Computers and Education

Symbsys 100
Ling 144
Psych 130
Phil 190

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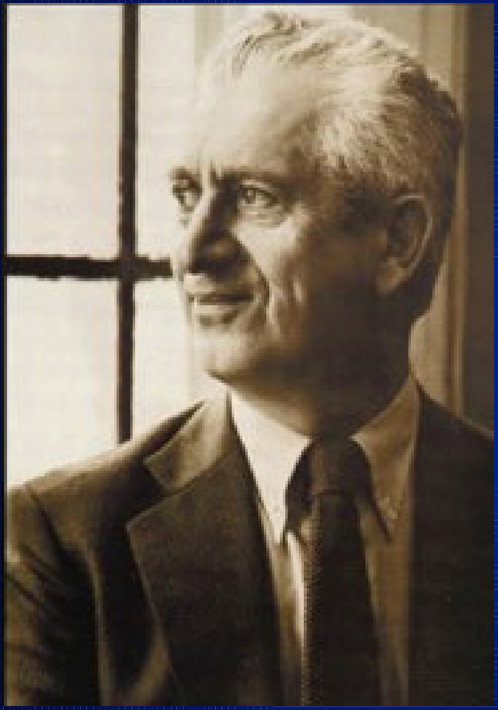
and Education

May 27, 2008

Three papers spanning 25 years

- Bloom's famed (1984) *2-sigma problem* paper on the effectiveness of tutoring
- Koedinger & Corbett's (2006) chapter on "cognitive tutors" from the *Cambridge Handbook of the Learning Sciences*
- Chan et al's (2006) paper with authors from 11 countries, on *one-to-one technology-enhanced learning* and the opportunities for global research collaborations. Beyond tutors.

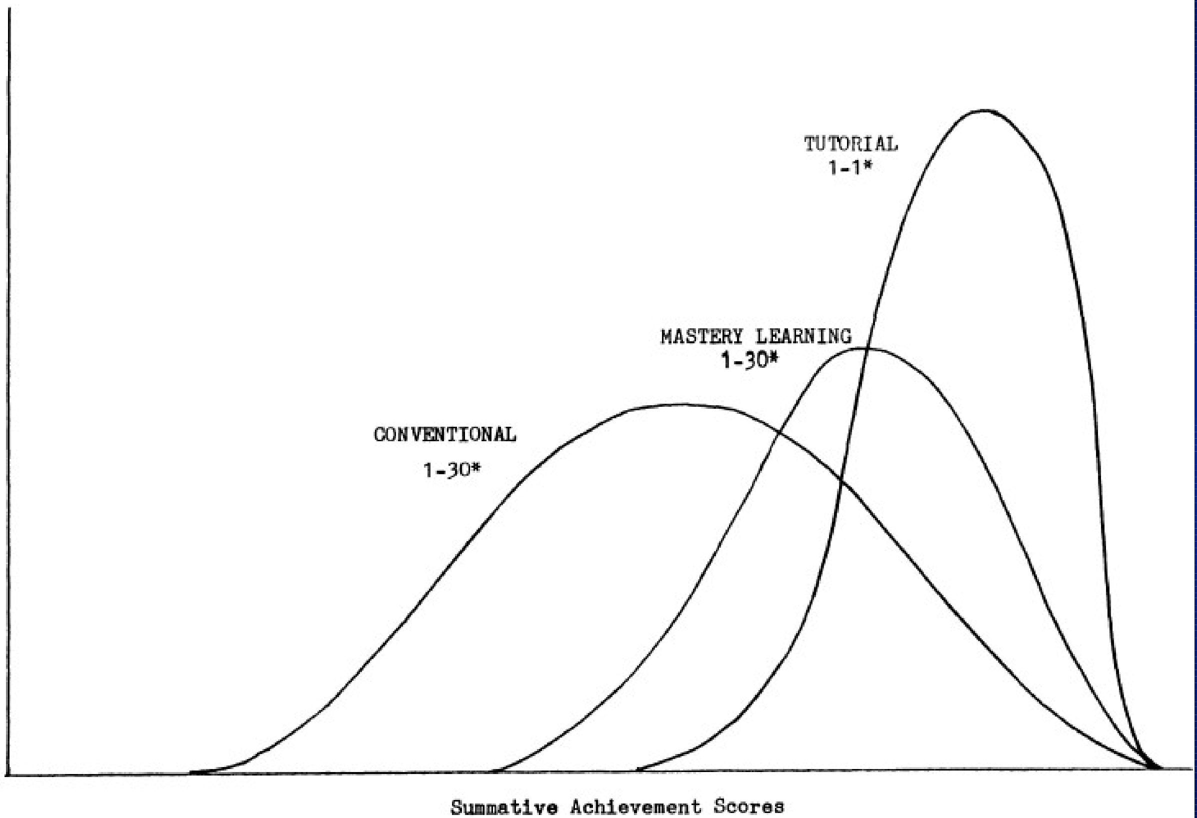
Bloom, Benjamin S. (1984)
The 2 Sigma Problem



