Research Results

Pittsburgh Public Schools, Pittsburgh, PA, 1994

Abstract

Students at three Pittsburgh Public High Schools were given post-tests to assess their performance on both standardized tests (Math SAT and Iowa) and complex mathematical problem solving (a multiple-representations test and a real-world problem solving test developed at Carnegie Mellon University). Experimental classes used Cognitive Tutor Algebra I, while comparison classes used a traditional curriculum. Two types of comparison classes were used, one a group of comparable students and the other a "scholars" group, selected based on prior academic performance. Results showed that the Cognitive Tutor Algebra I group significantly outperformed the comparable comparison group on all measures except for the Math SAT subset. On the multiple-representations exam, the Cognitive Tutor group outperformed the scholars comparison group.

Participants

Participants were students in 3 Pittsburgh Public High Schools (Langley, Brashear and Carrick). The three schools have similar demographics: about 50% African-American, 50% from single-parent families, 15% go on to college.

There were three classifications of students:

- CTAI – students who had used Cognitive Tutor Algebra I as their Algebra curriculum
- Matched Control – students who used a traditional Algebra curriculum
- Scholars Comparison – students who used a traditional curriculum and have previously been identified as "scholars" based on previous performance in mathematics.

With the exception of students who took algebra in 8th grade (prior to high school), all students at Langley High School used Cognitive Tutor Algebra I as their algebra curriculum. Langley had adopted an "Algebra for everyone" policy, meaning that all students were required to take Algebra. As a result, 12 classes at Langley were included in the CTAI group.

Study Design:
Matched control group

Measures:
Standardized exam; Math SAT, Iowa Algebra Aptitude Test
Other exam: Problem Situations Test, Multiple Representations Test

Study location:
Pittsburgh Public Schools, High Schools, Pittsburgh, PA (urban)

Study conducted by:
Carnegie Mellon University

Data analyzed by:
Carnegie Mellon University

Course assessed:
Cognitive Tutor Algebra I

Data collection date:
1993 – 1994

District Information:
Type: Public, urban
Students Enrolled: 46,700
% of Students Qualifying for Reduced Lunch: 22%

Ethnic Breakdown:
African American: 56%
Asian: 1%
Caucasian:42%

At Carrick and Brashear, some teachers used Cognitive Tutor Algebra I and some did not, resulting in eight standard-track classes using CTAI and five standard-track control classes using a traditional curriculum. In addition, two "scholars" classes (taught by one teacher) were used for the "scholars" comparison group.

In all, there were 470 CTAI students, 120 matched control students and 35 scholars comparison students in the classes studied.

Because Langley High School adopted Cognitive Tutor Algebra I for all of its students, including those who, in the other schools, would not be taking Algebra at all, the CTAI students were, overall, less well prepared for Algebra than students in the other groups. Grade point averages for the prior year's mathematics performance were 2.1 for CTAI students, 2.4 for matched control students and 2.6 for scholars comparison students.

Method

Students were administered exams during two (approx. 44-minute) class periods near the end of the school year. Four exams were used:

- A subset of the Math SAT (comprising questions pre-selected to emphasize Algebra)
- The Iowa Algebra Aptitude Test
- A Problem Situations test (see Appendix A)
- A Multiple Representations test (see Appendix B)

Results

Due to student absences on the test days, fewer students completed the tests than took the classes. As shown in Table 1, there were significant differences between the three groups on all measures. Planned comparisons show the Cognitive Tutor group to have performed significantly better than the matched control on all but the Math SAT subset (all $p<.05$). Although the effect size for the Math SAT is comparable to that for the Iowa test, the smaller number of students contributing to that measure accounts for the failure to reach statistical significance.

Results

	Cognitive Tutor Algebra I	Matched control	Scholars comparison	F value and significance	Effect size (CTAI vs. matched control)
Iowa Algebra Aptitude	**.52** (.19) N=287	**.46** (.17) N=80	**.68** (.17) N=34	F(2,398)=17.0, p<.0001	0.3
Math SAT subset	**.32** (.16) N=149	**.27** (.14) N=44	**.42** (.15) N=15	F(2,205)=5.1, p<.01	0.3
Problem Situation Test	**.39** (.33) N=127	**.22** (.22) N=42	**.38** (.26) N=20	F(2,186)=5.3, p<.01	0.7
Representations Test	**.37** (.32) N=124	**.15** (.18) N=44	**.12** (.16) N=18	F(2,183)=13.4, p<.0001	1.2

Table 1: Results of study, including mean proportion correct, standard deviation and number of students in each cell. Effect size is calculated as the difference in means, divided by the control group's standard deviation.

Discussion

The results favor the Cognitive Tutor students over the Matched Control group on all measures and significantly so on three of the four measures. On the Representations test, the Cognitive Tutor group even outscored the scholars comparison group.

As would be expected, the differences are larger on the Problem Situation and Representations tests, since those tests are better aligned with the Cognitive Tutor curriculum. The fact that the differences were still substantial on the standardized tests support the applicability of Cognitive Tutor course's instruction to more basic skills covered on these tests.

