

Introduction to Student Modeling and Bayesian Knowledge Tracing

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ASISTEMBE

Analytics, Simulations and Inquiry in STEM and Business Education
Research Group

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- Where is Student modeling being used?

did I get this

Here are the number of hours that 9 students spend on the computer on a typical day:

1 6 7 5 8 5 11 12 15

What is the median number of hours spent on the computer?

☐ 5
 ☐ 6.5
 ☐ 7
 ☐ 7.5
 ☐ 8

[Reset this Activity](#)

Image from the Statistics and Probability Course from the Open Learning Initiative

Student modeling and its context

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Here are the number of hours that 9 students spend on the computer on a typical day:

1 6 7 5 8 5 11 12 15

What is the median number of hours spent on the computer?

☒ 5 ☐ 6.5 ☐ 7 ☐ 7.5 ☐ 8

✗ Incorrect. This is the mode, or the most frequently occurring number. The median is the middle most number, $(n + 1)/2$, in an ordered list of values.

[Reset this Activity](#)

Image from the Statistics and Probability Course from the Open Learning Initiative

Student modeling and its context

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1 6 7 5 8 5 11 12 15

What is the median number of hours spent on the computer?

☐ 5 ☐ 6.5 ☒ 7 ☐ 7.5 ☐ 8



Correct. After you order the data, since $n = 9$, the median is $(9 + 1)/2 = 5$, or the 5th observation in the ordered list, which in this case is 7.



[Reset this Activity](#)

Image from the Statistics and Probability Course from the Open Learning Initiative

Student modeling and its context

Analyze real world problem scenarios

Tracked by knowledge tracing

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Cognitive Tutor Algebra I

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SysFB09

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.

1. 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?
2. 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?
3. 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