- Searching for methods of group instruction as effective as one-to-one tutoring
- Three conditions compared to begin to establish benchmarks:
  - "Conventional" teacher-led class
  - "Master learning teacher-led class
  - "Tutoring" (1-3 students at once)

tutoring

FIGURE 1. *Achievement distribution for students under conventional, mastery learning, and tutorial instruction.*



*Teacher-student ratio

- Using the standard deviation (sigma) of the control (conventional) class, it was typically found that the average student under tutoring was about two standard deviations above the average of the control class (the *average* tutored student was above 98% of the students in the control class).
- The average student under mastery learning was about one standard deviation above the average of the control class (the *average* mastery learning student was above 84% of the students in the control class).

Why is this exciting - and a quest?

- “The tutoring process demonstrates that *most* of the students do have the potential to reach this high level of learning.”
- “… an important task of research and instruction is to seek ways of accomplishing this under more practical and realistic conditions than the one-to one tutoring, which is too costly ... *this is the "2 sigma" problem.*

The 'toolkit'

Effect Size=

Difference between experimental and control groups divided by standard deviation of control group

TABLE I

Effect of selected alterable variables on student achievement (see Appendix)

		Effect size	Percentile equivalent
D[a]	Tutorial instruction	2.00	98
D	Reinforcement	1.20	
A	Feedback-corrective (ML)	1.00	84
D	Cues and explanations	1.00	
(A)D	Student classroom participation	1.00	
A	Student time on task	1.00[b]	
A	Improved reading/study skills	1.00	
C	Cooperative learning	.80	79
D	Homework (graded)	.80	
D	Classroom morale	.60	73
A	Initial cognitive prerequisites	.60	
C	Home environment intervention	.50[b]	69
D	Peer and cross-age remedial tutoring	.40	66
D	Homework (assigned)	.30	62
D	Higher order questions	.30	
(D)B	New science & math curricula	.30[b]	
D	Teacher expectancy	.30	
C	Peer group influence	.20	58
B	Advance organizers	.20	
	Socio-economic status (for contrast)	.25	60

Note. This table was adapted from Walberg (1984) by Bloom.

[a]*Object of change process*—A-Learner; B-Instructional Material; C-Home environment or peer group; D-Teacher.

[b]Averaged or estimated from correlational data or from several effect sizes.

The search: for two variable combinations that can reach 2 sigma

- Paper outlines 2 X 2 randomized designs with mastery learning and one other variable with 0.5 sigma effect or greater
- Replicated with 2+ subjects, 2 levels of schooling

Five different tacks are taken

- Improve student processing of conventional instruction
- Improve instructional materials and educational technology
- Enhance home environment and peer group
- Improve teaching
- Improve teaching of higher mental processes

processing of conventional instruction

- Teaching stays the same - can students learn more effectively?
- *Mastery learning*: formative tests plus a feedback-corrective approach provide learners with cognitive and affective prerequisites for each new learning task
- Leyton study used ML during advanced course in a sequence but refreshed prior course learning to enhance initial cognitive prerequisites (e.g., HS Algebra-2; French-2)
- *Results*?
  - ML+Enhanced Prereq's => 1.6 sigma effect
  - Note: extra time costs only in first week
- Related strategies:
  - Cooperative learning in student support group (0.8 effect size)
  - Improving reading and study skills (1.0 effect size)

materials and educational technology

- Fix the textbook by making it better organized around important ideas and their inter-relationships (but - new math and sci curric had avg effect size of 0.3 sigma)
- Advance organizers have modest effect size (0.2 sigma)
- He is optimistic that computer learning courses (*Plato* at that time) could come to attain the 2 sigma achievement effect.

