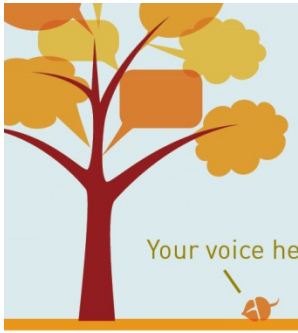

Conversations on Quality:
A Symposium on K-12 Online Learning

BILL & MELINDA GATES foundation

MIT

Intelligent tutoring systems (ITS) for online learning

Kurt VanLehn

Computing, Informatics and Decision Science Engineering

Arizona State University

Cite as: VanLehn, K. (2012, January). *Intelligent tutoring systems (its) for online learning.*
Presentation at Conversations on quality: a symposium on k-12 online learning, Cambridge, MA.

Join the conversation...

Outline

- Adding an ITS to an online course
- Will ITS improve the quality?
  - Increasing interaction and complexity of exercises
  - The Zone of Proximal Development
- Limitations

A typical online course consists of:

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- Discussion forum
- A sequence of modules, each comprised of a sequence of
  - Passive media (text, powerpoint)
  - Exercises
  - Quiz
- Final project
- Final exam

Adding an ITS makes these changes:

BILL & MELINDA GATES foundation

- Discussion forum
- A sequence of modules, each comprised of a sequence of
  - Passive media (text, powerpoint)
  - Exercises
  - Quiz
- Final project
- Final exam

dynamically adaptive

complex, dynamically scaffolded

unnecessary

How does an ITS work?

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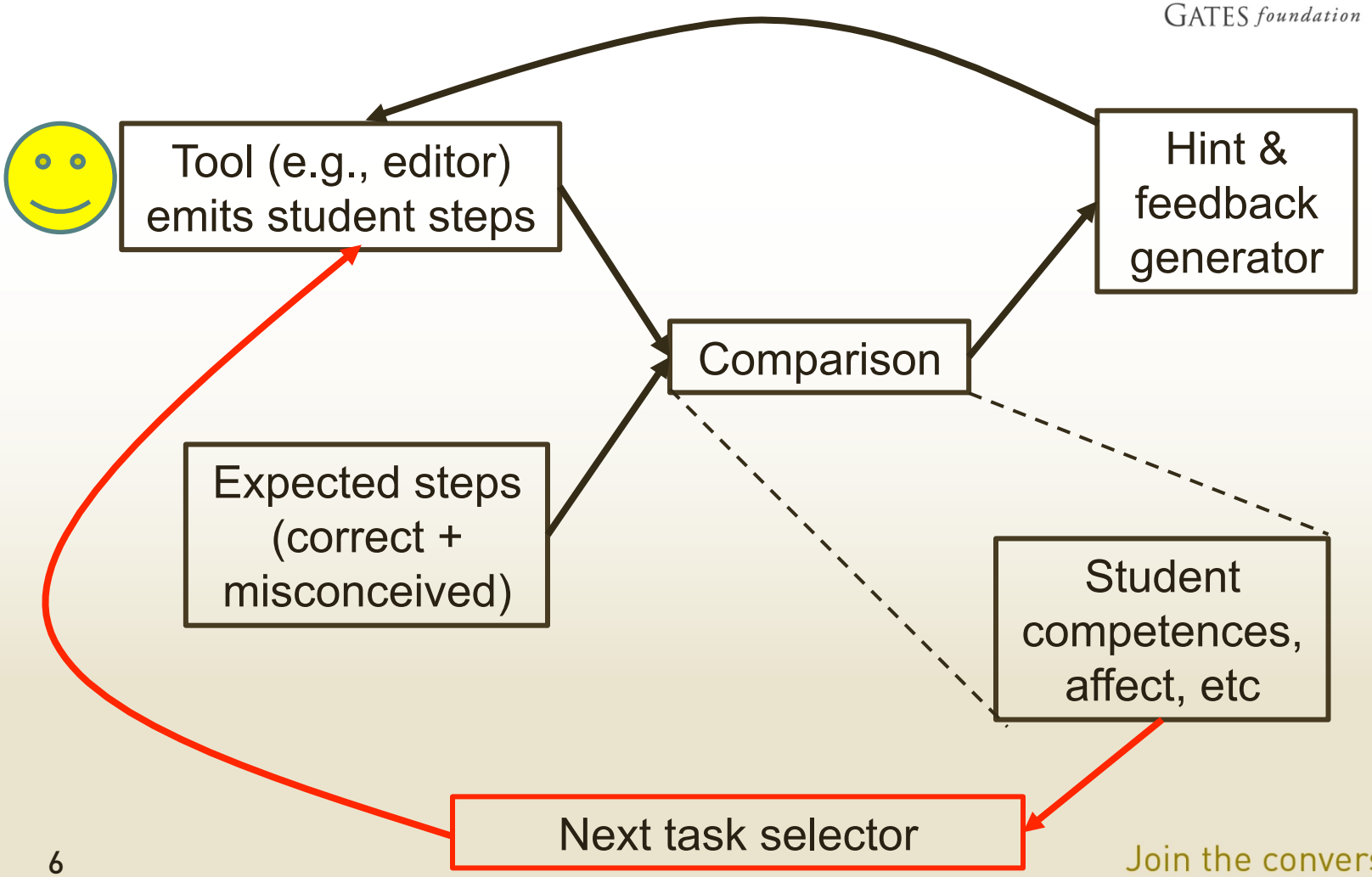
- It chooses the next activity/task for the student to do based on a model of the student's current competence, affect and interest.
- It conducts stealth assessment
  - Shute, V. J. (2011). Stealth assessment in computer-based games to support learning. In S. Tobias & J. D. Fletcher (Eds.), *Computer games and instruction* (pp. 503-524). Charlotte, NC: Information Age Publishers
- If the task is a complex, multi-step activity
  - It understands each step the student makes
  - It can provide hints & feedback on every step
  - Students often control hints & feedback

What is the structure of an ITS?



ITS require expected steps

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- Task must be solvable in advance (by experts)
- e.g., For an essay on "Why is the sky blue?"
  - ITS insures essay mentions that shorter wavelengths of light are absorbed and re-emitted
  - ITS insures essay has good organization, mechanics
- e.g., For an essay on "Why are the blues popular?"
  - ITS could help *only* with mechanics
  - Because nobody can anticipate argument's steps
  - Unless.... wisdom of crowds

Andes3 is like power-point, but gives correct (green) vs. incorrect (red) feedback

s5a Physics

Submit

A model airplane hangs from two strings S1 and S2 which are attached to the ceiling. String S1 is inclined at 45.0 deg, and string S2 is inclined at 60.0 deg, as shown in the figure below.

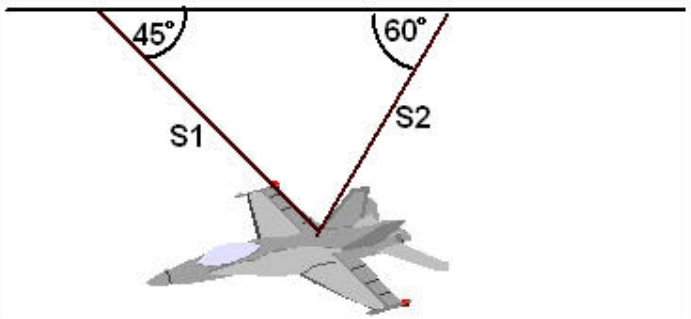
If the tension in string S1 is 50.0 N,

a) find the tension in string S2.

Answer:

b) find the mass of the airplane.

Answer:



g is the acceleration of gravity on earth

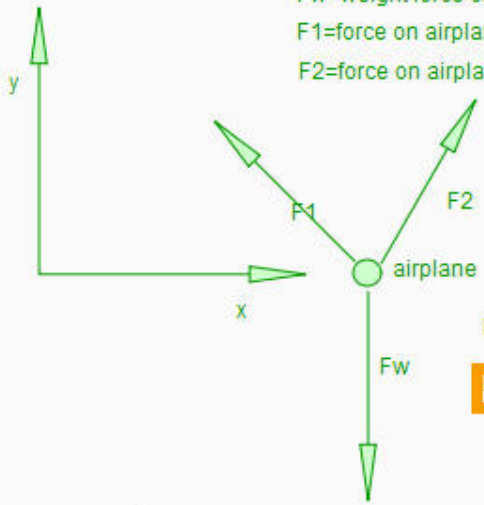
g=9.8 m/s^2

m=mass of the airplane

Fw=weight force on the airplane

F1=force on airplane due to S1

F2=force on airplane due to S2



F1=50 N

Fw=m*g

Fw_x+F1_x+F2_x=0

Fw_y+F1_y-F2_y=0

Help Score: 57%

If you need help, click the help button ? below. Click the button above to hide this window.

Check your signs.

Explain more

Perhaps the sign of the F2_y term should be changed.

