

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

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Intelligent tutoring systems (ITS) for online learning

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Presentation at Conversations on quality: a symposium on k-12 online learning, Cambridge, MA.

Join the conversation...



Outline

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- 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:

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

How does an ITS work?

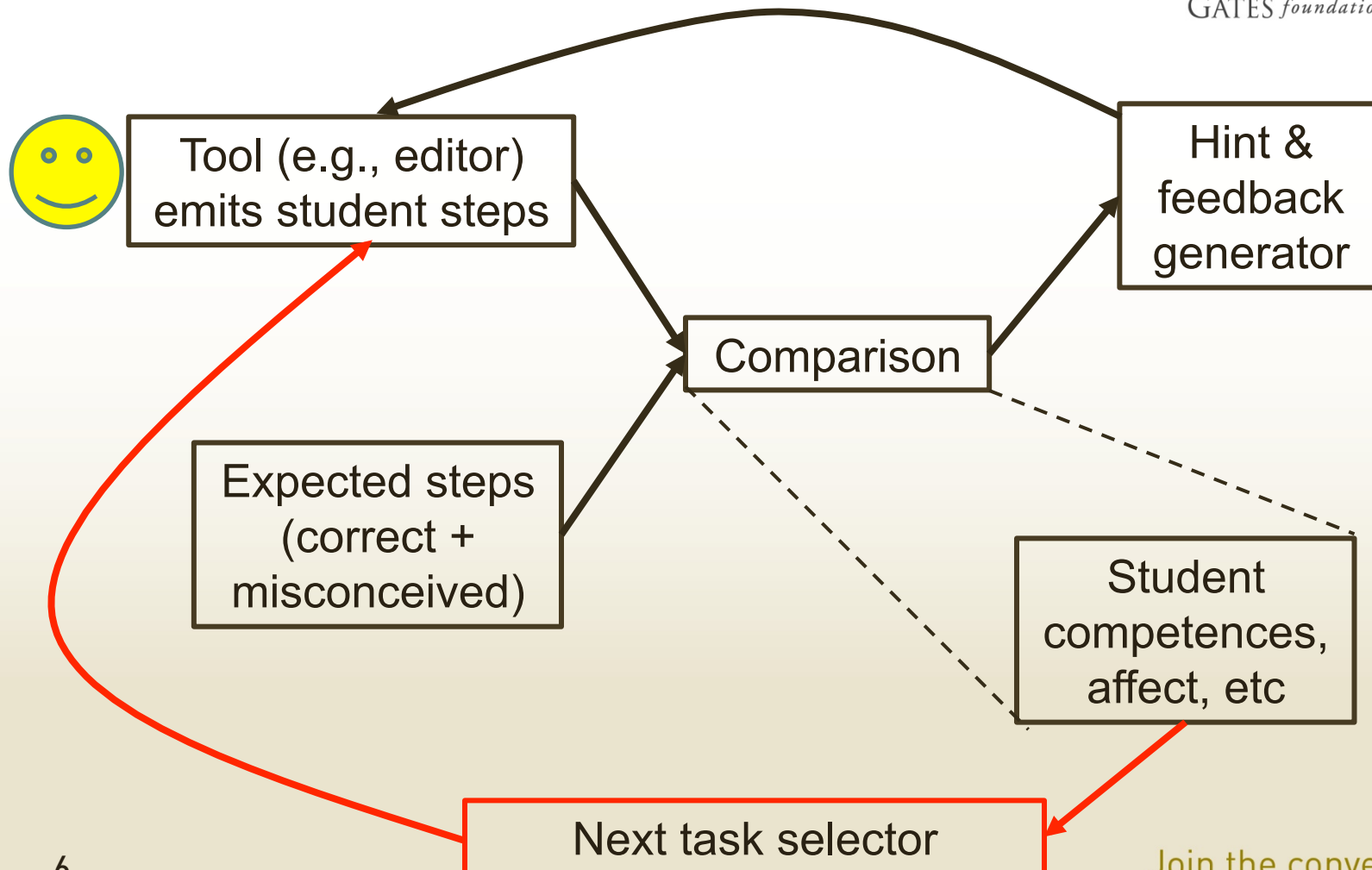
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- It chooses the next activity/task for the student to do based on a model of the student's current competence, affect and interest.
- It conducts stealth assessment
 - Shute, V. J. (2011). Stealth assessment in computer-based games to support learning. 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?

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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
 $g = 9.8 \text{ m/s}^2$
 m = mass of the airplane
 F_w = weight force on the airplane
 F_1 = force on airplane due to S1
 F_2 = force on airplane due to S2

$F_1 = 50 \text{ N}$
 $F_w = m \cdot g$

$F_w_x + F_1_x + F_2_x = 0$
 $F_w_y + F_1_y - F_2_y = 0$

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 F_2_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.

Join the conversation...

Cognitive Algebra I Tutor has multiple tools

www.carnegielearning.com

Problem

A rock climber is currently on the side of a cliff 67 feet off the ground. She can climb on average about two and one-half feet per minute.

- 1 When will she be 92 feet off the ground?
- 2 In twenty minutes, how many feet above the ground will she be?
- 3 In 75 seconds, how far above the ground will she be?
- 4 Ten minutes ago, how far above the ground would she

