ASISTEMBE

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

Introduction to Student Modeling and Bayesian Knowledge Tracing

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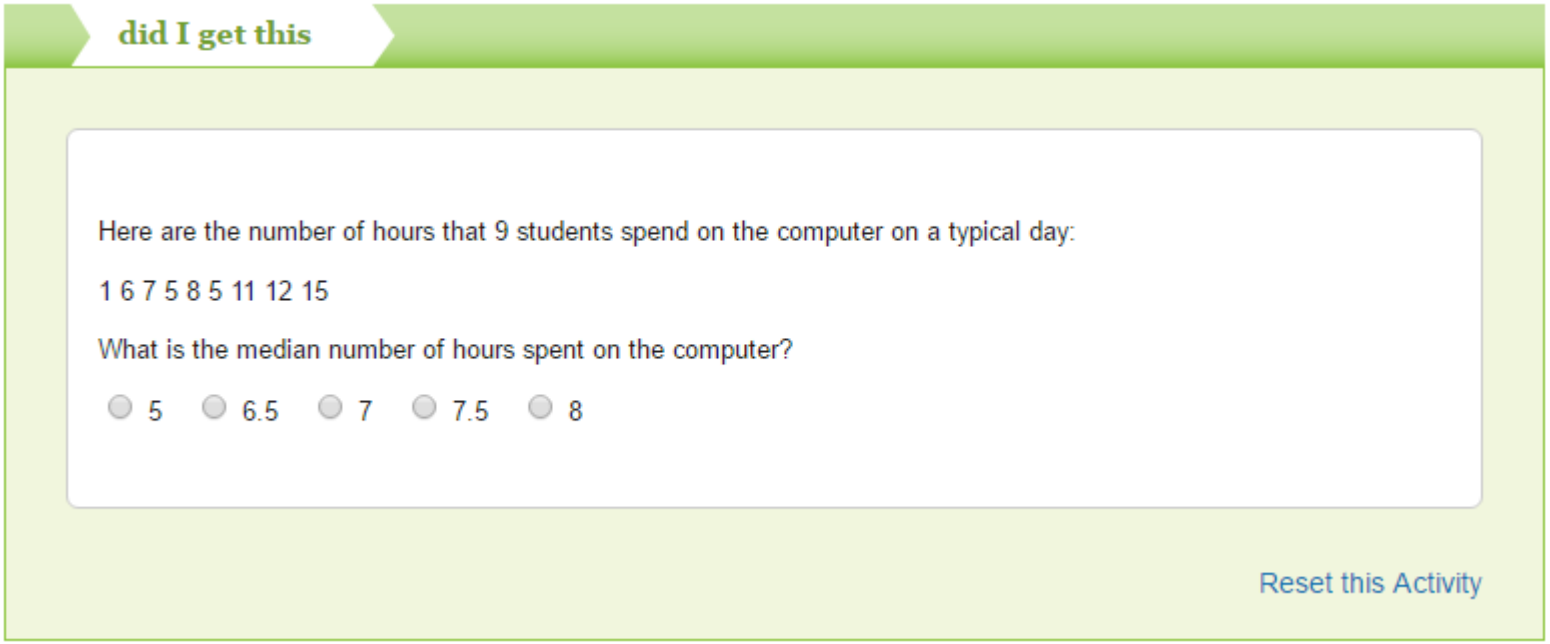
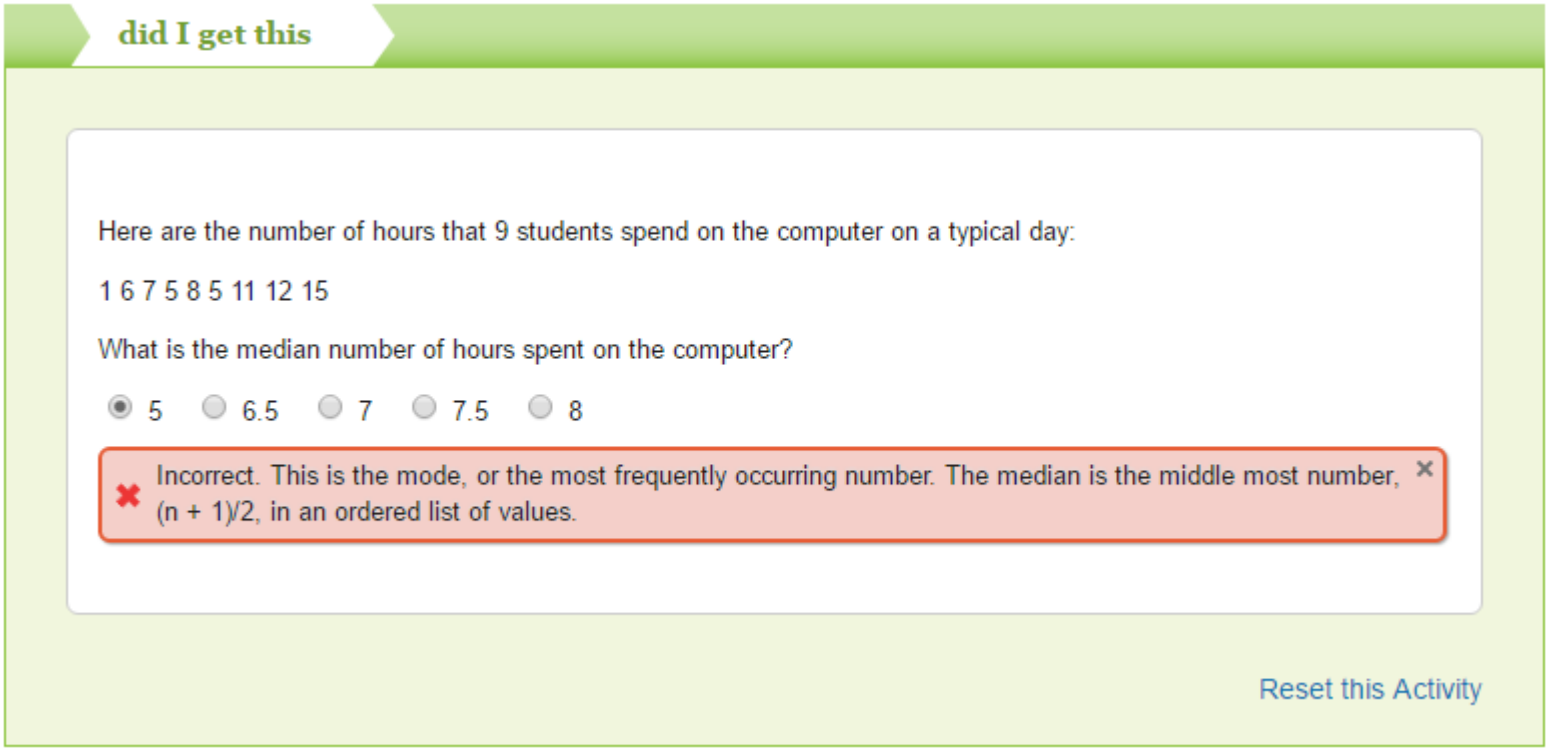