help messages

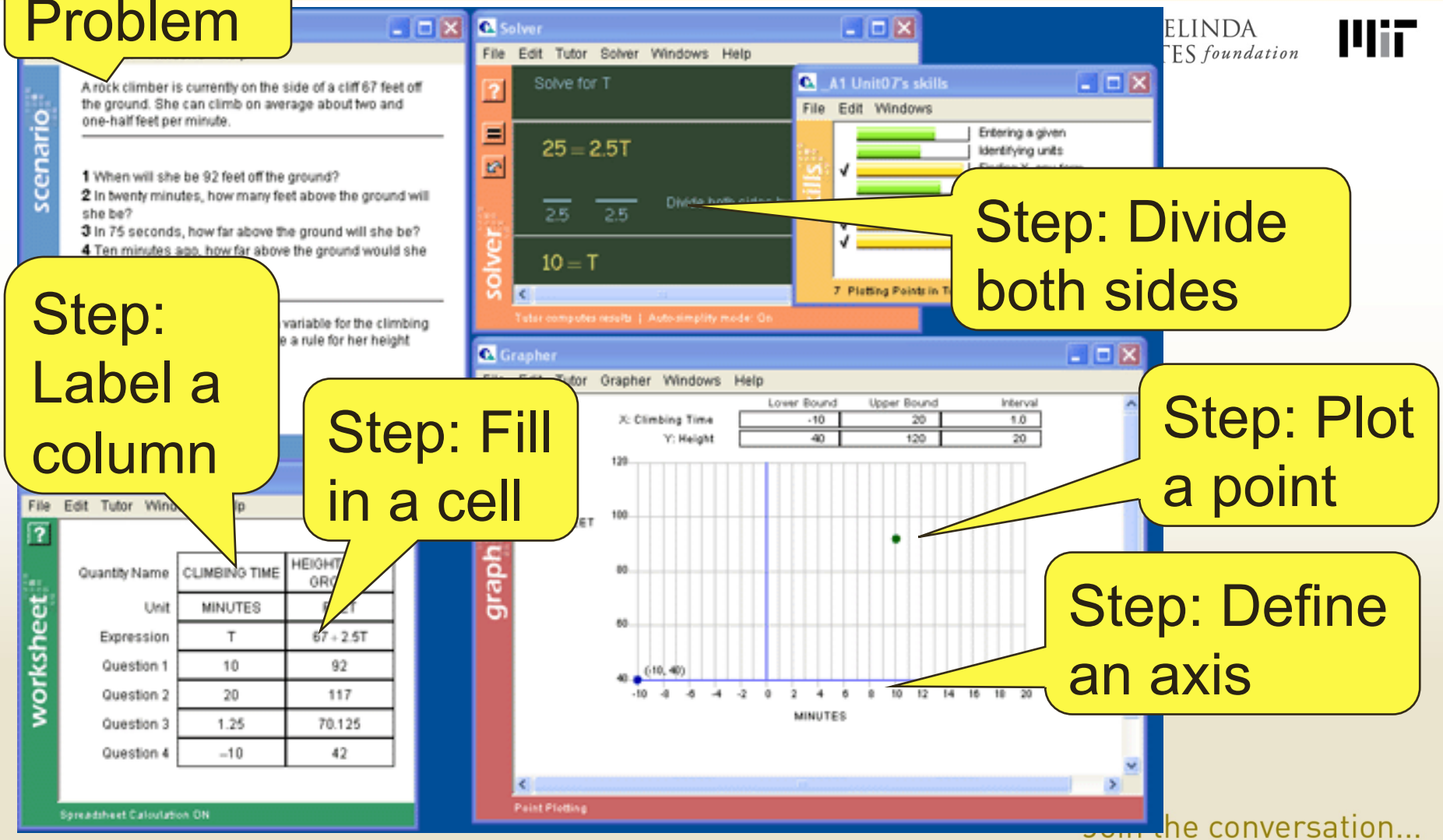
Click here for "what's wrong" and "next step help"

?

VanLehn, K., Lynch, C., Schultz, K., Shapiro, J. A., Shelby, R. H., Taylor, L., et al. (2005). The Andes physics tutoring system: Lessons learned. *International Journal of Artificial Intelligence and Education, 15(3), 147-204.*

Cognitive Algebra I Tutor has multiple tools

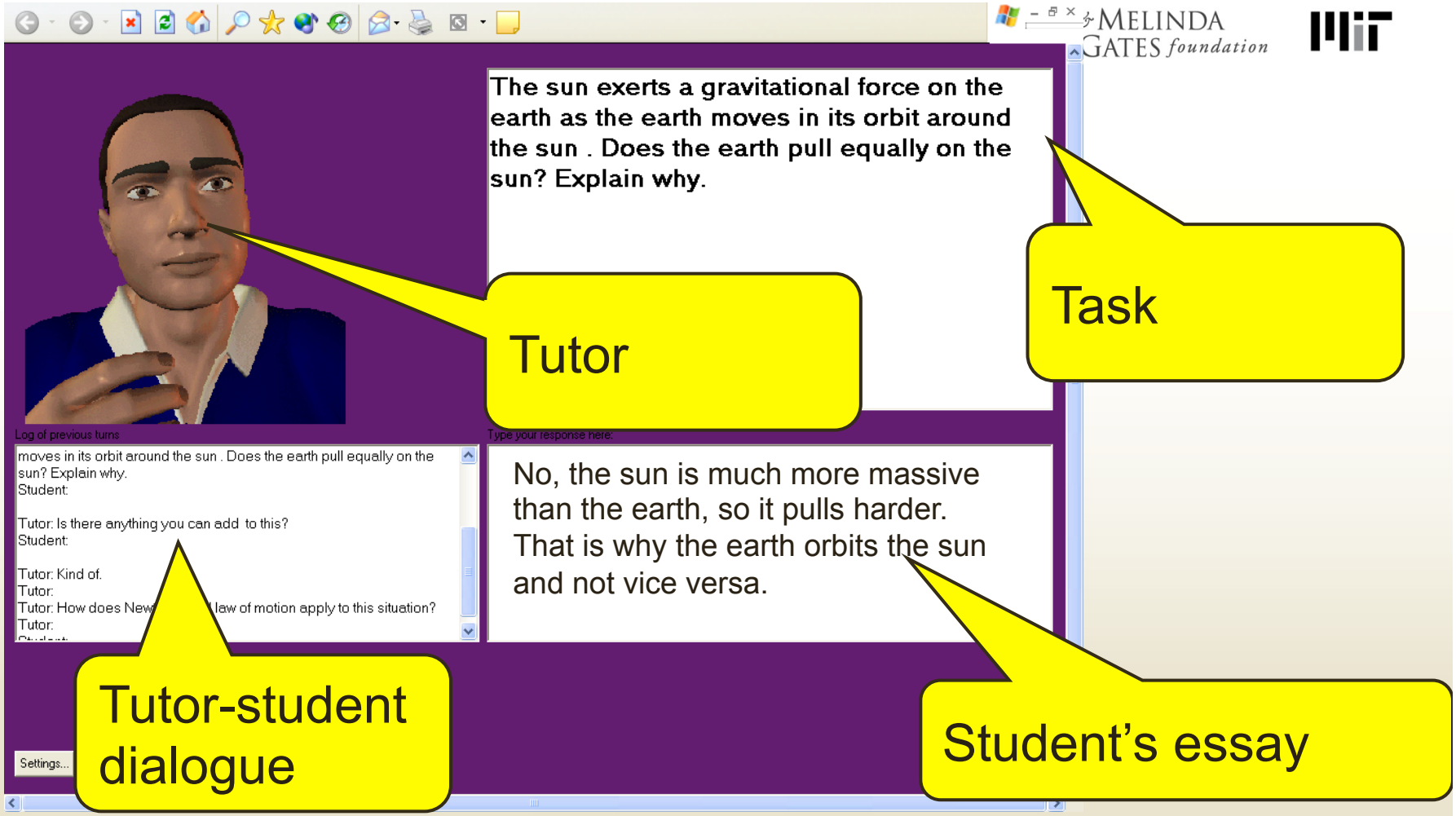
www.carnegielearning.com



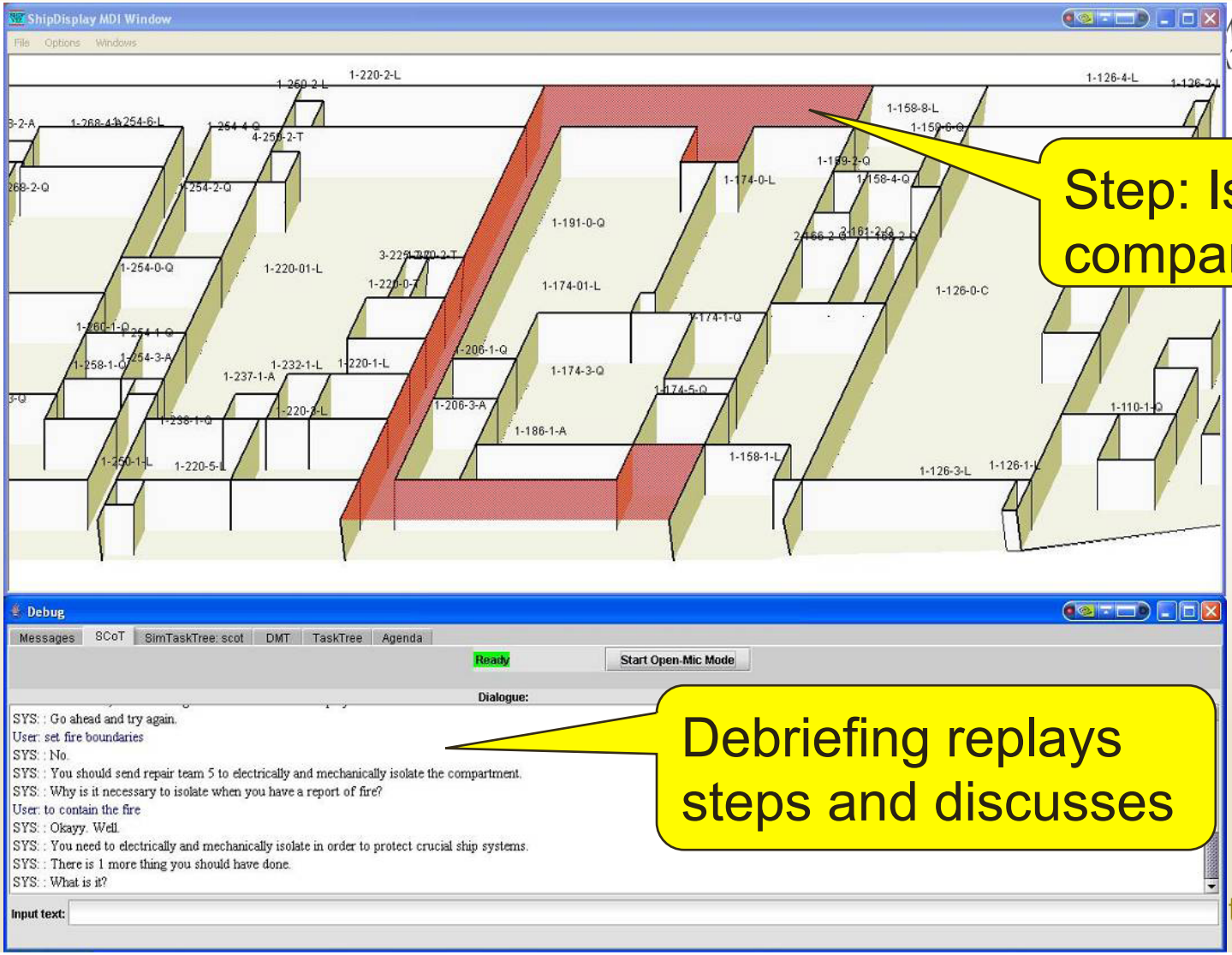
Join the conversation...