Although the differences between the Cognitive Tutor classes and the Matched Control classes are substantial, the absolute proportions correct for both groups leave much to be improved. In part, the low levels of absolute performance reflect the fact that students knew that these were low-stakes tests (administered as part of a research study).

Reference:

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, 30-43.

For more information or for additional copies of this report, please go to http://www.carnegielearning.com/results/reports or send email to researchpartner@carnegielearning.com

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Appendix A: Problem Situation Test

This is an example of the Problem Situation Test. Several different variants were administered to students, in order to minimize cheating, to sample a wider variety of problems, and to assess what features of problems are most difficult for students.

015

Currently I have $1125 in my savings account and I am spending at a rate of $17 per week.

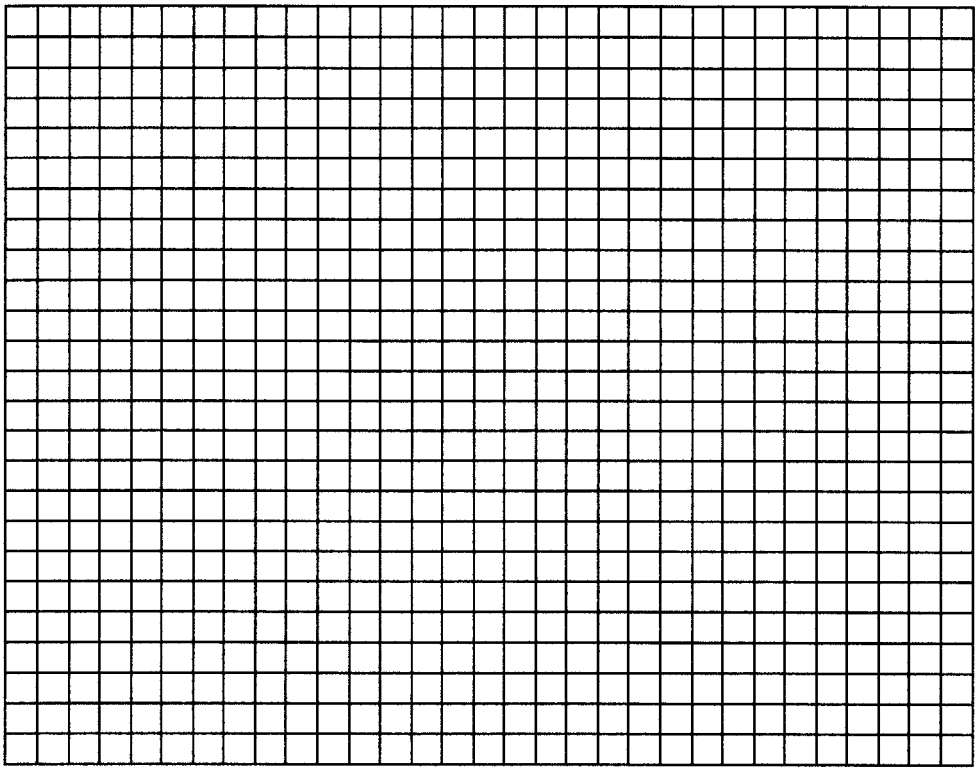
Answer the following questions by filling in the TABLE below.
1. How much money do I have after 6 weeks?
2. How much money do I have after 364 days?
3. How many weeks before I have a total of $3?

TABLE:

	Time (weeks)	Savings
1		
2		
3		

4. Define two variables for time and savings and write an equation that expresses the relationship between them:

5. Create a graph of the relationship between time and savings and plot the 3 points in the Table above. Be sure to label which axis is time and which is savings. Also put numbers on the axes to indicate the scale.



Problem Situation test, page 1

There are 2 Mediterranean Fruit Flies and each minute 3 more are born.

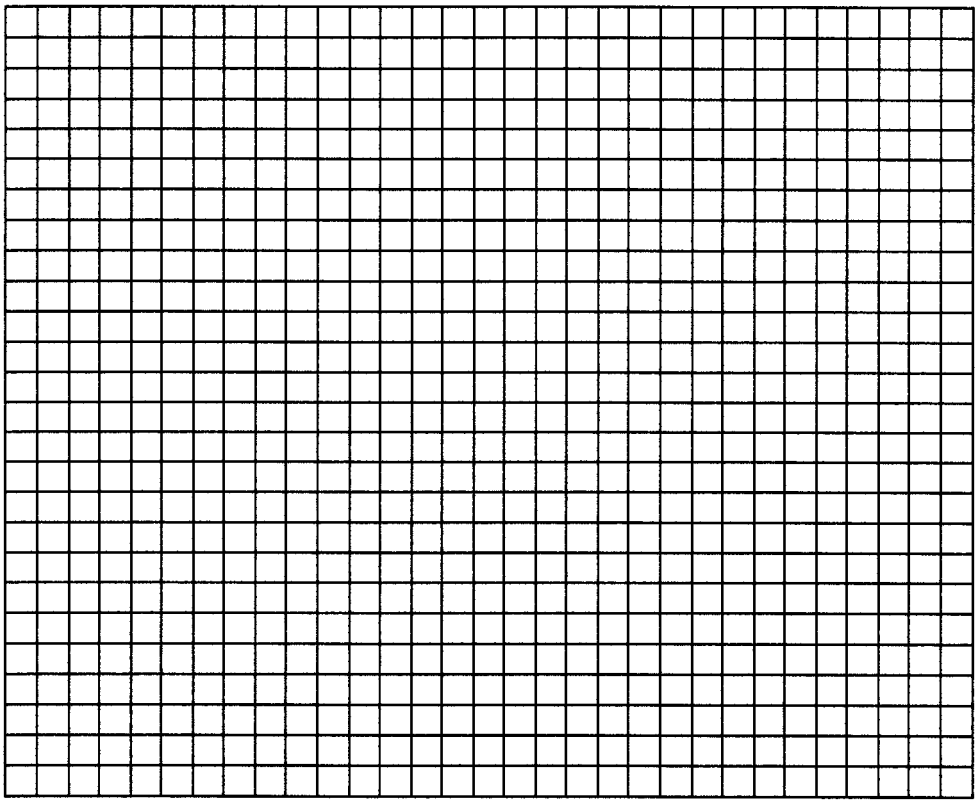
Answer the following questions by filling in the TABLE below.
1. How many Fruit Flies are there after 2 minutes?
2. How many Fruit Flies are there after 1/10 of an hour?
3. How long before there are 17 Fruit Flies?