Step: Label a column

variable for the climbing time
a rule for her height

Step: Fill in a cell

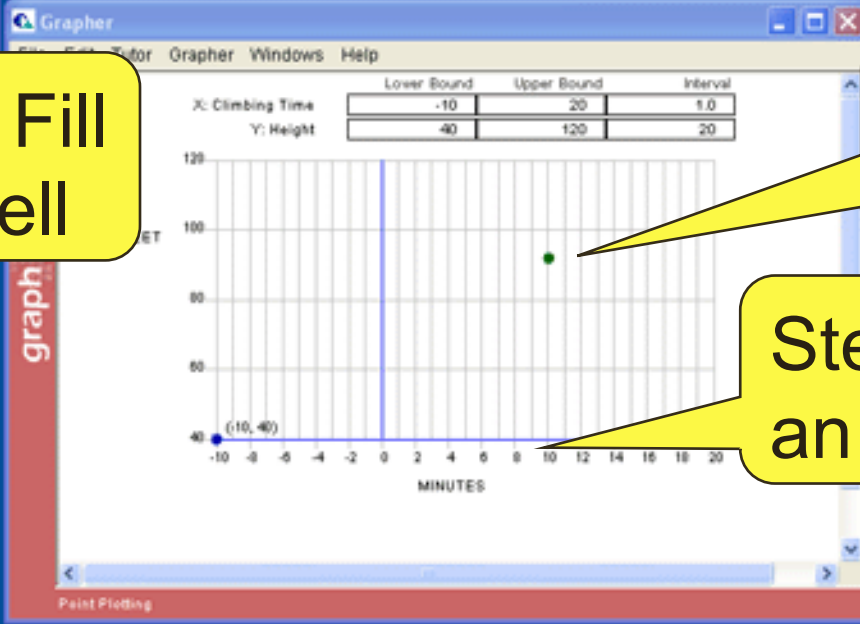
Quantity Name	CLIMBING TIME	HEIGHT ABOVE GROUND
Unit	MINUTES	FEET
Expression	T	$67 + 2.5T$
Question 1	10	92
Question 2	20	117
Question 3	1.25	70.125
Question 4	-10	42

Solver

Solve for T

$$25 = 2.5T$$
$$\frac{25}{2.5} = \frac{2.5T}{2.5}$$
$$10 = T$$

Step: Divide both sides



Step: Plot a point

Step: Define an axis

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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).

The screenshot shows the AutoTutor interface within a browser window. The browser's address bar displays 'MELINDA GATES foundation' and the MIT logo. The interface features a 3D avatar of a male tutor on the left. A large text box in the center contains the task: 'The sun exerts a gravitational force on the earth as the earth moves in its orbit around the sun . Does the earth pull equally on the sun? Explain why.' Below this, a text input area shows the student's response: 'No, the sun is much more massive than the earth, so it pulls harder. That is why the earth orbits the sun and not vice versa.' A 'Log of previous turns' on the left side of the interface shows a history of tutor and student interactions. Three yellow callout boxes with black outlines are overlaid on the screenshot: one labeled 'Tutor' points to the 3D avatar; one labeled 'Task' points to the central text box; and one labeled 'Student's essay' points to the student's response text. A fourth yellow callout box labeled 'Tutor-student dialogue' points to the 'Log of previous turns' area.

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

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The screenshot displays a 3D wireframe model of a ship's compartment layout. A red-shaded area indicates a fire zone. The interface includes a menu bar (File, Options, Windows) and a title bar (ShipDisplay MDI Window). Below the 3D view is a Debug window with a dialogue log. The dialogue shows a system (SYS) and a user interacting to isolate a compartment.

Step: Isolate a compartment

Debriefing replays steps and discusses

Messages: SCot, SimTaskTree.scot, DMT, TaskTree, Agenda

Ready Start Open-Mic Mode

Dialogue:

SYS: Go ahead and try again.
User: set fire boundaries
SYS: No.
SYS: You should send repair team 5 to electrically and mechanically isolate the compartment.
SYS: Why is it necessary to isolate when you have a report of fire?
User: to contain the fire
SYS: Okay. Well.
SYS: You need to electrically and mechanically isolate in order to protect crucial ship systems.
SYS: There is 1 more thing you should have done.
SYS: What is it?

Input text:

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.

the conversation...

After-action reviews often use a timeline

www.stotler-henke.com

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ITS marks learning opportunities with red

Arty1 Conflict: Kaiser Sec intersection with Arty Trajectory

Playback

Artillery Bty A
Kaiser Sec

Add Unit

17:10:00 17:12:00 17:14:00 17:16:00 17:18:00 17:20:00 17:22:00 17:24:00 17:26:00

Details BSG RTE 2D 2525 Description Causal Factors Comments Reset Cam Save Cam Done

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.

The screenshot displays a virtual environment interface with several key components:

- 3-D ENVIRONMENT WINDOW:** Shows a virtual room with a desk, a bookshelf, and a character named Brian Nelson.
- TEAM CHAT WINDOW:** Displays a conversation between Dr. Jones and Brian Nelson. Dr. Jones congratulates Brian on his hypothesis and asks for feedback. Brian asks about the frequency of cases during winter.
- INDIVIDUALIZED GUIDANCE SYSTEM:** A window titled "Admissions Chart Hints" with a question: "Where are the sick people coming from? Are there any differences in numbers between different areas?"
- Hospital Admissions Chart:** A table with columns for Name, Age, Address, Reason for Visit, and Date.

Name	Age	Address	Reason for Visit	Date
Agatha Pearson	54	Tenement #2	diarrhea and stomach pain	10/10/1879
Abby Woods	8	Tenement #2	nightsweats, severe cough, chest pain-- 2nd admission	10/3/1879
Cliff Johnson	51	Tenement #1	Mild stomach pain and	10/12/1879
- TOOLBAR:** Contains navigation icons and a "TOOLBAR" label.
- HEALTH METER:** A blue bar at the bottom right labeled "HEALTH METER".



ITS

ITS

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

Teachable Agents Group at Vanderbilt University

Bettydian

Porter

Teach Concept

Teach Link

Teach Theme

Reverse Link

Edit

Delete

Themes

- artery muscle system
- cold detection
- skin muscle system
- skeletal muscle system