ITS can tutor steps in an argument/essay

Graesser, A. C., Lu, S., Jackson, G. T., Mitchell, H. H., Ventura, M., Olney, A., et al. (2004). AutoTutor: A tutor with dialogue in natural language. *Behavioral Research Methods, Instruments and Computers, 36(180-193).*



A simulation-based ITS where all feedback is delayed until done fighting fire



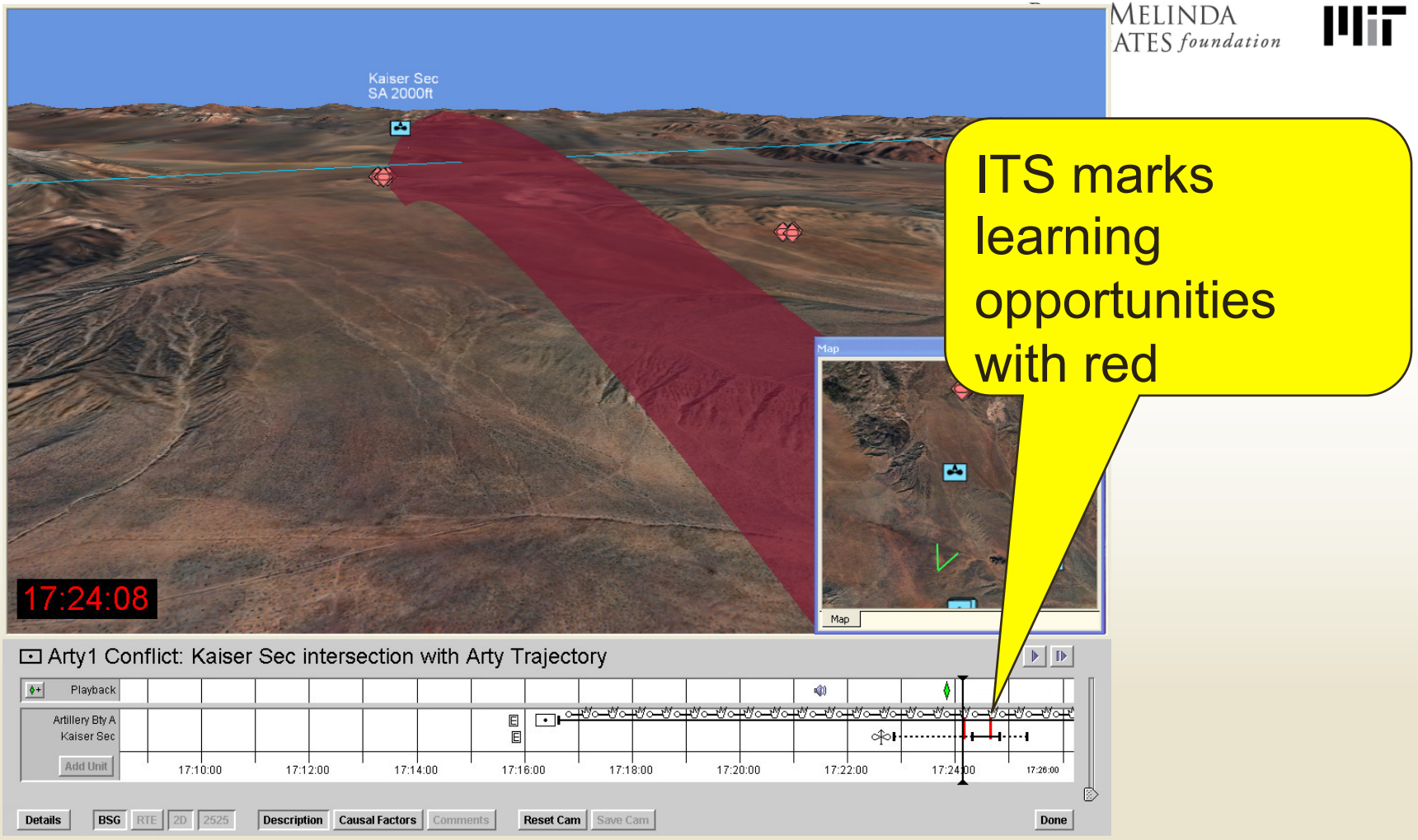
Step: Isolate a compartment

Debriefing replays steps and discusses

Pon-Barry, H., Schultz, K., Bratt, E. O., Clark, B., & Peters, S. (2006). Responding to student uncertainty in spoken tutorial dialogue systems. *International Journal of Artificial Intelligence and Education, 16, 171-194.*

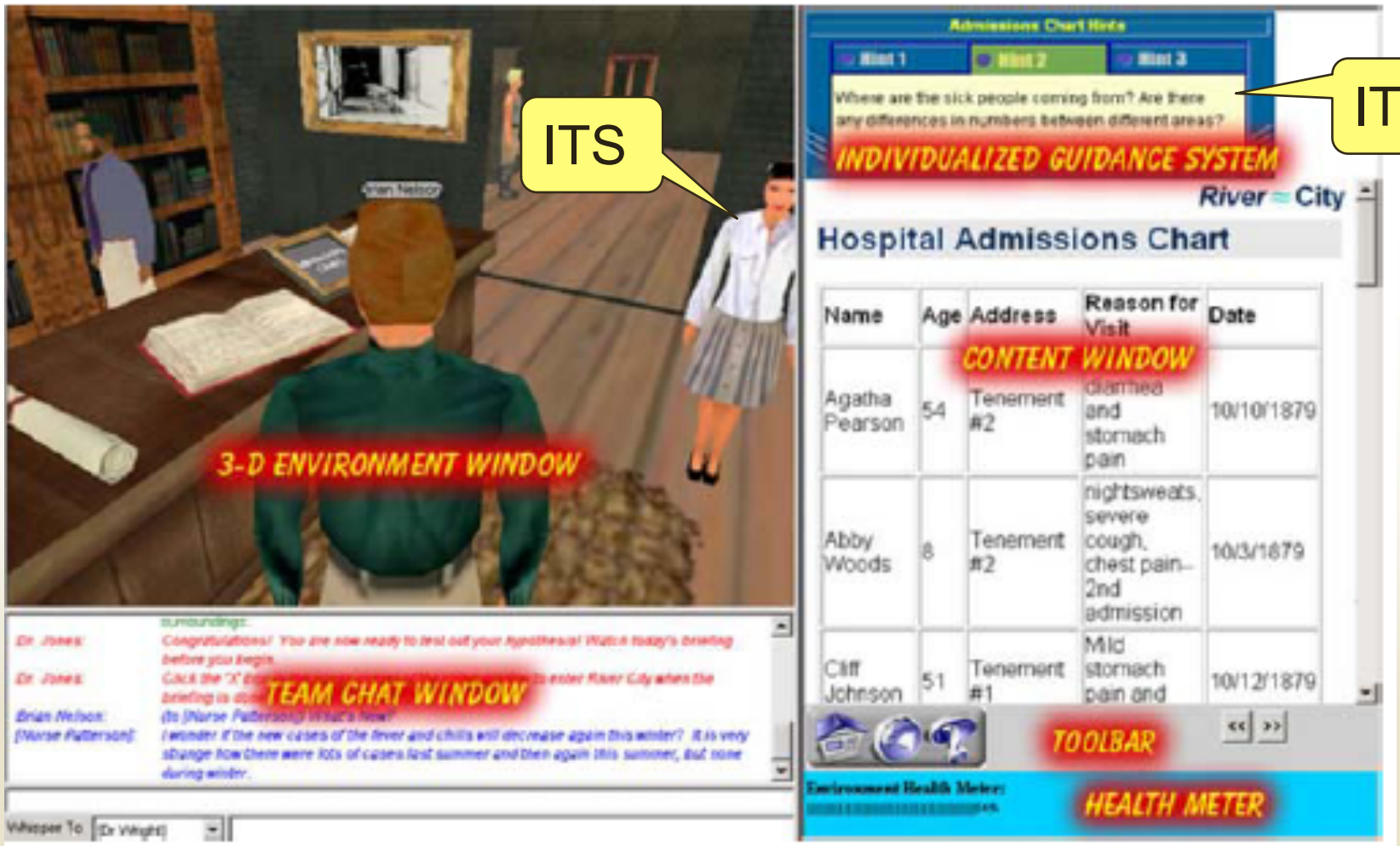
After-action reviews often use a timeline

www.stotler-henke.com



ITS can be an non-player character

Nelson, B. C. (2007). Exploring the use of individualized, reflective guidance in an educational multi-user virtual environment. *Journal of Science Education and Technology, 16(1), 83-97.*



Join the conversation...

