

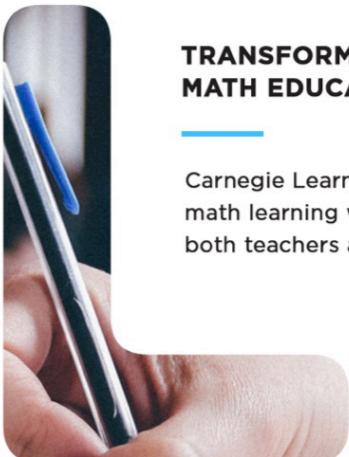
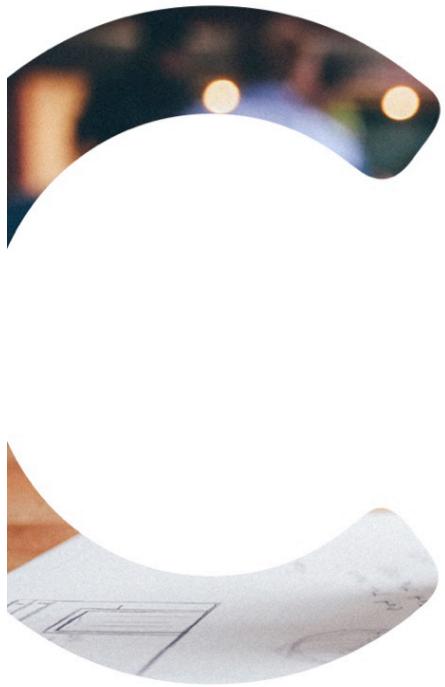
CARNEGIE
LEARNING



Blended learning with intelligent tutoring systems

LONG + LIVE + MATH

Steve Ritter
Founder and Chief Scientist
Carnegie Learning



TRANSFORMING MATH EDUCATION

Carnegie Learning puts better math learning within reach for both teachers and students.



Carnegie Learning Quick Facts

We provide innovative, **research-proven** Grade 6 through Algebra II mathematics

Product suite is completely aligned with CCSS and are consistent with the Standards for Mathematical Practice

Over half a million students in 2,000 school districts across the country





25 years of research

- \$6 million study funded by US DOE shows Carnegie Learning nearly doubles student math gains
- Co-founder John Anderson recognized by National Academy of Sciences
- Continually study how real students and practitioners engage with mathematics
- 25 years of data and millions of students



MATHia Implementation

The image shows the Carnegie Learning Middle School Math Solution Course 1 Student Text book and a computer screen displaying the MATHia X software. The software interface includes a navigation bar with 'Home', 'System Help', 'Glossary', and 'SDK Student'. Below the bar, there's a progress indicator and a 'I'm Done' button. The main area displays a math problem involving a graph of a line with points at (0, 500) and (20, 1100). A horizontal dashed line is drawn at y = 1825, and a vertical dashed line is drawn at x = 73. The intersection point is highlighted in blue. The problem asks: "Drag the point to the coordinate that represents the equivalent ratio." At the bottom of the software window, there's a footer with the text "Problem: equivalent_ratio_ratio_writing_graph007 Client Version: local Server Version: unspecified © 2014 Carnegie Learning Carnegie Learning >".