Image from the Statistics and Probability Course from the Open Learning Initiative

Student modeling and its context

- **Intelligent Tutoring Systems**



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Student modeling and its context

- **Intelligent Tutoring Systems**

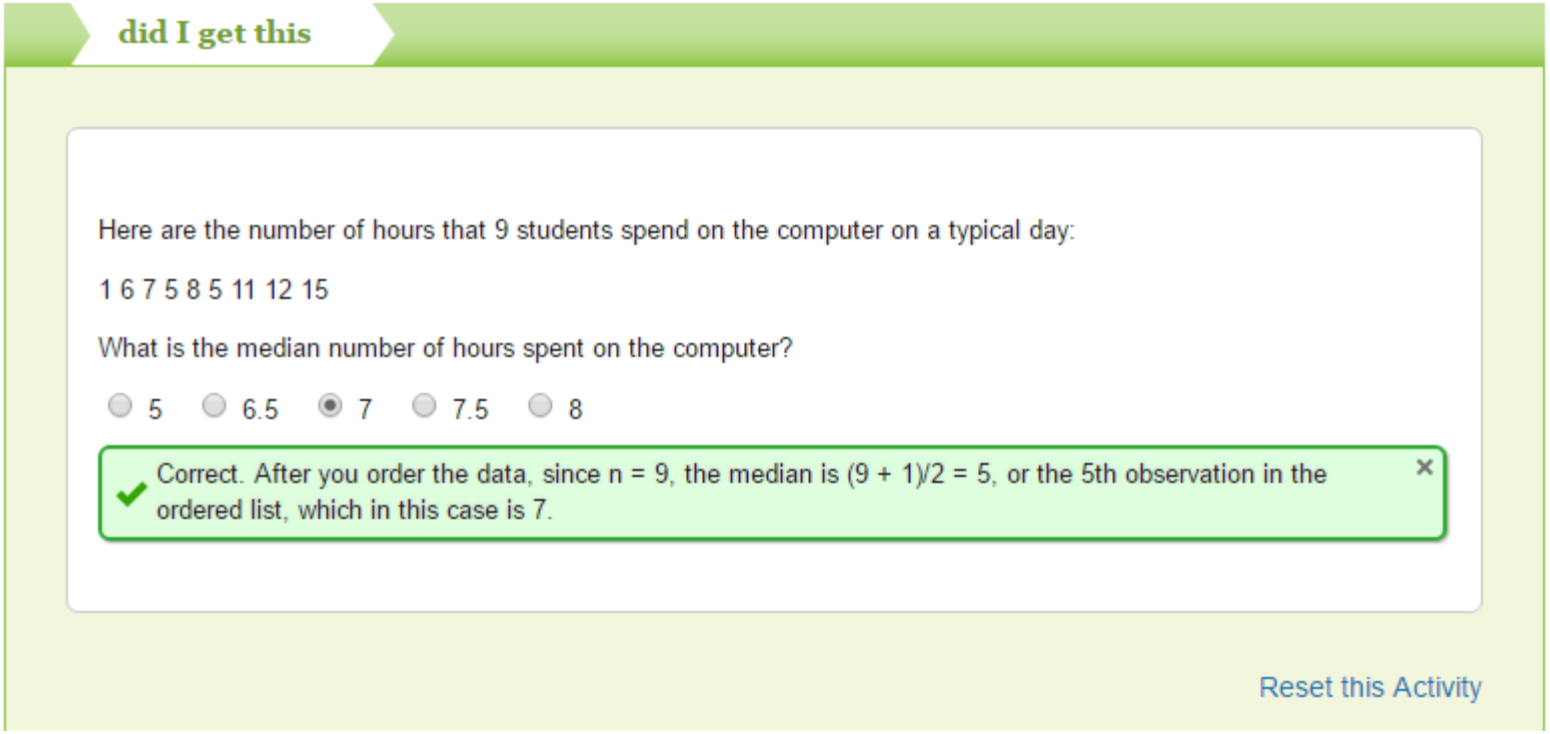


Image from the Statistics and Probability Course from the Open Learning Initiative