Grapher

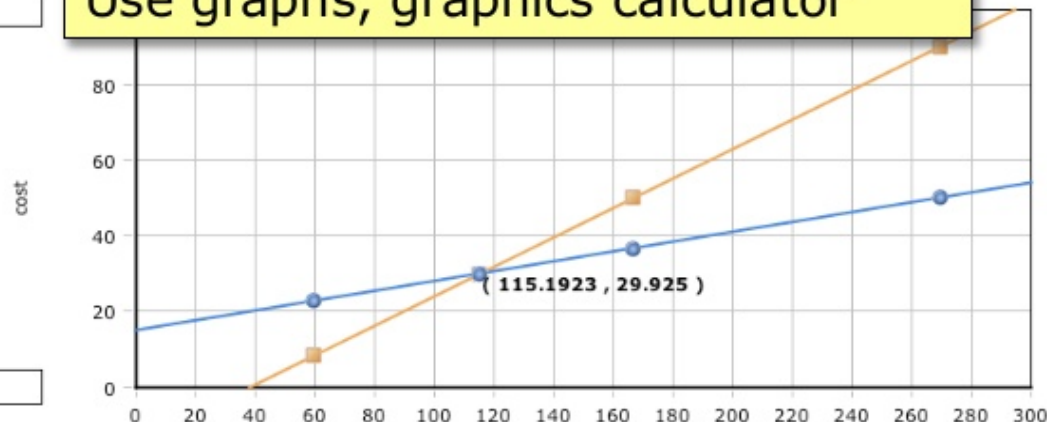
X Interval

20

Y Interval

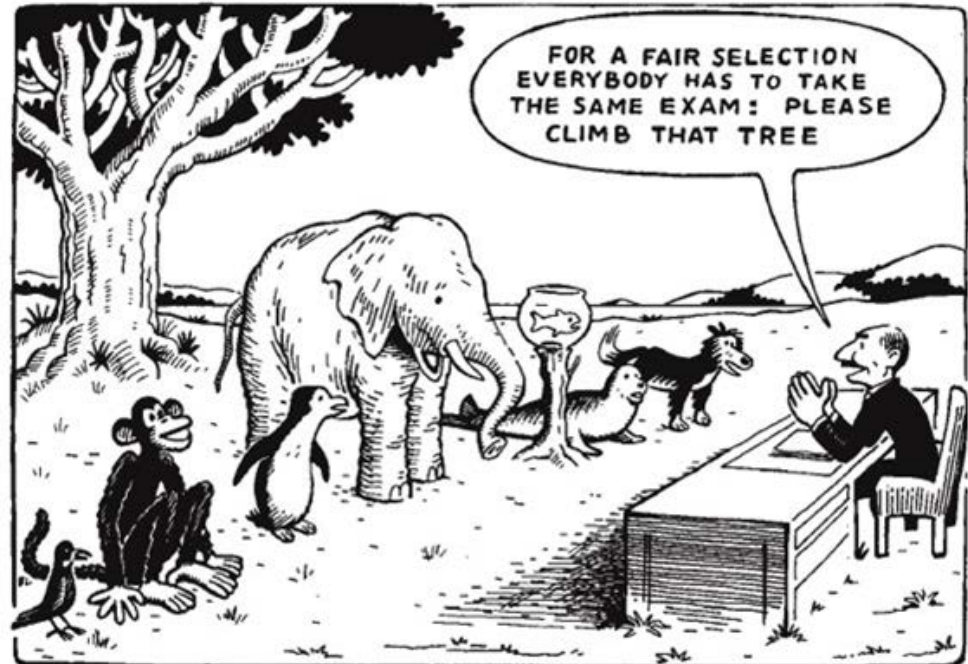
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Use graphs, graphics calculator

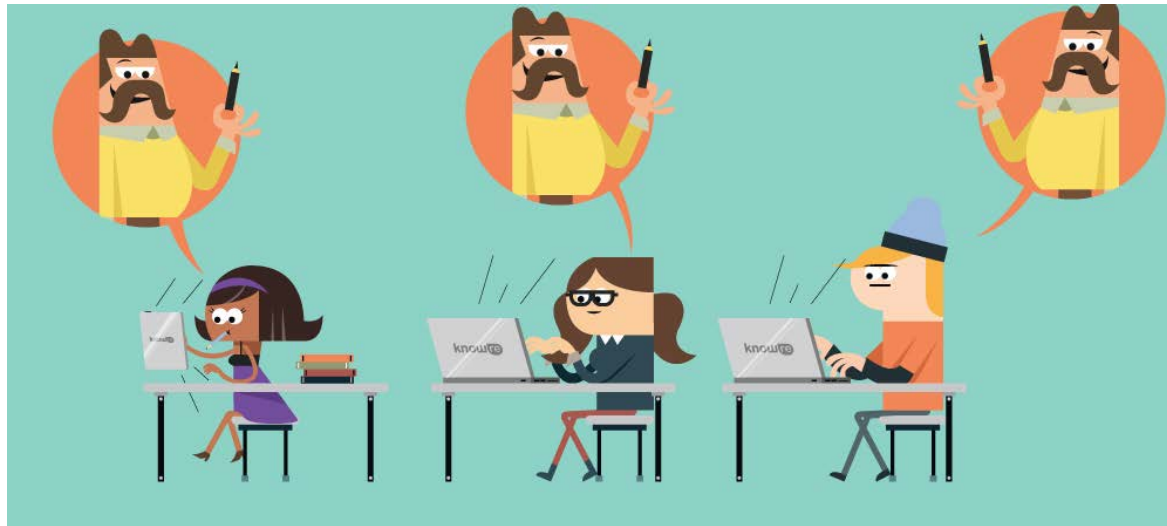


ITS detect and fit to individual differences in:

- student knowledge,
- engagement, and
- motivation,



Student modeling and its context



The area of study covering the set of tools and techniques to achieve this assessment is
student modeling

