What Works Clearinghouse

ies INSTITUTE OF EDUCATION SCIENCES

Carnegie Learning Curricula and Cognitive Tutor® Software

Program Description[1]

The combination of *Carnegie Learning Curricula and Cognitive Tutor® Software* merges algebra textbooks with interactive software developed around an artificial intelligence model that identifies strengths and weaknesses in an individual student's mastery of mathematical concepts. The software customizes prompts to focus on areas in which the student is struggling and routes the student to problems that address those specific concepts.

Research[2]

Two studies of the combination of *Carnegie Learning Curricula and Cognitive Tutor® Software* that fall within the scope of the High School Math review protocol meet What Works Clearinghouse (WWC) evidence standards, and two studies meet WWC evidence standards with reservations. The four studies included 1,723 high school students in 27 schools across 7 districts.[3]

Based on these four studies, the WWC considers the extent of evidence for the combination of *Carnegie Learning Curricula and Cognitive Tutor® Software* on high school students to be medium to large for mathematics achievement.

Effectiveness

Carnegie Learning Curricula and Cognitive Tutor® Software was found to have no discernible effects on mathematics achievement for high school students.

	Mathematics achievement	
Rating of effectiveness	No discernible effects	
Improvement index[4]	Average: –4 percentile points	Range: –7 to +2 percentile points

1. The descriptive information for this program was obtained from a publicly available source: the program's website (http://carnegielearning.com/secondary-curricula/, downloaded April 2010). 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. The literature search reflects documents publicly available by January 2010.
2. The studies in this report were reviewed using WWC Evidence Standards, Version 2.0 (see the WWC Procedures and Standards Handbook, Chapter III), as described in protocol Version 2.0.
3. The evidence presented in this report is based on available research. Findings and conclusions may change as new research becomes available.
4. These numbers show the average and range of student-level improvement indices for all findings across the studies.

Absence of conflict of interest

The Campuzano et al. (2009) study summarized in this intervention report was prepared by staff of Mathematica Policy Research. Because the principal investigator for the WWC review of High School Math also is a Mathematica staff member, the study was rated by staff members from RAND and SRI. The report was then reviewed by the principal investigator, a WWC Quality Assurance reviewer, and an external peer reviewer.

Additional program information

Developer and contact

Carnegie Learning Curricula and Cognitive Tutor® Software was developed 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/secondary-curricula. Telephone: (888) 851-7094.

Scope of use

Pilot implementation of the program began in 1992 with 84 students in one school. As of January 2010, components of *Carnegie Learning Curricula and Cognitive Tutor® Software*—Bridge to Algebra, Algebra I, Geometry, Algebra II, and Integrated Math—have been used by more than 500,000 students in approximately 2,600 schools across the United States.[5]

Teaching

Carnegie Learning Curricula and Cognitive Tutor® Software addresses both mathematical content and process standards. Generally, three periods per week are spent using *Carnegie Learning Curricula* text for classroom activities, and two periods per week are spent in the computer lab using the *Cognitive Tutor® Software*. The textbooks aim to foster a collaborative classroom environment in which 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 among verbal, numeric, graphic, and algebraic representations.

Cost

The Carnegie Learning website sells the following products related to Algebra I as of 2009–2010: Curriculum Kit (Software/Text) for $99, Teacher Text Set for $85, Software only for $84, and Student Text Set for $22. Volume discounts are available for school districts. The Campuzano et al. (2009) study estimates the annualized cost per student to be $69, of which 43% is the license fee and the remaining 57% is for teacher training and support, technical support, and printed materials and supplies.

Research

Twenty-four studies reviewed by the WWC investigated the effects of *Carnegie Learning Curricula and Cognitive Tutor® Software* on high school students. Two studies (Cabalo, Jaciw, & Vu, 2007; Campuzano et al., 2009) are randomized controlled trials that meet WWC evidence standards. Two studies (Shneyderman, 2001; Smith, 2001) are randomized controlled trials or quasi-experimental designs (QED) that meet WWC evidence standards with reservations. The remaining 20 studies do not meet either WWC evidence standards or eligibility screens.

Meets WWC evidence standards

Cabalo, Jaciw, and Vu (2007) randomly assigned 22 classrooms to receive either the *Carnegie Learning Curricula and Cognitive Tutor® Software* Algebra I program or the standard curriculum. Eight teachers taught at least one intervention class, and nine teachers taught at least one comparison class, at one of five Maui School District schools or at Maui Community College. The analysis sample consisted of 182 intervention and 162 comparison students who had taken both the pretest (in fall 2005) and the posttest (in May 2006).

5. The only available studies that meet WWC standards, with or without reservations, are those that cover *Cognitive Tutor®* for Algebra I.