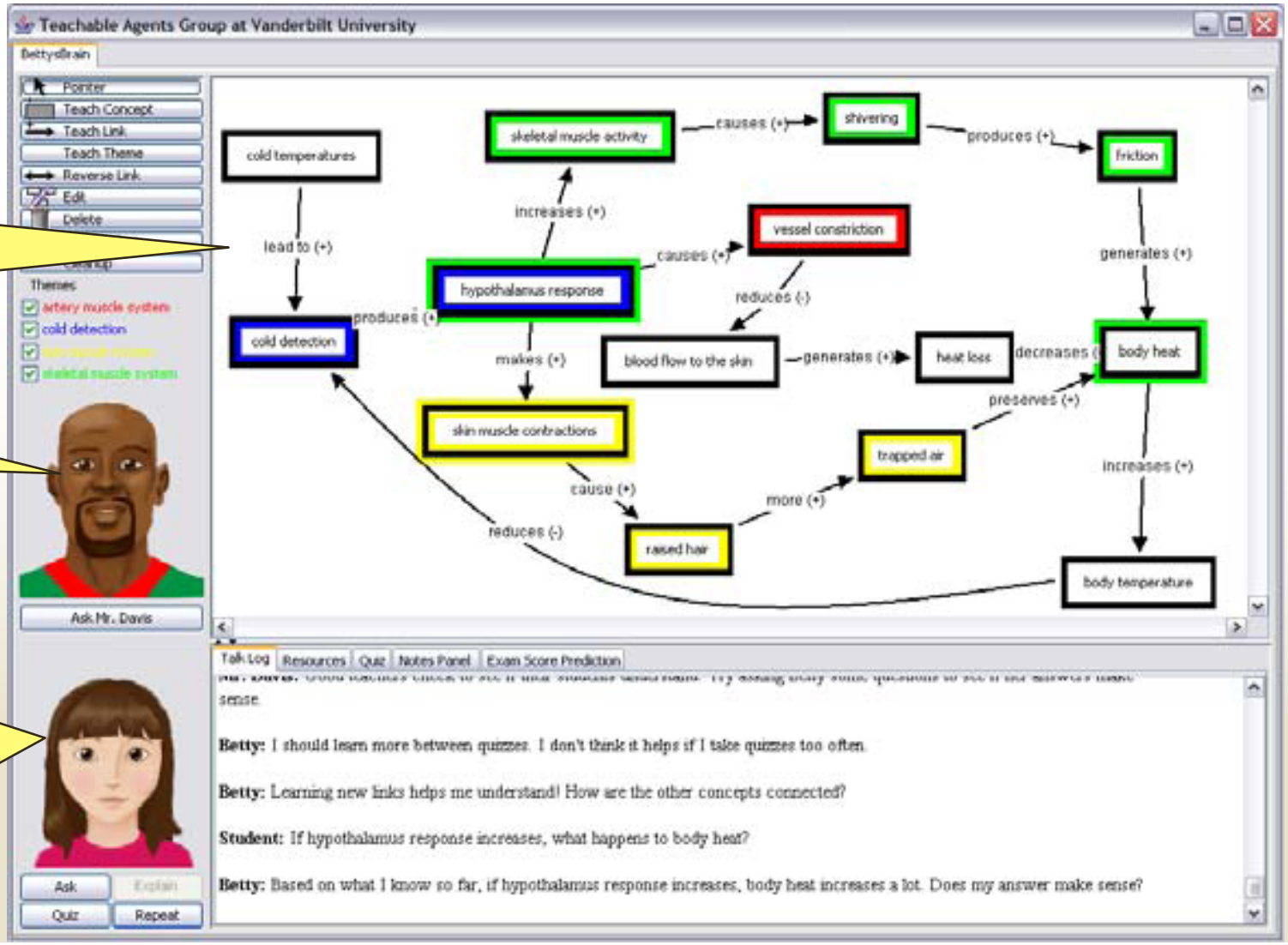
Learning companion(s) can accompany ITS

Schwartz, D. L., Blair, K. P., Biswas, G., Leelawong, K., & Davis, J. (in press). Animations of thought: Interactivity in the teachable agent paradigm. In R. Lowe & W. Schnotz (Eds.), *Learning with animations: Research and implications for design. Cambridge, UK: Cambridge University Press.*

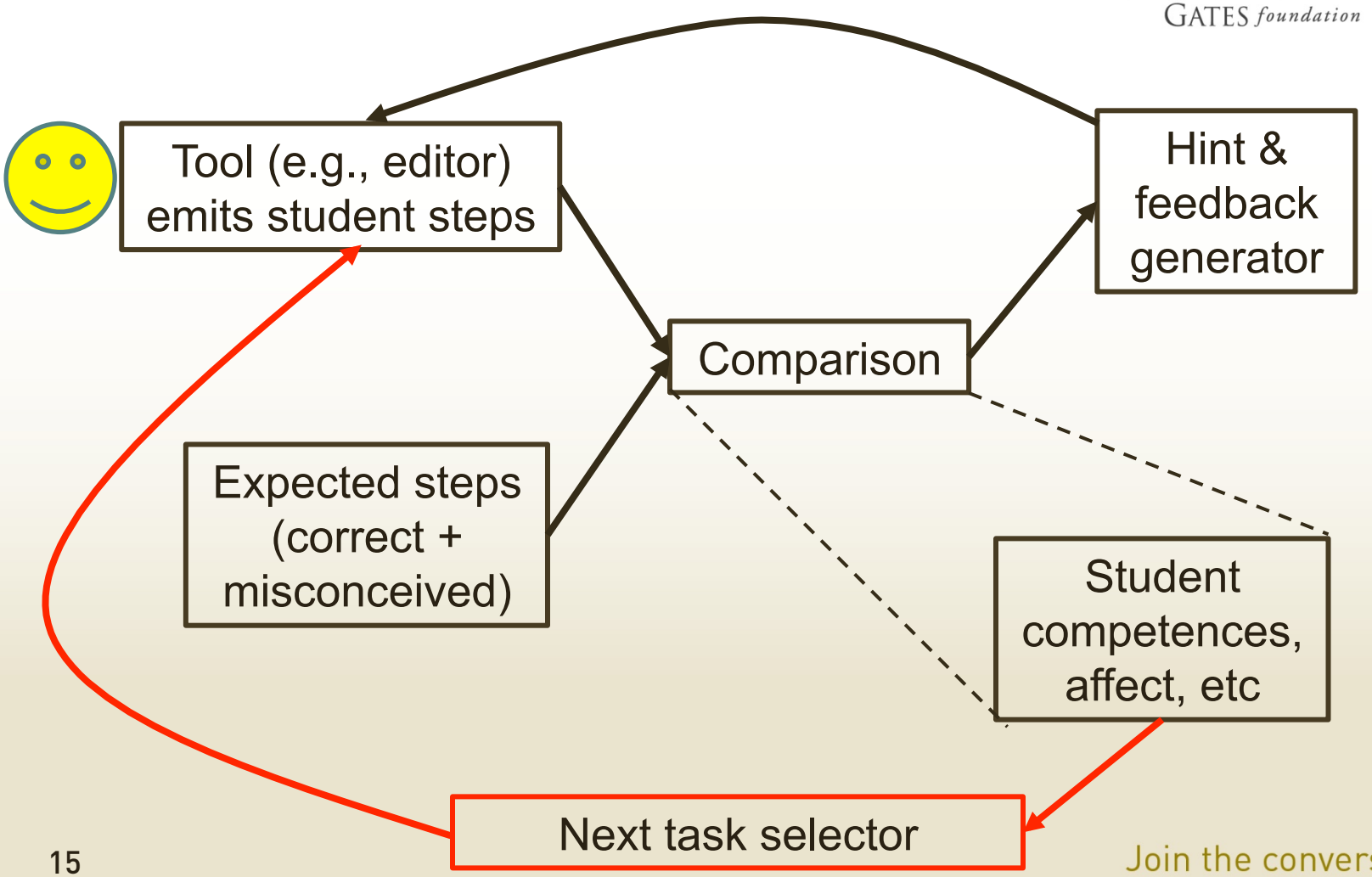
Concept map editor

ITS

Betty, a teachable agent



What is the structure of an ITS?



Adding an ITS makes these changes:

BILL & MELINDA GATES foundation

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Outline

BILL & MELINDA GATES foundation

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  - The Zone of Proximal Development
- Limitations

Next

Micki Chi's ICAP framework

Chi, M. T. H. (2009). Active-Constructive-Interactive: A conceptual framework for differentiating learning activities. *Topics in Cognitive Science, 1, 73-105.*

Student engagement activity	e.g., history	e.g., algebra equations	Effectiveness
Passive	Reading the text	Reading an example	Worst
Active	Highlighting the text	Copying an example	OK
Constructive	Answering questions	Solving a problem	Better
Interactive	Discussing questions with a peer **or tutor**	Solving a problem with a peer **or tutor**	Best

I > C > A > P

Do computer tutors interact frequently enough?

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MIT

- No tutoring (baseline for comparisons)
- Answer-based tutoring
  - Hints and feedback on short-answer questions
- Step-based tutoring
  - Hints and feedback on steps normally taken when using tool
- Substep-based tutoring
  - Tutor can discuss reasoning behind steps
- Human tutoring

CAI

ITS

Answer-based tutoring (CAI)

www.mastering.com

MasteringPHYSICS

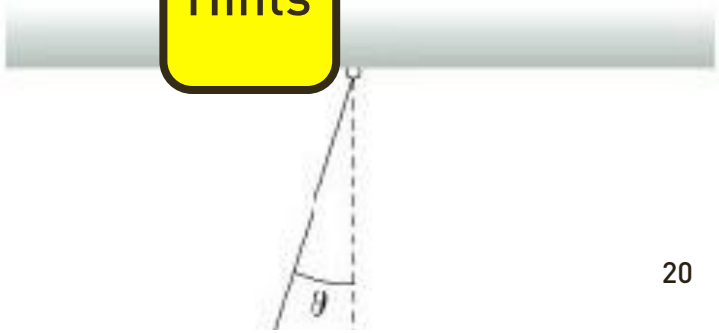
Intro | Problem Library | Tutorials | Gra

Conical Pendulum I

A bob of mass m is suspended from a fixed point with a massless string of length L (i.e., it is a pendulum). You are to investigate the motion in which the string moves in a cone with half-angle θ.

Solve on paper, enter **ANSWER** & get feedback

Intro 1



Hints

Part A

What tangential speed, v, must the bob have so that it mo
making an angle θ from the vertical?