Blended implementation

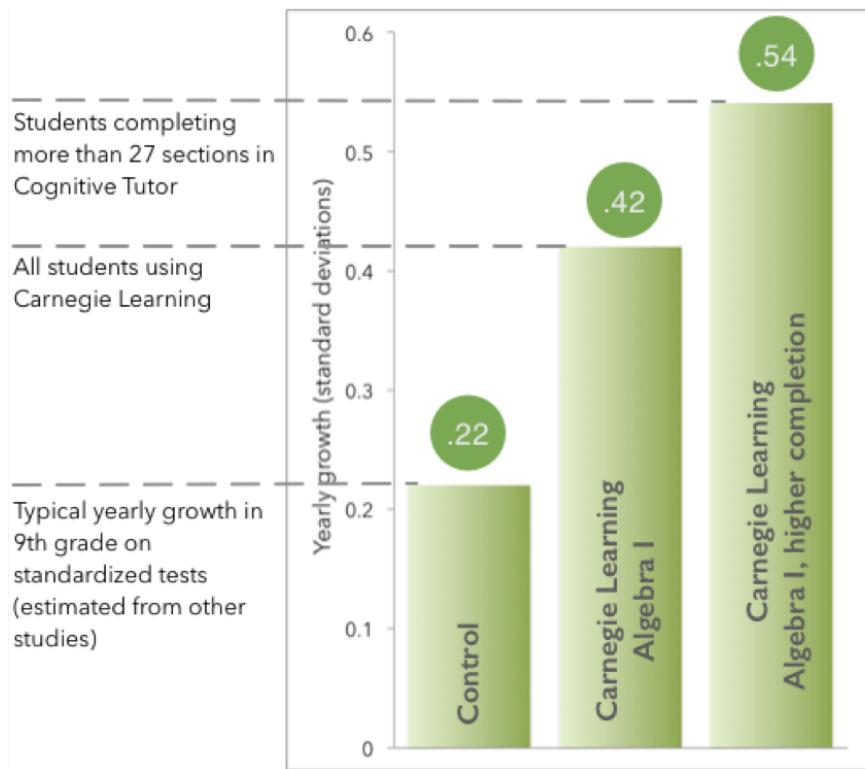
Software used 2 days/week

Text, collaborative activities 3 days/week

Parallel tracks

Teacher-paced classroom
Student-paced software





Effectiveness at scale

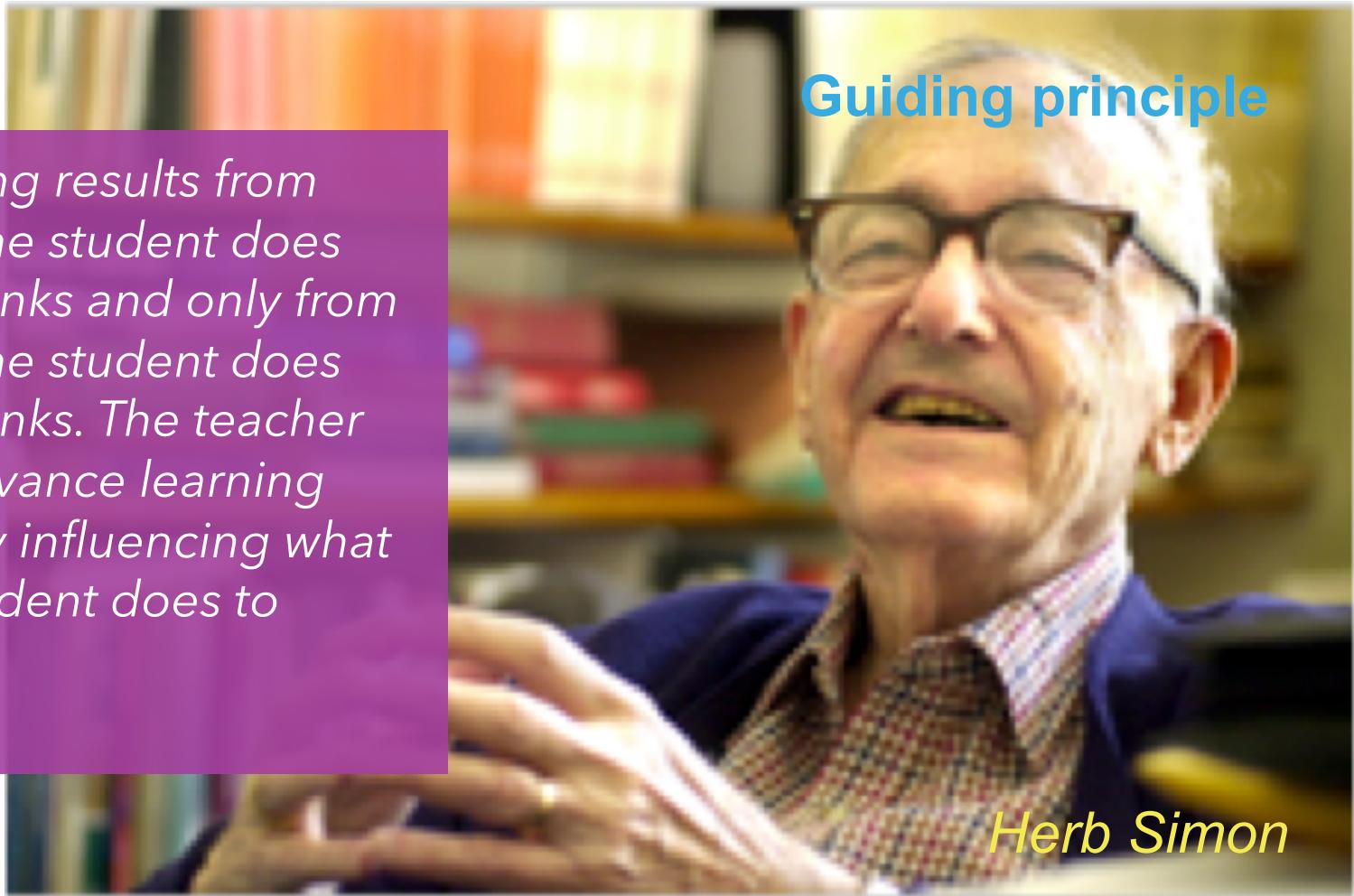
- Gold Standard study
- Funded by US Dept. of Education
 - Competitive application
- Conducted by RAND Corporation
- Algebra 1, blended implementation
- Randomized by school
 - Schools paired prior to randomization
 - Within site: school size, race, FRL, ELL, etc.
- McGraw-Hill Acuity prealgebra pretest, algebra posttest
- Middle and High Schools
- All schools in study for 2 years (2 cohorts)
- **No significant difference in first year; significant improvement in second year**

Cognitive Tutors

Modeling at the knowledge component level

Learning results from what the student does and thinks and only from what the student does and thinks. The teacher can advance learning only by influencing what the student does to learn.