Research *(continued)*

Campuzano et al. (2009) randomly assigned teachers in high-poverty schools to intervention and comparison groups as part of a national study of software products. During the second year of the study (presented in this report), *Carnegie Learning Curricula and Cognitive Tutor® Software* was implemented in nine schools in four districts. Nine teachers were randomly assigned to use the Algebra intervention, and nine were assigned to the comparison condition and used traditional instructional methods, with a pair of intervention and comparison teachers in each school. The fall and spring tests were administered to 145 intervention and 131 comparison students in 8th and 9th grades.

Meets WWC evidence standards with reservations

Shneyderman (2001) conducted a quasi-experiment in six senior high schools in Miami-Dade County, Florida, that had a computer lab by October 2000. For each school, two teachers were randomly selected from all teachers using the *Carnegie Learning Curricula and Cognitive Tutor® Software* Algebra I program. One class for each teacher was randomly selected into an intervention sample of 12 classrooms; the comparison sample was composed of 12 randomly selected nonintervention Algebra I classrooms in the same six schools. The analyses were conducted on 276 intervention and 382 comparison students in 9th and 10th grades.

Smith (2001) was a randomized controlled trial that was compromised by restrictions placed on the analysis sample after random assignment. Therefore, it was treated as a QED that demonstrated baseline equivalence of the analysis sample on a pretest and made the necessary statistical adjustments, allowing it to meet WWC evidence standards with reservations. The study involved all students in seven high schools in Virginia Beach City Public Schools who completed a three-semester Algebra I sequence during the 1999–2000 and 2000–01 school years. Students were randomly assigned to the sequence in which the math teacher was willing to implement the *Carnegie Learning Curricula and Cognitive Tutor® Software* program (229 students) or the sequence with the traditional curriculum (216 students).

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.[6]

The WWC considers the extent of evidence for *Carnegie Learning Curricula and Cognitive Tutor® Software* to be medium to large for high school students.

Effectiveness

Findings

The WWC review of interventions for High School Math addresses student outcomes in one domain: mathematics achievement. The findings below present the authors' estimates and WWC-calculated estimates of the size and the statistical significance of the effects of *Carnegie Learning Curricula and Cognitive Tutor® Software* on high school students.[7]

Mathematics achievement. Cabalo, Jaciw, and Vu (2007) reported a negative but not statistically significant effect of *Carnegie Learning Curricula and Cognitive Tutor® Software* on the Northwest Evaluation Association (NWEA) Algebra End-of-Course Achievement Level Test/Measures of Academic Progress. Campuzano et al. (2009) reported a negative but not statistically significant effect of *Carnegie Learning Curricula and*

6. 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 *Carnegie Learning Curricula and Cognitive Tutor® Software* is in Appendix A6.
7. 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 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. For the *Carnegie Learning Curricula and Cognitive Tutor® Software* studies summarized here, no corrections for clustering or multiple comparisons were needed.

Effectiveness *(continued)*

Cognitive Tutor® Software on the Educational Testing Service (ETS) Algebra I End-of-Course Assessment. Shneyderman (2001) reported a positive but not statistically significant effect of *Carnegie Learning Curricula and Cognitive Tutor® Software* on the Florida Comprehensive Assessment Test (FCAT) Norm-Referenced Component. Smith (2001) reported a negative but not statistically significant effect of *Carnegie Learning Curricula and Cognitive Tutor® Software* on the Virginia Standards of Learning (SOL) Algebra Assessment. None of the findings were large enough to be considered substantively important according to WWC criteria (i.e., an effect size of at least 0.25).

In sum, four studies showed indeterminate effects in the mathematics 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 *Carnegie Learning Curricula and Cognitive Tutor® Software* to have no discernible effects on mathematics achievement for high school students

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 mathematics achievement is –4 percentile points across the four studies, with a range of –7 to +2 percentile points across findings.

Summary

The WWC reviewed 24 studies on *Carnegie Learning Curricula and Cognitive Tutor® Software* for high school students. Two of these studies meet WWC evidence standards; two studies meet WWC evidence standards with reservations; the remaining 20 studies do not meet either WWC evidence standards or eligibility screens. Based on the four studies, the WWC found no discernible effects on mathematics achievement for high school students. The conclusions presented in this report may change as new research emerges.

References

Meets WWC evidence standards

Cabalo, J. V., Jaciw, A., & 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.

Campuzano, L., Dynarski, M., Agodini, R., & Rall, K. (2009). *Effectiveness of reading and mathematics software products: Findings from two student cohorts*. Washington, DC: U.S. Department of Education, Institute of Education Sciences.

Additional source:

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.

References *(continued)*

Meets WWC evidence standards with reservations

Shneyderman, A. (2001). *Evaluation of the* Cognitive Tutor *Algebra I program*. Unpublished manuscript. Miami, FL: Miami-Dade County Public Schools, Office of Evaluation and Research.

Smith, J. E. (2001). *The effect of the* Carnegie Algebra Tutor *on student achievement and attitude in introductory high school algebra*. Unpublished doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg.