Ask Mr. Davis

Ask Explain

Quiz Repeat

body temperature

body heat

heat loss

trapped air

raised hair

skin muscle contractions

blood flow to the skin

vessel constriction

shivering

friction

hypothalamus response

cold detection

cold temperatures

skeletal muscle activity

shivering produces (+) friction

friction generates (+) body heat

body heat increases (+) body temperature

body heat decreases (-) heat loss

heat loss preserves (+) body heat

trapped air preserves (+) body heat

skin muscle contractions cause (+) raised hair

raised hair more (+) trapped air

skin muscle contractions reduce (-) blood flow to the skin

blood flow to the skin generates (+) heat loss

heat loss reduces (-) body heat

hypothalamus response causes (+) skeletal muscle activity

skeletal muscle activity causes (+) shivering

hypothalamus response causes (+) vessel constriction

vessel constriction reduces (-) blood flow to the skin

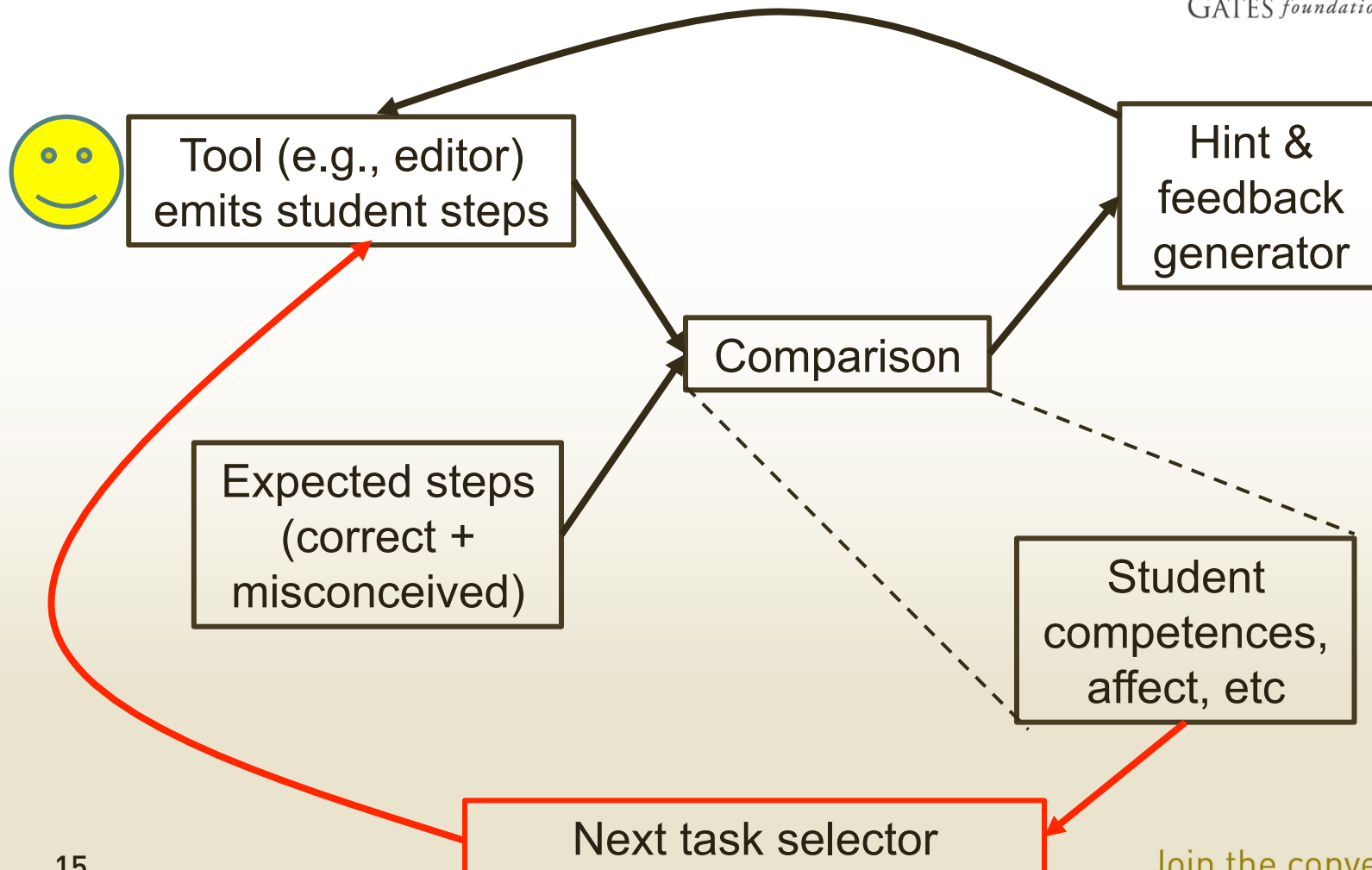
cold detection produces (+) hypothalamus response

hypothalamus response makes (+) skin muscle contractions

cold temperatures lead to (+) cold detection

What is the structure of an ITS?

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Adding an ITS makes these changes:

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- Will ITS improve the quality?

Next

- Increasing interaction and complexity of exercises
 - The Zone of Proximal Development
- Limitations

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

Join the conversation...

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

Part A

What tangential speed, v , must the bob have so that it moves in a circle making an angle θ from the vertical?

Express your answer in terms of some or all of the variables L , g , and θ .

$v =$

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

Hints

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 variables L , g , and θ .

Step-based tutoring

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s5a Physics

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:

Define time T0

g is the acceleration of gravity on earth
 $g = 9.8 \text{ m/s}^2$
 m = mass of the airplane
 Fw = weight force on the airplane

Help Score: 57%

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

Scenario

A rock climber is currently on the side of a cliff 67 feet off the ground. She can climb on average about two and one-half feet per minute.

- When will she be 92 feet off the ground?
- In twenty minutes, how many feet above the ground will she be?
- In 75 seconds, how far above the ground will she be?
- Ten minutes ago, how far above the ground would she have been?

To write the expression, define a variable for the climbing time and use this variable to write a rule for her height above the ground.

Worksheet for Problem B81T20

Quantity Name	CLIMBING TIME	HEIGHT ABOVE GROUND
Unit	MINUTES	FEET
Expression	T	67 + 2.5T
Question 1	10	92
Question 2	20	117
Question 3	1.25	70.125
Question 4	-10	42

Solver

Solve for T

$$25 = 2.5T$$

$$10 = T$$

Grapher

ShipDisplay MDI Window

Debug

Messages SCOT SimTaskTree:scot DMT TaskTree Agenda

Start Open Mic Mode

Dialogue:

SYS: Go ahead and try again.
 User: set fire boundaries
 SYS: No
 SYS: You should send repair team 5 to electrically and mechanically isolate the compartment.
 SYS: Why is it necessary to isolate when you have a report of fire?
 User: to contain the fire
 SYS: Okay. Well.
 SYS: You need to electrically and mechanically isolate in order to protect crucial ship systems.
 SYS: There is 1 more thing you should have done.
 SYS: What is it?

input text:

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.

Student Interface

Problem Statement | Dialog History | Variables | Equations

You said: definition of kinetic energy

Tutor said: Okay. Please write the equation for how the definition of kinetic energy applies to this problem at T1.