Guiding principle



Herb Simon

MATHia™ worksheet_graphe_a1_linear_systems_int

cdn.carnegielearning.com

System Help Glossary Curriculum Browser

Tour Lesson Step-by-Step Solver Hints Solve It Progress I'm Done

Ms. Williamson woke up one morning to find her basement flooded with water. She called two different plumbers to get their rates. The first plumber charges \$36 just to walk in the door plus \$28 an hour. The second plumber charges a flat \$64 an hour.

Define units for the length of the job, the first plumber's cost, and the second plumber's cost. Then enter a variable for the length of the job and use this variable to write expressions for the first plumber's cost and the second plumber's cost.

1. What is the cost if the job takes four hours?
2. How many hours did the first plumber take to do the job if he charged \$176?
3. How many hours did the second plumber take to do the job if she charged four hundred forty-eight dollars?
4. After how many hours will the cost for both plumbers be the same?

After completing the worksheet, graph your model.

Quantity Name Job Length 1st Plumber's Cost 2nd Plumber's Cost

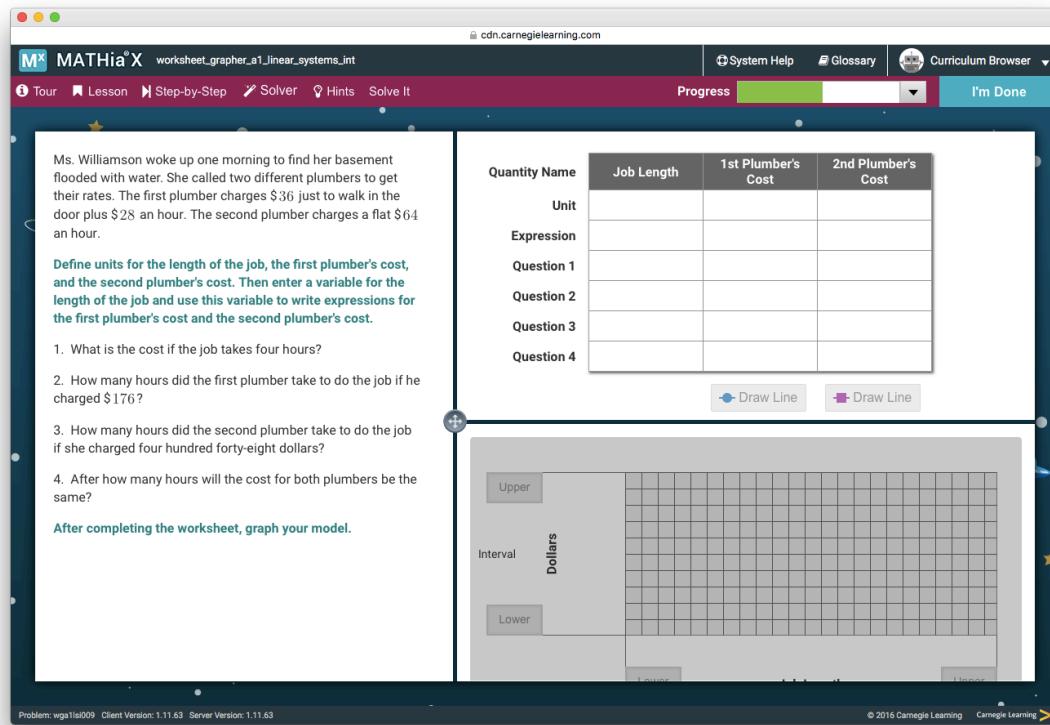
Quantity Name	Job Length	1st Plumber's Cost	2nd Plumber's Cost
Unit			
Expression			
Question 1			
Question 2			
Question 3			
Question 4			

Draw Line Draw Line

Upper Dollars Lower

Interval Hours

Problem: wga11s09 Client Version: 1.11.63 Server Version: 1.11.63 © 2016 Carnegie Learning Carnegie Learning >



Cognitive Tutor principle

The more we understand about how students think and learn, the better we can help them think and learn

Intelligent Tutoring Systems

Cognitive Model

MATHia Adaptation

- Model Tracing:
 - Tracks and provides feedback on individual student strategies
 - Provides Immediate feedback at each step through a solution
 - Diagnoses misconceptions leading to error and presents feedback to correct the misconception
- Knowledge Tracing:
 - Tracks students growth in knowledge at a low level
 - Picks problems for each student, based on individual student needs
 - Zone of proximal development
- Continuous formative assessment:
 - Each step is assessed and contributes to our knowledge about the student
 - Teacher reports emphasize areas that they can work on with students
 - Assessment is part of instruction
 - Mastery learning drives pacing and problem selection

Model Tracing

Students solve problems in different ways

To know what the student is thinking, you need to understand the process,
not just the answer

Show your work

Student strategy 1

Kevin Gluck

Daily income has risen 4 dollars per year in the time since 1980. That year, the average daily income in the United States was 55 dollars.