**Express your answer in terms of some or all of the varia
gravity g.**

$v =$ $L \cdot g \cdot \sin(\theta) \cdot \tan(\theta)$

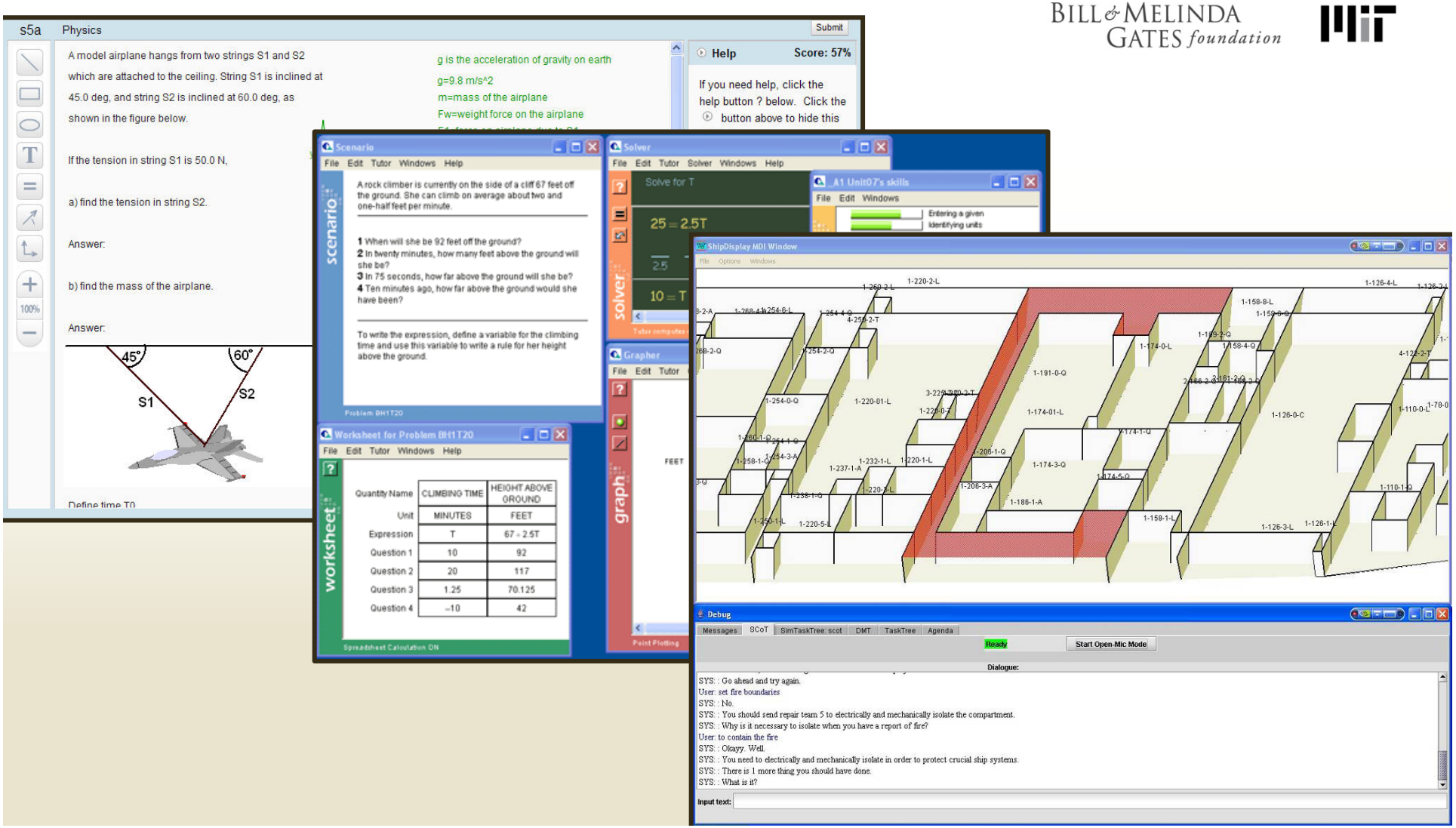
submit | hints | my answers | show answer | review part

Part B

How long does it take the bob to make one full revolution

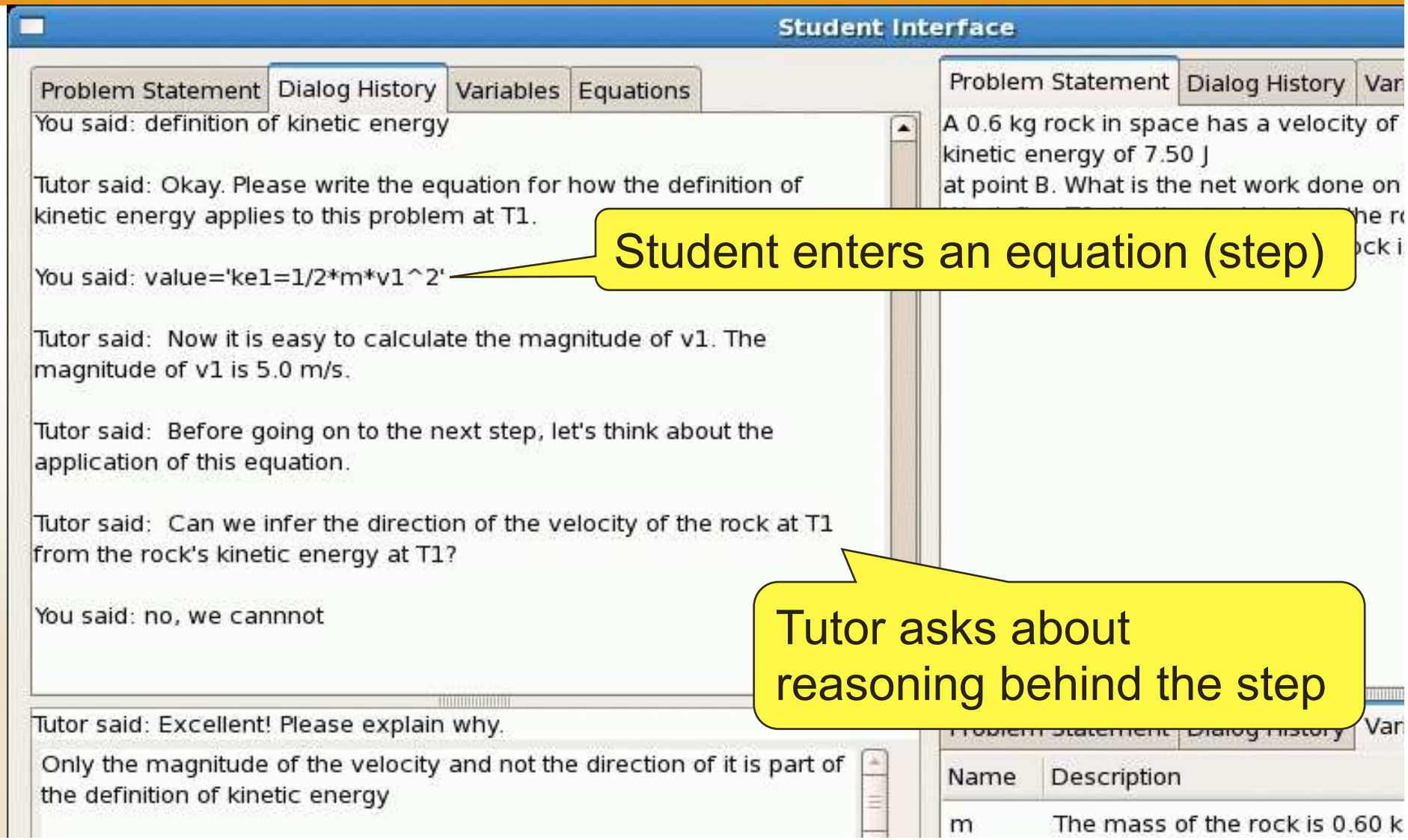
**Express your answer in terms of some or all of the varia
gravity g.**

Step-based tutoring

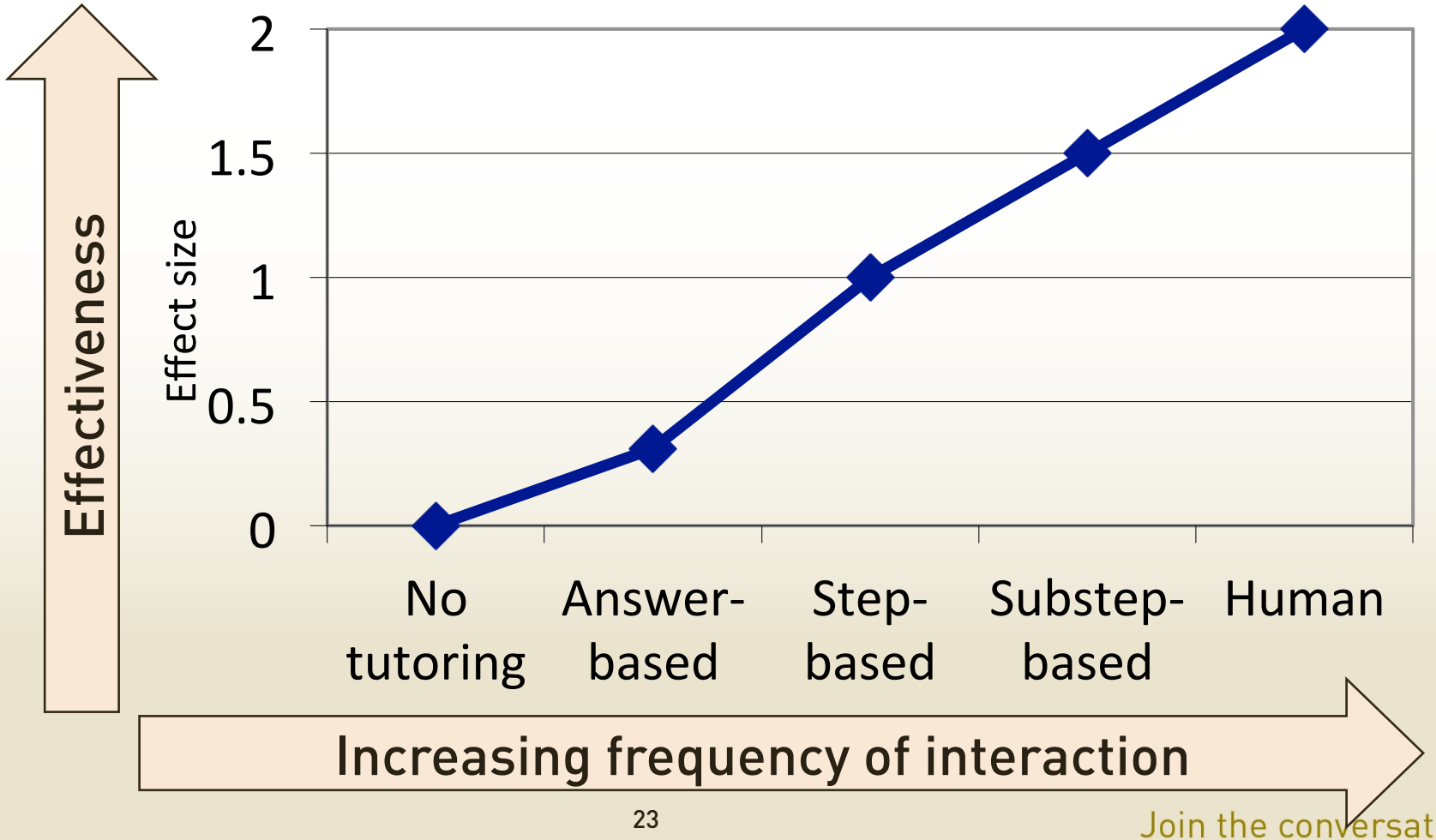


Substep-based tutoring

VanLehn, K., Jordan, P., & Litman, D. (2007). *Developing pedagogically effective tutorial dialogue tactics: Experiments and a testbed. Paper presented at the SLaTE Workshop on Speech and Language Technology in Education, Farmington, PA.*



A common belief: The more frequent the interaction, the more effective the tutoring