Student modeling and its context

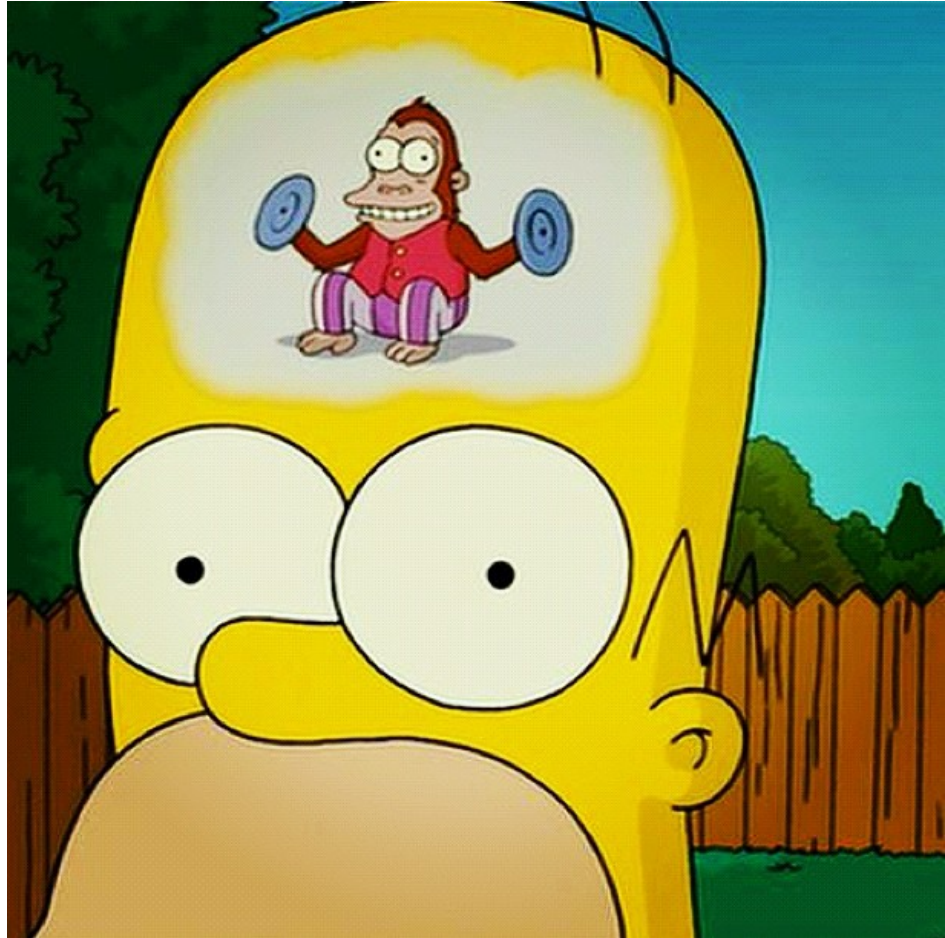



**NO
WHATSAPP
EXAM
TIME
NOW! >_<**



Student modeling and its context

... while student performance is observable, student knowledge remains latent.



Student modeling and its context

Knowledge Component

A skill or knowledge component is a description of a mental structure or process that a learner uses, alone or in combination with other knowledge components, to accomplish steps in a task or a problem.

(Koedinger et al, 2012)

Student modeling and its context

- **Student Models**

- Bayesian Knowledge Tracing (BKT)

- Corbett, Anderson, 1995

- Performance Factors Analysis (PFA)