Given that average, what was the daily income in 1985?

What was the daily income in 1997?

	time	income
Unit	years	dollars
Formula	x	$55+4x$
1	5	<input type="text"/>
2	$\frac{1}{4}$	\cdot <input type="text"/>

Help

Done

For the formula, define a variable for the time since 1980, and use this variable to write a rule for the average daily income.

Student strategy 2

You have been saving money and now have 20 dollars for video games. During your time at the arcade, you spend 4 dollars per hour.

How much money will you have after 2 hours?

How many hours can you play before you run out of money?

Unit	time		money
	hours	dollars	
Formula	x	20-4x	
1	2	<input type="text"/>	
2	<input type="text"/>	<input type="text"/>	

MATHia[®]X worksheet_grapher_a1_patterns_2step_eqn cdn.carnegielearning.com

System Help Glossary Curriculum Browser

Tour Lesson Step-by-Step Solver Hints Solve It Progress I'm Done

A local shop donated cell phone covers to the National Junior Honor Society to sell as a fundraiser. They sold each cover for \$3. At the end of the selling period, you also donated \$3 in cash.

Define a unit for the amount raised. Then enter a variable for the number of cell phone covers sold and use this variable to write an expression for the amount raised.

1. How much money did they raise if they sold 31 cell phone covers?

2. How much money did they raise if they sold 23 cell phone covers?

3. How many cell phone covers did they sell if they raised \$114?

Quantity Name	Cell Phone Covers Sold	Amount Raised
Unit	covers	dollars
Question 1	31	96
Question 2	23	72
Question 3	37	114
Expression	x	$3x + 3$

Skills Progress to Mastery

- Calculate input value.
- Writing expression, any form.
- Set axis interval.
- Set axis bounds.
- Label point of intersection.
- Enter given.
- Identify unit.

Problem: wga1p2se012 Client Version: 1.11.63 Server Version: 1.11.63

Knowledge tracing

What is learned? Knowledge components!