You said: value='ke1=1/2*m*v1^2'

Tutor said: Now it is easy to calculate the magnitude of v1. The magnitude of v1 is 5.0 m/s.

Tutor said: Before going on to the next step, let's think about the application of this equation.

Tutor said: Can we infer the direction of the velocity of the rock at T1 from the rock's kinetic energy at T1?

You said: no, we cannot

Tutor said: Excellent! Please explain why.

Only the magnitude of the velocity and not the direction of it is part of the definition of kinetic energy

Problem Statement | Dialog History | Variables

A 0.6 kg rock in space has a velocity of kinetic energy of 7.50 J at point B. What is the net work done on the rock i

the r
ock i

Name | Description

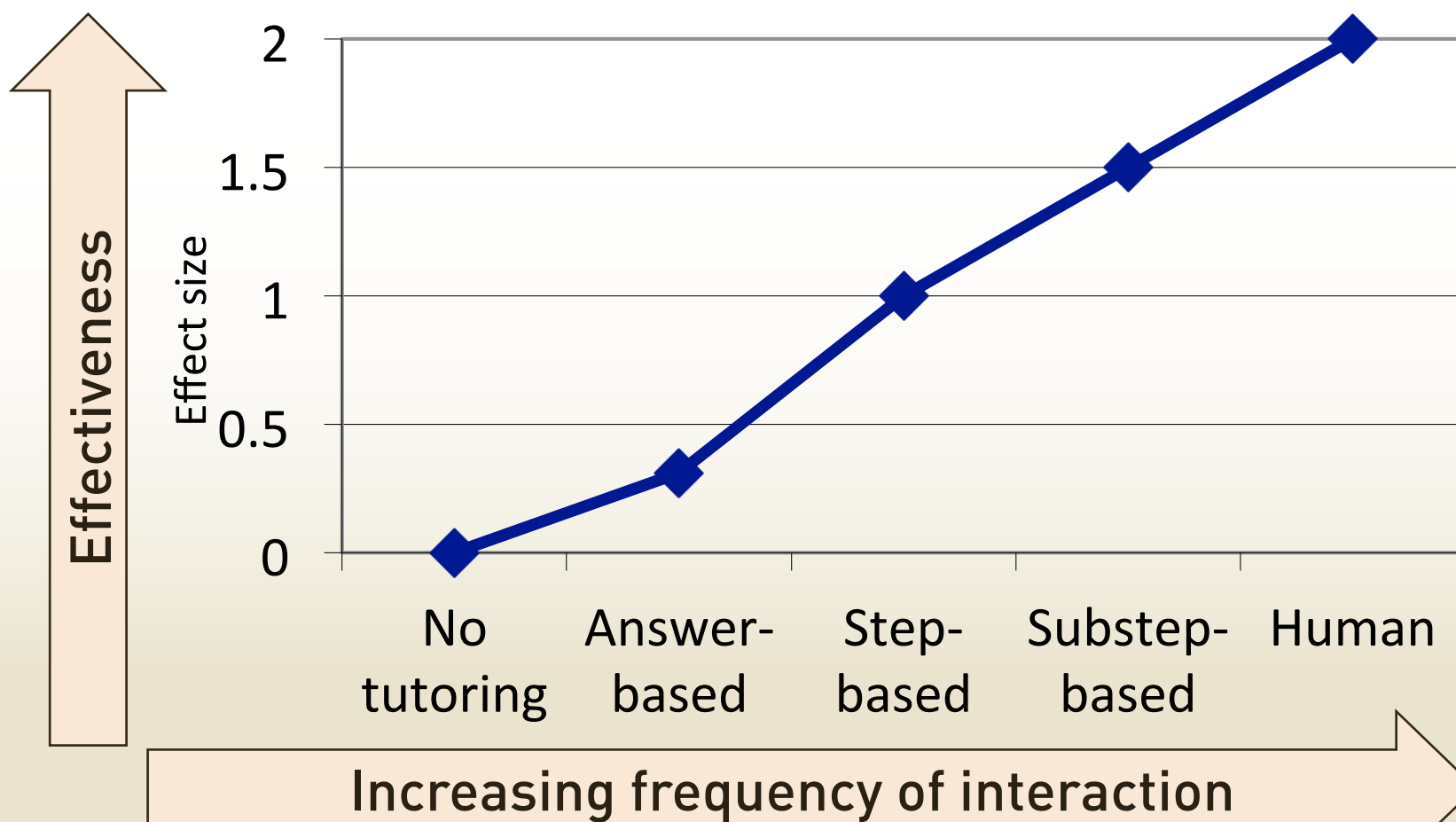
m | The mass of the rock is 0.60 k

Student enters an equation (step)