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

Aleven, V., & Koedinger, K. R. (2002). An effective metacognitive strategy: Learning by doing and explaining with a computer-based cognitive tutor. *Cognitive Science, 26*(2), 147. The study is ineligible for review because it does not use a comparison group design or a single-case design.

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 examine an intervention implemented in a way that falls within the scope of the review.

Arbuckle, W. J. (2005). *Conceptual understanding in a computer-assisted Algebra 1 classroom*. Norman, OK: 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.

Baker, R., Corbett, A., Roll, I., & Koedinger, K. (2008). Developing a generalizable detector of when students game the system. *User Modeling and User-Adapted Interaction, 18*(3), 287–314. The study is ineligible for review because it does not examine the effectiveness of an intervention.

Blessing, S. B., Gilbert, S. G., Oureda, S., & Ritter, S. (2009). Authoring model-tracing cognitive tutors. *International Journal of Artificial Intelligence in Education, 19*, 189–210. The study is ineligible for review because it does not examine the effectiveness of an intervention.

Corbett, A. T. (2001). Cognitive Tutor *results report: 7th grade.* Pittsburgh, PA: Carnegie Learning. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

Corbett, A. T. (2002). Cognitive Tutor *results report: 8th & 9th grade*. Pittsburgh, PA: Carnegie Learning. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

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, such as a meta-analysis or research literature review.

Koedinger, K. R., Alibali, M. W., & Nathan, M. J. (2008). Trade-offs between grounded and abstract representations: Evidence from algebra problem solving. *Cognitive Science, 32*(2), 366–397. The study is ineligible for review because it does not examine an intervention implemented in a way that falls within the scope of the review.

Mac Iver, M. A., & Mac Iver, D. J. (2009). Urban middle-grade student mathematics achievement growth under comprehensive school reform. *Journal of Educational Research, 102*(3), 223–236. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

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. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

Additional source:

Plano, G. S. (2004). The effects of the *Cognitive Tutor* Algebra on student attitudes and achievement in a 9th-grade algebra course. (Doctoral dissertation, Seton Hall University,

References *(continued)*

2004). *Dissertation Abstracts International 65*(04A), 47–291. (AAI3130130).

Ritter, S. (2005). Authoring model-tracing tutors. *Technology, Instruction, Cognition and Learning, 2*(3), 231–247. The study is ineligible for review because it does not examine the effectiveness of an intervention.

Ritter, S., Anderson, J. R., Koedinger, K. R., & Corbett, A. (2007). *Cognitive Tutor*: Applied research in mathematics education. *Psychonomic Bulletin and Review, 14*(2), 249–255. The study is ineligible for review because it is not a primary analysis of the effectiveness of an intervention, such as a meta-analysis or research literature review.

Ritter, S., Haverty, L., Koedinger, K., Hadley, W., & Corbett, A. (2008). Integrating intelligent software tutors with the math classroom. In G. Blume & K. Heid (Eds.), *Research on technology and the teaching and learning of mathematics: Vol. 2. Cases and perspectives*. Charlotte, NC: Information Age Publishing. The study is ineligible for review because it is not a primary analysis of the effectiveness of an intervention, such as a meta-analysis or research literature review.

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. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

Additional source:

Morgan, P., & Ritter, S. (2002). *An experimental study of the effect of* Cognitive Tutor *Algebra I on student knowledge and attitude*. Retrieved from http://www.carnegielearning.com/web_docs/morgan_ritter_2002.pdf.

Salden, R., Aleven, V., Renkl, A., & Schwonke, R. (2009). Worked examples and tutored problem solving: Redundant or synergistic forms of support. *Topics in Cognitive Science, 1*, 203–213. The study is ineligible for review because it does not examine the effectiveness of an intervention.

Sarkis, H. (2004). Cognitive Tutor *Algebra I program evaluation: Miami-Dade County Public Schools*. Lighthouse Point, FL: The Reliability Group. The study does not meet WWC evidence standards because it uses a quasi-experimental design in which the analytic intervention and comparison groups are not shown to be equivalent.

Stylianou, D. A., & Shapiro, L. (2002). Revitalizing algebra: The effect of the use of a cognitive tutor in a remedial course. *Journal of Educational Media, 27*(3), 147. The study is ineligible for review because it does not use a sample aligned with the protocol—the sample is not within the specified age or grade range.

Vinogradova, E., King, C., & Rhoades, T. (2008). *Success for all students: What works? Best practices in Maryland public schools.* Paper presented at the American Sociological Association Annual Meeting, Boston, MA. Retrieved from http://www.allacademic.com/meta/p_mla_apa_research_citation/2/4/1/0/5/p241050_index.html. The study is ineligible for review because it does not examine an intervention implemented in a way that falls within the scope of the review.

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 does not meet WWC evidence standards because it uses a quasi-experimental design in which the analytic intervention and comparison groups are not shown to be equivalent.

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.