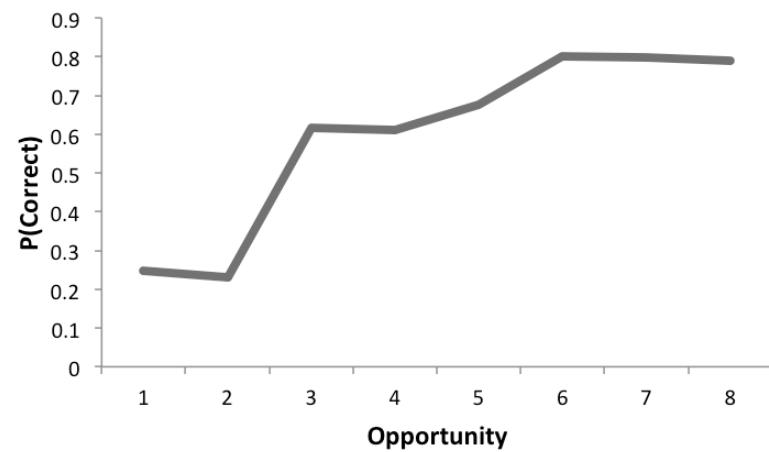
Learning curve

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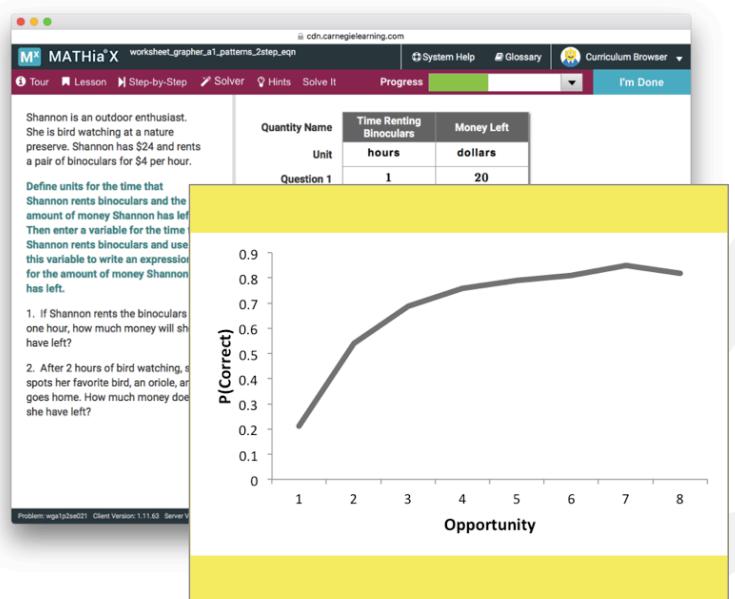
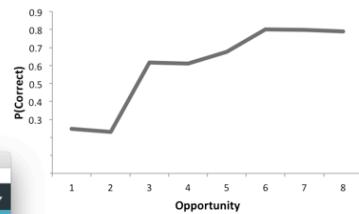
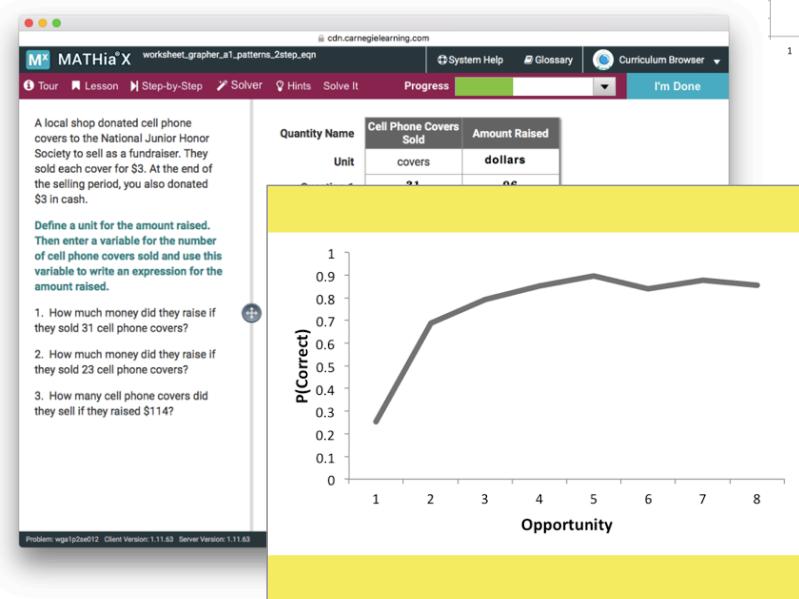
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Splitting knowledge components



Using data to understand teaching with technology

- Online developmental math
 - University of Phoenix
 - Two course sequence
- MATHia required
 - Adaptive, mastery-based instruction
 - Contextual hints and immediate feedback
- Unlimited access to tutor.com (TDC)
- 16,000+ students
- Complete logs of:
 - Student interactions with software
 - Chat dialogs through tutor.com

The image shows a screenshot of the Carnegie Learning MATHia software. On the left, there is a text-based worksheet titled "worksheet_grapher_a1.linear.systems.int". It describes a scenario where Ms. Williamson woke up one morning to find her basement flooded with water. She called two different plumbers to get their rates. The first plumber charges \$36 just to walk in the door plus \$28 an hour. The second plumber charges a flat \$64 an hour. The task is to define units for the length of the job, the first plumber's cost, and the second plumber's cost. Then enter a variable for the length of the job and use this variable to write expressions for the first plumber's cost and the second plumber's cost.

Below the text, there is a list of four questions:

1. What is the cost if the job takes four hours?
2. How many hours did the first plumber take to do the job if he charged \$176?
3. How many hours did the second plumber take to do the job if she charged four hundred forty-eight dollars?
4. After how many hours will the cost for both plumbers be the same?

After completing the worksheet, graph your model.

On the right side of the software interface, there is a table titled "Quantity Name" with columns for "Job Length", "1st Plumber's Cost", and "2nd Plumber's Cost". Below the table, there are four rows labeled "Question 1" through "Question 4". At the bottom of the software window, there is a grid for graphing with axes labeled "Upper", "Interval", "Dollars", "Lower", and "Euros".