Student modeling and its context

Algebra Cognitive Tutor

Analyze real world problem scenarios

Tracked by knowledge tracing

Use table, spreadsheet

Use graphs, graphics calculator

Use equations, symbolic calculator

Model tracing to provide context-sensitive Instruction

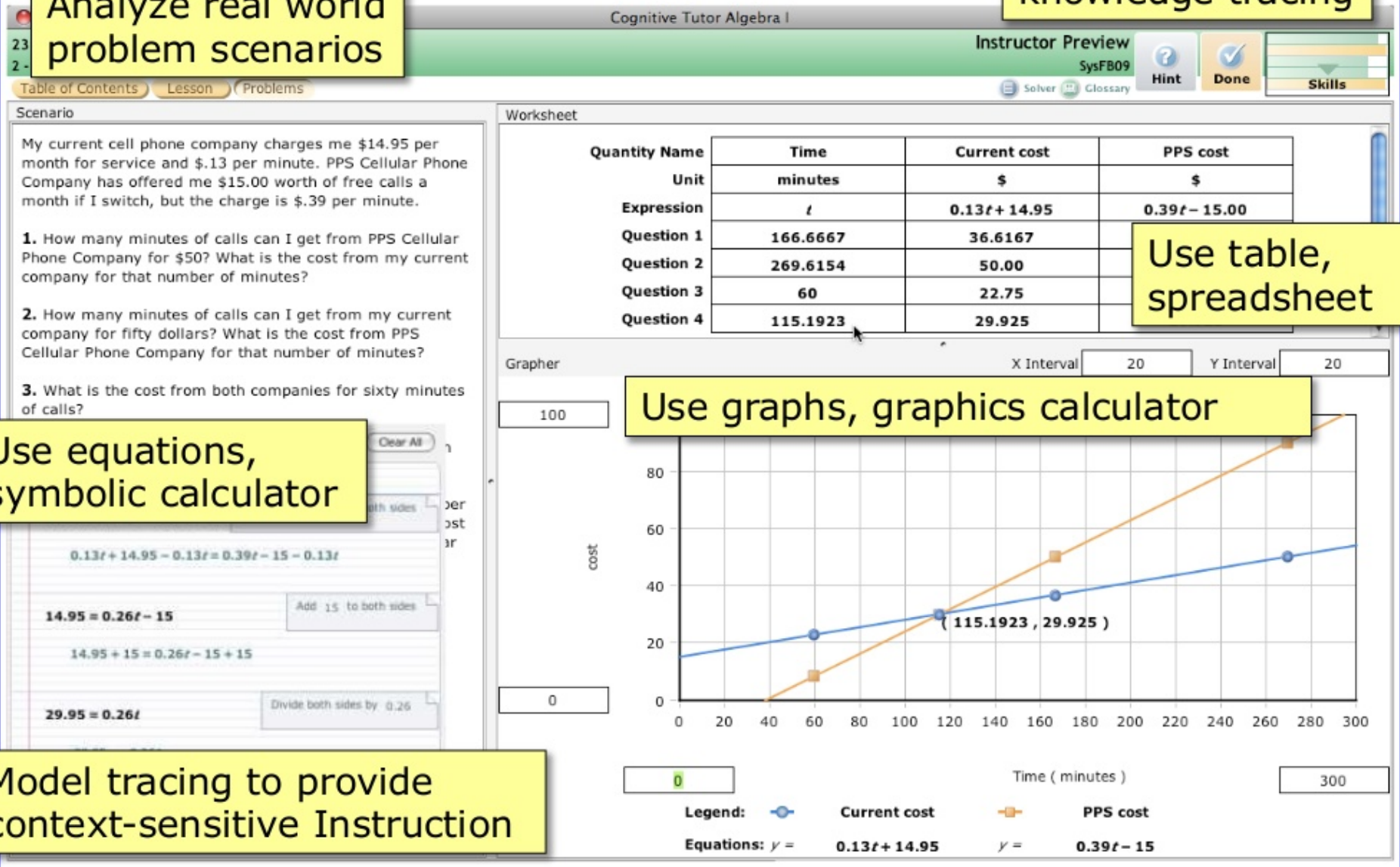
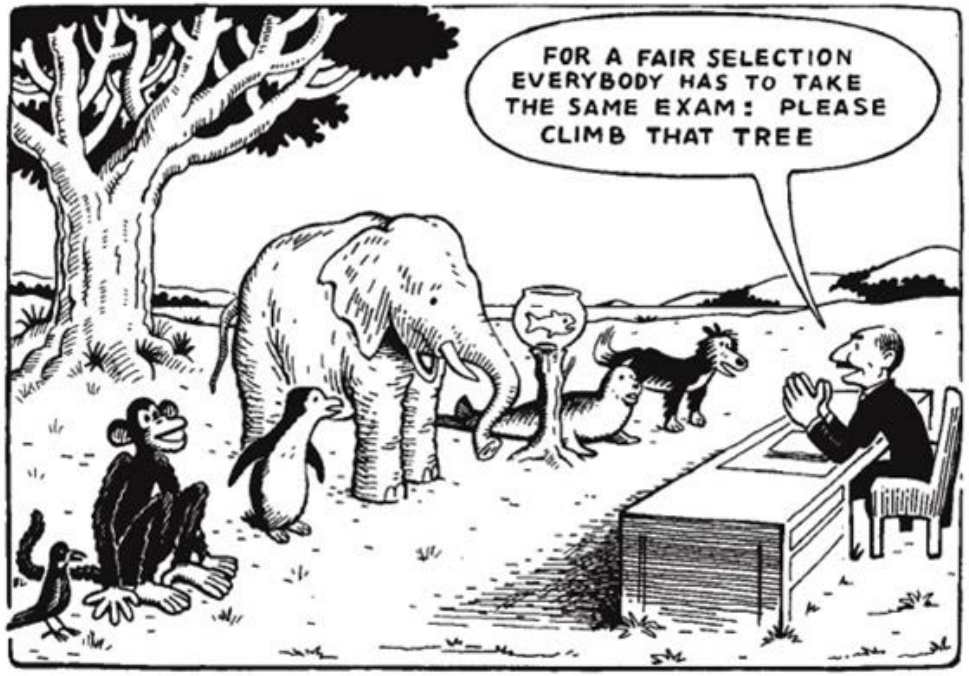


