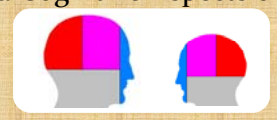
ALT-Pathway: Technology for Studying Social and Cognitive Aspects of Learning



Chris Nakamura
K-State Physics Education Research Group:
Sytil Murphy, Nasser Juma, Sanjay Rebello, Dean Zollman
Carnegie Mellon Entertainment Technology Center:
Scott Stevens & Mike Christel
Kansas State University Physics Education Seminar
Physics Education Research Group 5/1/2009
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Project Overview

ALT-Pathway:

- Joint Project between K-State Physics Education Researchers and Carnegie Mellon Computer Science Researchers
- Seek to Develop a Web-based Tutoring System to Study and Improve Learning.

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Topics for Discussion

1. Motivation for Studying Tutoring
2. Connections to Educational Theories
3. Developing our Synthetic Tutor
4. Research Opportunities
5. Summary and Future Work

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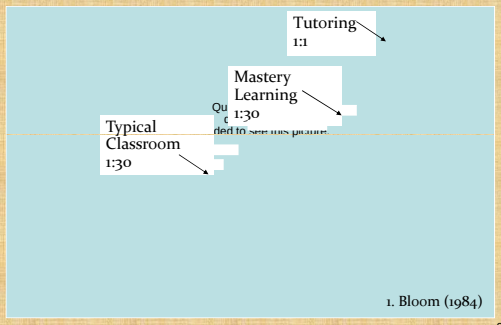
The Effectiveness of Tutoring



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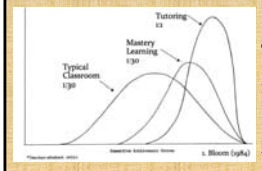
The Effectiveness of Tutoring



This Prompts Several Questions…

1. Why is tutoring so much more effective?
2. What is holding the bottom students back?
3. Can we obtain similar results without human tutoring, which appears cost-prohibitive?

Operational Definition: A Tutor is someone whose domain knowledge is good, but may be pedagogically untrained, who provides instruction, often informally.

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Why is Tutoring So Effective?

Logically we might infer that tutoring lets the tutor:

- Recognize students' understanding & misconceptions
- Provide personalized scaffolding
- Fine-tune the interaction in general

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Why is Tutoring So Effective?

Research indicates that tutoring lets the student:[2,3]

- Construct explanations
- Challenge the veracity of those explanations
- Learn in a socially interactive manner

2. Chi et. al, (2001) , 3. Chi et. al (2004) 6

Why is Tutoring So Effective?

Meanwhile the tutor:[2,3]

- Failed to correctly assess understanding
- Failed to correctly assess misunderstanding
- Often missed opportunities to provide scaffolding

Bottom line: Tutoring is a more student-centered instructional method.

(Matches up with our Constructivist perspective[4])

2. Chi et. al, (2001), 3. Chi et. al (2004), 4. Inhelder & Piaget (1958) 7

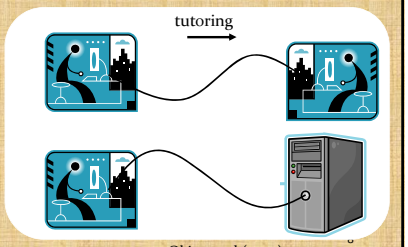
Is it Really All Just the Student?

Kind of…?

An interesting V.R. tutoring experiment[5]:

Group I Thinks This:

Group II Thinks This:



5. Okita et. al (2007)

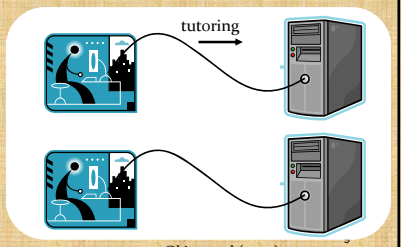
Is it Really All Just the Student?

Kind of…?

While in reality[5]:

Group I Does This:

Group II Does This:



5. Okita et. al (2007)

Is it Really All Just the Student?

