

Cognitive Tutors

NAPLeS Webinar, Feb 2014

Vincent Aleven

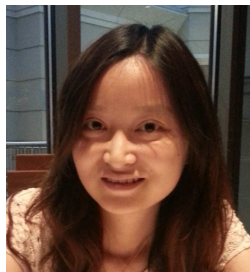
Associate Professor

Human-Computer Interaction Institute

Pittsburgh Science of Learning Center (LearnLab)

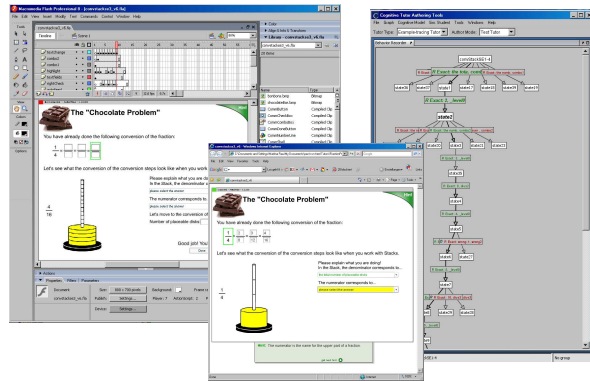
Carnegie Mellon University

**Based on work by many, many people, including
Kenneth Koedinger (CMU) and Yanjin Long (CMU)**

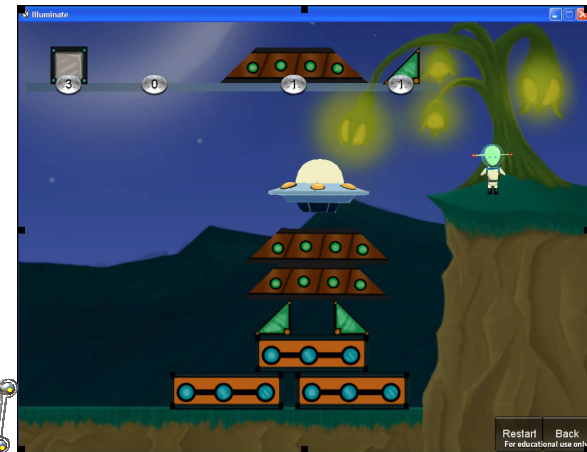


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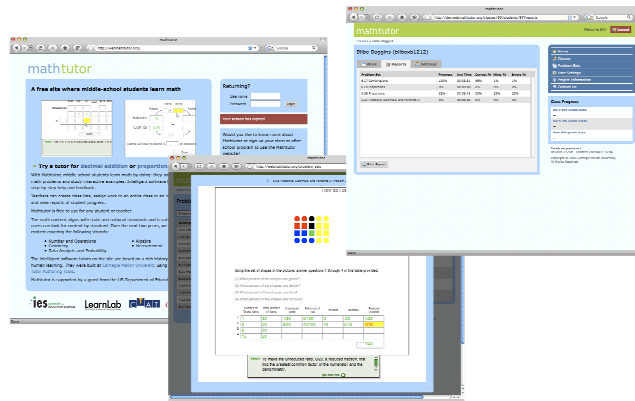
My Other Research in Adaptive Learning Technologies



CTAT: Authoring tools for rapid development of Intelligent Tutoring Systems with Ken Koedinger



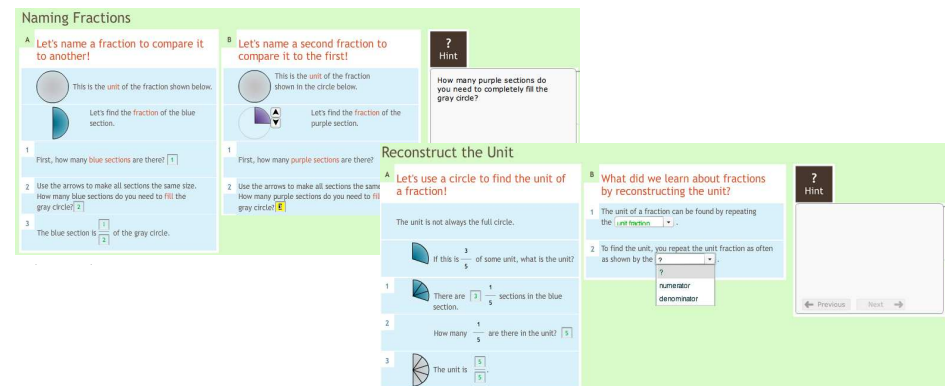
ENGAGE: game for grades 1-3 science learning
Collaboration between HCII, ETC, and Psych; with Steven Dow, Ken Koedinger, and Carolyn Rosé



Mathtutor: free web-based tutors for middle-school math

with Bruce McLaren

<http://mathtutor.web.cmu.edu>



Individual and collaborative learning with tutors for 4th and 5th grade fractions

With Nikol Rummel, Martina Rau, Jenny Olsen, and Dan Belenky

Overview

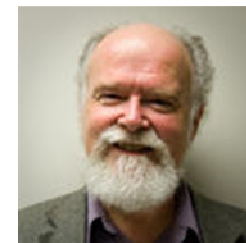
- Cognitive Tutors
- Supporting metacognition with Cognitive Tutors
 - Self-Assessment
 - Self-Explanation
- Non-Programmer Authoring Tools for creating tutor

Take-Home Messages

- Cognitive Tutors
 - Practical application of cognitive science that demonstrably improves student learning in schools and has been commercially successful
 - Combination of cognitive theory, cognitive task analysis, cognitive modeling, AI technology, and math education expertise
 - Provides individualized, detailed guidance during complex problem solving
- Cognitive Tutors can support self-assessment and self-explanation effectively
 - Good to include metacognition and self-regulated learning in the theoretical perspective
- Non-programmer tools reduce authoring time and cost
 - Used widely for research purposes

Overview

- Cognitive Tutors
- Supporting metacognition with Cognitive Tutors
 - Self-Assessment
 - Self-Explanation
- Non-Programmer Authoring Tools for creating tutor



John Anderson, Ken Koedinger, Albert Corbett, Steve Ritter, and others

What is an “Intelligent Tutoring System” (ITS)?

- A kind of educational software
 - Supports “learning by doing” with personalized, step-by-step guidance
- Uses cognitive modeling and artificial intelligence techniques to
 - Provide human tutor-like behavior
 - Be flexible, diagnostic & adaptive
 - Provide personalized instruction (e.g., select problems on an individual basis)

President Obama on Intelligent Tutoring Systems

"[W]e will devote more than three percent of our GDP to research and development. Just think what this will allow us to accomplish: solar cells as cheap as paint, and green buildings that produce all of the energy they consume; *learning software as effective as a personal tutor*; prosthetics so advanced that you could play the piano again; an expansion of the frontiers of human knowledge about ourselves and world the around us. We can do this."

<http://my.barackobama.com/page/community/post/amyhamblin/gGxW3n>

Algebra Cognitive Tutor

Analyze real world problem scenarios

Tracked by knowledge tracing

Cognitive Tutor Algebra I

Instructor Preview SysFB09

Table of Contents Lesson Problems

Solver Glossary Hint Done Skills

Scenario

My current cell phone company charges me \$14.95 per month for service and \$.13 per minute. PPS Cellular Phone Company has offered me \$15.00 worth of free calls a month if I switch, but the charge is \$.39 per minute.

- How many minutes of calls can I get from PPS Cellular Phone Company for \$50? What is the cost from my current company for that number of minutes?
- How many minutes of calls can I get from my current company for fifty dollars? What is the cost from PPS Cellular Phone Company for that number of minutes?
- What is the cost from both companies for sixty minutes of calls?

Use equations, symbolic calculator

$$0.13t + 14.95 - 0.13t = 0.39t - 15 - 0.13t$$

$$14.95 = 0.26t - 15$$

$$14.95 + 15 = 0.26t - 15 + 15$$

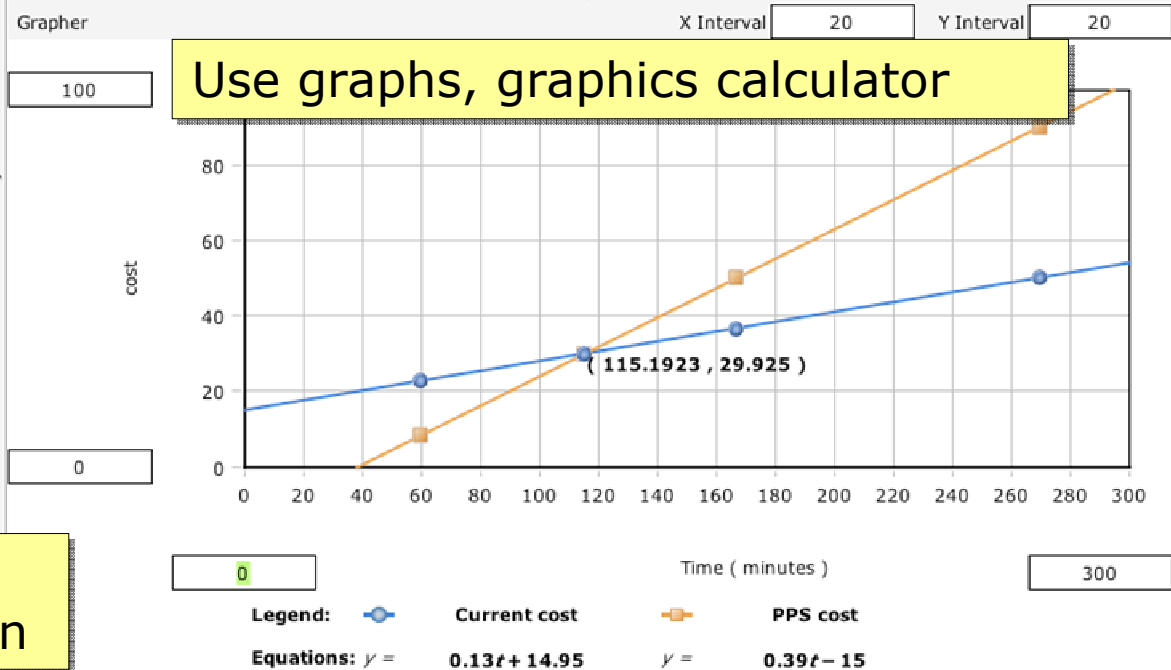
$$29.95 = 0.26t$$

Model tracing to provide context-sensitive Instruction

Worksheet

Quantity Name	Time	Current cost	PPS cost
Unit	minutes	\$	\$
Expression	t	$0.13t + 14.95$	$0.39t - 15.00$
Question 1	166.6667	36.6167	
Question 2	269.6154	50.00	
Question 3	60	22.75	
Question 4	115.1923	29.925	

Use table, spreadsheet



Use graphs, graphics calculator

Cognitive Tutor Geometry

Cognitive Tutor Geometry

Instructor Preview
Three-Parallel-Lines-9-050

Example
Hint
Done
Skills

5 - Lines Cut by a Transversal
3 - Calculating Angles Formed by Multiple Transversals

Table of Contents
Lesson
Problems

Diagram Tool

Given:

- $\overleftrightarrow{AZ} \parallel \overleftrightarrow{JM}$
- $\overleftrightarrow{JM} \parallel \overleftrightarrow{RW}$
- $m\angle GEW = 117^\circ$

Use the Diagram Tool to enter the measures and reasons to justify each step needed to calculate $m\angle XBZ$.

☐ The measure of $\angle XBZ$ can be calculated.

$m\angle XBZ =$ $^\circ$

☐ The measure of $\angle XBZ$ cannot be calculated because

Diagram Notes:

$m\angle GEW$ is given.
 $m\angle GEW = 117^\circ$.

$m\angle BGJ = 117^\circ$.
 $\angle BGJ$ and $\angle GEW$ are corresponding angles.

$m\angle XBZ = 117^\circ$.

The nested loop of conventional teaching

For each chapter in curriculum

- Read chapter
- For each exercise, solve it
- Teacher gives feedback on all solutions at once
- Take a test on chapter

VanLehn, K. (2006). The behavior of tutoring systems. *International Journal of Artificial Intelligence in Education*, 16(3), 227-265.

The nested loops of Computer-Assisted Instruction (CAI)

For each chapter in curriculum

- Read chapter
- For each exercise
 - Attempt answer
 - Get feedback & hints on answer; try again
 - If mastery is reached, exit loop
- Take a test on chapter

VanLehn, K. (2006). The behavior of tutoring systems. *International Journal of Artificial Intelligence in Education*, 16(3), 227-265.