Image from V. Aleven, 2015 Supporting Self Regulated Learning with Intelligent Tutoring Systems

ITS detect and fit to individual differences in:

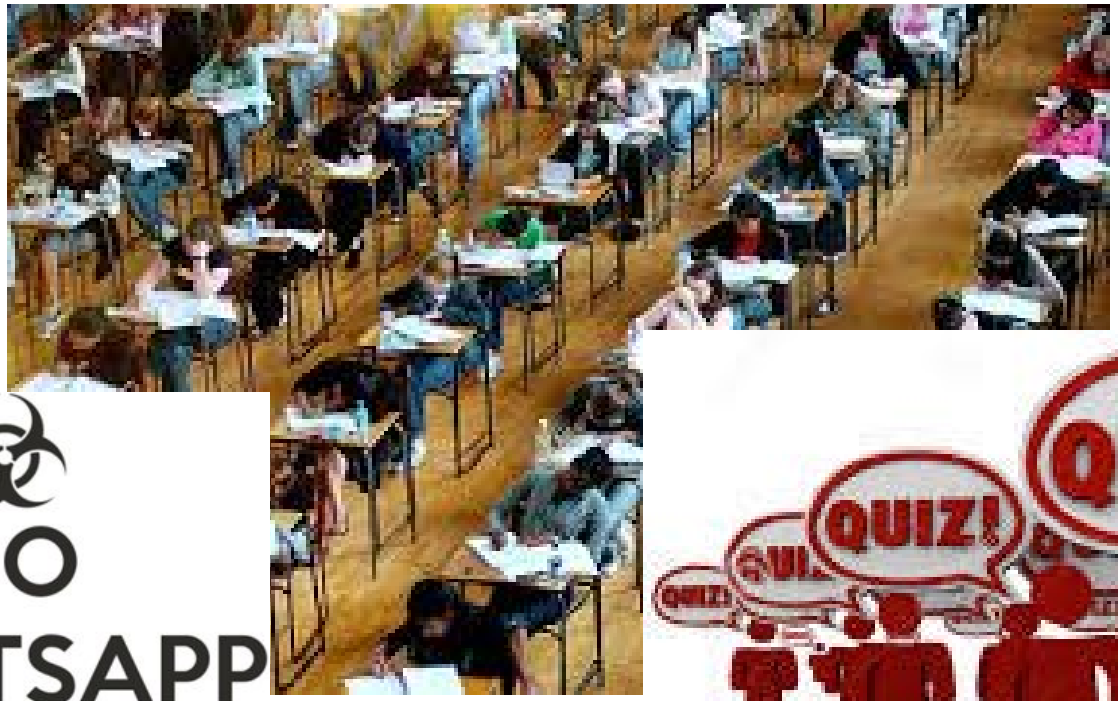
- student knowledge,
- engagement, and
- motivation,