Kind of…?

The result[5]:

People appear to learn better if they perceive social interaction.

(Connection to Vygotsky's social constructivism[6]…)

But more work can be done in this area…

5. Okita et. al (2007) 6. Vygotsky (1978) 10

Research Motivations

- Tutoring is a relatively intimate teaching method.
- Just because tutors need not accurately gauge students' learning doesn't mean they *cannot*.
- Tutoring is inherently social, but in a complex way

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Research Motivations

- Tutoring is a relatively intimate teaching method.
- Just because tutors need not accurately gauge students' learning doesn't mean they *cannot*.
  - → Gives direct access to students' knowledge construction processes (Mirrors Interview)
- Tutoring is inherently social, but in a complex way
  - → This facet alone warrants further study

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Why on a Computer?

Instruction advantages:
- Computers are always available for help and cheaper than human tutors.

Research advantages:
- Computers can log detailed interactions for 1000's of students.
- Computers provide reproducible stimuli and responses

Instruction disadvantages:
- Computers have no intelligent recognition of success or failure

Research disadvantages:
- Computers cannot intuit when to ask probing questions or tune protocols on the spot

A computerized tutoring system may provide a useful supplement to human instruction *and* human data collection (interviews).

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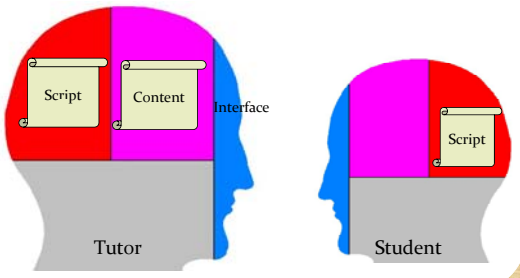
Developing A Synthetic Tutor

A Conceptualization of Tutoring:



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Developing the Lessons (Script)

- 3-stage learning cycle[7,8]
- Teach Newton's laws (3 lessons)
- Use video to emulate hands-on measurement
- Combine objective & subjective responses
- Must have online response collection

7. Karplus & Butts (1977) 8. Zollman (1990)

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Developing the Interface

CMU's Synthetic Interview (SI) Technology[9]:
- Matches natural language questions to pre-recorded video responses
- Can simulate simple conversations
- Has previously been employed for educational purposes

9. Stevens et. al (2007)

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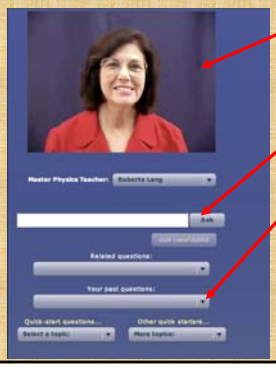
The Synthetic Interview



Pre-Recorded Video Responses

Enter Questions

Related Questions & Quick Start

Resembles Video-Chat

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Developing the Interface

Selected Three Tutors:

- Good domain knowledge => Provide Content
- Prior teaching experience
- Interest in physics education



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Connecting Interface & Content

The SI interface maps students' questions onto a master list of questions

→ We need a list of questions & responses

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Connecting Interface & Content

The SI interface maps students' questions onto a master list of questions

→ We need a list of questions & responses

Based on student interviews we've generated ~80 relevant content questions & videotaped responses from our tutors

Need to produce a database of variations ~4000 for the SI system to search

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Connecting Interface & Content

Potential Problem:

Failure matching questions & answers may frustrate (students may have low threshold)

Current Effort:

Working with CMU test tool to maximize the correct match-ups.

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Connecting Interface & Content

Potential Opportunity:

Tutors often use sketches, and written examples to aid students

We can also use support materials, but the Internet allows the addition of videos or applets as well

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Connecting Interface & Content

Potential Opportunity:

Tutors often use Socratic Dialogue to help students learn

We can try to simulate Socratic Dialogue by using appropriate "question hints" which they can ask for.