The nested loops of ITS

For each chapter in curriculum

- Read chapter
- For each exercise
 - For each step in solution
 - Student attempts step
 - Get feedback & hints on step; try again
 - If mastery is reached, exit loop
- Take a test on chapter

VanLehn, K. (2006). The behavior of tutoring systems. *International Journal of Artificial Intelligence in Education*, 16(3), 227-265.

Inner loop

Step-by-step guidance

Cognitive Tutor Algebra

The screenshot shows the Cognitive Tutor Algebra interface. The main window displays the equation $-6 + 2y = 7$ and a series of steps to solve it. Each step is accompanied by a hint button. The steps are:

- Solve for y
- Subtract -6 from both sides: $-6 + 2y - (-6) = 7 - (-6)$
- Combine like terms in $7 - (-6)$: $-6 + 2y - (-6) = 7 - (-6)$
- Combine like terms in -6 : $-6 + 2y - (-6) = 13$
- Perform multiplication: $-6 + 2y - (-6) = 13$
- Simplify signs: $-6 + 2y - (-6) = 13$
- Combine like terms in -6 : $-6 + 2y + 6 = 13$
- Combine like terms in $-6 + 2y + 6$: $-6 + 2y + 6 = 13$
- Divide both sides by 2: $2y = 13$
- Simplify fractions in $2y$: $\frac{2y}{2} = \frac{13}{2}$
- Simplify fractions in $\frac{2y}{2}$: $\frac{2y}{2} = \frac{13}{2}$
- Simplify fractions in $\frac{2y}{2}$: $y = \frac{13}{2}$

The interface also includes a 'Solver' panel on the right with 'Transform' and 'Simplify' sections, and a 'Skills' panel at the bottom.

No inner loop

Multiple choice, end-of-quiz explanation

Math Success 2010

The screenshot shows the Math Success 2010 Quiz interface. The screen displays the question: "Solve the equation $\frac{y}{4} - 7 = \frac{-6y}{11} + \frac{1}{2}$ ". The multiple-choice options are:

- A. $y = \frac{66}{7}$
- B. $y = \frac{67}{2}$
- C. $y = \frac{9}{10}$
- D. $y = \frac{54}{11}$

The interface includes a 'Quiz' header and a 'Question 9 / 15' indicator.

The screenshot shows the Math Success 2010 Explanation interface. The screen displays the equation $\frac{y}{4} - 7 = \frac{-6y}{11} + \frac{1}{2}$ and a series of steps to solve it. The steps are:

- Add 7 to both sides: $\frac{y}{4} - 7 + 7 = \frac{-6y}{11} + \frac{1}{2} + 7$
- Simplify: $\frac{y}{4} = \frac{-6y}{11} + \frac{15}{2}$
- Add $\frac{6y}{11}$ to both sides: $\frac{y}{4} + \frac{6y}{11} = \frac{-6y}{11} + \frac{6y}{11} + \frac{15}{2}$
- Simplify: $\frac{11y}{44} + \frac{24y}{44} = \frac{15}{2}$
- Find a common denominator for the left side: $\frac{11y}{44} + \frac{24y}{44} = \frac{15}{2}$
- Simplify: $\frac{35y}{44} = \frac{15}{2}$
- Multiply both sides by $\frac{44}{35}$: $\left(\frac{44}{35}\right)\left(\frac{35y}{44}\right) = \left(\frac{44}{35}\right)\left(\frac{15}{2}\right)$
- Simplify: $y = \frac{66}{7}$

The interface includes an 'Explanation' header and a 'Question 9 / 15' indicator.

Real-world Impact of Cognitive Tutor Courses

The New York Times

Technology

Software Tutors Offer Help and Customized Hints



Chris Maynard for The New York Times

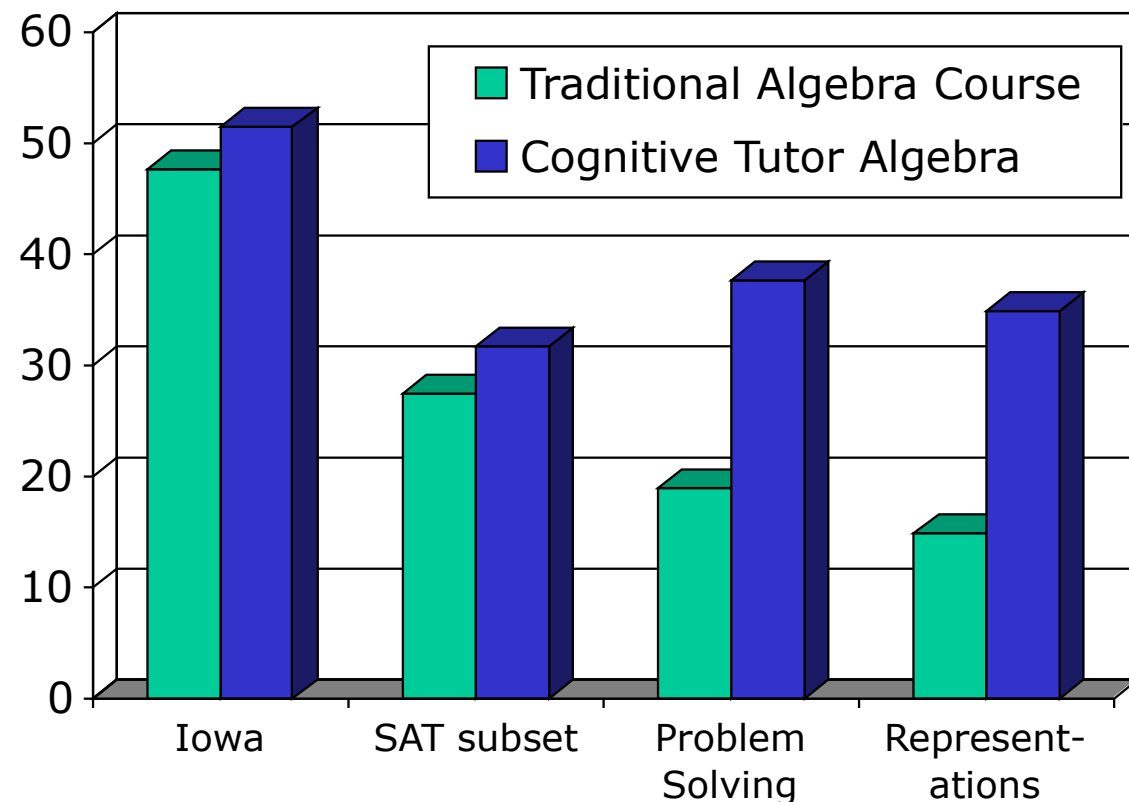
MATH COACH - Rochelle Brown, left, and Iesha Antonetti, students at Middle School 103 in the Bronx, use Cognitive Tutor software to reinforce math skills. The software is designed to give students individualized instruction when personal attention is scarce.

- Spin-off company Carnegie Learning, Inc.
- Over 500,000 students per year

 **Carnegie Learning™**
THE COGNITIVE TUTOR® COMPANY

Replicated Field Studies

- Controlled, full year classroom experiments
- Replicated over 3 years in urban schools
- In Pittsburgh & Milwaukee
- Results:
 - 50-100% better on problem solving & representation use.
 - 15-25% better on standardized tests.

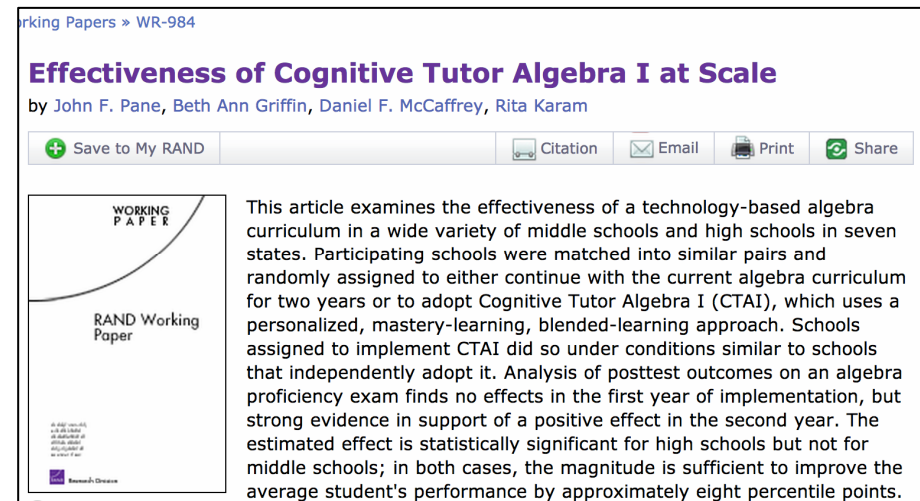


Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, 8(1), 30-43.

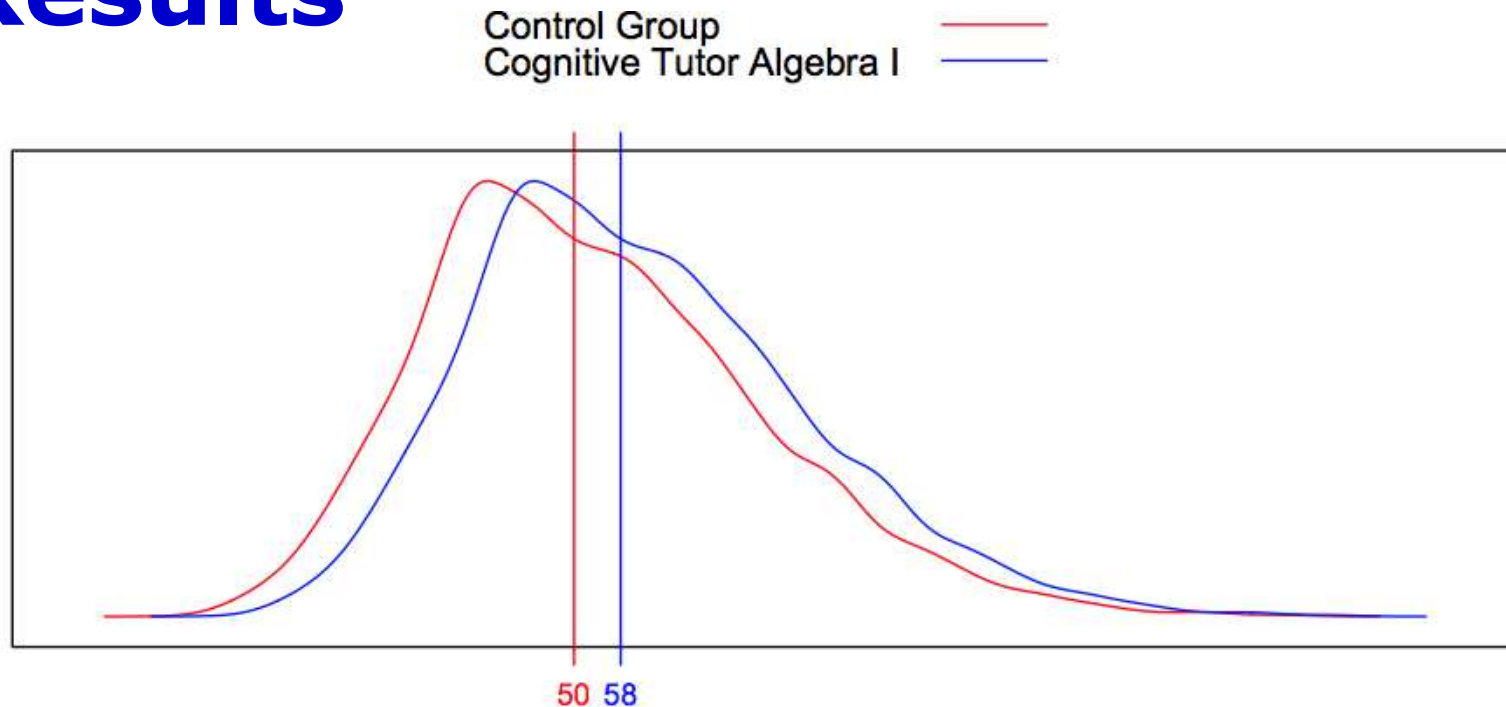
Effectiveness of Cognitive Tutor Algebra at Scale

- Funded by US Dept. of Ed (\$6M); conducted by RAND
- 147 schools, 7 geographic areas, over 19,000 students
- Random assignment by school

- No special implementation support
 - Intent-to-treat study
- Standardized test outcome (McGraw Hill Acuity)



Results



High School study

.21 standard deviation improvement relative to control group (in year 2)