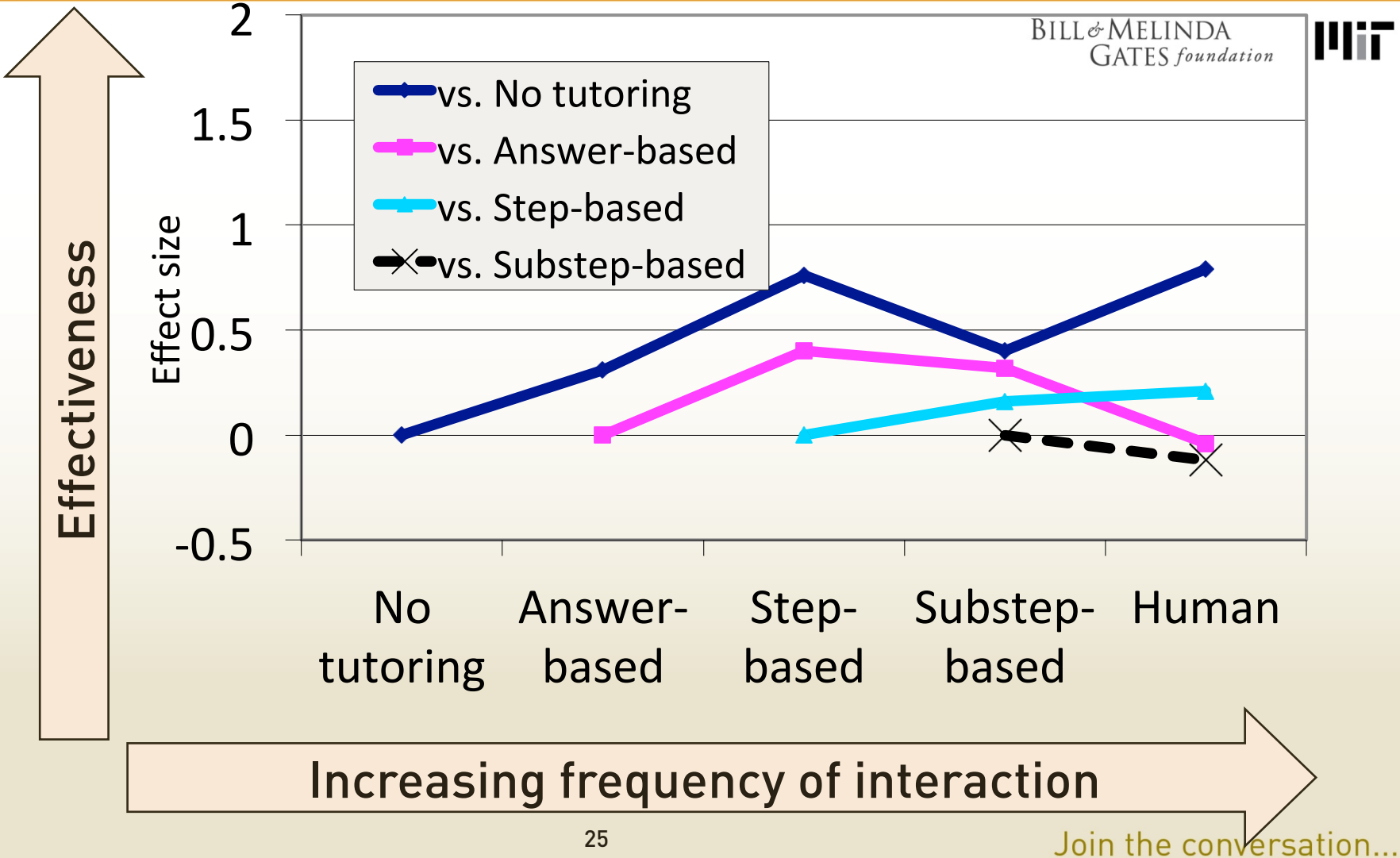
Join the conversation...

All possible pairwise comparisons

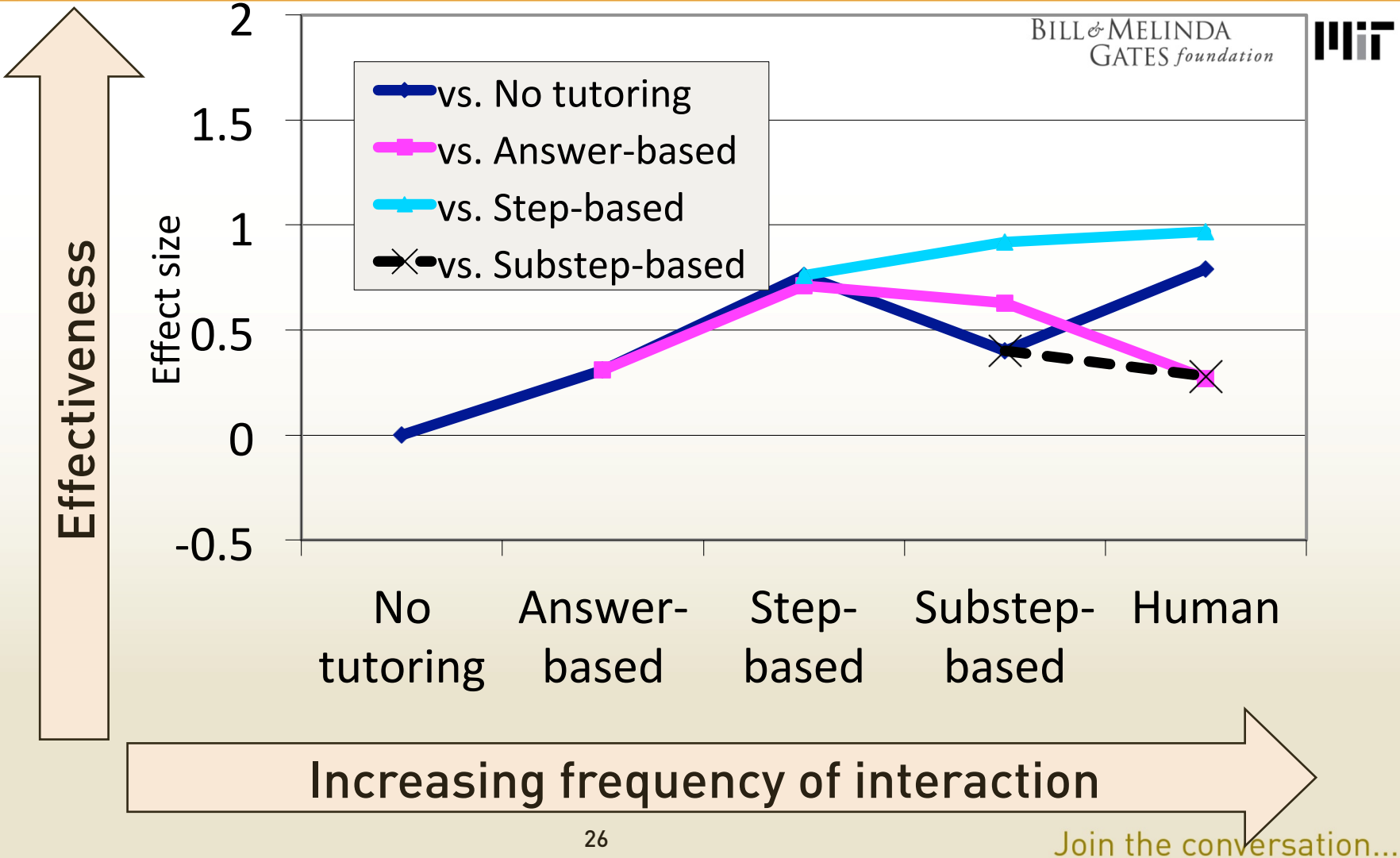
VanLehn, K. (2011). The relative effectiveness of human tutoring, intelligent tutoring systems and other tutoring systems. *Educational Psychologist, 46(4), 197-221.*

Tutoring type	vs. other tutoring type	Num. of effects	Mean effect	% reliable
Answer-based	no tutoring	165	0.31	40%
Step-based		28	0.76	68%
Substep-based		26	0.40	54%
Human		10	0.79	80%
Step-based	answer-based	2	0.40	50%
Substep-based		6	0.32	33%
Human		1	-0.04	0%
Substep-based	step-based	11	0.16	0%
Human		10	0.21	30%
Human	sub-step based	5	-0.12	0%

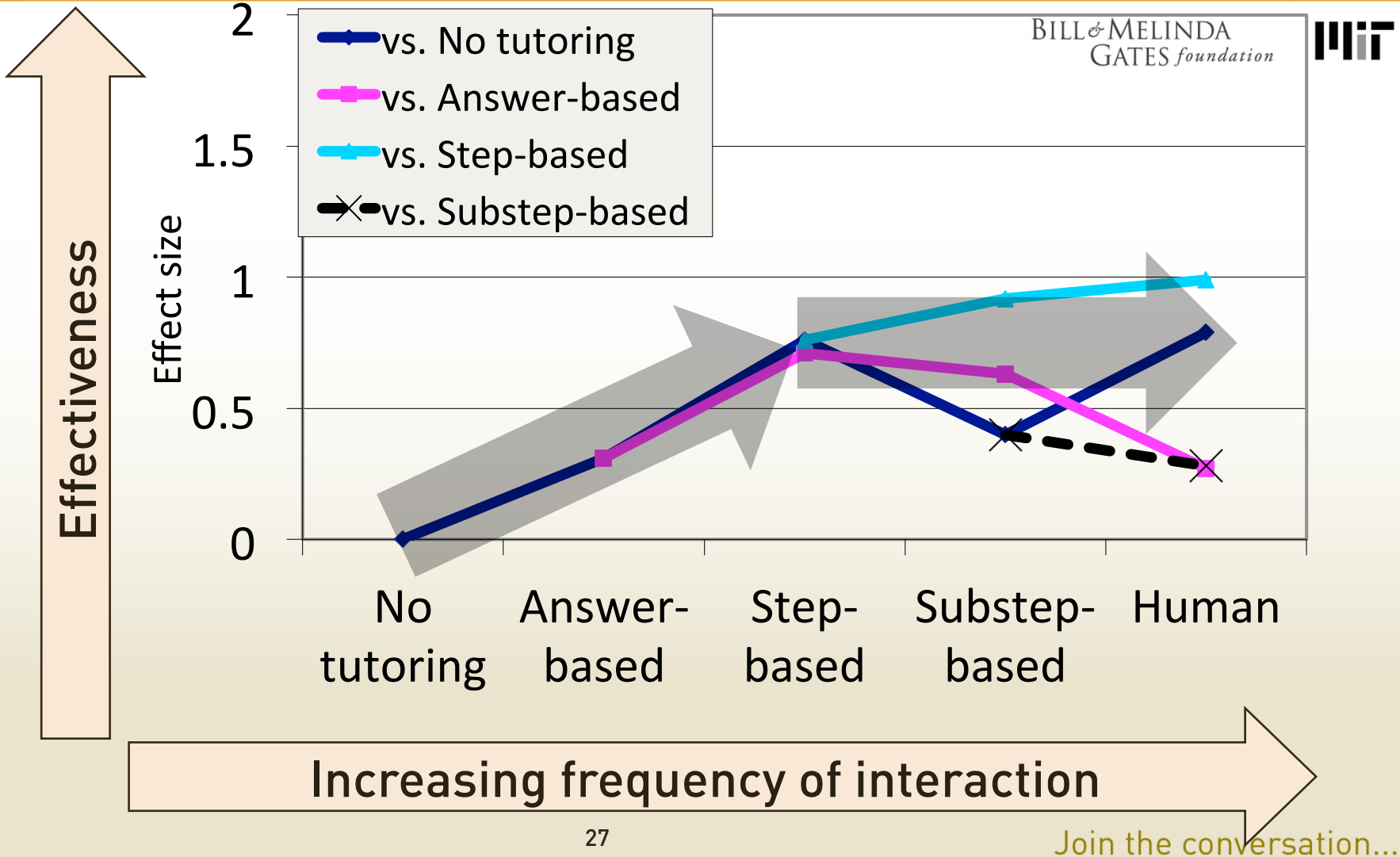
Graphing all 10 comparisons:
But the graph is hard to understand…