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Let's Put it all Together

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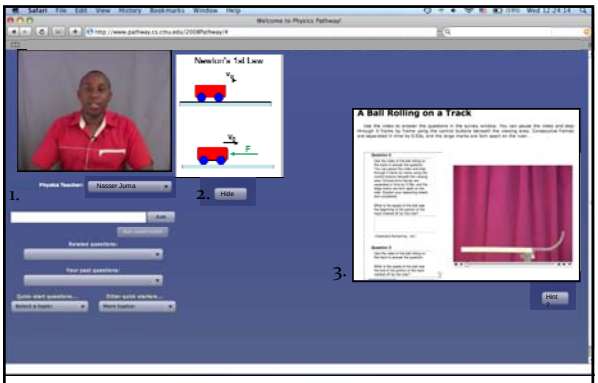

1. SI Persona answers students' Physics content questions.
2. Supporting multimedia is displayed along side SI persona.
3. Lesson materials are displayed on the right. Students can ask for Socratic hints.

Accessibility

Important Questions

1. How does Internet access vary by geography, and other contextual parameters?
2. How do students' technical capabilities vary? (How do we measure it?)
3. How do we produce a tutor that is useful for everyone?

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Testing the Synthetic Tutor

Four Facets to Test

1. Test the Content
2. Test the Lessons
3. Test the Interface
4. Test the System

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Testing the Synthetic Tutor

Four Facets to Test

1. Test the Content — Continuous process
2. Test the Lessons — Our Current Focus
3. Test the Interface — Our Current Focus
4. Test the System — For another talk

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Testing the Lessons

Key Ideas:

- Students must complete them un-guided
- Lessons must use calculation & explanation as tests of understanding
- The lessons must probe deep understanding

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Testing the Lessons

Test Groups

Fall 2008:

15 High School Physics Students in AZ

Spring 2009:

30 High School Physics Students in KS

89 College Algebrab-based Physics Students

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Preliminary Observations

- Students are familiar with kinematics concepts but still need scaffolding
- Feedback is probably necessary to inform students when their numerical answers are far off
- Students explanations can reflect memorized information that contradicts their calculations and observations
- Students need a lot of encouragement to explain their reasoning, but some do explain in detail.

A detailed analysis is necessary…

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Evaluating Socratic Hints

Spring 2009

~100 College students were surveyed to assess utility and abstraction of possible hints

Students who had already worked with the lesson materials were selected

Data is hot of the presses

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Research Designs

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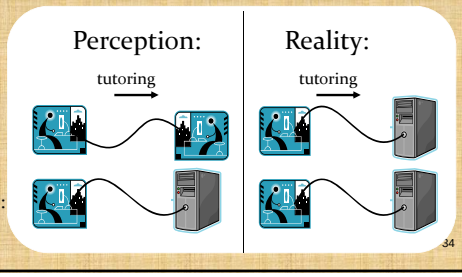
Wizard of Oz Experiment

(Toto, I have a feeling we're not in Kansas, anymore)

Recall the Schwartz Group's Design:



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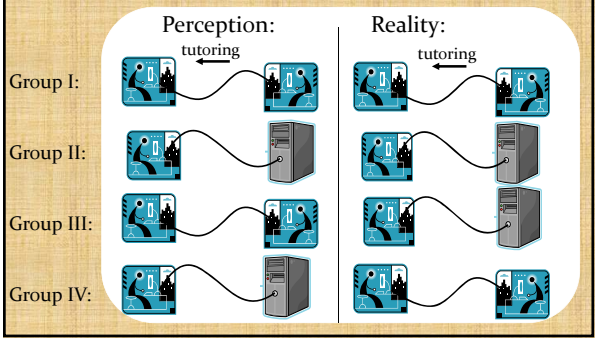
Wizard of Oz Experiment

(Pay no attention to that man behind the computer behind the curtain)

Our Proposed Design (Pre/Post comparison):



Wizard of Oz Experiment

Challenges to meet:

- Technology Challenges: The interactions cannot be perceptibly different
- Find/Develop Pre/Post Test (FCI[10]?)
- Content Challenges: Lessons may be too long
- Standard Volunteer Recruitment Issues (This study requires 40 people minimum)

Questions Answered:

- Can we expect to reap benefits similar to real tutors with video?
- Is the effect observed by Okita purely psychological or also external to the subject?
- Do people respond differently to video as compared to V.R. avatars?