Equivalent to year-over-year improvement on standardized test (CT students *doubled* normal improvement)

Chicago – HS Transformation Project

- HS students in CPS below median on ITBS assign to double-period math
 - 1 period Algebra, 1 Bridge to Algebra
- Either CT or Agile Mind (by school)
- Studied students just above or below median
- Study done by Chicago Consortium on School Research

Results

- Relative to other students, double-dose students had
 - Significantly higher grades in Algebra (esp for better-prepared students)
 - Significant increase in passing Trig (11th grade)
 - Significant increase in ACT Math scores
 - Significant increase in graduation rates (7.9 percentage points – 17% increase)
 - Significant increase in college enrollment (8.6 percentage points – 30% increase)

Cognitive Tutor Technology:

Use ACT-R theory to individualize instruction

- **Cognitive Model:** A system that can solve problems in the various ways students can

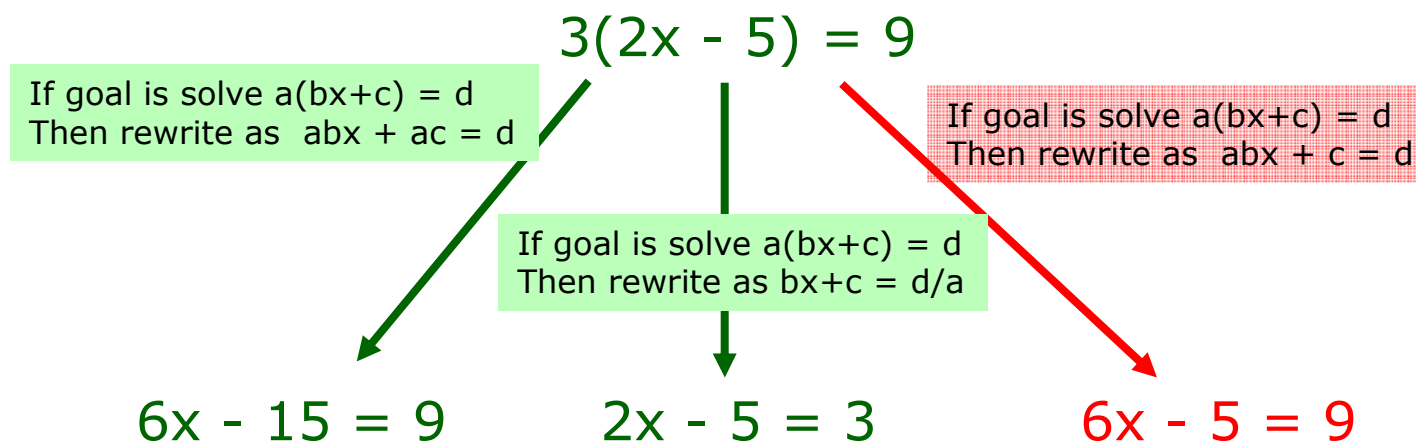
Strategy 1: IF the goal is to solve $a(bx+c) = d$
THEN rewrite this as $abx + ac = d$

Strategy 2: IF the goal is to solve $a(bx+c) = d$
THEN rewrite this as $bx + c = d/a$

Misconception: IF the goal is to solve $a(bx+c) = d$
THEN rewrite this as $abx + c = d$

Cognitive Tutor Technology: Use ACT-R theory to individualize instruction

- **Cognitive Model:** A system that can solve problems in the various ways students can



- **Model Tracing:** Follows student through their individual approach to a problem -> context-sensitive instruction

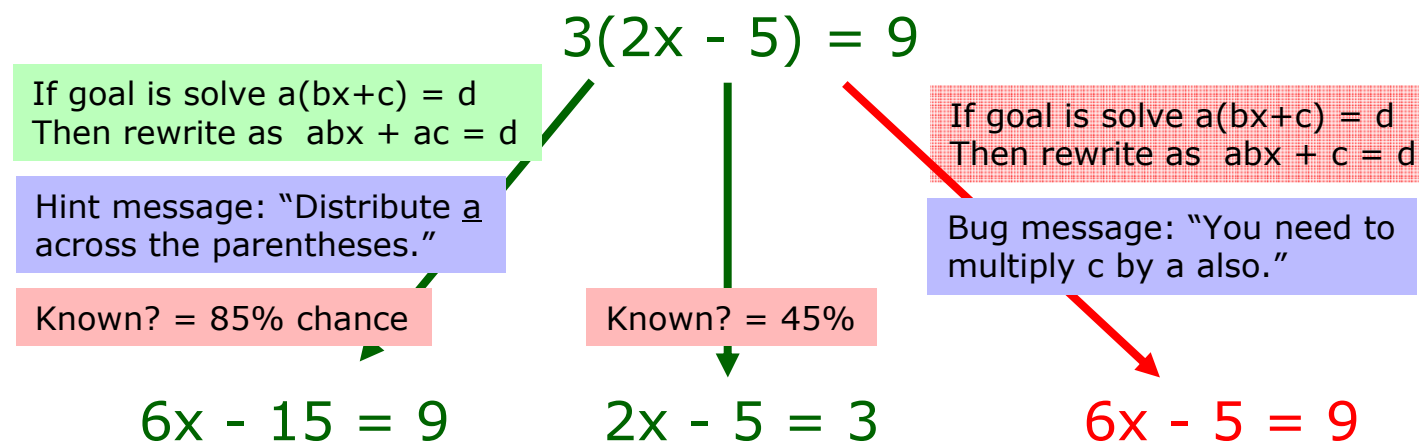
Folie 21

SoCS2 animate one by one?
Vincent Alevén; 17.12.2010

SoCS3 red for bug rule?
Vincent Alevén; 17.12.2010

Cognitive Tutor Technology: Use ACT-R theory to individualize instruction

- **Cognitive Model:** A system that can solve problems in the various ways students can



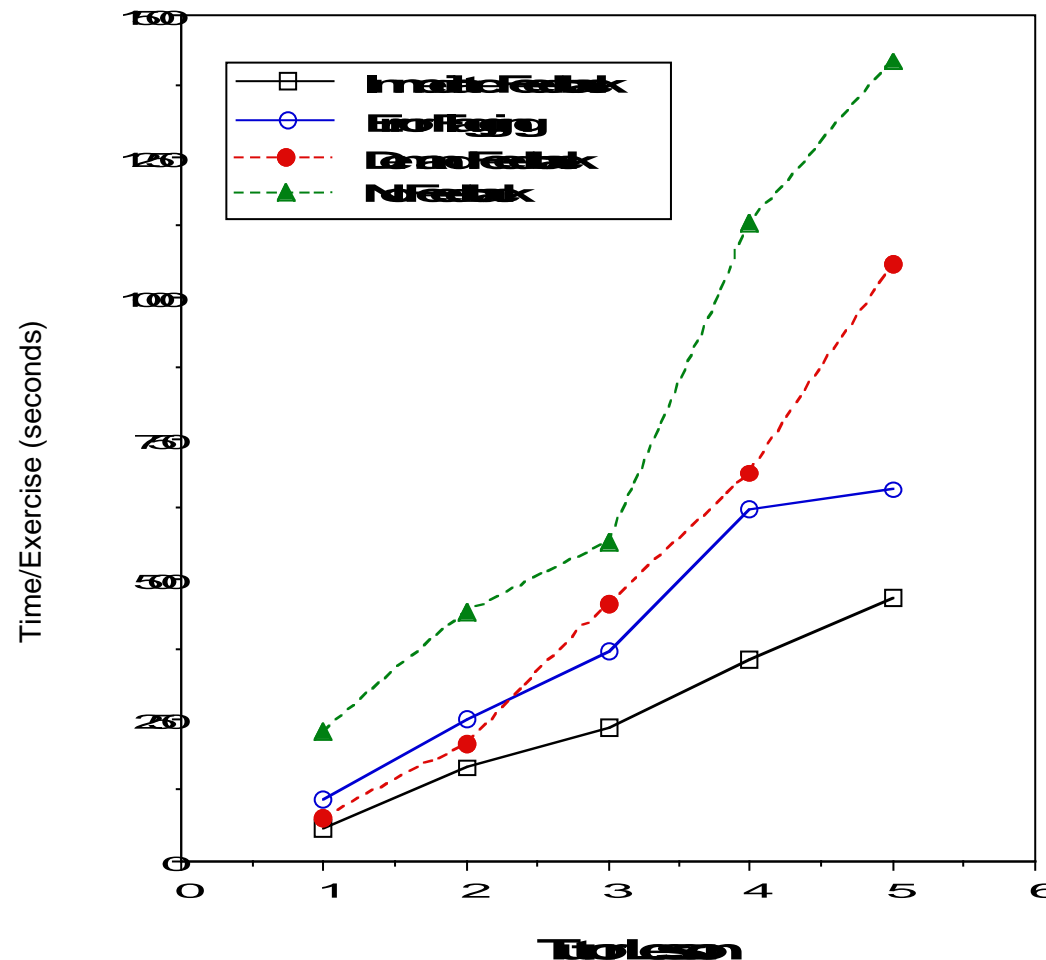
- **Model Tracing:** Follows student through their individual approach to a problem -> context-sensitive instruction
- **Knowledge Tracing:** Assesses student's knowledge growth -> individualized activity selection and pacing

could leave out knowledge tracing part - even though it is kind of cool

Vincent Alevén; 17.12.2010

Step-by-step Feedback

(Corbett & Anderson, 1991)



- Time to complete programming problems in LISP Tutor
- Immediate feedback vs. student-controlled feedback



Cognitive Mastery Learning

Individualized Problem Selection

Using the set of shapes in the picture, answer questions 1 through 4 in the worksheet provided.

	1	2	3	4
Number of Target Items	100	20	60	5
Total Number of Items	100	100	100	100
Unreduced Ratio	100/100	20/100	60/100	5/100
Ratio Out of 100	100/100	20/100	60/100	5/100
Percent	100%	20%	60%	5%
Decimal	1	.2	.6	.05
Reduced Fraction	1	1/5	3/5	

1. What percent of the shapes are squares?
2. What percent of the shapes are purple?
3. What percent of the shapes are not blue?
4. What percent of the shapes are red?

Count Target
Count Total
Enter As De
Enter As Fr
Enter As Pe
Enter Redu

- Bayesian Knowledge-Tracing is used to keep track of student skill growth
 - Displayed in "Skill Meter"
- Used to implement "Cognitive Mastery" learning; tutor selects problems with un-mastered skills until students has research mastery for all targeted skills

Count Target Items
Count Total Items
Enter As Decimal
Enter As Fraction Out 100
Enter As Percent
Enter Reduced Fraction
Enter Unreduced Ratio

Success factors in the Cognitive Tutor technology

- Technology: Rich problem-solving activities with step-by-step guidance; adaptivity (cognitive mastery)
- Research to investigate student thinking in the given domain
 - Cognitive task analysis
 - Cognitive modeling
- Collaboration with teachers
- Classroom research to improve the tutors

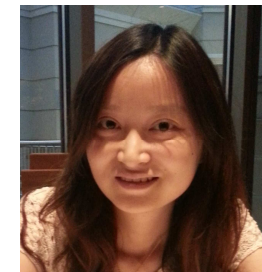
Further Reading

- Cognitive task analysis in tutor design
 - Koedinger, K. R., & Nathan, M. J. (2004). The real story behind story problems: Effects of representations on quantitative reasoning. *The Journal of the Learning Sciences*, 13(2), 129-164.
 - Baker, R. S. J. d., Corbett, A. T., & Koedinger, K. R. (2007). The difficulty factors approach to the design of lessons in intelligent tutor curricula. *International Journal of Artificial Intelligence and Education*, 17(4), 341-369.
- Feedback
 - Anderson, J. R., Conrad, F. G., & Corbett, A. T. (1989). Skill acquisition and the LISP tutor. *Cognitive Science*, 13(4), 467 - 505. doi: 10.1016/0364-0213(89)90021-9
 - Mathan, S. A., & Koedinger, K. R. (2005). Fostering the intelligent novice: Learning from errors with metacognitive tutoring. *Educational Psychologist*, 40(4), 257-265.
- Bayesian Knowledge Tracing and Cognitive Mastery
 - Corbett, A. T., & Anderson, J. R. (1995). Knowledge tracing: Modeling the acquisition of procedural knowledge. *User Modeling and User-Adapted Interaction*, 4(4), 253-278.
 - Corbett, A., McLaughlin, M., & Scarpinato, K. C. (2000). Modeling student knowledge: Cognitive tutors in high school and college. *User Modeling and User-Adapted Interaction*, 10, 81-108.