3) Enhance home environment and peer group

- Can out of school support from home or peers help the student?
- Home environment processes include:
  - Family work habits
  - Academic guidance & support
  - Home stimulation & encouragement in exploring ideas/events
  - Language development
  - Academic aspirations and expectations for child
- Can affect school learning aspirations and achievements - esp. elementary school
- Experimental studies of parent education yielded 0.5 sigma effect size (but costly interventions)

4) Improve teaching

- Observes that 20% of conventionally taught students do as well as tutored students
- One source? Unequal treatment of students within most classrooms
  - Teachers frequently direct teaching, explanations, active participation to some but not other students
  - Studies find top 1/3 get greatest attention
  - Teachers often unaware of inequitable treatment
- Conjecture:
  - when teachers are helped to secure an accurate picture of their teaching methods and how they of interact with students, they will increasingly be able to provide more favorable learning conditions for more of their students

4) Improve teaching (continued)

- Studies provide 'mirroring' of what teachers do and have them develop techniques for equalizing student interactions
  - Find something positive and encouraging for all
  - New ways to involve more students' active participation
  - Get feedback from small random sample on comprehension
  - Supply extra clarifications and illustrations when needed
- *Nordin*: 1.5 sigma effect size in achievement with enhanced cues (explanations), participation & reinforcement (CPR) compared to conventional instruction - Observations: time on task -75% vs 57% of classtime
- *Tenenbaum*: 1.7 sigma effect size for ML + CPR - and 87% vs 68% time on task

5) Improve teaching of higher mental processes

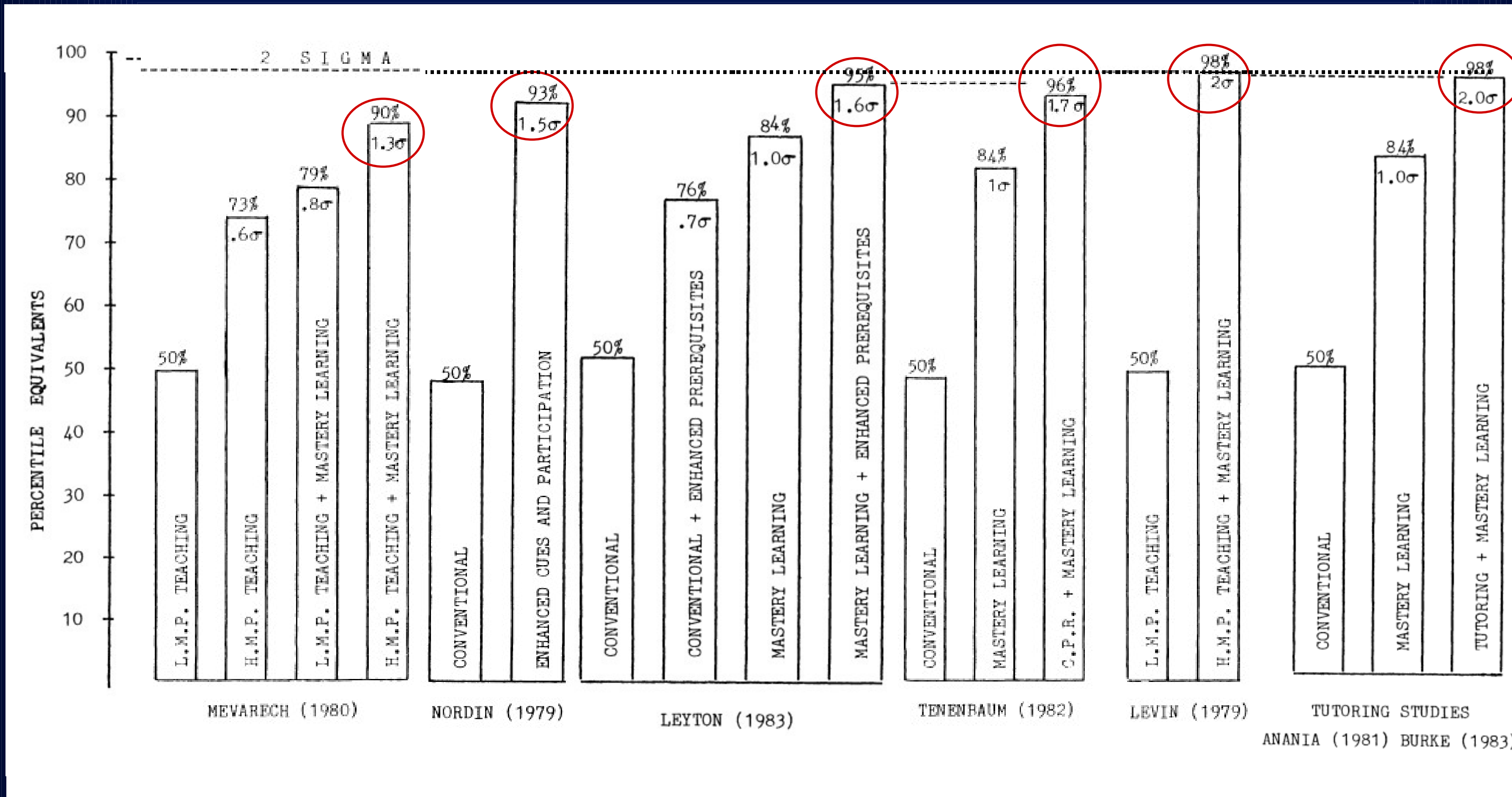
- Problem-solving, analytical skills, creativity…
- National curriculum centers (Israel, South Korea, Malaysia) focus for teaching domains as methods of inquiry into science, math, etc
  - Observations, reflections, experimentation, first hand data, problem solving heuristics
  - Reflected in activities, L&T processes, problems for formative and summative testing
- *Contrast*: estimate 90% US public school test questions “deal with little more than information” (rote learning)