- Pavlik, Cen, Koedinger, 2009

- ELO Rating System

- Pelánek, 2014

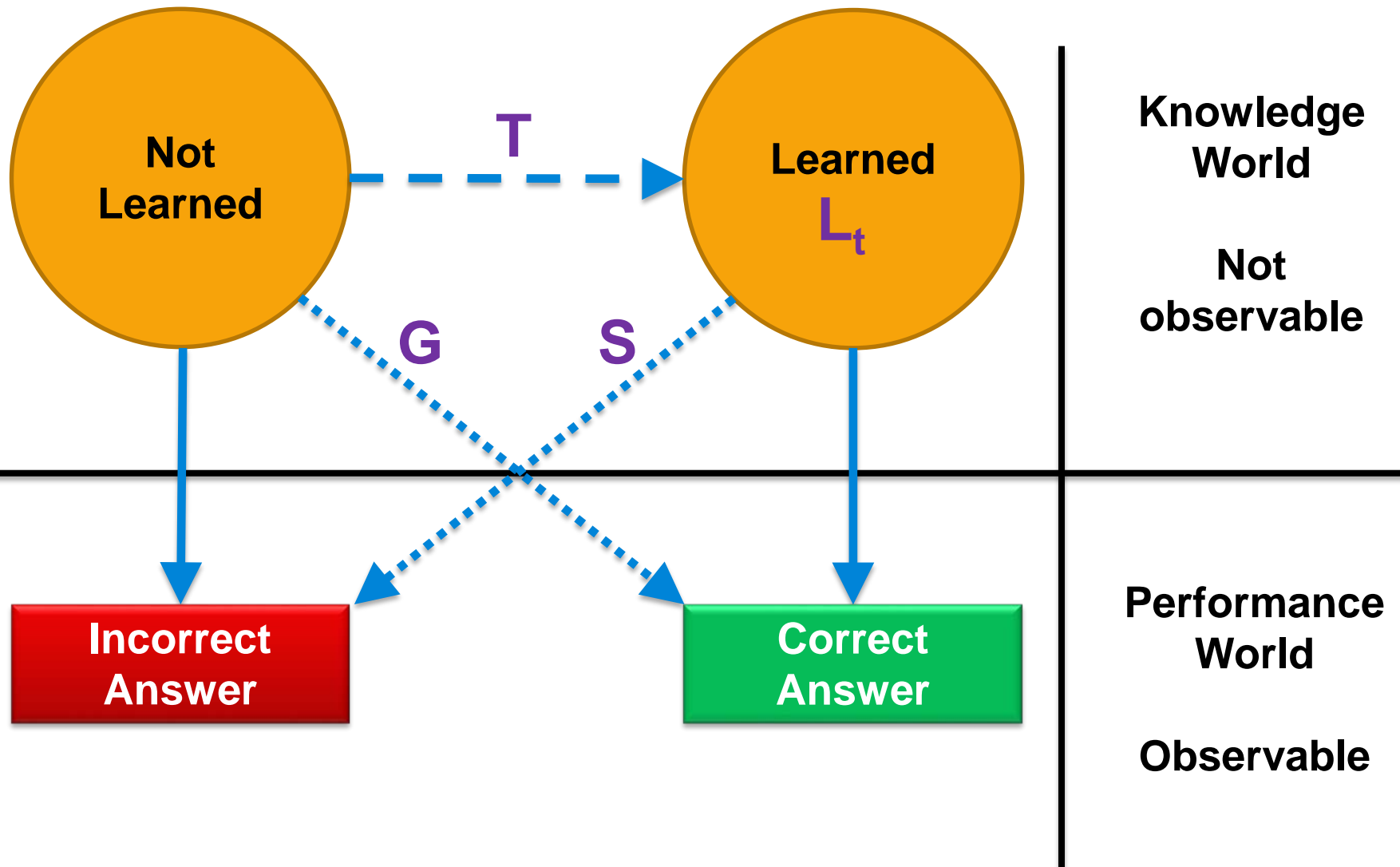
- Item Response Theory

- ...