Overview

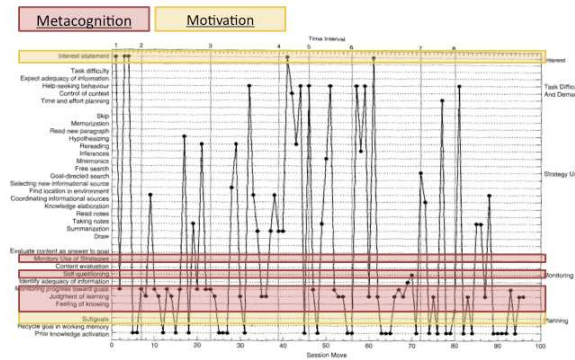
- Cognitive Tutors
- Supporting metacognition with Cognitive Tutors
 - Self-Assessment
 - Self-Explanation
- Non-Programmer Authoring Tools for creating tutor

Long, Y., & Aleven, V. (2013). Skill diaries: Improve student learning in an intelligent tutoring system with periodic self-assessment. In H. C. Lane, K. Yacef, J. Mostow, & P. Pavlik (Eds.), *Proceedings of the 16th international conference on artificial intelligence in education AIED 2013* (pp. 249-258). Berlin Heidelberg: Springer. doi:10.1007/978-3-642-39112-5_2

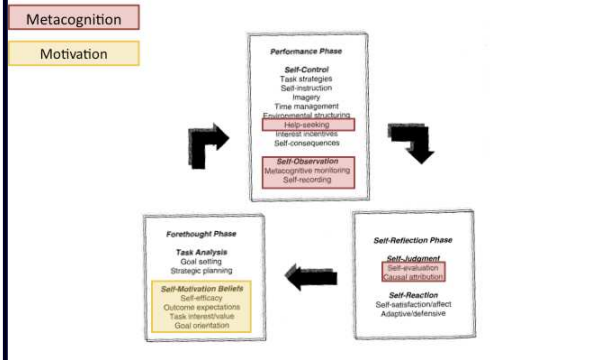


Self-Regulated Learning: Great Theoretical Diversity

Azevedo's (2005) Model of SRL in HLEs



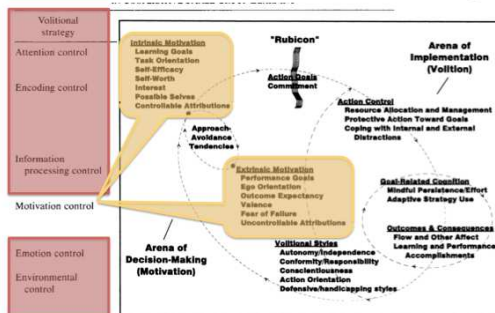
Zimmerman's (2000) Model of SRL



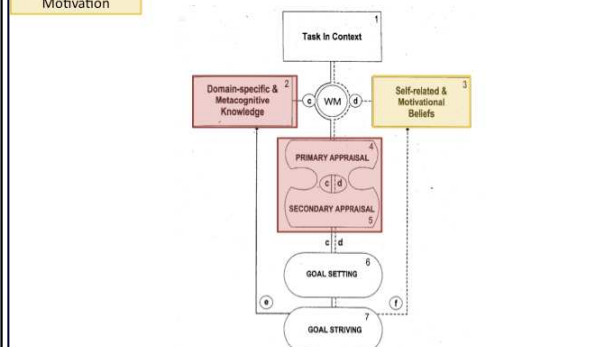
Pintrich's (2004) SRL Model

Metacognition	Table 1. Phases and Areas for Self-Regulated Learning			Motivation
	Areas for regulation			
Phases and relevant scales	Cognition	Motivation/Affect	Behavior	Context
Phase 1 Forethought, planning, and activation	Target goal setting Prior content knowledge activation Metacognitive knowledge activation	Goal orientation adoption Efficacy judgments Perceptions of task difficulty Task value activation Interest activation	Time and effort planning Planning for self-observations of behavior	Perceptions of task Perceptions of context
Phase 2 Monitoring	Metacognitive awareness and monitoring of cognition	Awareness and monitoring of motivation and affect	Awareness and monitoring of effort, time use, need for help Self-observation of behavior	Monitoring changing task and context conditions
Phase 3 Control	Selection and adaptation of cognitive strategies for learning, thinking	Selection and adaptation of strategies for managing, motivation, and affect	Increase/decrease effort Persist, give up Help-seeking behavior	Change or renegotiate task Change or leave context
Phase 4 Reaction and reflection	Cognitive judgments	Affective reactions	Choice behavior	Evaluation of task
Relevant MSI Q Scales	Attribution Relevant Goals Elaboration Organization Critical Thinking Metacognition	Attributions Relevant Goals Intrinsic Goals Task Value Control Beliefs Test Anxiety	Effort Regulation Help-Seeking Time/Study Environment	Evaluation of context Peer Learning Study Environment

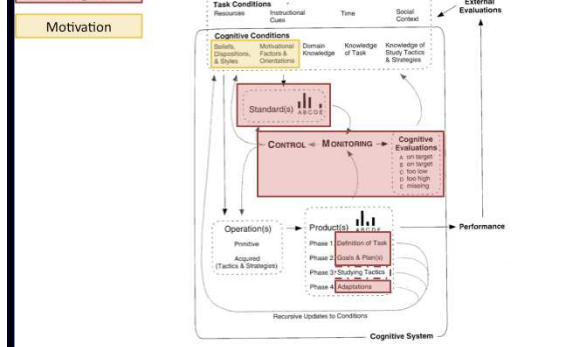
M&M in Corno's (1986; 1993) Theory of Volition in Self-Regulated Learning



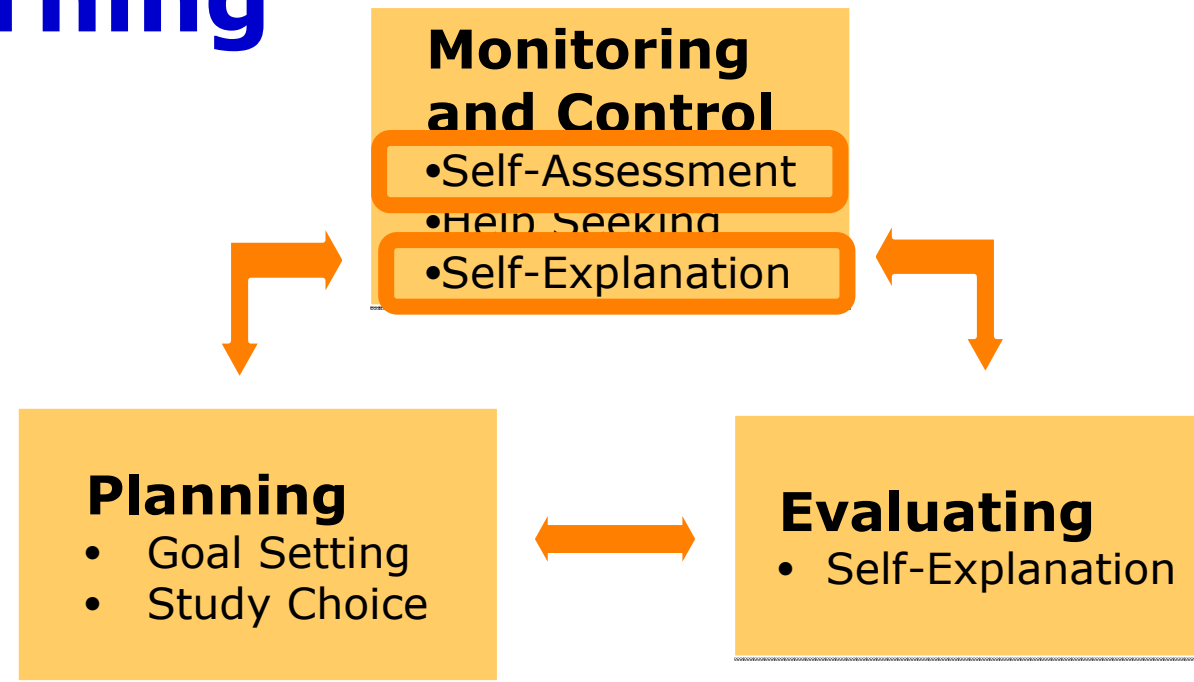
Boekaerts' (2000) Model of Adaptable Learning



Winne & Hadwin's (1998) SRL Model



Background: Self-Regulated Learning



- How do instructional intervention aimed at supporting these elements affect robust learning?

Why is Self-Assessment Important?

- The process of self-assessing can facilitate deep thinking and reflection
(Boud, 2004; White & Frederiksen, 1998)
- The results of self-assessment can lead to better learning plans and study choices, as well as better learning outcomes
(Thiede, Anderson & Therriault, 2003; Winne & Hadwin, 1998)
- However, students' self-assessment is often inaccurate
(Dunlosky & Lipko, 2007; Nelson, 1996)

Research Question

- Can self-assessment be supported effectively by means of (paper) skill diaries?
- Does such support for self-assessment lead to enhanced learning?

Geometry Cognitive Tutor with Skill Meter

File Tutor Go To View Help

35 - Volume and Surface Area of Right Prisms
1 - Finding Volume of Right Prisms

Instructor Preview
RP-C-volume-FF-block-p116

Example Hint Done Skills

Table of Contents Lesson Problems

Scenario

Your younger cousin likes playing with blocks. One type of block is a right rectangular prism.

Answer each question using the given information.







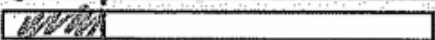
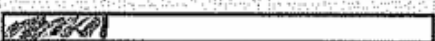



- In the prism, $CD = 6.4$ centimeters, $AD = 6$ centimeters, and $DH = 12.5$ centimeters. What is the volume of the block?
- In the prism, $CD = 4.9$ centimeters, $AD = 4.7$ centimeters, and $DH = 9.7$ centimeters. What is the volume of the block?

Skillometer

	Enter given prism height.
	Enter given rectangular prism dimension of base.
	Enter given triangular prism dimension of base.
	Find area of base of rectangular prism.
	Find area of base of triangular prism.
	Find rectangular prism volume.
	Find triangular prism volume.
	Work with prism in context.
	Work with prism out of context.
	Work with rotated triangular prism.
	Work with triangular prism in standard position.

Skill Diary, Part 1

1. Please write down the current time on your computer: 10:21 am
2. Please complete the following blank skillbar (draw the bars) to make it the same as your current skillbar in the Tutor. The bars that you draw do not need to be perfect—do your best to make it look like your real bars in the Tutor.

	Enter given prism height
	Enter given rectangular prism dimension of base
	Enter given triangular prism dimension of base
	Find area of base of rectangular prism
	Find area of base of triangular prism
	Find rectangular prism volume
	Find triangular prism volume
	Work with prism in context
	Work with prism out of context
	Work with rotated triangular prism
	Work with triangular prism in standard position

Skill Diary, Part 2

3. Please fill out the table below based on your current learning status in the Tutor:

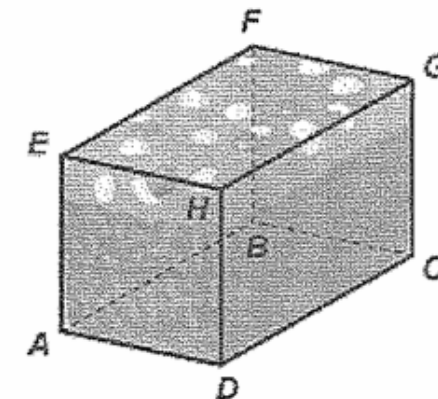
Skill	Since the last tutor problem, this skill has become.... (check one)	Have you had any practice on this skill yet in this unit? (check one)	In your own opinion, rate your mastery of this skill from 1-7. 1 = poor to 7 = very good	In your own opinion, do you need more practice on this skill? (check one)
Enter given prism height	<input checked="" type="checkbox"/> Better <input type="checkbox"/> Same <input type="checkbox"/> Worse	<input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input checked="" type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure
Enter given rectangular prism dimension of base	<input checked="" type="checkbox"/> Better <input type="checkbox"/> Same <input type="checkbox"/> Worse	<input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input checked="" type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure
Enter given triangular prism dimension of base	<input checked="" type="checkbox"/> Better <input type="checkbox"/> Same <input type="checkbox"/> Worse	<input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input type="checkbox"/> 5 <input checked="" type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure
Find area of base of rectangular prism	<input type="checkbox"/> Better <input checked="" type="checkbox"/> Same <input type="checkbox"/> Worse	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input checked="" type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure
Find area of base of triangular prism	<input type="checkbox"/> Better <input type="checkbox"/> Same <input checked="" type="checkbox"/> Worse	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input checked="" type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input type="checkbox"/> 4 <input checked="" type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure
Find rectangular prism volume	<input type="checkbox"/> Better <input type="checkbox"/> Same <input checked="" type="checkbox"/> Worse	<input type="checkbox"/> Yes <input type="checkbox"/> No <input checked="" type="checkbox"/> Not sure	<input type="checkbox"/> 1 <input type="checkbox"/> 2 <input type="checkbox"/> 3 <input checked="" type="checkbox"/> 4 <input type="checkbox"/> 5 <input type="checkbox"/> 6 <input type="checkbox"/> 7	<input type="checkbox"/> Yes <input checked="" type="checkbox"/> No <input type="checkbox"/> Not sure

Skill Diary, Part 3

4. Look at problems A, B, C, D, E and F below (do NOT solve them!). Rate how confident you are that you can solve each of them from 1 – 7. (**Circle one number**: 1= Not Confident, 7=Very Confident.)