higher mental processes (continued)

- HMP: Group instruction on higher mental proceses and feedback-correct processes (formative assessment)
- Tutoring studies found Higher Mental Process achievement 2 sigma above conventional
- *Levin*: 2 sigma effect, for Higher Mental Process teaching (HMP) principle application for different problem situations plus Mastery Learning
- *Mevarech*: 1.3 sigma effect for HMP + Mastery Learning (vs those learning algorithms only)
- Bloom notes extensive corrective help needed for higher mental processes questions and problems

Summary

- The different tacks were productive in establishing a range of ways to approve the 2-sigma effectiveness of tutoring
- Six solutions to the 2 sigma problem were identified - none quite as effective as tutoring but getting close



PERCENTILE EQUIVALENTS
100
90
80
70
60
50
40
30
20
10
2 SIGMA
50%
L.M.P. TEACHING
73%
.6σ
H.M.P. TEACHING
79%
.8σ
L.M.P. TEACHING + MASTERY LEARNING
90%
1.3σ
H.M.P. TEACHING + MASTERY LEARNING
MEVARECH (1980)
50%
CONVENTIONAL
93%
1.5σ
ENHANCED CUES AND PARTICIPATION
NORDIN (1979)
50%
CONVENTIONAL
76%
.7σ
CONVENTIONAL + ENHANCED PREREQUISITES
84%
1.0σ
MASTERY LEARNING
95%
1.6σ
MASTERY LEARNING + ENHANCED PREREQUISITES
LEYTON (1983)
50%
CONVENTIONAL
84%
1σ
MASTERY LEARNING
96%
1.7σ
C.P.R. + MASTERY LEARNING
TENENBAUM (1982)
50%
L.M.P. TEACHING
98%
2σ
H.M.P. TEACHING + MASTERY LEARNING
LEVIN (1979)
50%
CONVENTIONAL
84%
1.0σ
MASTERY LEARNING
98%
2.0σ
TUTORING + MASTERY LEARNING
TUTORING STUDIES
ANANIA (1981) BURKE (1983)

Koedinger & Corbett Cognitive Tutors

- Integrating CAI and computational models of cognition => Cognitive Tutors
- Intelligent Tutoring Systems built around computational cognitive models of knowledge students are acquiring
- *Pedagogy*: learning-by-doing, applying skills and concepts in increasingly challenging problems
- Cog model includes representation of early learner strategies & misconceptions

Cognitive tutors: Domains & Results

- Middle and high school mathematics
  - Full year high school algebra - in 1000's of schools
- Computer programming
- College level genetics
- *Cognitive Tutor Algebra I* students score 50-100% better on summative open-ended problem solving tests and 15%-25% higher on SAT type items than control course

Cognitive tutors provide aspects of human tutoring

- *Goals*: monitor student performance & provide context-specific instruction when needed
- *Goals*: monitor student learning and select problem-solving activities involving goals just beyond student reach
- *Methods*: Use cognitive model and do ‘model tracing’ and ‘knowledge tracing’