TABLE:

	Time (minutes)	Fruit Flies
1		
2		
3		

4. Define two variables for time and fruit flies and write an equation that expresses the relationship between them:

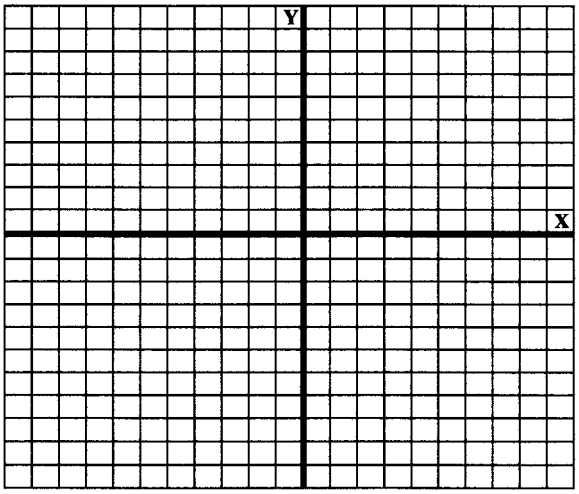
5. Create a graph of the relationship between time and fruit flies and plot the 3 points in the Table above. Be sure to label which axis is time and which is fruit flies. Also put numbers on the axes to indicate the scale.



Appendix B: Multiple Representations Test

ST-1

1) Sketch the graph of Y = 3X - 5.



2) What is the y-intercept of this graph?

3) What is the slope of this graph?

4) How would the graph of this equation change if the slope was -2?

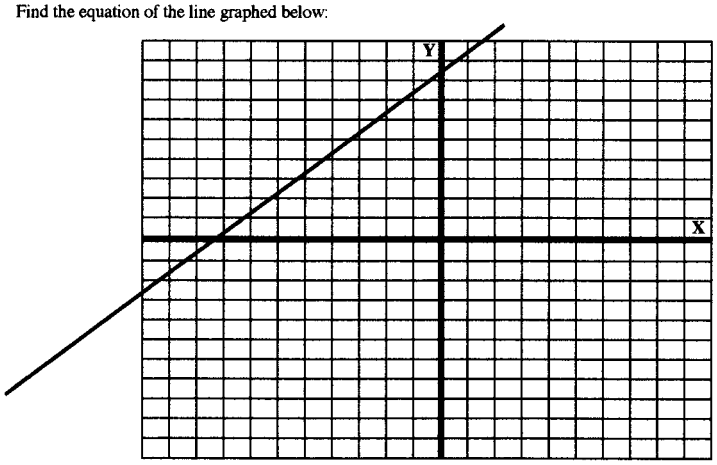
5) How would the graph of this equation change if the y-intercept was 2?

6) Write a situation that could be modeled by the following equation:

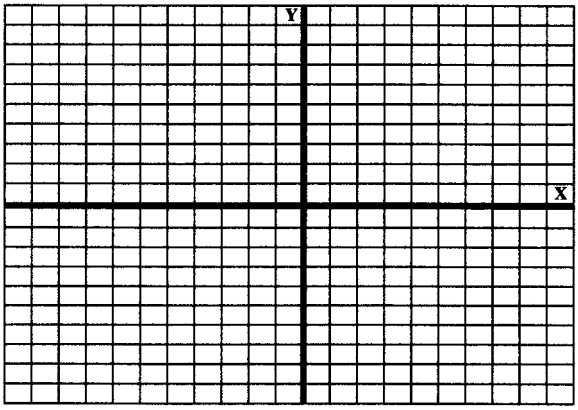
$$Y = 3x + 2$$

Multiple Representations Test, page 1

7) Find the equation of the line graphed below:



8) Draw the graph of the line parallel to the graph of the line, $Y = 2X + 5$ that passes through the origin.



Multiple Representations Test, page 2