A. Your aunt makes a fruit cake for a family reunion. The pan she uses is a right rectangular prism. In the prism, $CD = 4$ centimeters, $AD = 2$ centimeters, and $DH = 3$ centimeters, what is the volume of this block?

Not Confident						Very Confident
1	2	3	4	5	6	7



Skill Diary Study

- **Hypothesis:** Periodically filling out structured Skill Diaries helps students self-assess and learn better
- **Participants:**
 - 122 students from 2 teachers' 6 classes in a local high school
 - Complete data for 95 students
- **Procedure:** Students worked on tutor for 3 class periods (volume and surface areas for spheres and right prisms), took paper pre-test before and post-test after
- **Experimental condition:** Skill Diary
- **Control condition:** Control Diary (no self-assessment)

Control Diary

3. Look at problems A, B, C and D below (do NOT solve them!). Check if you have seen each problem in this unit so far.

A. You play volleyball in gym class. A volleyball is a sphere. The radius of the volleyball is 10 centimeters.

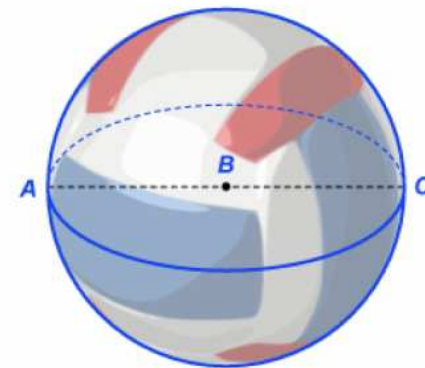
What is the VOLUME of the volleyball?

☐

Yes

☐

No



Summary of Findings

- Post-Test:
 - Skill Diary group better on near-transfer problems than Control Diary group
 - Especially among lower-performing students
- Across conditions, higher-performing students have more accurate self-assessment
- In the Skill Diary condition, accuracy of SA improves from Pre to Post for lower-performing students
- Skill Diary students used the tutor in a more deliberate manner

Post-Test: Experimental Group Better on Reproduction Problems

	Mean Test Scores (SD)			
	Pre-Test Reproduction	Post-Test Reproduction	Pre-Test Transfer	Post-Test Transfer
Exp. Group	0.55 (.34)	0.62 (.29)	0.50 (.28)	0.58 (.26)
Ctrl. Group	0.46 (.44)	0.49 (.33)	0.46 (.22)	0.57 (.24)

$$F(1, 93) = 3.86, p = .052, \eta^2 = .040$$

Caveat: when pre-test score is used as co-variate, the difference between two groups on reproduction problems was on the borderline of significance ($F(1, 92) = 2.75, p = .101, \eta^2 = .029$)

Post-test: Lower Performing Students Who Used Skill Diaries Did Better

	Test Scores on Reproduction Problems (SD)			
	Pre-Test		Post-Test	
	Exp	Ctrl	Exp	Ctrl
Lower-Performing Group	0.35 (.45)	0.16 (.35)	0.53 (.47)	0.30 (.39)
Higher-Performing Group	0.74 (.41)	0.74 (.75)	0.71 (.38)	0.68 (.41)

($F(1, 44) = 4.586, p = .038, \eta^2 = .094$; pre-test reproduction problem score was used as co-variate)

Measuring Self-assessment Accuracy on Pre- and Post-Tests

Problem 1: How confident are you that you can solve this problem? (Circle one number: 1= Not Confident, 7=Very Confident.)

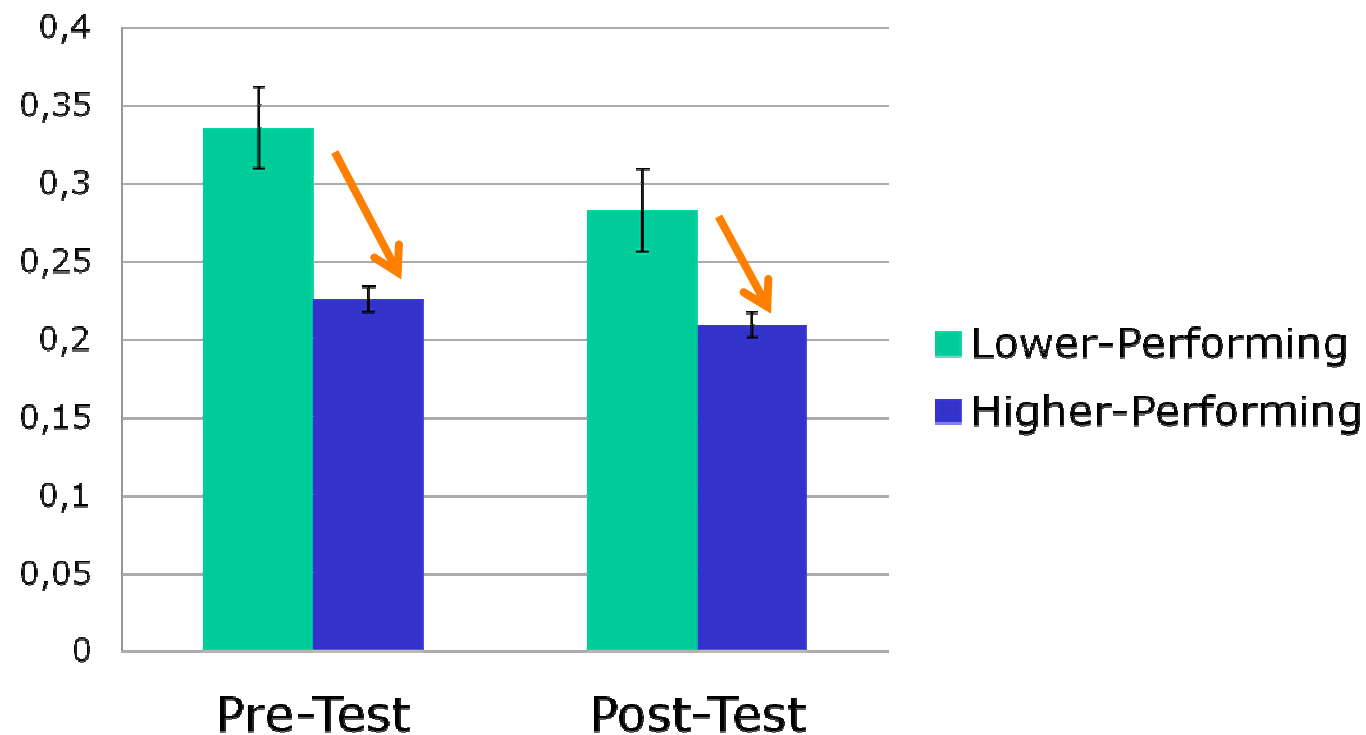
Not Confident							Very Confident
1	2	3	4	5	6	7	

$$\text{Absolute Accuracy Index} = \frac{1}{N} \sum_{i=1}^N (c_i - p_i)^2 \quad (\text{Schraw, 2009})$$

- Measures the *discrepancy* between self-assessed and actual performance.

Self-Assessment Accuracy

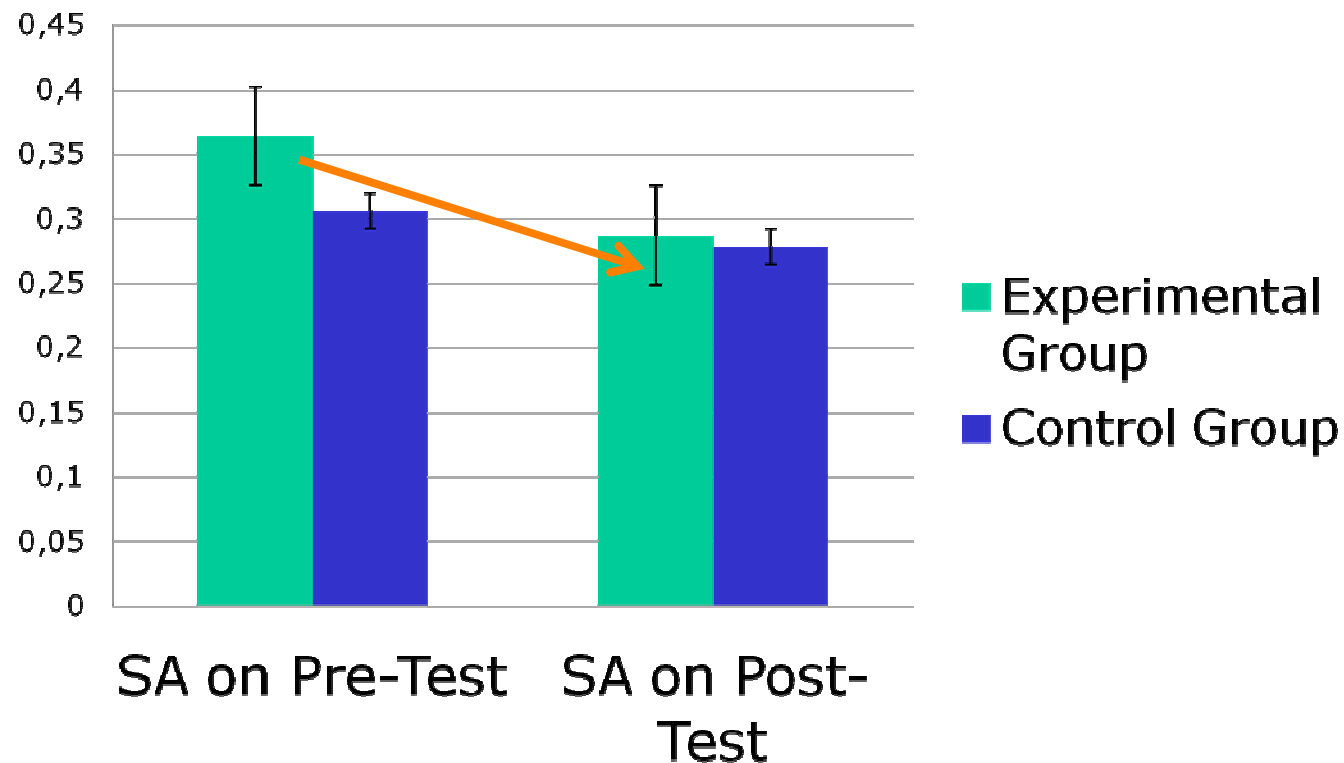
Absolute Accuracy Index



- Higher performing students have more accurate self-assessment

Self-Assessment Accuracy of Lower-Performing Students

Absolute Accuracy Index



- Accuracy of SA improves from Pre to Post for lower-performing students

$$t(23) = 2.257, p = .034$$

Process Measures

Correlations

	Pre- Test	Post- Test
Number of Hints	-.56**	-.47**
Time Spent on Each Hint	.20	.34**
Number of Incorrect Attempts	-.35**	-.32**
Assistance Score	-.52**	-.47**
Time Spent on Each Step	-.19	-.20

* $p < .05$

** $p < .01$

Process Measures

	Correlations		Condition Differences		
	Pre-Test	Post-Test	Exp	Ctrl	η^2
Number of Hints	-.56**	-.47**	.054	.082	.049*
Time Spent on Each Hint	.20	.34**	17.5	12.4	.037*
Number of Incorrect Attempts	-.35**	-.32**	.085	.092	.031
Assistance Score	-.52**	-.47**	.140	.174	.055*
Time Spent on Each Step	-.19	-.20	15.4	14.4	.027

* $p < .05$

** $p < .01$

Contributions

of the Skill Diary Study

- Skill Diaries practical way of supporting effective self-assessment for lower-performing students
- Demonstrates a beneficial role of self-assessment in students' learning of problem-solving tasks with an ITS