Graphing all 10 comparisons:
Lines raised to make it easier to integrate evidence



The Interaction Plateau Hypothesis: human = substep = step > answer > none



Outline

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Next

The Zone of Proximal Development (ZPD)

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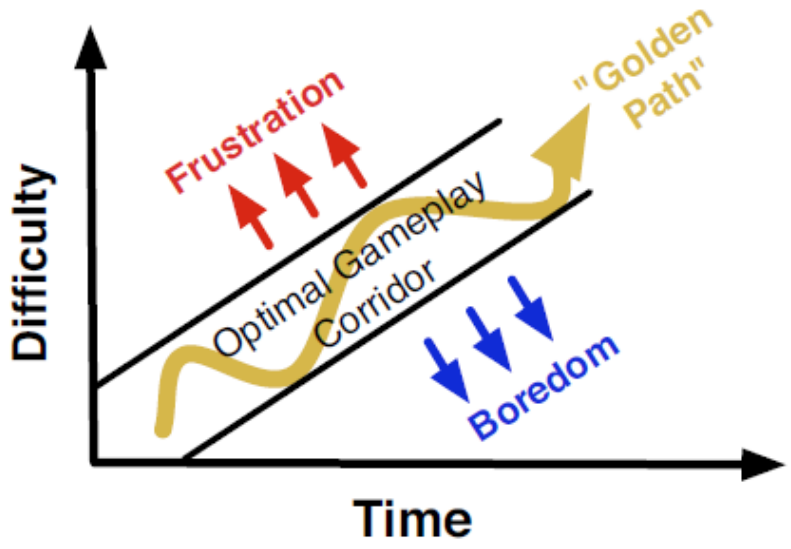
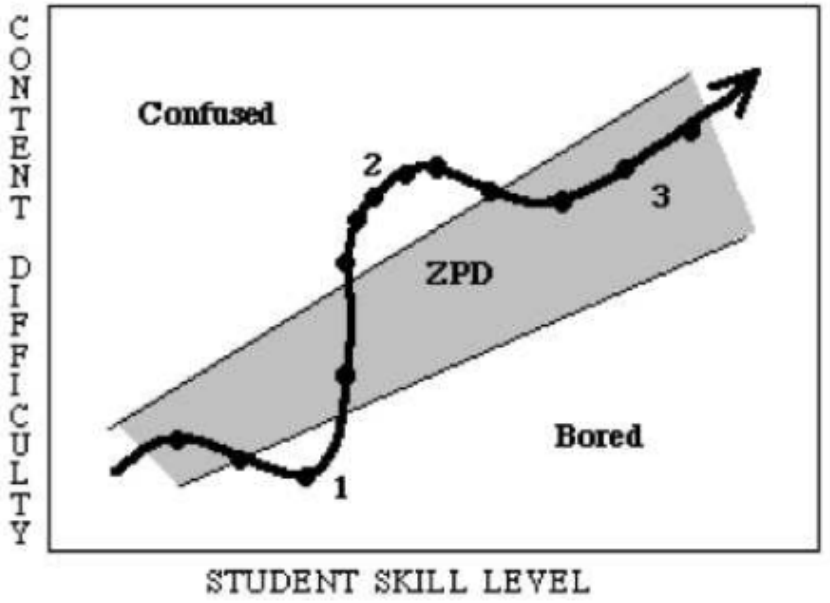


(a) Optimal Game Play Corridor



(b) Zone of Proximal Development

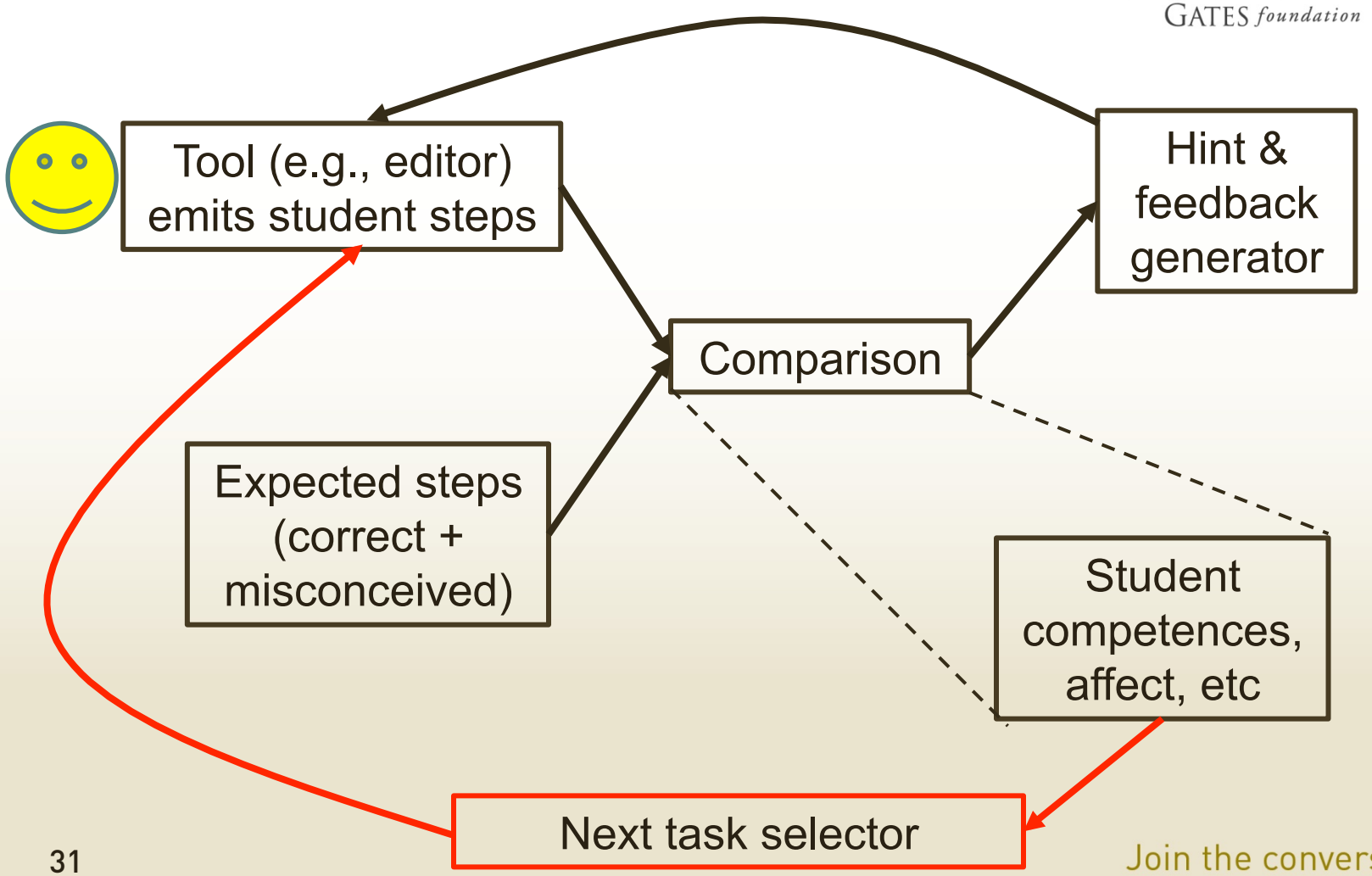
Join the conversation...

How can we keep students in their ZPDs?