Tutor asks about reasoning behind the step

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

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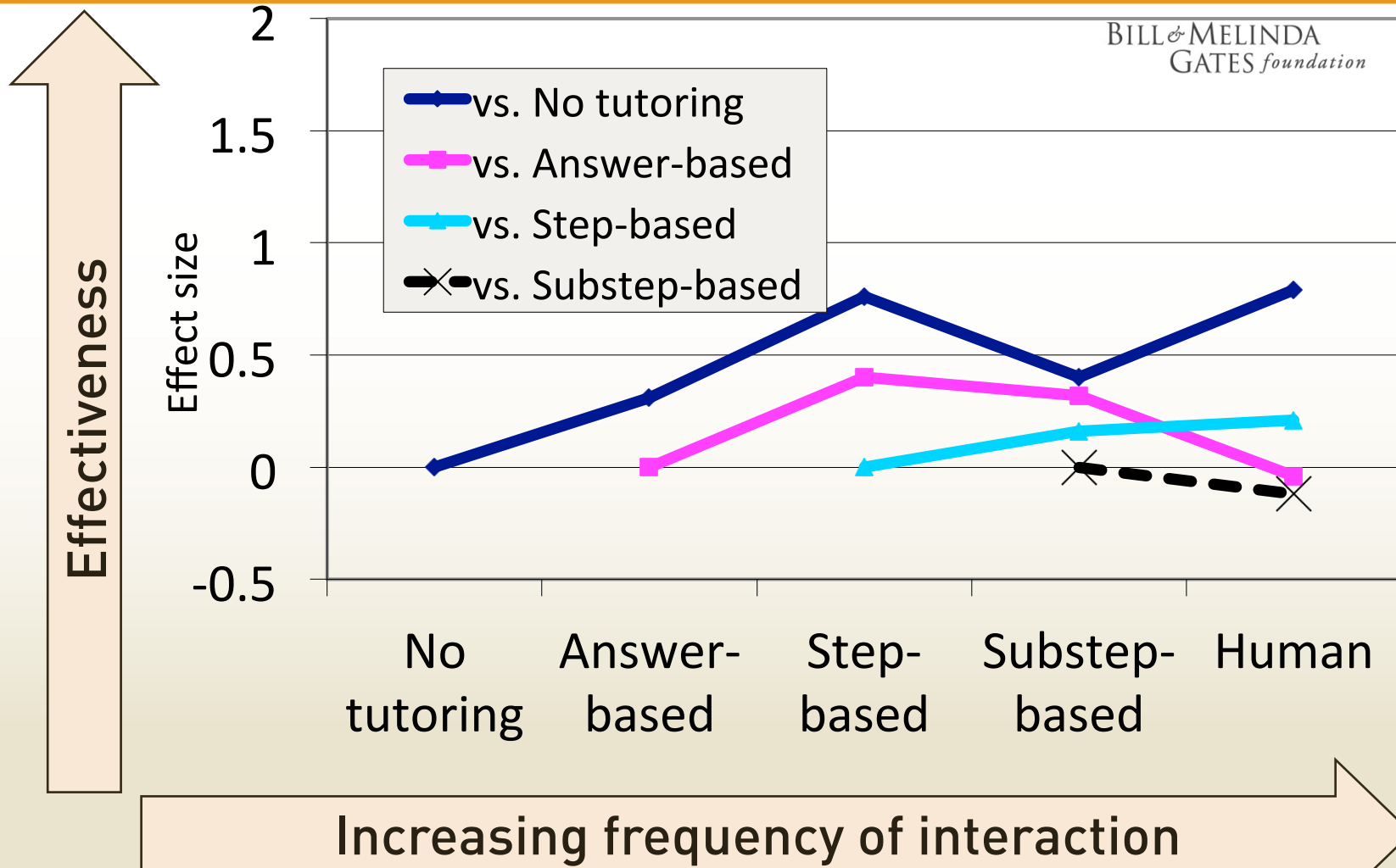
All possible pairwise comparisons

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%

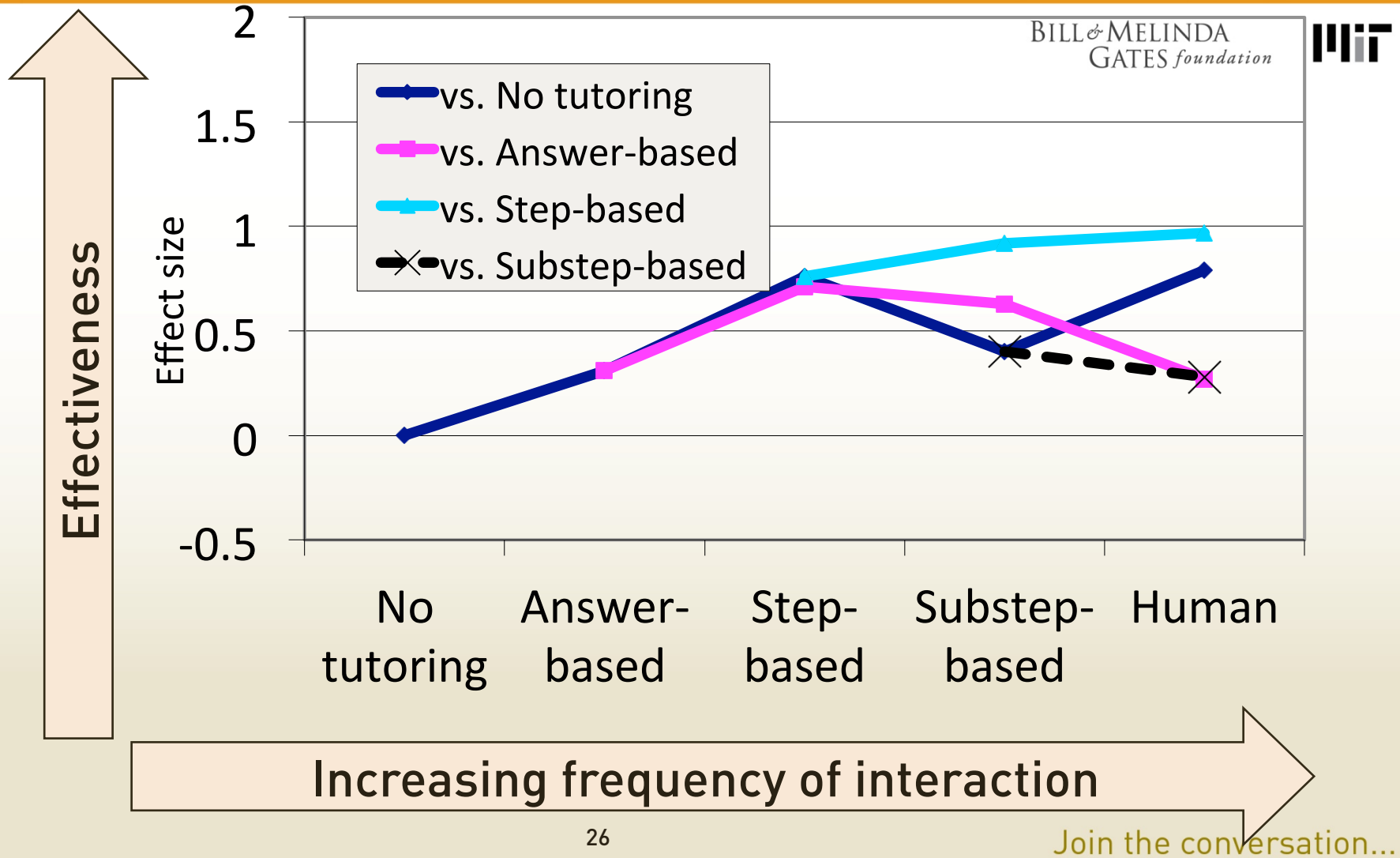
Graphing all 10 comparisons: But the graph is hard to understand...