Model tracing // Knowledge tracing

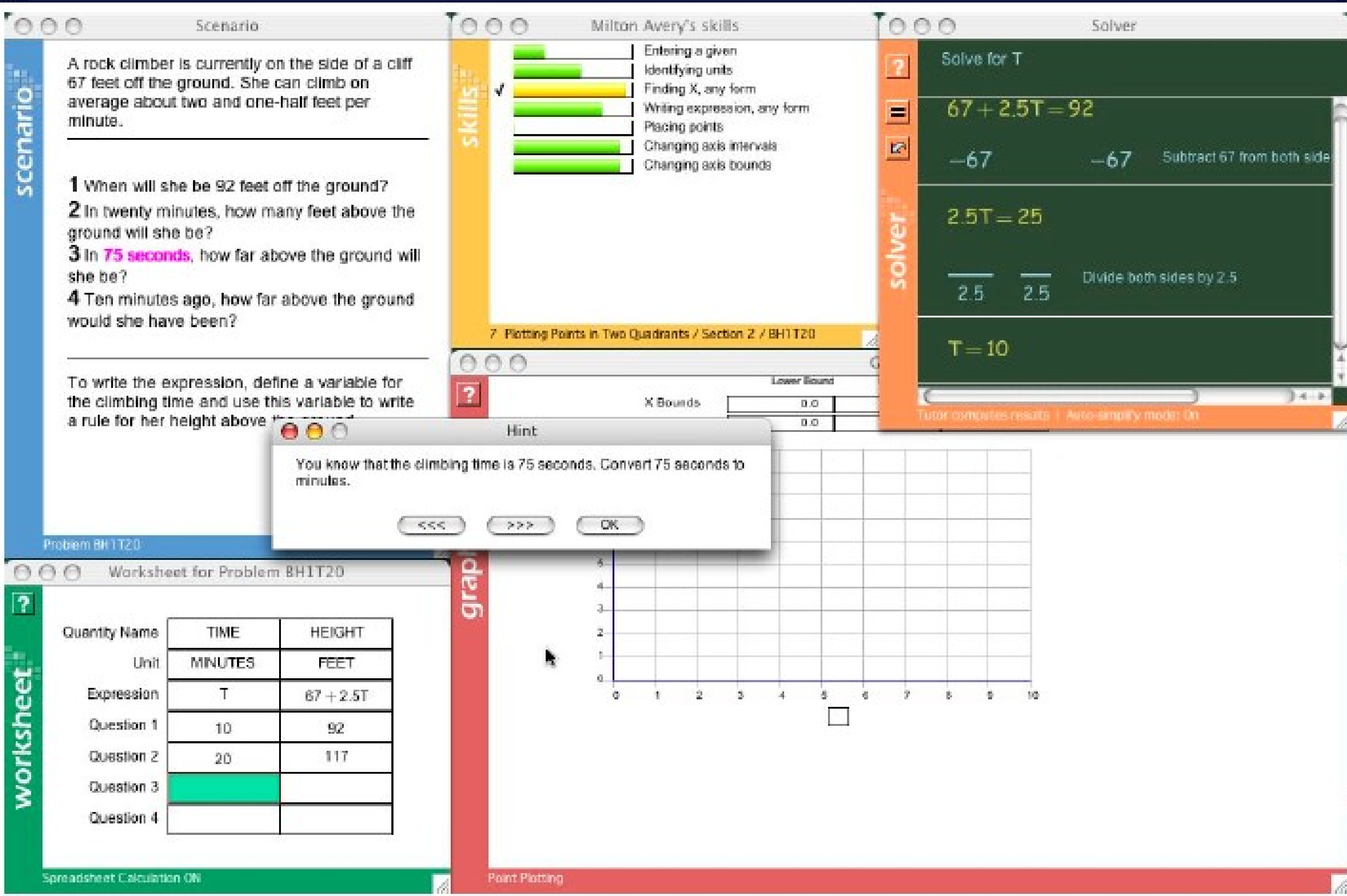
- Model tracing:
  - Cognitive tutor runs cognitive model forward step by step as student works, and gives just-in-time accuracy feedback and hints as needed
- Knowledge tracing
  - Tutor uses simple Bayesian method to estimate student's knowledge and uses the student model to select apt problems

Based on ACT-R cognitive architecture

- John R. Anderson's cognitive theory for modeling framework used to develop six general principles of ITS design
- Cannot however:
  - Prescribe curriculum objectives or activities
  - Anticipate student prior knowledge
  - Prescribe scaffolding activities that will help students develop deep domain understanding

Figure 1 (next page)

- A screen shot of a problem solving activity within *Cognitive Tutor Algebra.*
- Students receive a problem situation and use various tools, like the Worksheet, Grapher, and Solver to analyze and model the problem situation.
- As they work, “model tracing” is used to provide just-in-time feedback or on-demand solution-sensitive hints through the Messages window.
- Results of “knowledge tracing” are displayed in the *skills chart* in the top center.