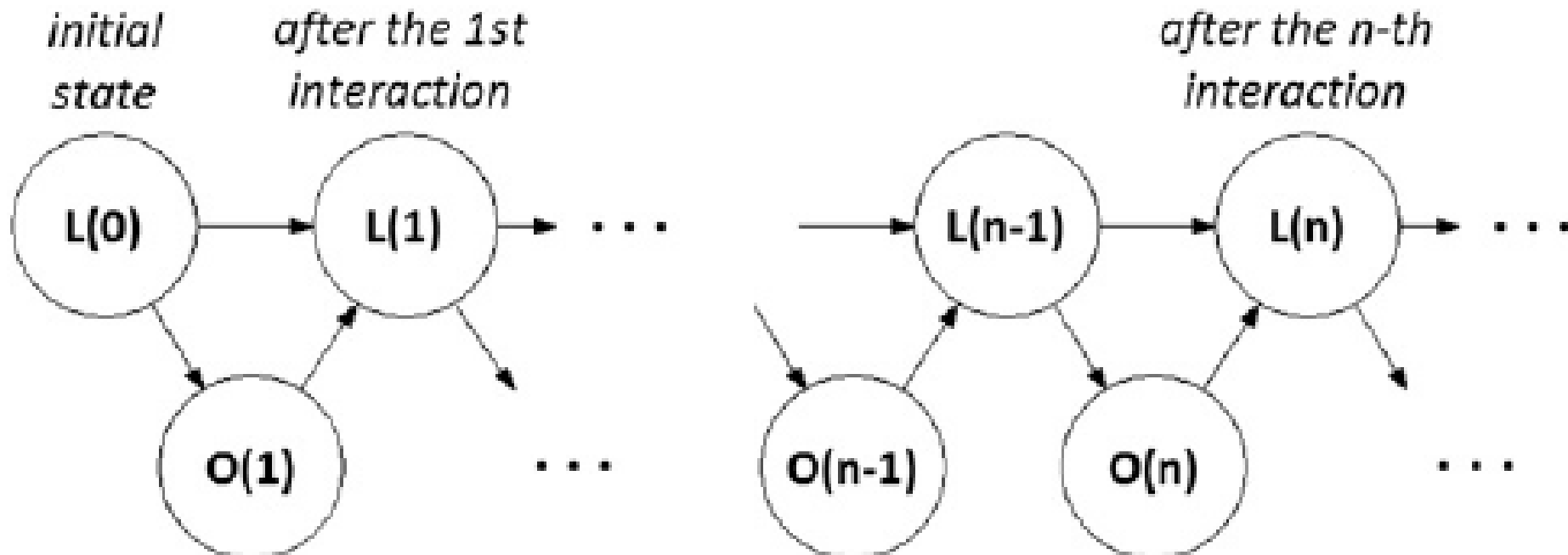
Student modeling and its context

Bayesian Knowledge Tracing (BKT)

- BKT is a model used to infer student's knowledge given their history of responses to problems and can be used to predict future performance.
- BKT is a two state Hidden Markov Model, these states being the one in which the student knows a given skill, and the one where the student does not. Once the student knows a skill, it will not be forgotten
- Usually, a separate BKT model is fit for each skill and only the first attempt at each question is taken for each student.



- ... So in general ...



$$P(L_{t-1}|Correct_t) = \frac{P(L_{t-1}) \cdot (1 - S)}{P(L_{t-1}) \cdot (1 - S) + (1 - P(L_{t-1})) \cdot G} \quad \text{Eq. 1}$$

$$P(L_{t-1}|Incorrect_t) = \frac{P(L_{t-1}) \cdot S}{P(L_{t-1}) \cdot S + (1 - P(L_{t-1})) \cdot (1 - G)} \quad \text{Eq. 2}$$

$$P(L_t) = P(L_{t-1}|Action_t) + (1 - P(L_{t-1}|Action_t)) \cdot T \quad \text{Eq. 3}$$

$$C_{t+1} = P(L_t) \cdot (1 - S) + (1 - P(L_t)) \cdot G \quad \text{Eq. 4}$$

Where,

- L_0 , the probability a student knows the skill before attempting the first problem,
- T , is the transition probability at each practice opportunity,
- G , the probability of Guessing
- S , the probability of Slipping
- L_t is the probability of knowing a skill at the “time-attempt” point t
- C_{t+1} is the probability of answering correctly the next question