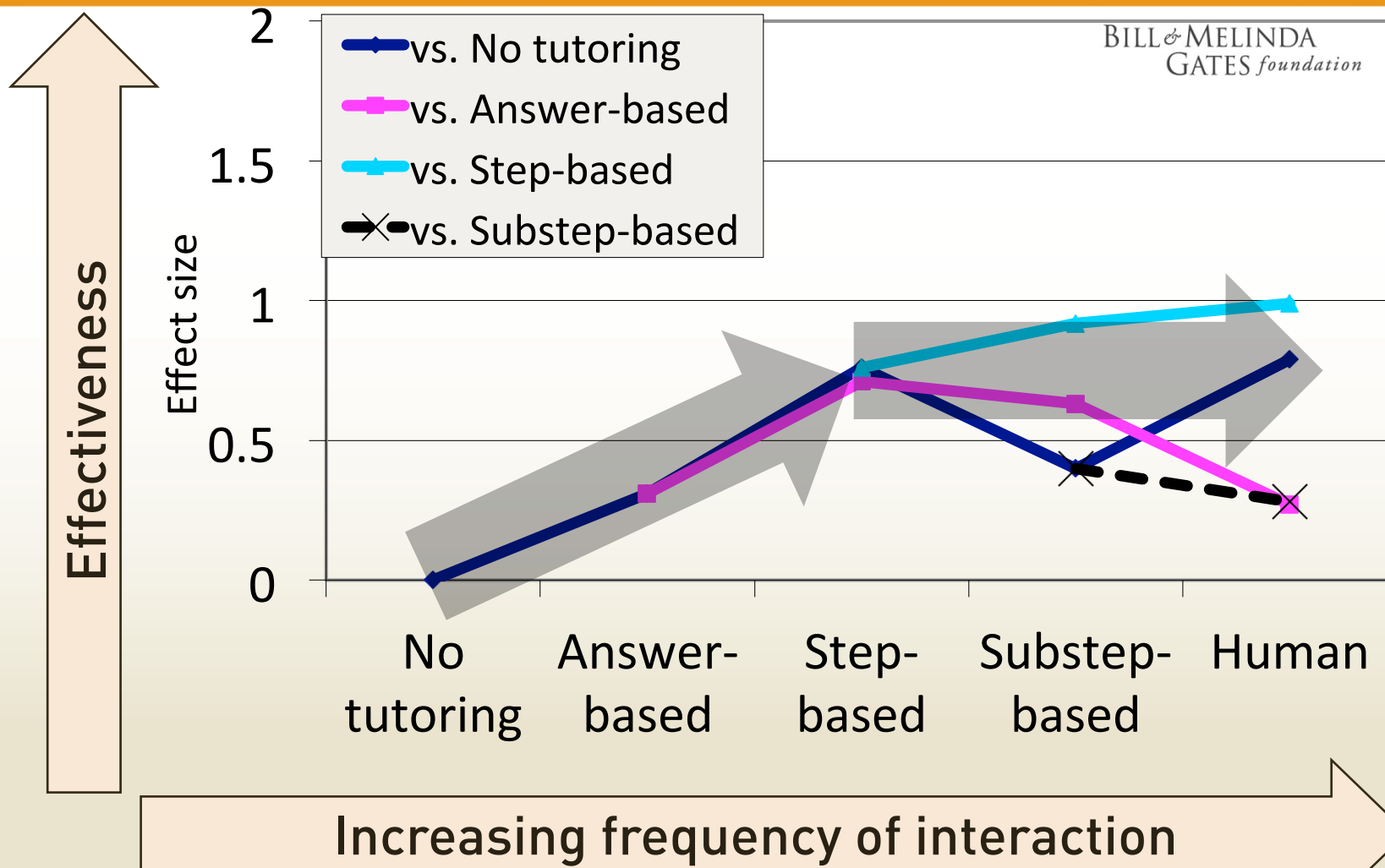
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Graphing all 10 comparisons: Lines raised to make it easier to integrate evidence



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



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Outline

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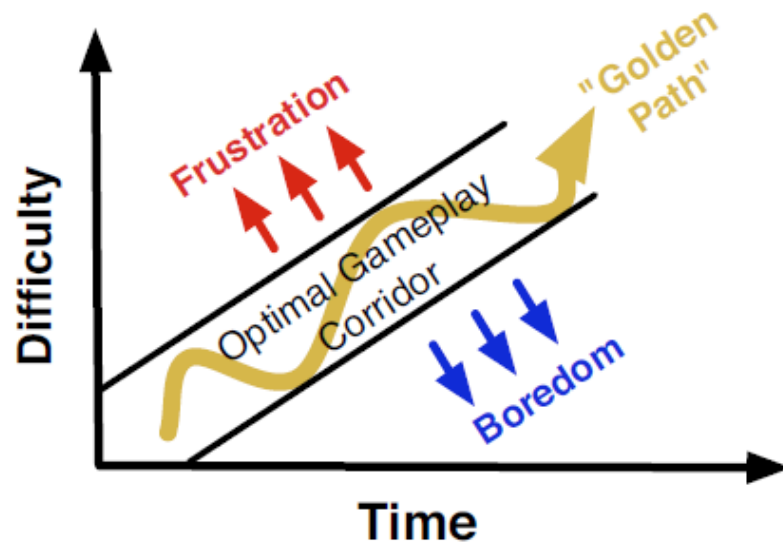