Scenario
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.
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 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
Problem BH1T20
Milton Avery's skills
skills
Entering a given
Identifying units
Finding X, any form
Writing expression, any form
Placing points
Changing axis intervals
Changing axis bounds
7 Plotting Points in Two Quadrants / Section 2 / BH1T20
Solver
solver
Solve for T
67 + 2.5T = 92
−67 −67 Subtract 67 from both side
2.5T = 25
2.5 2.5 Divide both sides by 2.5
T = 10
Hint
You know that the climbing time is 75 seconds. Convert 75 seconds to minutes.
<<<
>>>
OK
Lower Bound
X Bounds
graph
Point Plotting
Worksheet for Problem BH1T20
worksheet
Quantity Name TIME HEIGHT
Unit MINUTES FEET
Expression T 67 + 2.5T
Question 1 10 92
Question 2 20 117
Question 3
Question 4
Spreadsheet Calculation ON

Class Use scenarios for Cog Tutors

- Complete Cognitive Tutor courses
  - Textbooks as well as tutor software
- 2 days a week in Computer Lab
- 3 days a week using textbook materials in classroom - active learning by doing
  - Teachers don't do conventional whole group instruction but support of collaborative group learning
  - Teachers bridge text and computer activities

Cog tutors: Learning sciences theory

- ACT-R theory of learning and performance: performance knowledge can only learned by *doing* not by listening to declarative knowledge or watching.
- *Procedural knowledge*: implicit performance knowledge
- *Declarative knowledge*: explicit verbal knowledge and visual images
- Performance knowledge is represented by *if-then* rules that associate internal goals/perceptual cues with new internal goals and/or external actions.

Example if-then rules (production)