Skill: Calculate the median

$$L_0 = 0.25$$

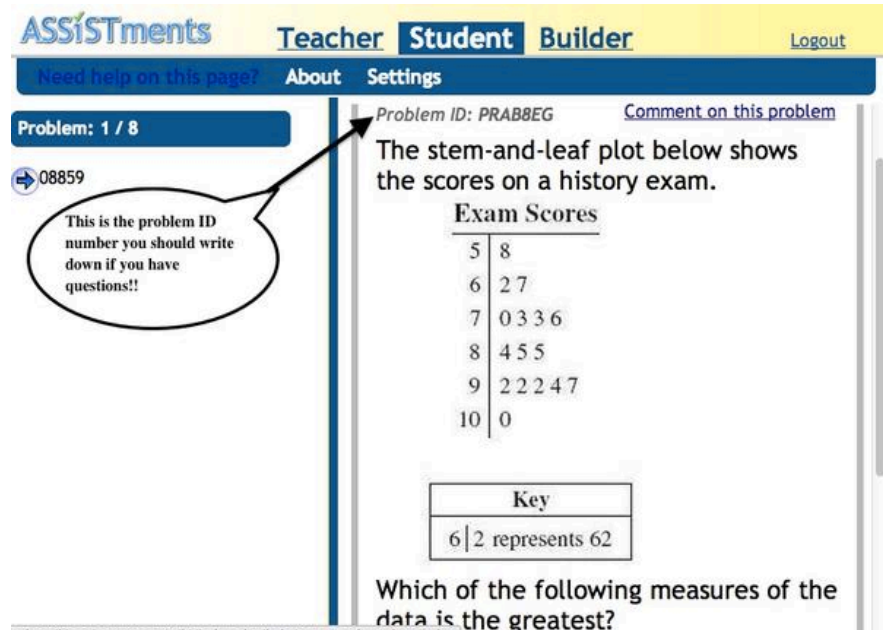
$$T = 0.2$$

$$S = 0.15$$

$$G = 0.1$$

| Student | Right | L_t | $P(L_{t-1} \text{Action}_t)$ | C_{t+1} |
|-----------|-------|-------|--------------------------------|-----------|
| Student 1 | 0 | | | |
| Student 1 | 1 | | | |
| Student 1 | 1 | | | |
| Student 1 | 0 | | | |
| Student 1 | 1 | | | |

- ASSISTments:**
[\(https://www.assistments.org/\)](https://www.assistments.org/) This intelligent tutor developed by the Worcester Polytechnic Institute is used by more than 600 teachers from 42 American states and 14 countries and their students solved 10^6 problems in 2015.

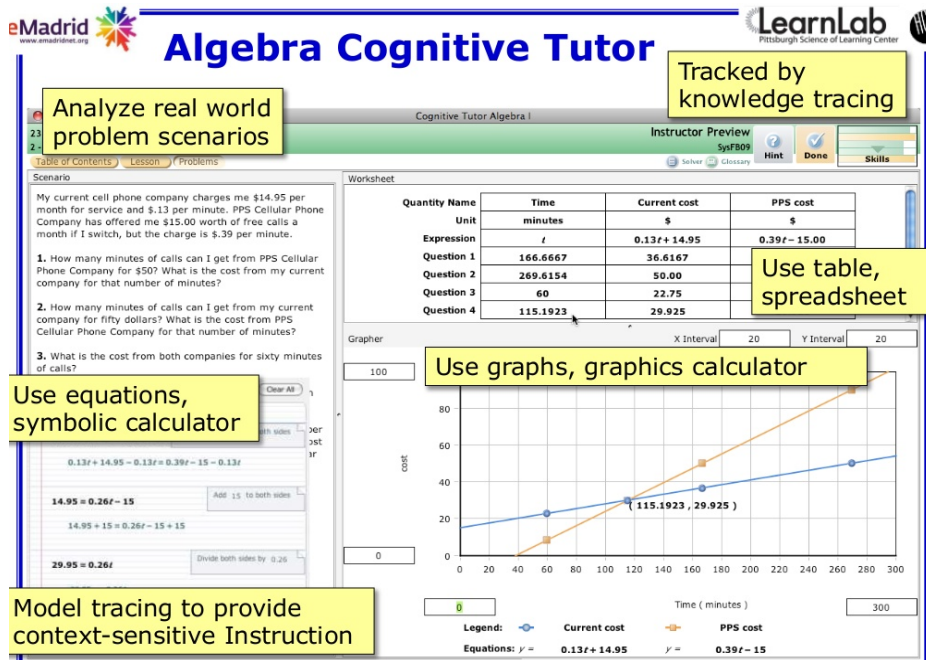


The screenshot shows the ASSISTments interface. At the top, there are tabs for 'Teacher', 'Student', and 'Builder', along with a 'Logout' link. Below these are links for 'Need help on this page?', 'About', and 'Settings'. The main content area displays 'Problem: 1 / 8' and a problem ID '08859'. A callout bubble points to the problem ID, stating: 'This is the problem ID number you should write down if you have questions!!'. The problem text reads: 'The stem-and-leaf plot below shows the scores on a history exam.' Below this is a stem-and-leaf plot titled 'Exam Scores'.

| Exam Scores | |
|-------------|-----------|
| 5 | 8 |
| 6 | 2 7 |
| 7 | 0 3 3 6 |
| 8 | 4 5 5 |
| 9 | 2 2 2 4 7 |
| 10 | 0 |

Below the plot is a 'Key' box containing the text: '6 | 2 represents 62'. At the bottom, a question asks: 'Which of the following measures of the data is the greatest?'.