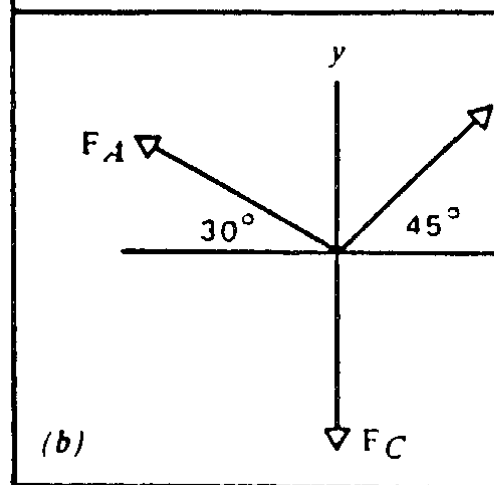
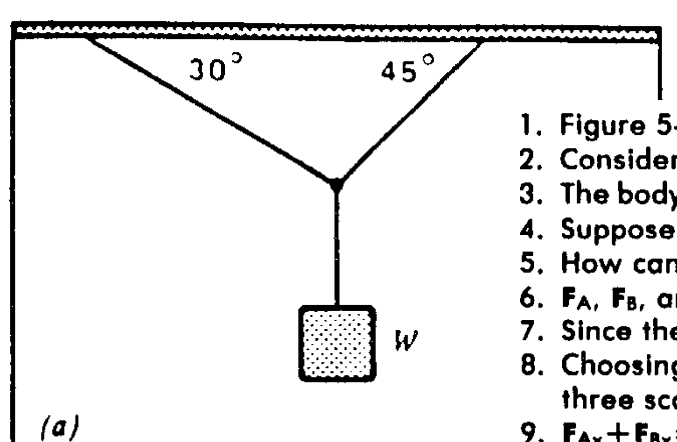
Overview

- Cognitive Tutors
- Supporting metacognition with Cognitive Tutors
 - Self-Assessment
 - Self-Explanation
- Non-Programmer Authoring Tools for creating tutor

Aleven, V. A., & Koedinger, K. R. (2002). An effective metacognitive strategy: Learning by doing and explaining with a computer-based cognitive tutor. *Cognitive Science*, 26(2), 147-179.



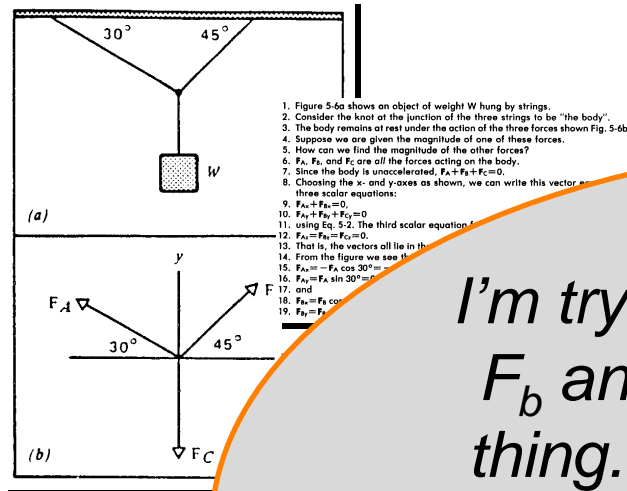
A typical self-explanation scenario



1. Figure 5-6a shows an object of weight W hung by strings.
2. Consider the knot at the junction of the three strings to be "the body".
3. The body remains at rest under the action of the three forces shown Fig. 5-6b.
4. Suppose we are given the magnitude of one of these forces.
5. How can we find the magnitude of the other forces?
6. F_A , F_B , and F_C are all the forces acting on the body.
7. Since the body is unaccelerated, $F_A + F_B + F_C = 0$.
8. Choosing the x - and y -axes as shown, we can write this vector equation as three scalar equations:
9. $F_{Ax} + F_{Bx} = 0$,
10. $F_{Ay} + F_{By} + F_{Cy} = 0$
11. using Eq. 5-2. The third scalar equation for the z -axis is simply
12. $F_{Az} = F_{Bz} = F_{Cz} = 0$.
13. That is, the vectors all lie in the x - y plane so that they have no z -components.
14. From the figure we see that
15. $F_{Ax} = -F_A \cos 30^\circ = -0.866F_A$,
16. $F_{Ay} = F_A \sin 30^\circ = 0.500F_A$,
17. and
18. $F_{Bx} = F_B \cos 45^\circ = 0.707F_B$,
19. $F_{By} = F_B \sin 45^\circ = 0.707F_B$.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-Explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.

A typical self-explanation scenario



I'm trying to think where Forces F_b and F_a are going to get the thing. They'd just be the force, the rest mass of the thing holding it up would be the force ... it's the resistance to weight W . It would all be equal.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-Explanations: How students study and use examples in learning to solve problems. *Cognitive Science*, 13, 145-182.

Classic Cognitive Science Results on Self-Explanation

- People learn better when they explain materials to themselves (Chi et al., 1989)
 - Google Scholar: 1657 citations (Sep 17, 2011)
 - Prompting helps (Chi et al., 1994), but even so many students do not provide good self-explanations (Renkl et al., 1997).
 - Instruction in self-explanation helps (Bielaczyc et al., 1995), but individual differences remain
- How can we support self-explanation, beyond simple prompting?

Hypothesis

- Supporting self-explanation in an ITS results in deeper understanding:
 - Less shallow procedural knowledge
 - More general declarative knowledge
- Consequences:
 - Better reason giving
 - Near transfer as good or better
 - Better far transfer

VA4

stuff like number of subjects ?

length of time

done in a school

etc

--> realism!

Vincent Alevén; 17.09.2011

Explanation Condition

(Experimental condition)

External Angle of Parallel Lines

Given: $QN \parallel EC$. If the measure of Angle QSR is a right angle, find the measure of Angle SRN .

m \angle QSR	90	Reason	given
m \angle QSC	90	Reason	Int angles same side
m \angle QSR	45	Reason	angle bisection
m \angle ESR	135	Reason	angle addition
m \angle SRN		Reason	

Messages

Some reasons dealing with parallel lines are highlighted in the Glossary. Which of these reasons is appropriate?

You can click on each reason in the Glossary to find out more.

Glossary

- Converse of Isosceles Triangle (Theorem)
- Isosceles Right Triangle
- Triangle Sum (Theorem)
- Linear Pair
- Linear Trio
- Parallel Lines --- Corr. Angles Are Cong.**
- Parallel Lines --- Alt. Int. Angles Are Cong.**
- Parallel Lines --- Alt. Ext. Angles Are Cong.**
- Parallel Lines --- Int. Angles on the Same Side are Supp.**

If two parallel lines are intersected by a transversal, then alternate interior angles are congruent.

Example: L_1 and L_2 are parallel lines, intersected by transversal T . $\angle 1$ and $\angle 2$ are alternate interior angles. If $m\angle 1$ is 37° , then $m\angle 2$ is also 37° .

Problem solving answers

Explanation by menu

Problem Solving Condition

(Control condition)

External Angle of Parallel Lines

Given: $ON \parallel EC$. If the measure of Angle SOR is a right angle, find the measure of Angle SRN .

$m\angle SOR$

$m\angle OSC$

$m\angle OSR$

$m\angle ESR$

$m\angle SRN$

Messages

Some reasons dealing with parallel lines are highlighted in the Glossary. Which of these reasons is appropriate?

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Glossary

- Converse of Isosceles Triangle (Theorem)
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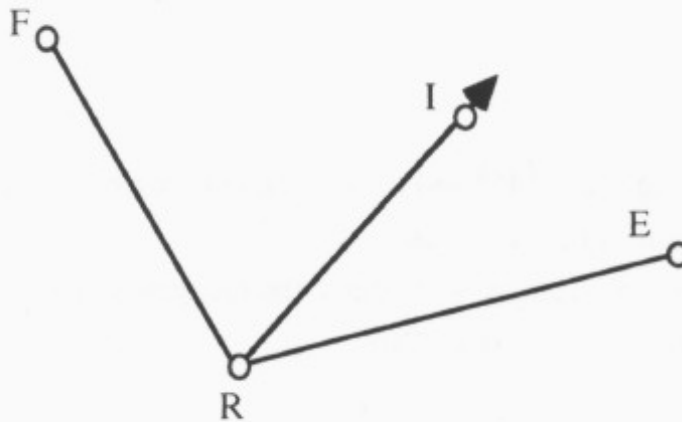
If two parallel lines are intersected by a transversal, then alternate interior angles are congruent.

Example: L_1 and L_2 are parallel lines, intersected by transversal T . $\angle 1$ and $\angle 2$ are alternate interior angles. If $m\angle 1$ is 37° , then $m\angle 2$ is also 37° .

Pre/Post Test Items

- Problem-solving items
 - Numerical Steps - Finding unknown quantities
- Items associated with deeper understanding
 - Reason - Explain answers by citing geometry rule
 - Not Enough Info - Transfer items where students are asked to judge if there is enough information to find quantities, and the answer is “No”.

Assessing Transfer: "Not Enough Info" Item

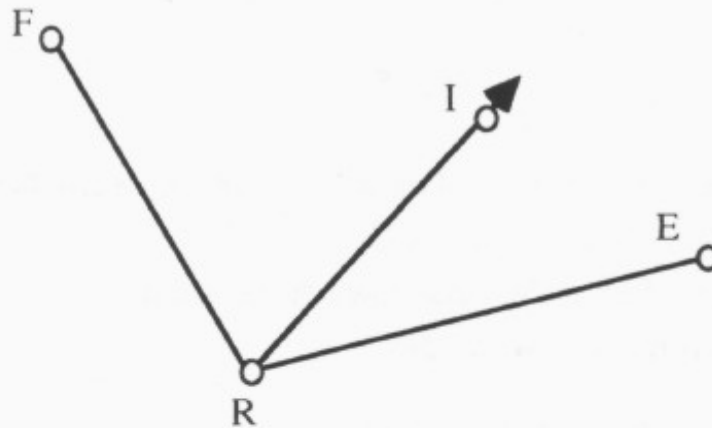


1. If the measure of Angle IRE is 55° , do you have enough information to find the measure of angle FRI?

If there is enough information to find the measure of Angle FRI, write down the measure and a reason for your answer. If there is not enough information, write "No."

m \angle FRI : no Reason: need to know \angle FRE

Assessing Transfer: Incorrect Over-generalization

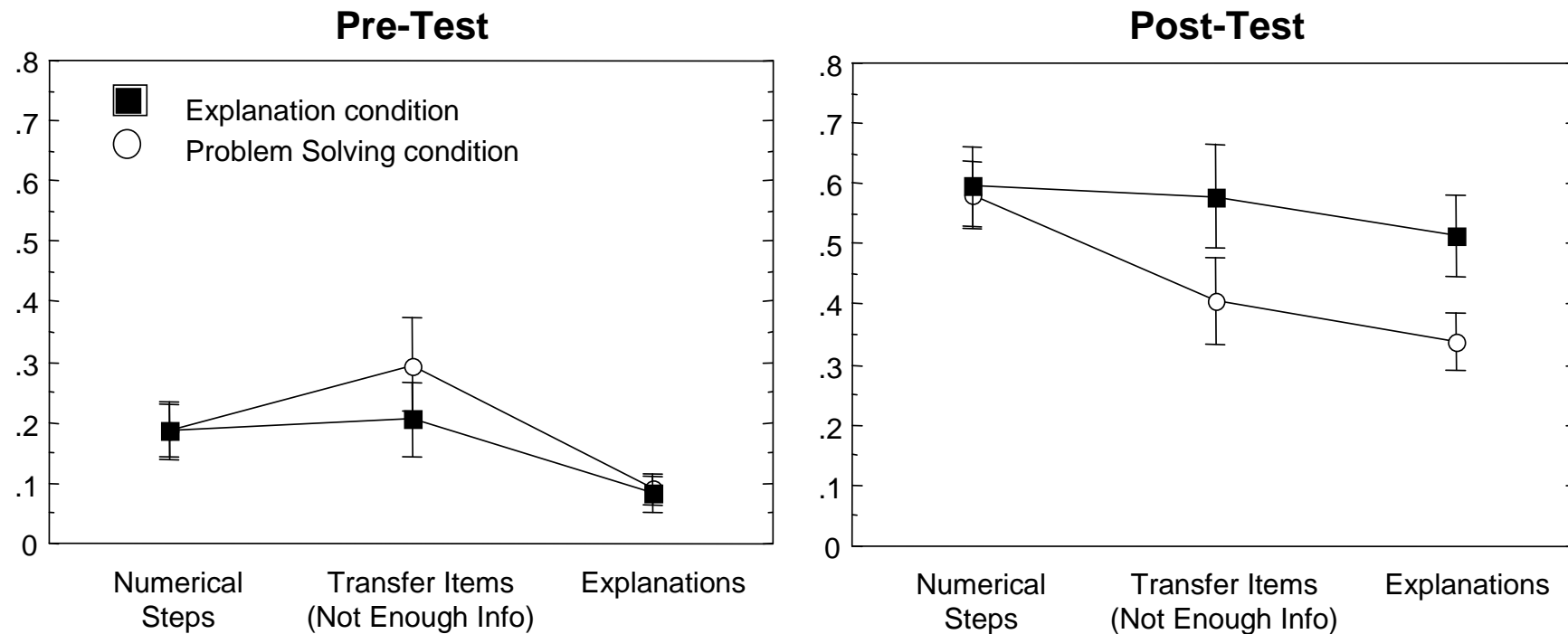


1. If the measure of Angle IRE is 55° , do you have enough information to find the measure of angle FRI?

If there is enough information to find the measure of Angle FRI, write down the measure and a reason for your answer. If there is not enough information, write "No."