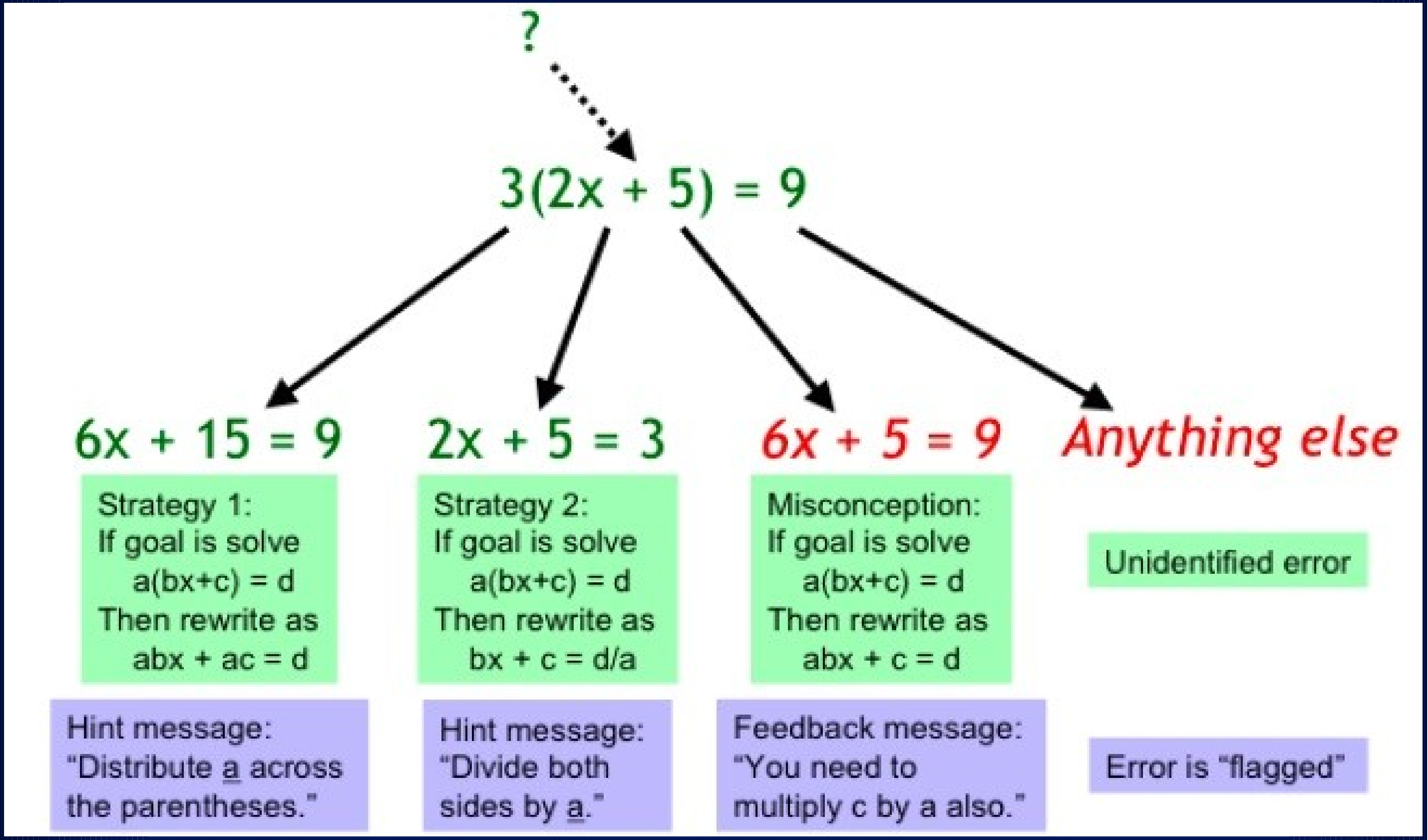
Production Rules in English	Example of its application
1. *Correct production possibly acquired implicitly* IF the goal is to find the value of quantity Q and Q divided by Num1 is Num2 THEN find Q by multiplying Num1 and Num2.	To solve "You have some money that you divide evenly among 8 people and each gets 40" find the original amount of money by multiplying 8 and 40.
2. *Correct production that does heuristic planning* IF the goal is to prove two triangles congruent and the triangles share a side THEN check for other corresponding sides or angles that may congruent.	Try to prove triangles ABC and DBC are congruent by checking whether any of the corresponding angles, like BCA and BCD, or any of the corresponding sides, like AB and DB, are congruent.
3. *Correct production for a non-traditional strategy* IF the goal is to solve an equation in X THEN graph the left and right sides of the equation and find the intersection point(s).	Solve equation sin $\mathbf{x} = \mathbf{x}^2$ by graphing both sin $\mathbf{x}$ and $\mathbf{x}^2$ and finding where the lines cross.
4. *Correct but overly specific production* IF "**ax** + b**x**" appears in an expression and c = a + b THEN replace it with "c**x**"	Works for "*2x* + 3**x**" but not for "*x* + 3**x**"
5. *Incorrect, overly general production* IF "Num1 + Num2" appears in an expression THEN replace it with the sum	Leads to order of operations error: "**x** * *3 + 4*" is rewritten as "**x** * *7*"

Why are production rules important?

- Argument that they characterize how students reason in a domain
- Informal, incorrect or heuristic rules may be acquired outside textbook instruction in experience
- *If*-part of production rule can help identify when knowledge students acquire not at right level of generality (too specific or too general)

Cognitive model and model tracing

- ACT-R theory and empirical studies of learners used to create a ‘cognitive model’ embodied in cog-tutor software
- Cognitive model uses production system to represent different strategies students may use including typical misconceptions
- Fig2:
  - Model tracing uses production rules to trace different possible actions students may take. S has reached state “3(2x + 5) = 9”. The "?" at the top means production rules work no matter how the student reached this state. Fig shows how production rules apply to generate 3 possible next steps. Feedback msgs for common errors or next-step hints Ss can request if stuck are tied to production rules.


?
3(2x + 5) = 9
6x + 15 = 9
2x + 5 = 3
6x + 5 = 9
Anything else
Strategy 1: If goal is solve a(bx+c) = d Then rewrite as abx + ac = d
Strategy 2: If goal is solve a(bx+c) = d Then rewrite as bx + c = d/a
Misconception: If goal is solve a(bx+c) = d Then rewrite as abx + c = d
Unidentified error
Hint message: "Distribute a across the parentheses."
Hint message: "Divide both sides by a."
Feedback message: "You need to multiply c by a also."
Error is "flagged"

Cognitive tutor: “model tracing”