Student modeling and its context

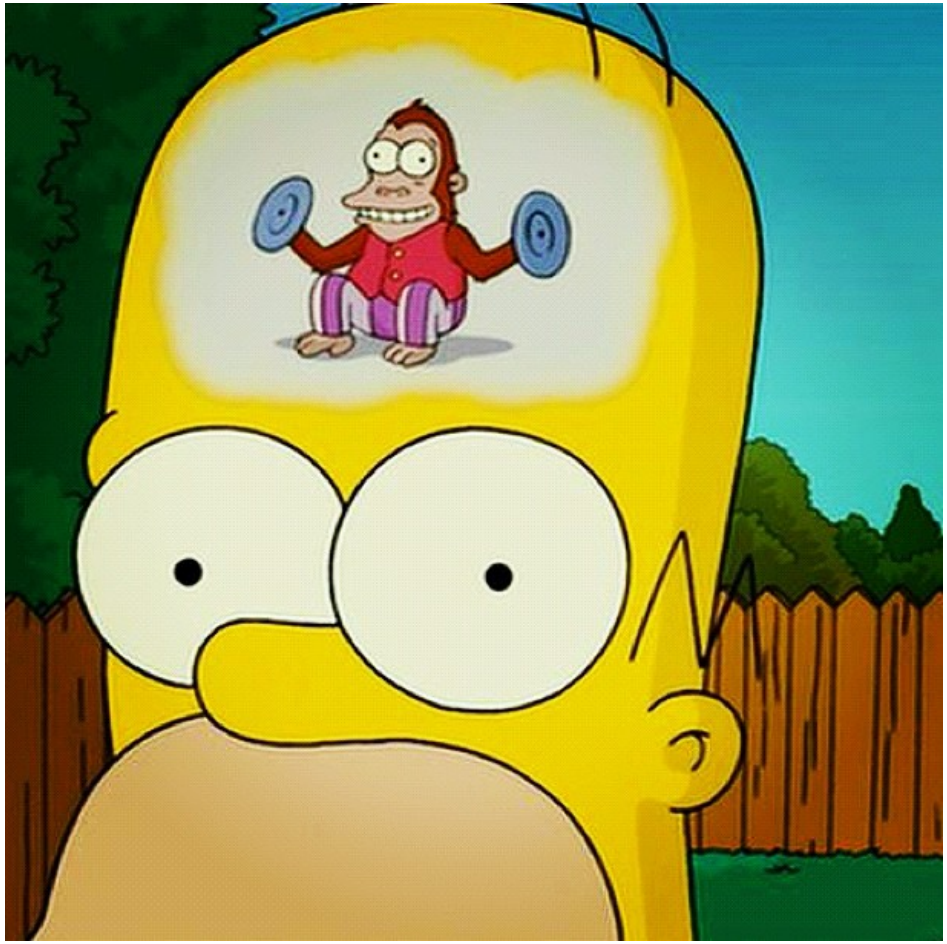
The area of study covering the set of tools and techniques to achieve this assessment is student modeling

Student modeling and its context



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

  ...