m \angle FRI : 125° Reason: Supplementary

Results

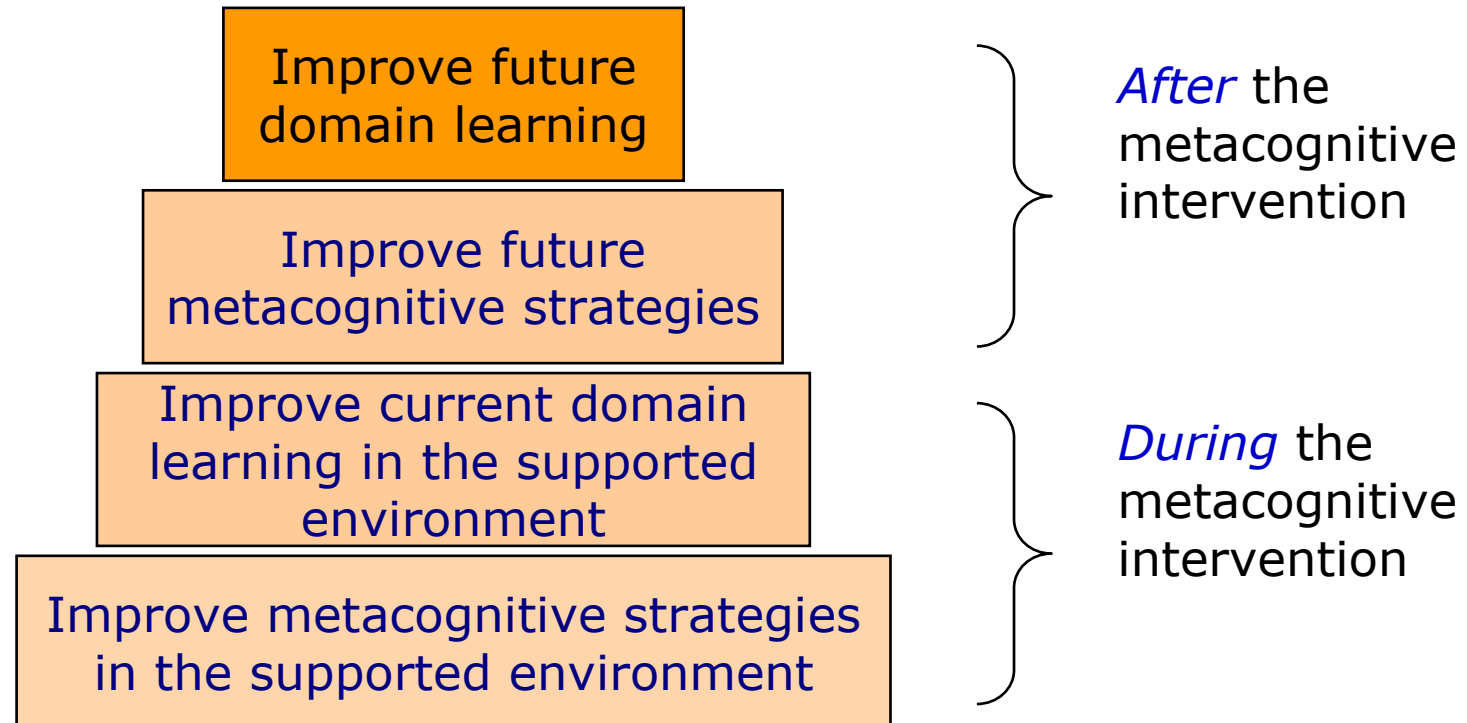


Aleven, V., & Koedinger, K. R. (2002). An effective meta-cognitive strategy: Learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive Science*, 26(2), 147-179.

Objectives in Supporting Metacognition



Ido Roll



Koedinger, K. R., Aleven, V., Roll, I., & Baker, R. (2009). In vivo experiments on whether supporting metacognition in intelligent tutoring systems yields robust learning. In D. J. Hacker, J. Dunlosky, & A. C. Graesser (Eds.), *The Educational Psychology Series: Handbook of metacognition in education* (pp. 897-964). London: Routledge Press.

Folie 58

SoCS7

Take the top of the pyramid?

Vincent Alevén; 17.12.2010

SoCS8

illustrate which layers will be addressed in each study?

Vincent Alevén; 17.12.2010

Overview

- Cognitive Tutors
- Supporting metacognition with Cognitive Tutors
 - Self-Assessment
 - Self-Explanation
- Non-Programmer Authoring Tools for creating tutor

Aleven, V., McLaren, B. M., Sewall, J., & Koedinger, K. R. (2009). A new paradigm for intelligent tutoring systems: Example-Tracing tutors. *International Journal of Artificial Intelligence in Education*, 19(2), 105-154.



CTAT motivation: Make tutor development easier and faster!

- Cognitive Tutors:
 - Large student learning gains as a result of detailed cognitive modeling
 - ~200 dev hours per hour of instruction (Koedinger et al., 1997)
 - Requires PhD level cog scientists and AI programmers
- Development costs of instructional technology are, in general, quite high
 - E.g., ~300 dev hours per hour of instruction for Computer Aided Instruction (Murray, 1999)

Murray, T. (1999). Authoring Intelligent Tutoring Systems: An Analysis of the state of the art. *The International Journal of Artificial Intelligence in Education*, 10, 98-129.

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

CTAT: Cognitive Tutor Authoring Tools

The screenshot displays the CTAT software interface, which is used for creating intelligent tutoring systems. It consists of several interconnected windows:

- Problem Editor (6-16b.swf):** This window shows a geometry problem involving a parallelogram ABDE. The problem text states: "Using the information in the problem, answer questions in the table below: Shape ABDE is a parallelogram, that means segment AB and DE are parallel to each other, and BD and AE are parallel to each other as well. Using this information, solve the following question." The diagram shows a parallelogram with vertices A, B, D, and E. Side AB is labeled 14 cm, and side AE is labeled 6 cm. A table for questions is also present.

	Base	Side adjacent to the base	Other base	Other side adjacent to the base	Perimeter of parallelogram ABDE
Unit	cm	cm	cm	cm	cm
Diagram Labels	AE	AB	BD	ED	---
Question 1					
Expression	S	T			
- Variable Viewer:** This window displays the current state of variables in the tutor. It includes a table with columns for Variable and Value.

Variable	Value
Q1	Question 1
Q2	TRUE
Q3	FALSE
col1.Unit1	cm
col2.Unit2	cm
col3.Unit3	cm
col4.Unit4	cm
col5.Unit5	cm
col1.Heading1	Base
col2.Heading2	Side adjacent...
col3.Heading3	Other base
- Behavior Recorder:** This window shows the flow of the tutoring process, including states (e.g., state26, state27, state29, state33, state1) and actions (e.g., selection[0], action[0], input[0]). It also includes a section for editing hint and success messages, such as "Please Edit Hint Message 1: Enter the length of the parallelogram's base here. Not sure which segment is the base? What is the label of the base segment?".

Aleven, V., McLaren, B. M., Sewall, J., & Koedinger, K. R. (2009). A new paradigm for intelligent tutoring systems: Example-Tracing tutors. *International Journal of Artificial Intelligence in Education*, 19(2), 105-154.

Tutors supported by CTAT

- Cognitive Tutors
 - Use rule-based cognitive model to guide students
 - Difficult to build; for AI programmers
 - Can handle problems with a large solution space (e.g., algebra, computer programming)
- Example-Tracing Tutors
 - Use generalized examples to guide students
 - (Relatively) novel ITS technology
 - Much easier to build; for non-programmers
 - For problem types with a limited number of solution paths (there are many!)
 - End-user programming techniques: Programming by demonstration

Vote-with-your-feet evidence of CTAT's utility

- Over 500 CTAT users in summer schools, courses, workshops, research, and tutor development projects
 - Domains: mathematics, chemistry, genetics, French culture, Chinese, ESL, thermodynamics
 - At least 44 research studies used CTAT to build tutors and deploy them in real educational settings
- In the past two years
 - CTAT was downloaded 6,600 times
 - the CTAT website drew over 2.9M hits from 164k unique visitors
 - URL: <http://ctat.pact.cs.cmu.edu>

Some CTAT tutors used in online courses and research

In *S. cerevisiae*, which produces unordered tetrads, the following tetrad types were observed from this cross: trp5 cly8 X + + (t = trp5, c = cly8)

Type 1	Type 2	Type 3
t +	+ c	t c
t +	+ +	+ +
+ c	t +	t c
+ c	t c	+ +
141	925	232

Total = 1298

1) Classify Type 1 npd Type 2 tt Type 3 pd [Click here for a hint](#)

2) Totals PD Total 232 NPd Total 141 TT Total 925

3) Quantitative conclusions

PD = NPD
100% PD
NPD = 0
TT = 0
0 < TT < 2/3

PD >> NPD > 0
NPD > 0
TT = 2/3

4) Qualitative conclusions

Genes are tightly linked to each other
Genes are not tightly linked to each other
Both genes are tightly cen-linked
Both genes are cen-linked
One or both genes are not cen-linked

Genes are linked to each other
Linkage to cen cannot be determined

5) Map Distance Calculation (Choose one answer)

☐ $((1/2 * TT) / \text{Total}) * 100 \text{ cM}$

☒ $((1/2 * TT + 3 * NPD) / \text{Total}) * 100 \text{ cM}$

☐ Map distance cannot be calculated

☐ Map distance between the genes is 0

☐ M.D. between each gene and its cent. is 0

Enter an expression for calculating the map distance you selected

$((1/2 * 925 + 3 * 141) / 1298) * 100$

[Click here when DONE](#)

Genetics

Stoichiometry Tutor | [Help](#)

Problem Statement

Suppose the WHO recommended limit for arsenic in drinking water is equal to 0.000014 grams of arsenite (AsO₂⁻) / L solution. To determine the concentration of arsenite in a solution sample that is safe, one needs to check it against the WHO recommendation. How many grams of arsenite (AsO₂⁻) / L solution are in a sample with 0.58 moles of arsenite (AsO₂⁻) in 100 kiloliters (100 kL) of solution? The result should have 2 significant figures. (Hint: the molecular weight of arsenite (AsO₂⁻) is 106.9 g AsO₂⁻ / mol AsO₂⁻.)

Problem

#	Units	Substance	#	Units	Substance	#	Units	Substance	#	Units	Substance	Result
0.58	mol	AsO ₂ ⁻	1	kL	solution	1.06	---	---	---	---	---	---
100	kL	solution	1000	L	solution	---	---	---	---	---	---	---

Reason

Given Value Unit Conversion

[Done](#)

Hint: The goal is to convert the amount of substance in moles to grams by using molecular weight

[Next >](#)

Chemistry

Bonjour - Mozilla Firefox

File Edit View History Delicious.us Bookmarks Tools Help

https://oll.web.cmu.edu/course/workbook/activity/page/contextid=b47253e80020c6900d51fca090e5

openlearninginitiative

Elementary French 1 Online - Open and Free

HELP TRY ANOTHER COURSE! Not logged in

Syllabus Course Materials

Test and Configure Email this page Link to this page

Module 1: Départ > Se présenter > Communication 1 > Bonjour 1 2 3

Bonjour

Listen to the sentence, then drag each word to its correct position

Listen

merci Très bien et vous?