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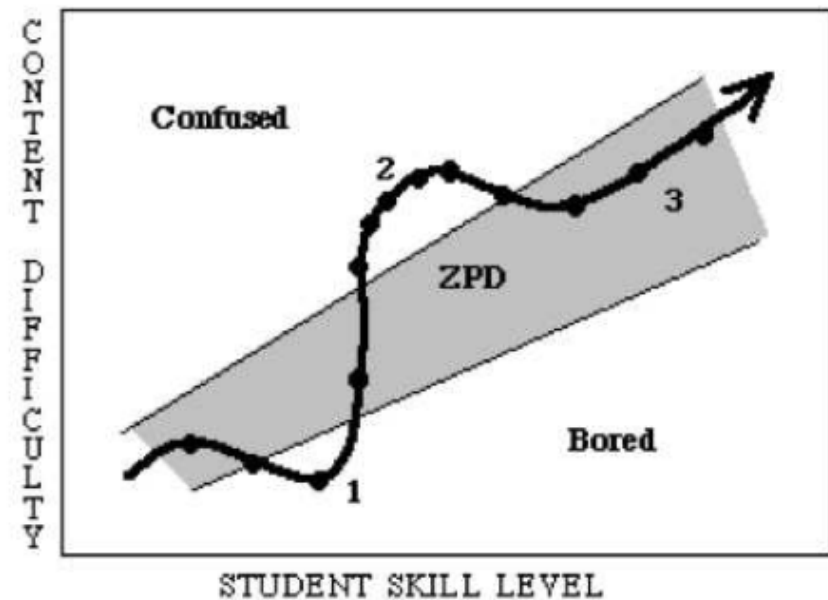
Next

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?

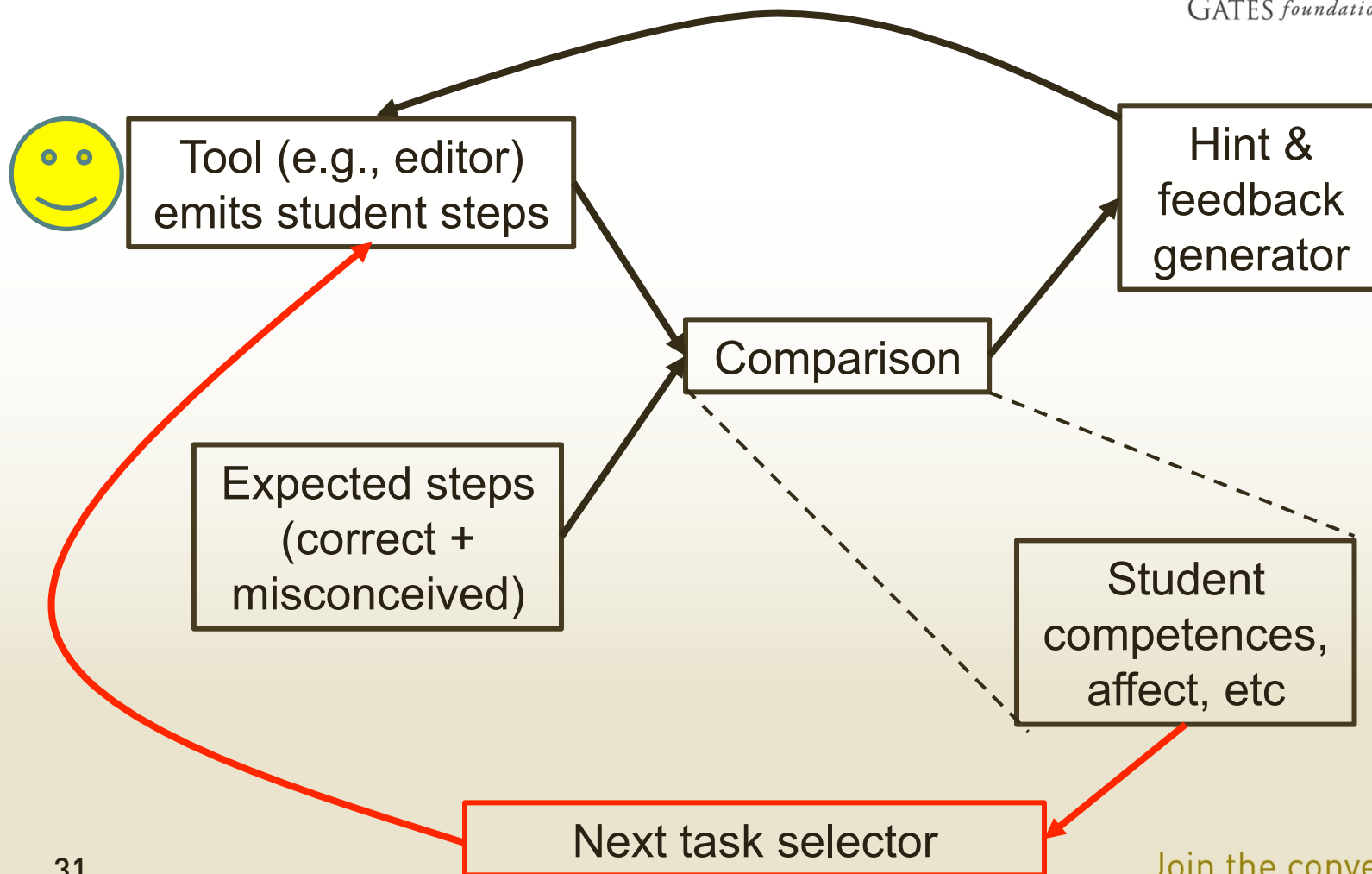
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- “Mastery (-paced) learning” means continuing to work on a module until you have mastered it.
 - Bloom, B. S. (1984). The 2 sigma problem: The search for methods of group instruction as effective as one-to-one tutoring. *Educational Researcher*, 13,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