10. Hestenes et. al (1992) 36

Media's Role in Learning

Recent research indicated[11]:

•Multimedia improved student learning over a popular textbook

•An image free script containing similar content also improved learning over the textbook (thought not as much)

11. Stelzer et. al (2009) 37

Media's Role in Learning

Recent research indicated[11]:

•Multimedia improved student learning over a popular textbook

•An image free script containing similar content also improved learning over the textbook (though not as much)

⟶Optimization is important

11. Stelzer et. al (2009) 38

Media's Role in Learning

Our proposed comparison:

Level I: The SI Speaks alone

Level II: The SI & a static image

Level III: The SI & other video/applets[11]

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12. Bennett (2007)

Media's Role in Learning

Our proposed comparison:

Level I: The SI Speaks alone

Level II: The SI & a static image

Level III: The SI & other video/applets[11]

Research Question: Which level best promotes learning?

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12. Bennett (2007)

Media's Role in Learning

Our proposed comparison:

Level I: The SI Speaks alone

Level II: The SI & a static image

Level III: The SI & other video/applets[11]

Research Question: How does image or video abstraction affect student learning?

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12. Bennett (2007)

Summary

- A synthetic tutor may be useful both for instruction and studying learning
- Progress has been made toward that goal
  - Lessons have been written & undergone a first test
  - First 80 video responses recorded for 3 tutors
  - Static image supplemental materials are made
  - Work has begun on generating the SI master question list
- Several interesting research designs have been presented

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Ongoing Efforts

- Detailed analysis of our HS & College data
- Record static image video responses
- Develop video supplemental materials & record responses
- See the prototype system (this summer!)
- Establish H.S. & college collaborations
- Develop technology for Wiz. of Oz exp.
- Study student web access and technological sophistication in depth

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References

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2. Chi, M. T. H., (1996). "Constructing self-explanations and scaffolded explanations in tutoring," *Journal of Applied Cognitive Psychology*, 10(S), S33-S49
3. Chi, M. T. H., Siler, S. A., and Jeong, H., (2004). "Can tutors monitor students' understanding accurately?," *Cognition and Instruction*, 22(3), 363-38
4. Inhelder, B. and Piaget, J. (1958). *The growth of logical thinking for childhood to adolesence*. New York: Basic Books
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8. Zollman, D., (1990). "Learning cycles for a large enrollment class," *The Physics Teacher*, 28, 20-25
9. Stevens S., Zollman, D., Christel M., and Adrian B., (2007) "Virtual Pedagogical Agents as Aids for High School Physics Teachers," *International Conference on Interactive Computer-aided Learning*
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11. Stelzer, T., Gladding, G., Mestre, J. & Brookes, D.T. (2009). "Comparing the efficacy of multimedia modules with traditional textbooks for learning introductory physics content" *American Journal of Physics*, 77(2), 184-190
12. Andy Bennett, "I-Pod Math," Kansas State University Physics Education Seminar Unpublished.
13. I. Ivanov, Private Communication

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Jacki's Discussion Questions

1. Is the synthetic interview authentic enough to get buy-in from students?
2. How much is too much when adding additional content alongside the SI?
3. How would the use of eye-tracking software benefit this study (if at all)?
4. If Chris *et al.* see a desired result with this context, would the results generalize to other content areas in physics?