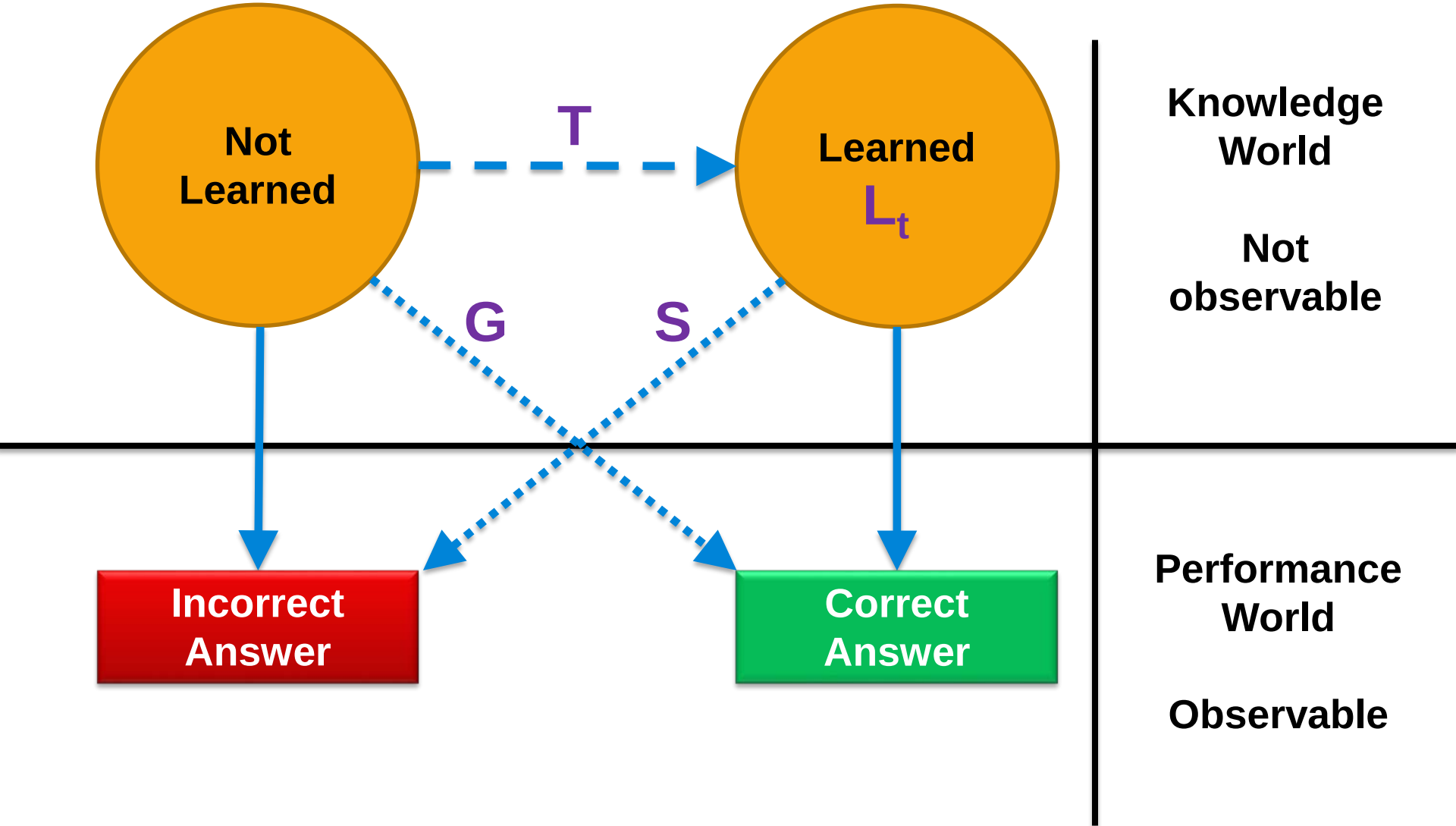
Student modeling and its context

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.


Not Learned
T
Learned
L_t
G
S
Incorrect Answer
Correct Answer
Knowledge World
Not observable
Performance World
Observable