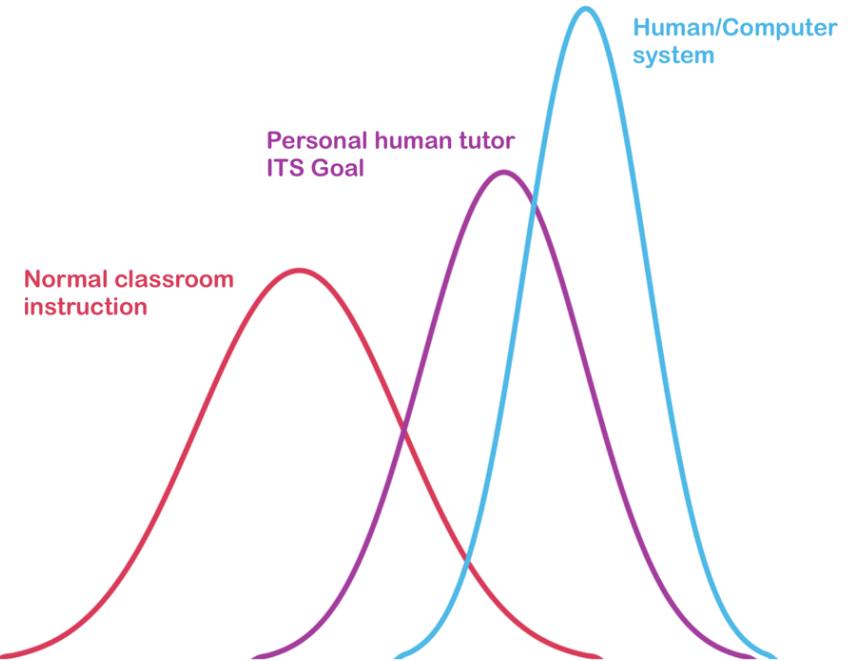
At the bottom of the slide, there is a banner for tutor.com with the text "Better Grades Guaranteed." and "Our online tutors are ready to help you 24/7". It also features a search bar and links for "For Libraries", "For U.S. Military", "For Higher Education", and "For Corporate Partners".

Systems approach

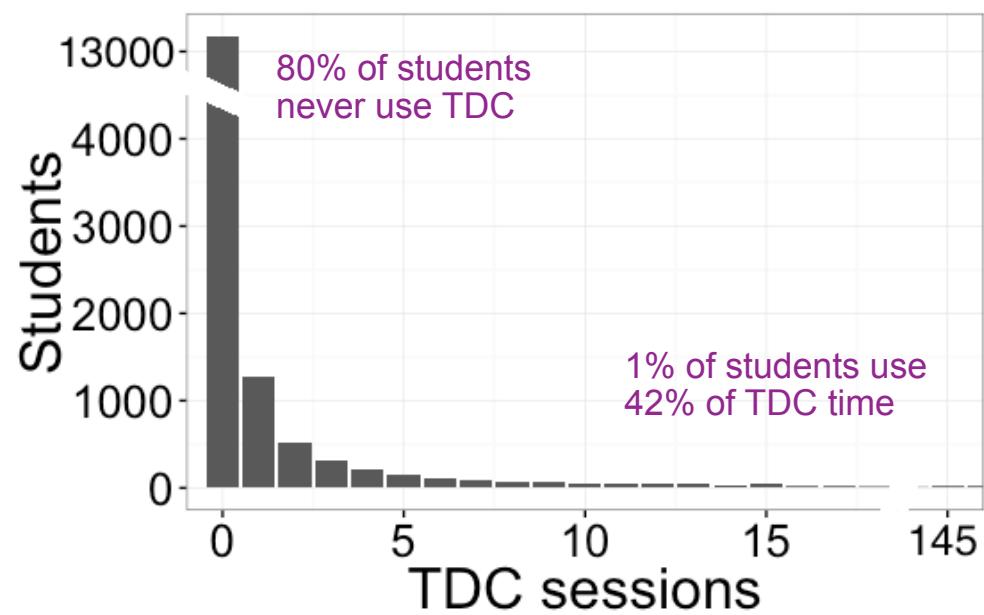
What if humans and ITS work as partners?

Human tutors are 0.79 sigma more effective than no tutoring and not the 2.0 sigma found in the Bloom (1984) studies. The second surprise is that step-based tutoring is almost as good as human tutoring, with a 0.76 mean effect size.

vanLehn (2011)

