the WWC computes an average improvement index for each study and an average improvement index across studies (see WWC Procedures and Standards Handbook, Appendix F). The improvement index represents the difference between the percentile rank of the average student in the intervention condition and the percentile rank of the average student in the comparison condition.

Unlike the rating of effectiveness, the improvement index is entirely based on the size of the effect, regardless of the statistical significance of the effect, the study design, or the analysis. The improvement index can take on values between –50 and +50, with positive numbers denoting favorable results for the intervention group.

The average improvement index for math achievement is +15 percentile points for the one study.

7. The extent of evidence categorization was developed to tell readers how much evidence was used to determine the intervention rating, focusing on the number and size of studies. Additional factors associated with a related concept—external validity, such as the students' demographics and the types of settings in which studies took place—are not taken into account for the categorization. Information about how the extent of evidence rating was determined for *Cognitive Tutor® Algebra I* is in Appendix A6.
8. The level of statistical significance was reported by the study authors or, when necessary, calculated by the WWC to correct for clustering within classrooms or schools and for multiple comparisons. For an explanation, see the WWC Tutorial on Mismatch. For the formulas the WWC used to calculate the statistical significance, see WWC Procedures and Standards Handbook, Appendix C for clustering and WWC Procedures and Standards Handbook, Appendix D for multiple comparisons. In the case of Ritter, Kulikowich, Lei, McGuire, & Morgan (2007), no corrections for clustering or multiple comparisons were needed.

The WWC found *Cognitive Tutor® Algebra I* to have potentially positive effects for math achievement *(continued)*

Summary

The WWC reviewed 14 studies on *Cognitive Tutor® Algebra I*. One of these studies meets WWC evidence standards; the remaining 13 studies do not meet either WWC evidence standards or eligibility screens. Based on the one study, the WWC found potentially positive effects on math achievement. The conclusions presented in this report may change as new research emerges.

References

Meets WWC evidence standards

Ritter, S., Kulikowich, J., Lei, P., McGuire, C., & Morgan, P. (2007). What evidence matters? A randomized field trial of *Cognitive Tutor® Algebra I*. In T. Hirashima, H. U. Hoppe, & S. Shwu-Ching Young (Eds.), *Supporting learning flow through integrative technologies* (pp. 13–20). Netherlands: IOS Press.

Additional source:

Morgan, P., & Ritter, S. (2002). *An experimental study of the effects of* Cognitive Tutor® Algebra I *on student knowledge and attitude*. Retrieved November 22, 2006, from http://www.carnegielearning.com/research/research_reports/morgan_ritter_2002.pdf.

Studies that fall outside the Middle School Math review protocol or do not meet WWC evidence standards

Aleven, V., McLaren, B., Roll, I., & Koedinger, K. (2006). Toward meta-cognitive tutoring: A model of help seeking with a cognitive tutor. *International Journal of Artificial Intelligence in Education, 16*(2), 101–128. The study is ineligible for review because it does not include an outcome within a domain specified in the protocol.

Arbuckle, W. J. (2005). *Conceptual understanding in a computer-assisted Algebra 1 classroom*. Unpublished doctoral dissertation, University of Oklahoma. The study does not meet WWC evidence standards because it does not provide adequate information to determine whether it uses an outcome that is valid or reliable.

Cabalo, J. V., & Vu, M-T. (2007). *Comparative effectiveness of Carnegie Learning's* Cognitive Tutor® Algebra I *curriculum: A report of a randomized experiment in the Maui school district*. Palo Alto, CA: Empirical Education Inc. The study is ineligible for review because it does not disaggregate findings for the age or grade range specified in the protocol.

Campuzano, L., Dynarski, M., Agodini, R., and Rall, K. (2009). *Effectiveness of reading and mathematics software products: findings from two student cohorts* (NCEE 2009-4041). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education. The study is ineligible for review because it does not use a sample within the age or grade range specified in the protocol.

Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Campuzano, L., Means, B., Murphy, R., Penuel, W., Javitz, H., Emery, D., & Sussex, W. (2007). *Effectiveness of reading and mathematics software products: Findings from the first student cohort*. Washington, DC: U.S. Department of Education, Institute of Education Sciences. The study is ineligible for review because it does not use a sample within the age or grade range specified in the protocol.

Koedinger, K. R., & Aleven, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review, 19*(3), 239–264. The study is ineligible for review because it is not a primary analysis of the effectiveness of an intervention.

Plano, G. S., Ramey, M., & Achilles, C. M. (2005). *Implications for student learning using a technology-based algebra program in a ninth-grade algebra course*. Unpublished manuscript. Available from the Mercer Island School District, 4160 86th Ave.

References *(continued)*

SE, Mercer Island, WA 98040. The study does not meet WWC evidence standards because the intervention and comparison groups are not shown to be equivalent at baseline.

Additional source:

Plano, G. S. (2004). The effects of the *Cognitive Tutor® Algebra* on student attitudes and achievement in a 9th grade algebra course. *Dissertation Abstracts International, 65*(04), 1291A. (UMI No. 3130130)

Rigeman, S., & McIntire, N. (2005). Enhancing curriculum and instruction through technology. *T.H.E. Journal, 32*(12), 31–34. The study is ineligible for review because it does not include an outcome within a domain specified in the protocol.

Ritter, S., Anderson, J., Koedinger, K., & Corbett, A. (2007). *Cognitive Tutor®*: Applied research in mathematics education. *Psychonomic Bulletin & Review, 14*(2), 249–255. The study is ineligible for review because it does not include an outcome within a domain specified in the protocol.

Rittle-Johnson, B., & Koedinger, K. (2005). Designing knowledge scaffolds to support mathematical problem solving. *Cognition and Instruction, 23*(3), 313–349. The study is ineligible for review because it does not use a comparison group.

Sarkis, H. (2004). Cognitive Tutor® Algebra 1: *Miami-Dade County Public Schools*. Lighthouse Point, FL: The Reliability Group. The study does not meet WWC evidence standards because the intervention and comparison groups are not shown to be equivalent at baseline.

Shneyderman, A. (2001). *Evaluation of the* Cognitive Tutor® Algebra I *program*. Unpublished manuscript. Available from the Miami-Dade County Public Schools Office of Evaluation and Research, 1500 Biscayne Boulevard, Miami, FL 33132. The study is ineligible for review because it does not use a sample within the age or grade range specified in the protocol.

Wolfson, M., Koedinger, K., Ritter, S., & McGuire, C. (2008). Cognitive Tutor® Algebra I: *Evaluation of Results (1993–1994)*. Pittsburgh, PA: Carnegie Learning, Inc. The study is ineligible for review because it does not use a sample within the age or grade range specified in the protocol.

Additional source:

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education, 8*(1), 30–43.