- **... So in general ...**

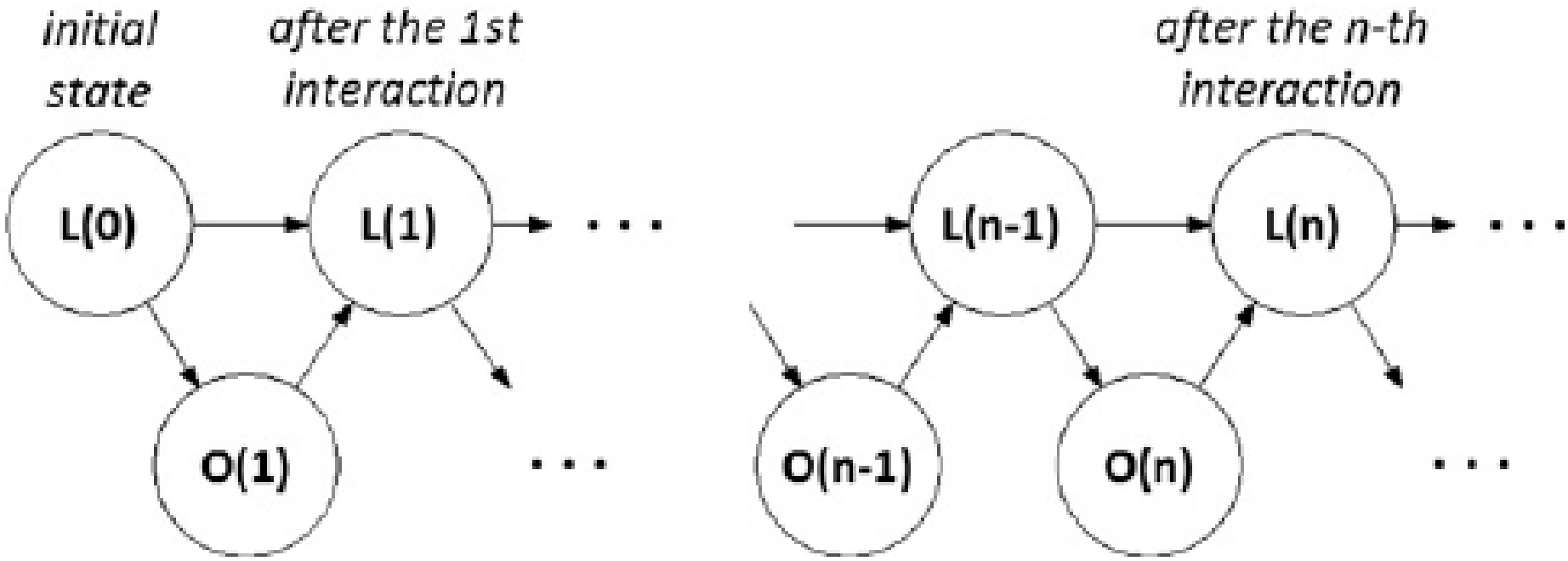


Image from Millan, Loboda, Perez-de-la-Cruz, 2010

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

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

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

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

Where,

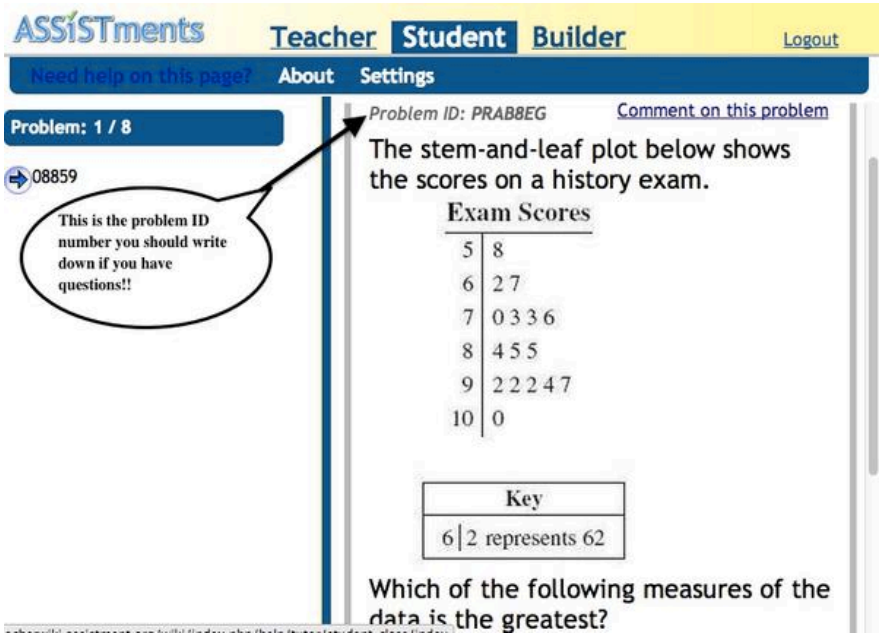
- L_0, the probability a student knows the skill before attempting the first problem,
- *T*, is the transition probability at each practice opportunity,
- *G*, the probability of Guessing
- *S*, the probability of Slipping
- L_t is the probability of knowing a skill at the “time-attempt” point t
- C_{t+1}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