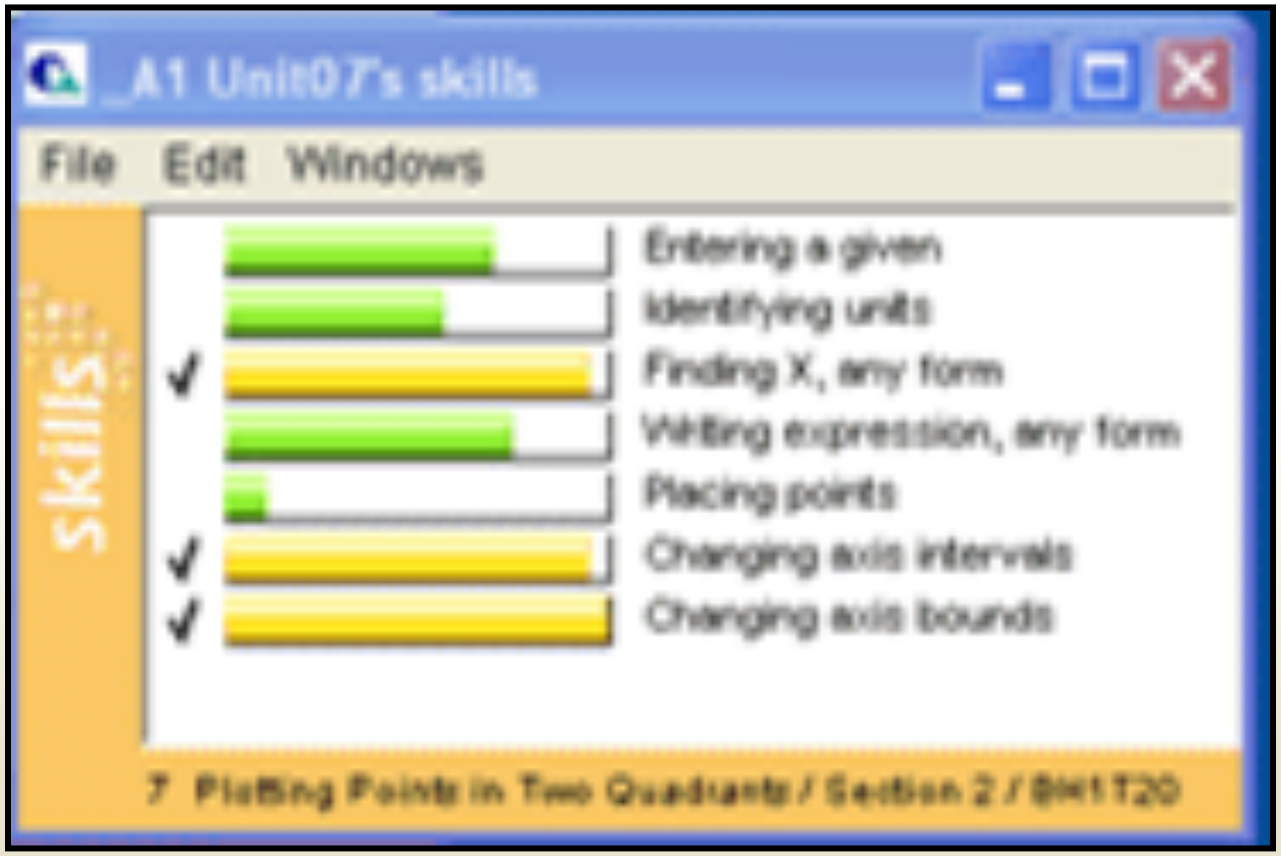
BILL & MELINDA GATES foundation

- "Mastery (-paced) learning" means continuing to work on a module until you have mastered it.
  - Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher, 13, 4-16.*
- With an ITS, traditional mastery tests are replaced by the stealth assessment

Mastery-paced learning implemented by the red path below



Assessment can be shown to student



Students may be allowed to work at own pace

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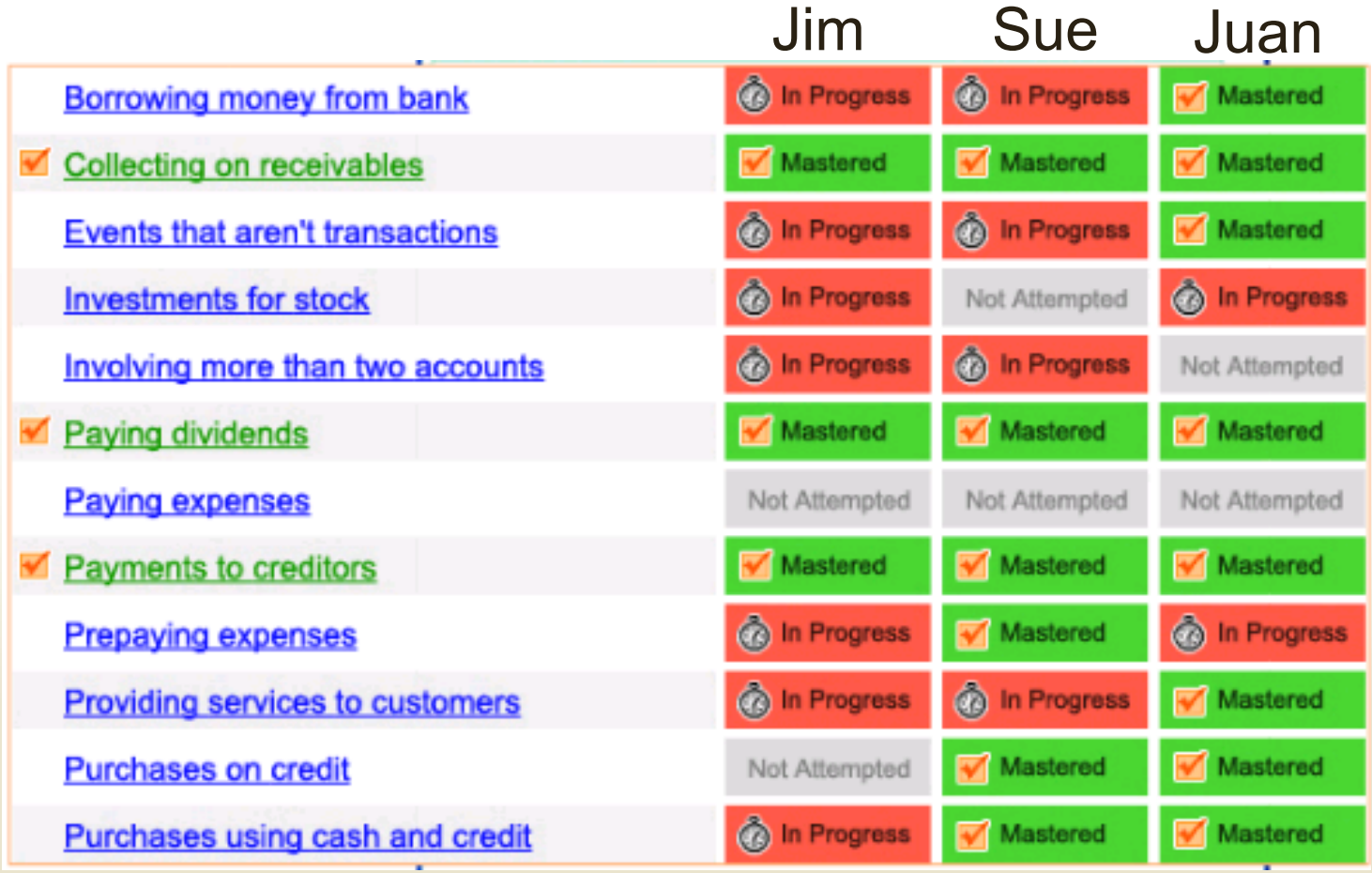

	Jim	Sue	Juan
Borrowing money from bank	In Progress	In Progress	Mastered
Collecting on receivables	Mastered	Mastered	Mastered
Events that aren't transactions	In Progress	In Progress	Mastered
Investments for stock	In Progress	Not Attempted	In Progress
Involving more than two accounts	In Progress	In Progress	Not Attempted
Paying dividends	Mastered	Mastered	Mastered
Paying expenses	Not Attempted	Not Attempted	Not Attempted
Payments to creditors	Mastered	Mastered	Mastered
Prepaying expenses	In Progress	Mastered	In Progress
Providing services to customers	In Progress	In Progress	Mastered
Purchases on credit	Not Attempted	Mastered	Mastered
Purchases using cash and credit	In Progress	Mastered	Mastered

Outline

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An ITS does not do everything

BILL & MELINDA GATES foundation

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dynamically adaptive

complex, dynamically scaffolded

unnecessary

Some learners do not need and do not like ITS (or any other scaffolding)

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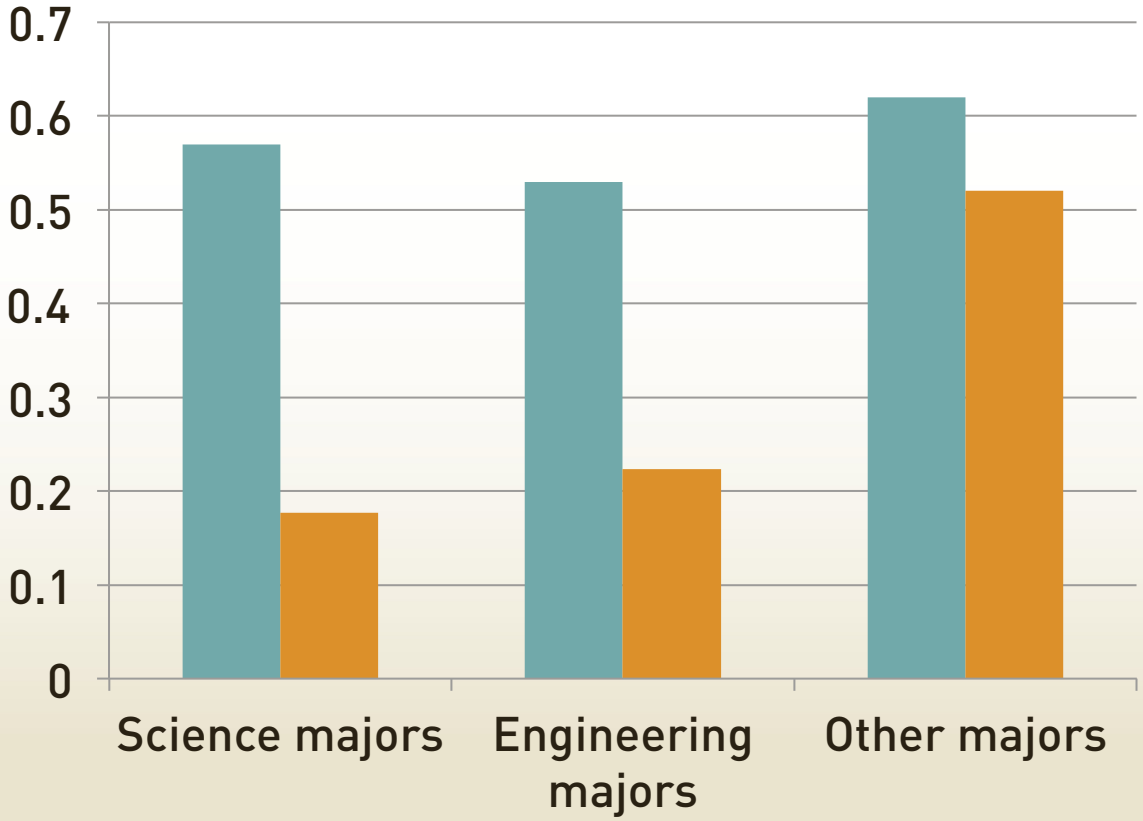
Effect size: How much better is Andes than hand-graded paper & pencil homework?



Costs

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Graded exercises

- Initial Development
  - Design exercises ($)
  - Solutions & rubric ($)
- Per student costs
  - Human graders ($$)
  - Sold as service

ITS

- Initial development
  - Design exercises ($)
  - Author ITS ($$$)
- Per student costs
  - nothing
  - Sold as service (new)

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Thank you!