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Emergency Back-Up Slides

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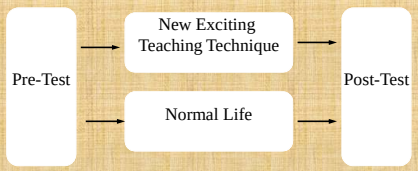
Assessing Learning

Simplest Experimental Design:



Advantages:

High scientific credibility (if done right)

Disadvantages:

Systematics must be considered carefully

Most Importantly- Teaching to the test

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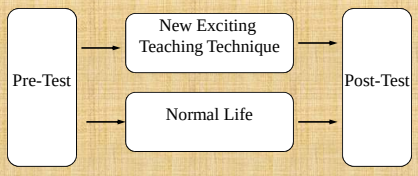
Assessing Learning

Simplest Experimental Design:



For pre- and post-test multiple choice assessments already exist:
Use Force Concept Inventory[11], or similar-style questions.

Question: What kind of information can we extract?

[10] Hestenes(1992)

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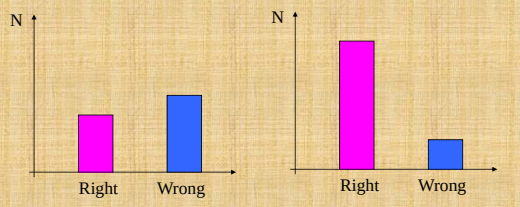
Assessing Learning

Simplest Analysis of Learning:
Given a 4-choice multiple choice question



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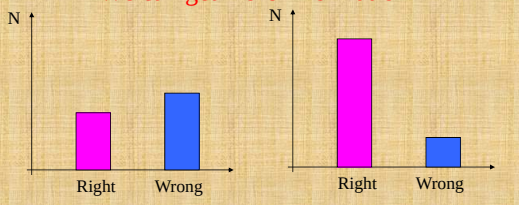
Assessing Learning

Simplest Analysis of Learning:
Given a 4-choice multiple choice question
We can get more information



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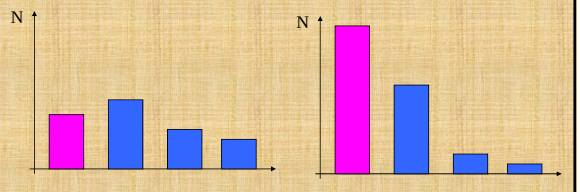
Assessing Learning

Next Simplest Analysis of Learning:
Given a 4-choice multiple choice question



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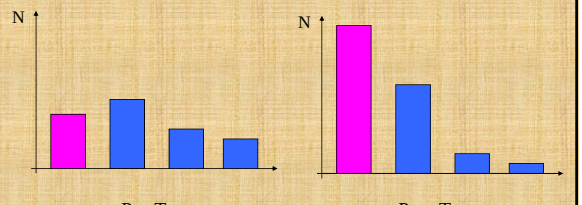
Assessing Learning

Next Simplest Analysis of Learning:
Given a 4-choice multiple choice question
We can still get more information



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Assessing Learning

Analysis of Learning:
Given a test with several multiple choice questions

Q1: A B C D

Q2: A B C D

Students' wrong answers may exhibit correlations
Correlations may reveal unobserved, latent variables
Categorical Data => Latent Class
This has been done in Physics before[13]

[13] Ivanov (2008)

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Assessing Learning

Our Ultimate Goal:
Use Latent Class Analysis to

1. Observe latent classes of understanding in High School & College Physics students
2. Characterize the probability of a student transitioning between these classes as a result of our various instructional materials
3. Use these results to evaluate the efficacy of our synthetic tutor

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Matching Up Questions

You type: How does an object move when it feels no net force?
The List Contains:

1. What is the behavior of an object with zero net force?
2. What is the acceleration of an object with zero velocity?
3. How does an object move when it feels no friction?
4. What is the acceleration of an object moving in a circle?

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3. **How does an object move when it feels no friction?**
4. What is the acceleration of an object moving in a circle?

The system got it wrong because:

1. Common words are scarce in the search list (how, move, etc…).
2. Too few variations on the questions were used (Shallow list)

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Matching Questions

List Development

1. Make a master list of questions
2. Query it many times (count successes & failures)
3. Refine

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