[Check](#)

Module 1: Départ > Se présenter > Communication 1 > Bonjour 1 2 3

Syllabus Open Learning Initiative

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oll.web.cmu.edu

Transferring data from oll.web.cmu.edu...

oll.web.cmu.edu

Open Notebook

French

Some CTAT tutors used in research

Thermo-dynamics

The "Chocolate Problem"

You have 1/2 of a chocolate bar. Write this as a fraction in three different ways! Before you do this, please explain the steps you need to do to convert a fraction.

First, multiply the numerator with a number > 1.

multiply the denominator with the same number

This Number Line will help you to solve the conversion problems. To set the number of sections on the line, enter a number in the Divisions field.

1/2 = 2/4

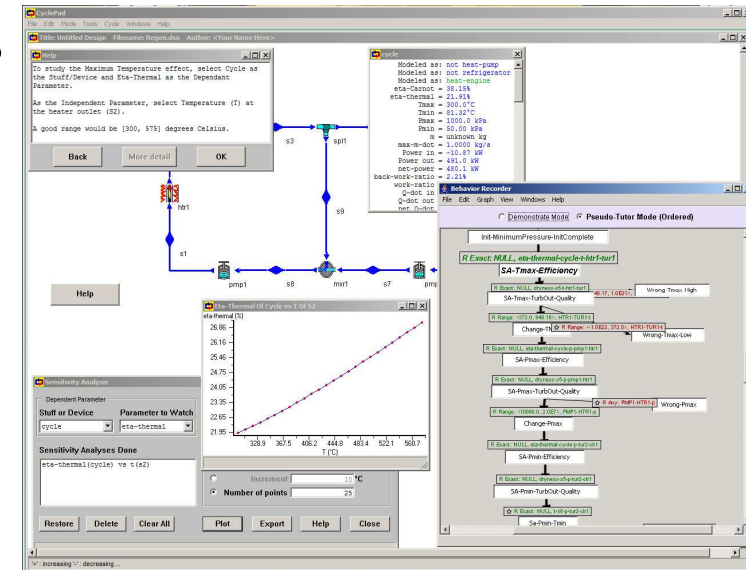
1/2 = 3/6

1/2 = 8/16

No, this is not correct. Think back - what is the denominator and what is the numerator in the fraction?

Elementary Math

French (intercultural competence)



Now that you've seen the result...

Was your prediction correct?

yes

no

close but not quite

In this clip from the end of the school year, the two oldest students are about to hear the results of their exams and whether they will move on to middle school the following year.

Continue

Mathtutor: free web-based tutors for middle-school math

Vincent Aleven, Bruce McLaren

mathtutor
A free site where middle-school students learn math

Returning?
Username:
Password:
Login

Your session has expired

Would you like to know more about Mathtutor or sign up your class or after-school program to use the Mathtutor

Try a tutor for decimal addition or proportional reasoning

With Mathtutor, middle school students learn math by doing: they solve math problems and study interactive examples. Intelligent software tutors provide step-by-step help and feedback.

Teachers can create class lists, assign work to an entire class or an individual student, and view reports of student progress.

Mathtutor is free to use for any student or teacher.

The math content aligns with state and national standards and is categorized by standard. Over the next two years, we will add content covering the following strands:

- Number and Operations
- Algebra
- Geometry
- Measurement
- Data Analysis and Probability

The intelligent software tutors on the site are based on a rich history of research in human learning. They were built at Carnegie Mellon University using the Tutor Authoring Tools.

Mathtutor is supported by a grant from the US Department of Education.

Problem Set

Problem Set	Progress	Avg Time	Correct %	Hints %	Errors %
6.1.7 Combinations	100%	00:03:31	98%	1%	1%
6.2.8 Proportions	0%	00:00:00	0%	0%	0%
6.2.8 Proportions	22%	00:08:45	53%	25%	23%
6.2.1 Fractions, Decimals, and Percents II	0%	00:00:00	0%	0%	0%

Class Progress

Bill's 6th-Grade class

Bill's 7th-Grade Class

New 6th-grade class

Trunk on pact-cv1
Revision 2126M - Updated 20090423 16:04
Copyright © 2009 Carnegie Mellon University, All Rights Reserved

How do I use

Using the set of shapes in the picture, answer questions 1 through 4 in the table below.

	Number of Target Items	Total Number of Items	Unreduced Ratio	Ratio out of 100	Percent	Decimal	Reduced Fraction
1	20	20	1/20	5/100	5	.05	1/20
2	20	20	8/20	40/100	40	0.40	4/10
3	20	20					
4	20	20					

Hint: To make the unreduced ratio, 8/20, a reduced fraction, first find the greatest common factor of the numerator and the denominator.

<http://mathtutor.web.cmu.edu>

Use of CTAT Tutors in Research

Learning Fractions by Yourself and with a Peer

How can complementary strengths of individual and collaborative learning best be combined?



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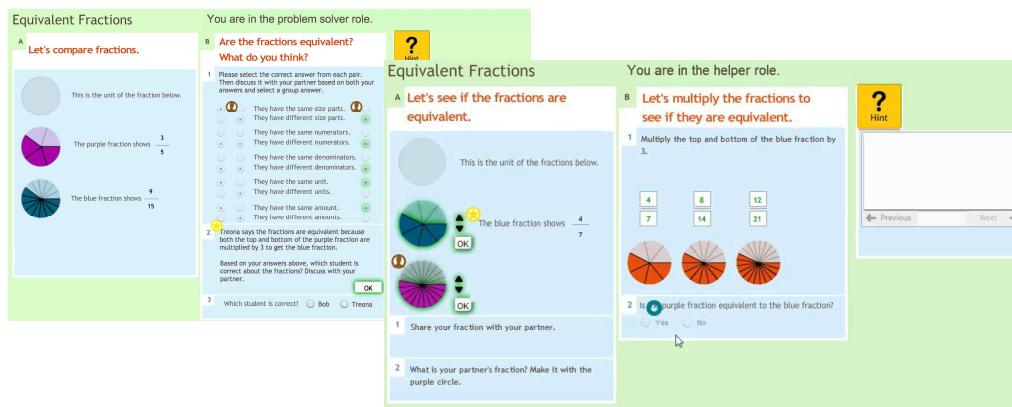
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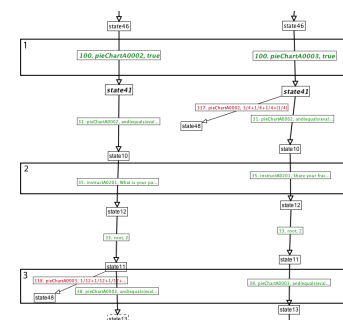
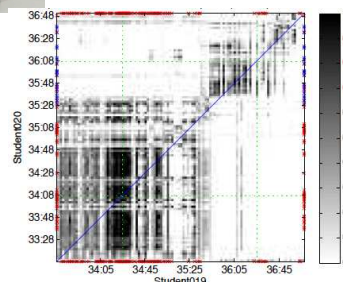
Mike Ringenberg



Fractions Tutor:
intelligent tutoring system
for 4th and 5th grade
fractions learning used as
platform for the research



Dual eye tracking:
Gaze convergence
to assess
collaboration



CTAT enhanced to support collaborative learning – dual synched tutors allow collaborators to have slightly different views of the same problem they work on

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CTAT Tutors in Research

Strategy use in linear equation solving

Log data: Students seldom use non-standard strategies

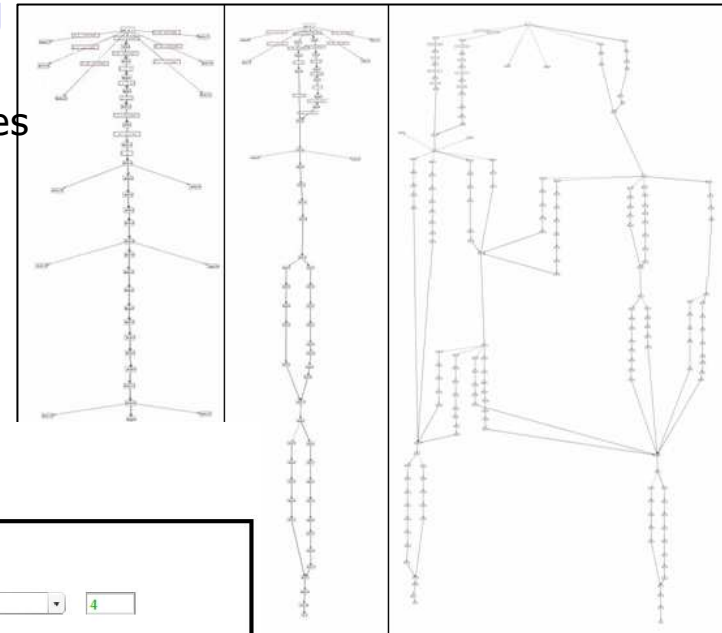
$2(x+1)$	$= 4$	
$2x + 2$	$= 4$	distribute
$2x$	$= 2$	move
x	$= 1$	divide

E.g., in $2(x+1) = 4$
Standard strategy
used 96% of the
time

Strict
Standard
Strategy

Flexible
Standard
Strategy

Multi-Strategy



=
 =

? Hint
 This is correct, but you must start with using the distributive property. Click on the 'Instructions' button to see the order of steps that you must use in these tutors.
i Instructions
 Previous Next



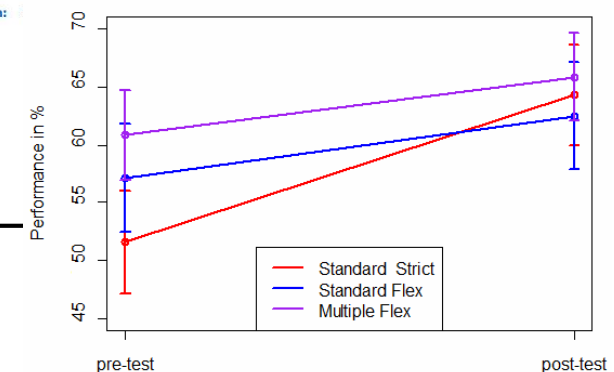
Waalkens, M., Aleven, V., & Taatgen, N. (2013). Does supporting multiple student strategies lead to greater learning and motivation? Investigating a source of complexity in the architecture of intelligent tutoring systems. *Computers & Education*, 60(1), 159–171.

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divide both sides by [?]
 Solution:

? Hint
 Instructions
 Previous Next

Performance Procedural Items by Condition



In vivo study: Correct and incorrect worked examples in Algebra learning

Julie Booth, Ken Koedinger

Ben was asked to solve the following equation for x , and he made a WRONG first step to solve the problem. Look at his first step.

$$2 = 5x - 3$$

$$2 = 2x$$

What did Ben do?

Added -3 to 5x

Added -3 to 5x

Add

Why is that a WRONG step for Ben to take?

It is illegal because

choose one...

choose one...

equality was not preserved

it combines terms that are not like terms

it performs the operation to only one side of the equation

it moved a term without changing the sign

the math was not correct

Hint

Incorrect worked example with self-explanation prompt, built with CTAT

Ben was asked to solve the following equation for x , and he made a GOOD first step to solve the problem. Look at his first step.

$$3 = 2x - 7$$

$$10 = 2x$$

What did Ben do?

Choose One... Choose One... Choose One...

Add

Why is that a GOOD step for Ben to take? Please answer both why it was a LEGAL and a HELPFUL step.

It is legal because

Choose One...

Add

It is helpful because

choose one...

Add

Hint

Correct worked example with self-explanation prompt, built with CTAT

Study Design

Self-Explanation of Correct Examples

Self-Explanation of Incorrect Examples

	No	Yes
No	Control	Typical
Yes	Corrective	Typical + Corrective (half of each)

CTAT tutors interleaved with Carnegie Learning Cognitive Tutor

Booth, J. L., Lange, K. E., Koedinger, K. R., & Newton, K. J. (2013). Using example problems to improve student learning in algebra: Differentiating between correct and incorrect examples. *Learning and Instruction*, 25, 24 - 34.

doi:10.1016/j.learninstruc.2012.11.002

Take-Home Messages

- Cognitive Tutors
 - Practical application of cognitive science that demonstrably improves student learning in schools and has been commercially successful
 - Combination of cognitive theory, cognitive task analysis, cognitive modeling, AI technology, and math education expertise
 - Provides individualized, detailed guidance during complex problem solving
- Cognitive Tutors can support self-assessment and self-explanation effectively
 - Good to include metacognition and self-regulated learning in the theoretical perspective
- Non-programmer tools reduce authoring time and cost
 - Used widely for research purposes