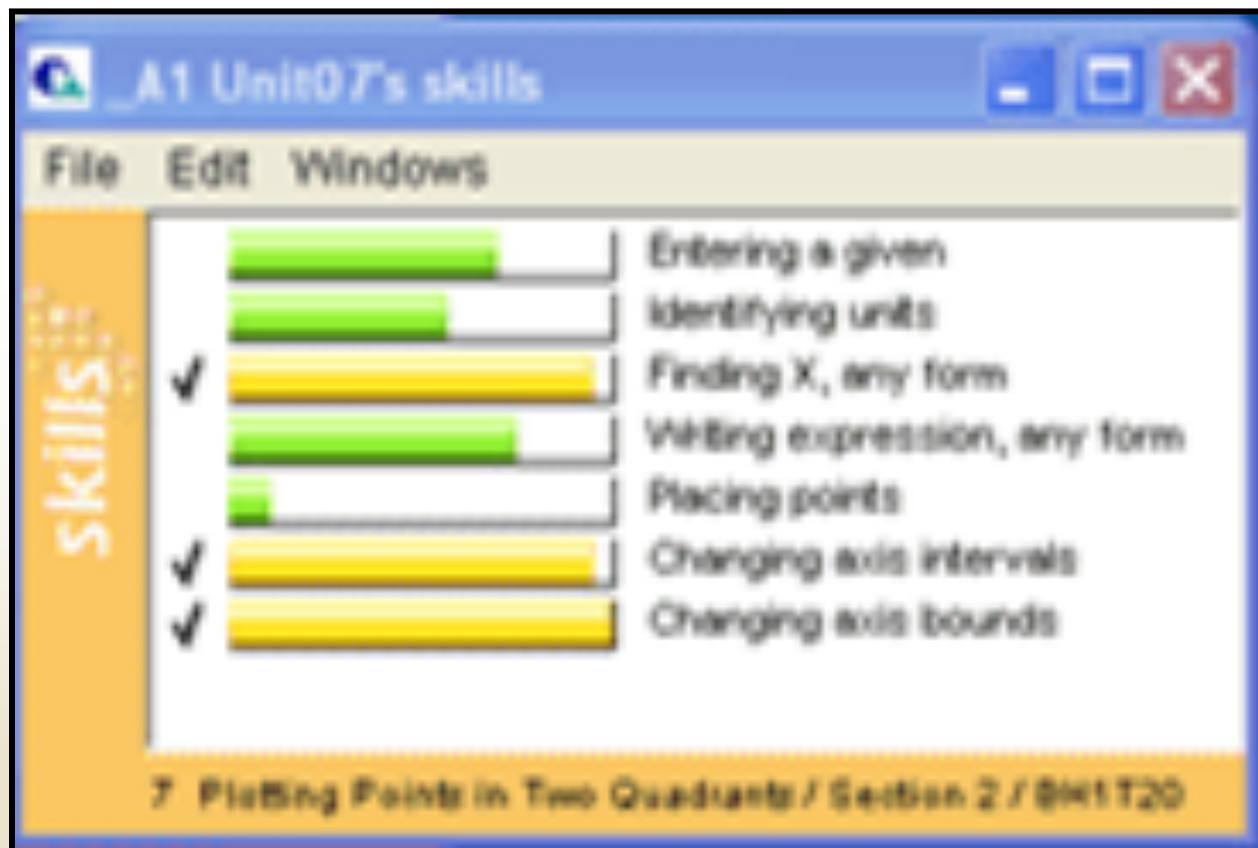
Mastery-paced learning implemented by the red path below

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Assessment can be shown to student

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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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Next

An ITS does not do everything

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- Discussion forum
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 - Final exam
- dynamically adaptive
- complex, dynamically scaffolded
- unnecessary

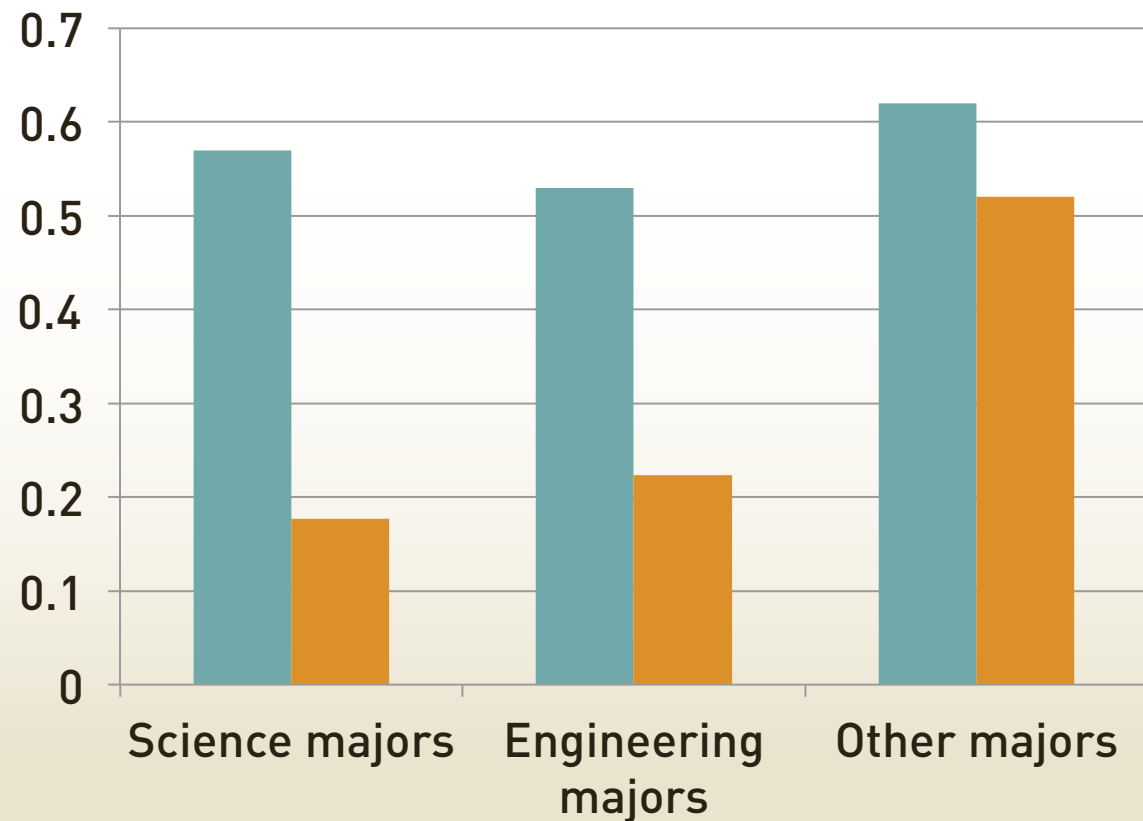
Some learners do not need and do not like ITS (or any other scaffolding)

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

- Open response problem solving midterms
- Multiple choice final exam



Costs

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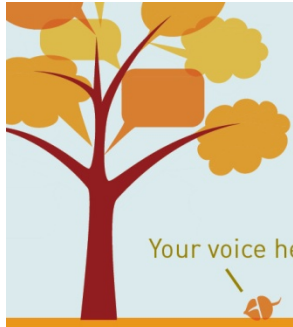


Graded exercises

- 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)



Your voice here

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Thank you!