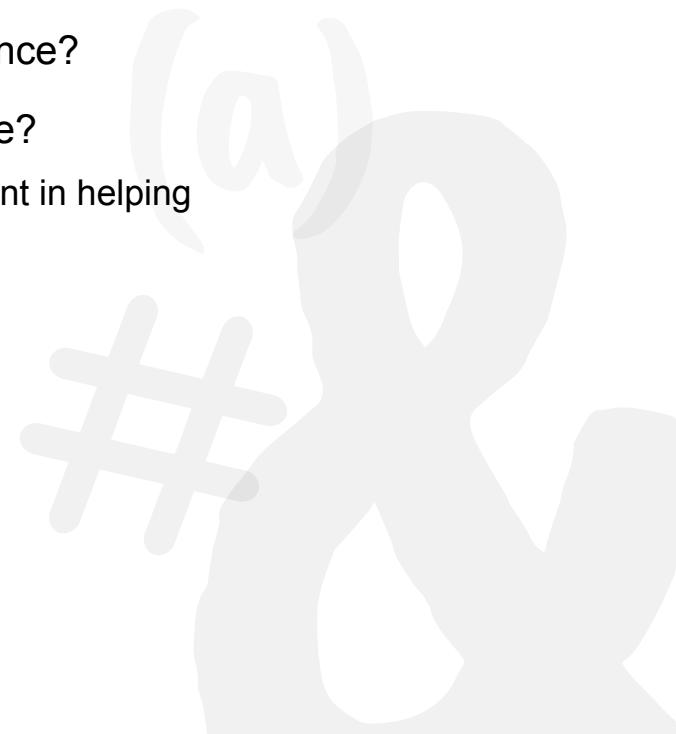


Human resources are both under-used and over-used



Intelligent handoffs between teachers and ITS

1. Why do students access human assistance?
2. What human assistance is most effective?
 - How can we help teachers to be more efficient in helping students.

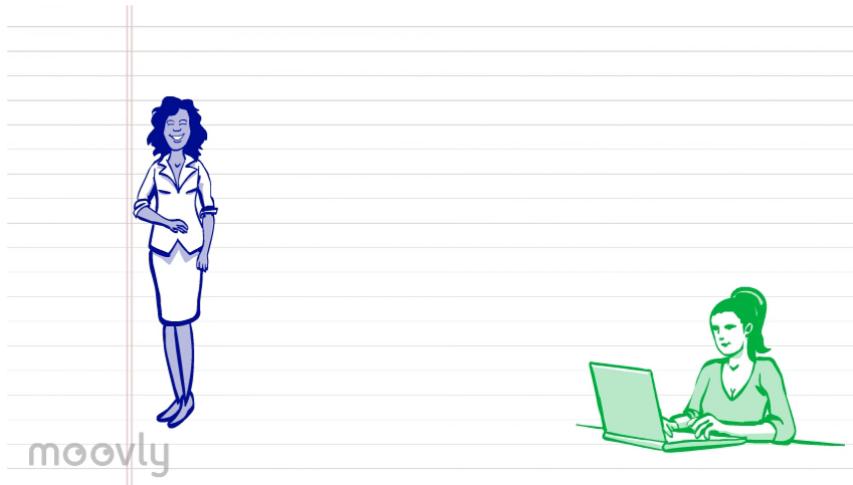


Q1: Why do students request human assistance?

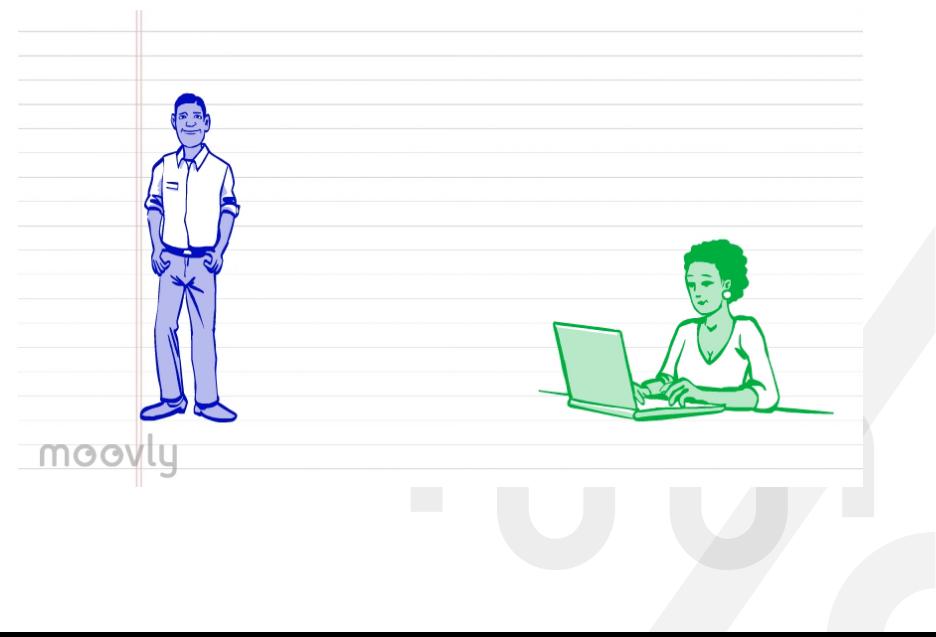
A: Not just because they're stuck

Information v. Affirmation

- [Information video](#)



- [Affirmation video](#)



Information v. Affirmation

- **Tutor** Hi. How can I help you today?
- **Student:** hello I am stuck on a problem I will load it so you can see
- **Student:** I just need to know how to type the expression in the answer box
- **Tutor:** Okay, you need plug 4.2 in $1/2h(6+4)$
- 4.2 is height right?
- **Student** yes i'm going to try it
- **Student** 4.2 goes where
- **Tutor** in h. since 4.2 is height
- **Student:** would it been in ()
- **Tutor** it will be 21
- $1/2(4.2)(6+4) = 21$
- **Student:** ok got cha
- **Tutor:** so, that is it.