Skill: Calculate the median

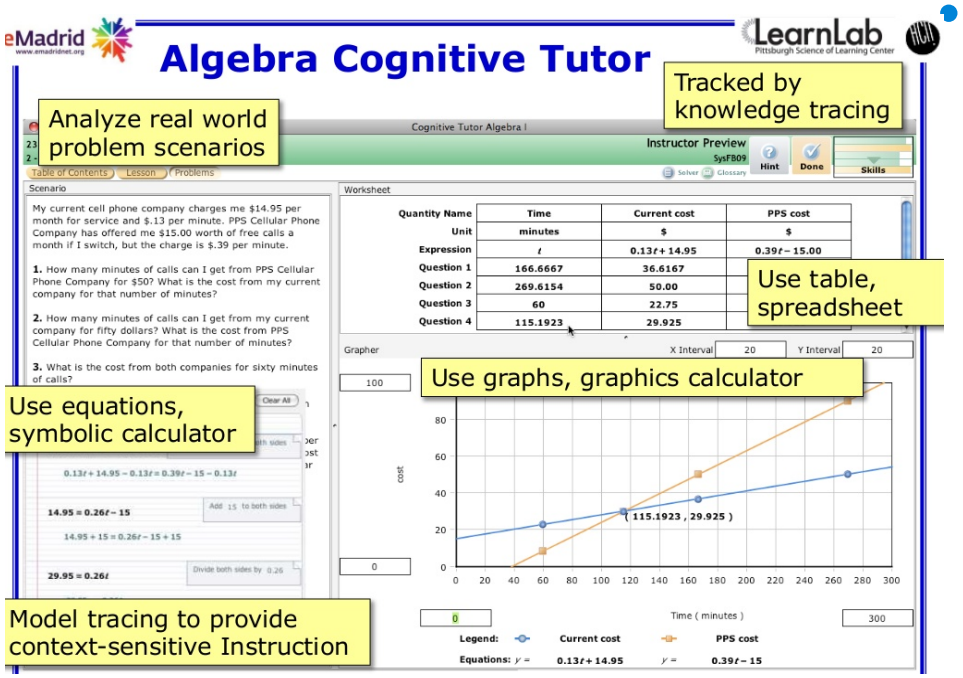
$L_0 = 0.25$	T = 0.2	S = 0.15	G = 0.1

Student	Right	L_t	$P(L_{t-1} \mid Action_t)$	C_{t+1}
Student 1	0	0,230	0,038	0,323
Student 1	1	0,714	0,642	0,685
Student 1	1	0,950	0,937	0,862
Student 1	0	0,752	0,690	0,714
Student 1	1	0,958	0,948	0,869

- **ASSISTments:** (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.



Where is Student modeling being used?



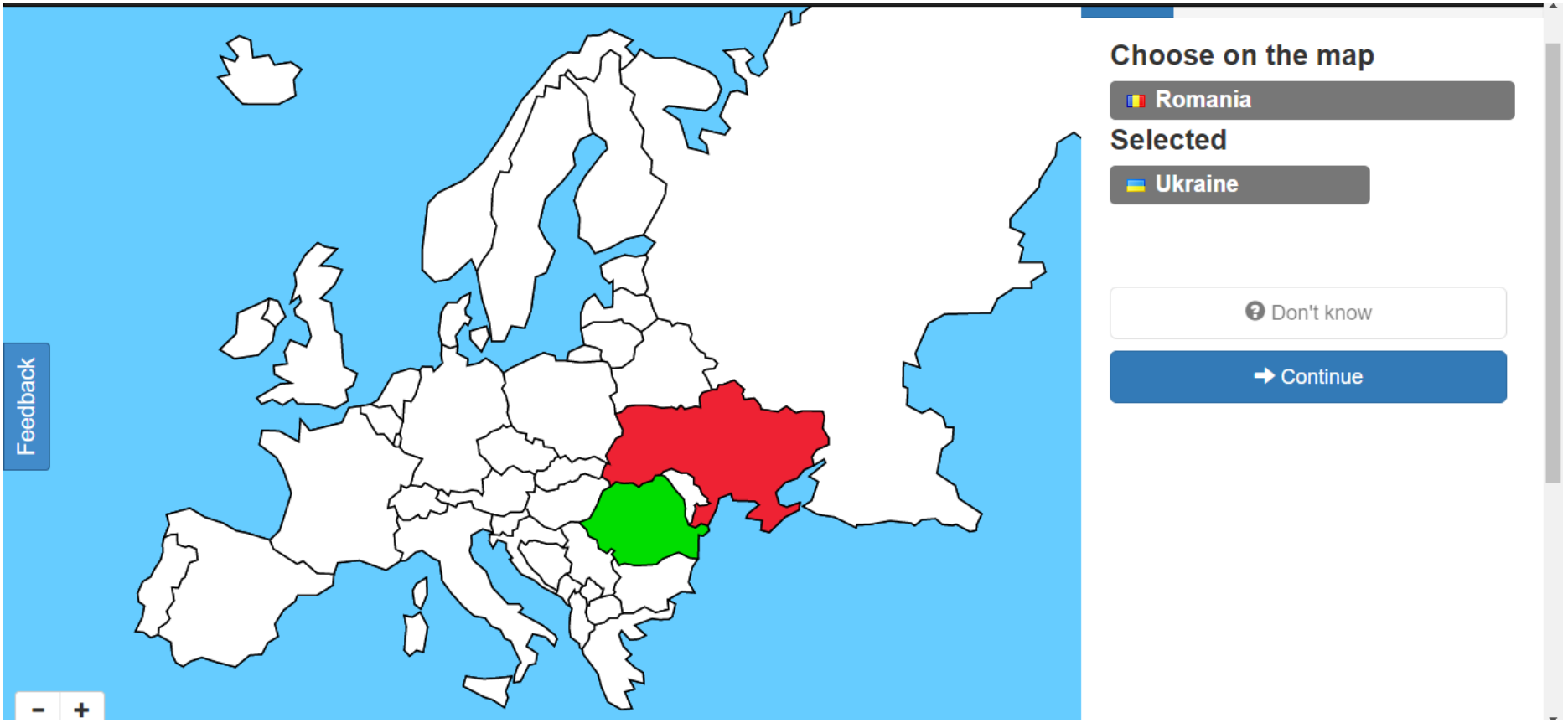
Cognitive tutors from Carnegie Learning Inc:

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

Thanks for your attention
Questions?

Thanks for your support

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