Where is Student modeling being used?

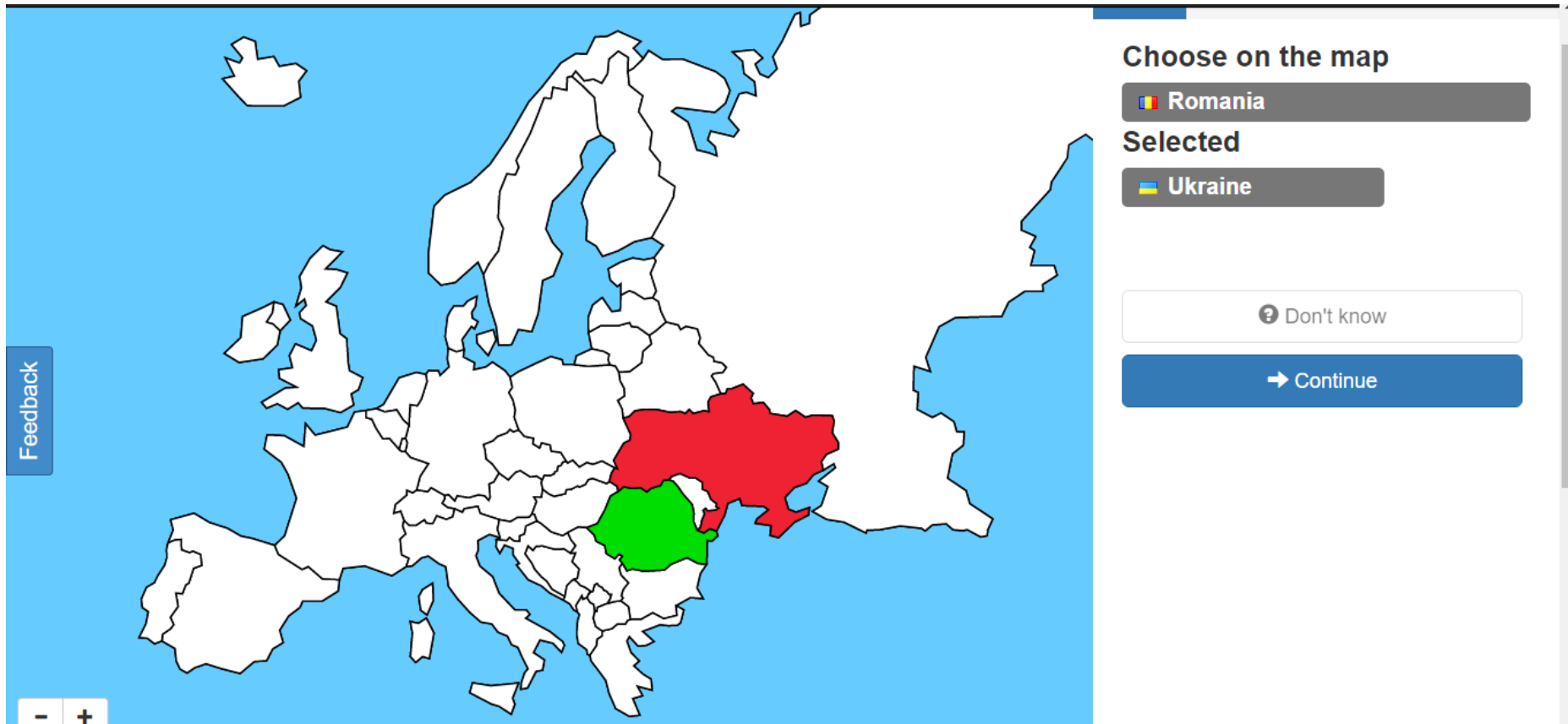


Cognitive tutors from Carnegie Learning Inc: Spin-off from Carnegie Mellon University

Over 500 000 students per year

The Algebra Tutor is being used by more than 17 000 students in 147 schools

Where is Student modeling being used?



Outline maps from Masaryk University Brno



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Thanks for your attention Questions?

Thanks for your support



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