- **Tutor:** hi! what can I help you with today?
- **Student:** Do you know how to do a factor table?
- **Tutor:** Hmm I am familiar with it. Is there a problem that you wanted to go over, that you could write on the board for us?
- **Student** This looks like an easy one, but I am not sure so I just want to make sure I understand this correctly
- **Student:** To check this table is all you do multiply the top row by the 7x and see if it matches the bottom row? Is this right?
- **Tutor:** Yeah everything looks good to me. Great job!
- **Student:** I was hoping that I did this right.

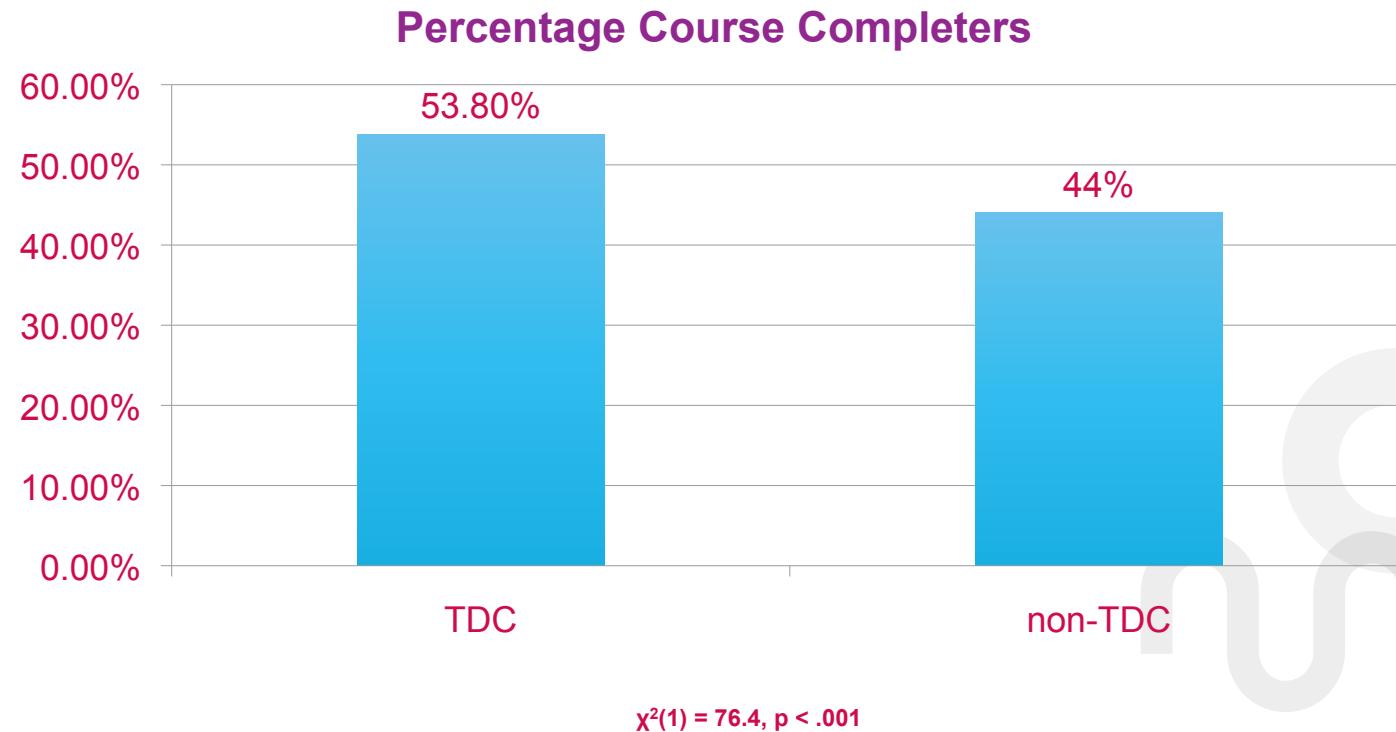
Factors provided by MATHia

- Cognitive:
 - Hints
 - Errors
 - Timing
 - Skill mastery
- Non-cognitive
 - Boredom
 - Frustration
 - Confusion
 - Engaged concentration
 - Carelessness
 - High-level motivation
 - Gaming the system
 - Off-task



**Q2: What kind of assistance
helps students?**

TDC users are more likely to complete the course



Conclusion: Building recommendation systems

- Intelligent Tutoring Systems are very effective, but they will not replace teachers
- Teachers have both cognitive and affective influence
- Better understanding of what leads students to ask for assistance and about what ITSs can tell teachers will improve the teacher/ITS instructional system