- Model tracing algorithm follows different students down the problem solving paths they choose since alt strategies for same goal are in cognitive model
- When S performs a step, it is compared against alternative next steps cog model generates
  - If S action matches model, move on
  - If S action matches buggy production, flag incorrect and present specific hint for improvement
  - If S action matches no rule in cog model, flagged as error
- Student can request hint at any time -> advice text is generated from next step in cognitive model

Cognitive tutor: "Knowledge tracing"

- ACT-R theory: frequency, recency and utility of knowledge built in memory including production rules
- Knowledge tracing (KT) algorithm monitors S's acquisiton of production rules across problems
- Tutor continually updating estimate of probability S knows rule based on whether rule applied correctly
- KT Bayesian update predicts S's performance & posttest accuracy (displayed to student as 'skill bars' - Figure 1)
- KT results are used to adapt pacing of instruction to match S needs - providing more practice on unmastered skills

cognitive models are powerful

- ***Modularity***! They represent knowledge components that can be flexibly recombined
- Makes Cog Tutors more feasible to develop since can use rules for potentially infinite variety of problems within and across courses
- Argument from ACT-R for *empirically testable predictions*: knowledge will transfer from one learning activity to an assessment activity to extent that the kind & number of productions apply.

Six principles for Cog Tutor Design

1) Represent student competence as a production set
2) Provide instruction in a problem-solving context
3) Communicate the goal structure underlying the problem solving
4) Promote a correct and general understanding of the problem-solving knowledge
5) Minimize working memory load that is extraneous to learning
6) Provide immediate feedback on errors relative to the model of desired performance

competence as a production set

- Need to design learning activities based on *the ways that students think about the content*, not based on the domain content per se
  - Domain competence is complex to build and many partial or mistaken ways of thinking are built up outside school (or in spite of instruction)
- Production rule modularity predicts we can diagnose specific weaknesses and improve with focused instructional feedback

2) Provide instruction in a problem-solving context

- "It is not the information or even the instructional activities students are given per se that matters, but how students experience and engage in such information and activities that determines what knowledge they construct from them."

structure underlying the problem solving

- Tracking subgoals is a challenge, yet underlying goal structure of a problem solution often remains hidden in traditional problem-solving representations.
- Two methods used for making explicit:
  - Make it visible in problem solving interface
  - Communicate it via help messages from model tracing, which describes current goal in context

4) Promote a correct and general understanding of the problem-solving knowledge

- Why? S's construct production rules based on their own, often idiosyncratic understanding or encoding of problem-solving activities and examples

- Reflection promotes general understanding:
  - Aleven & Koedinger had students "self explain" steps in problem solutions (by making reference to geometry rules or reasons from a glossary)
  - More effective transfer of learning since students thought more deliberately about the verbal declarative representation of domain rules

load that is extraneous to learning

- Errors in complex problem solving can stem from loss of information from working memory; and high working memory demands ("cognitive load") can impede learning
- Tactics for reducing cognitive load:
  - Efforts to make goal structure visible (Principle 3)
  - Simplify problem-solving actions irrelevant to current learning goals (e.g. auto-arithmetic mode during algebraic equation solving)

6) Provide immediate feedback on errors relative to the model of desired performance

- Human tutors tend to provide immediate feedback after each problem-solving step
- In a study with the Lisp Cognitive Tutor immediate feedback led to significantly faster learning
- Immediate feedback can also be more motivating for students

Cognitive tutor metadesign principles

- Design with instructors and classroom use from the start
  - What should students be learning?
  - What problem activities support that?
  - What relevant knowledge do students bring?
- Design the full course experience
- All design phases should be empirically based
  - Design experiments; formative evaluation; summative evaluations

Future work with cognitive tutors

- Natural language tutorial dialog
- Tutoring meta-cognitive skills in addition to cognitive skills (like self-explanation)
- Authoring tools to speed up cognitive tutor development (CTAT)

CTAT Cognitive Tutor Authoring Tools
Software that enables you to author intelligent tutor behavior

- Cognitive tutors as research platforms for “in vivo” rigorous experimental tests of learning principles
  - LearnLab: Pittsburgh Science of Learning Center
  - http://www.learnlab.org/

One-to-one technology enhanced learning

- 17 authors from 11 countries working to create G1:1 (global consortium)
- Broaden your palette of learning technologies beyond cognitive tutors
- To emphasize global community of researchers addressing design challenges
- To foreground learning scenarios as design drivers
- To emphasize community definition of research agenda priorities

Tak Wai-Chan, National Central University, Taiwan

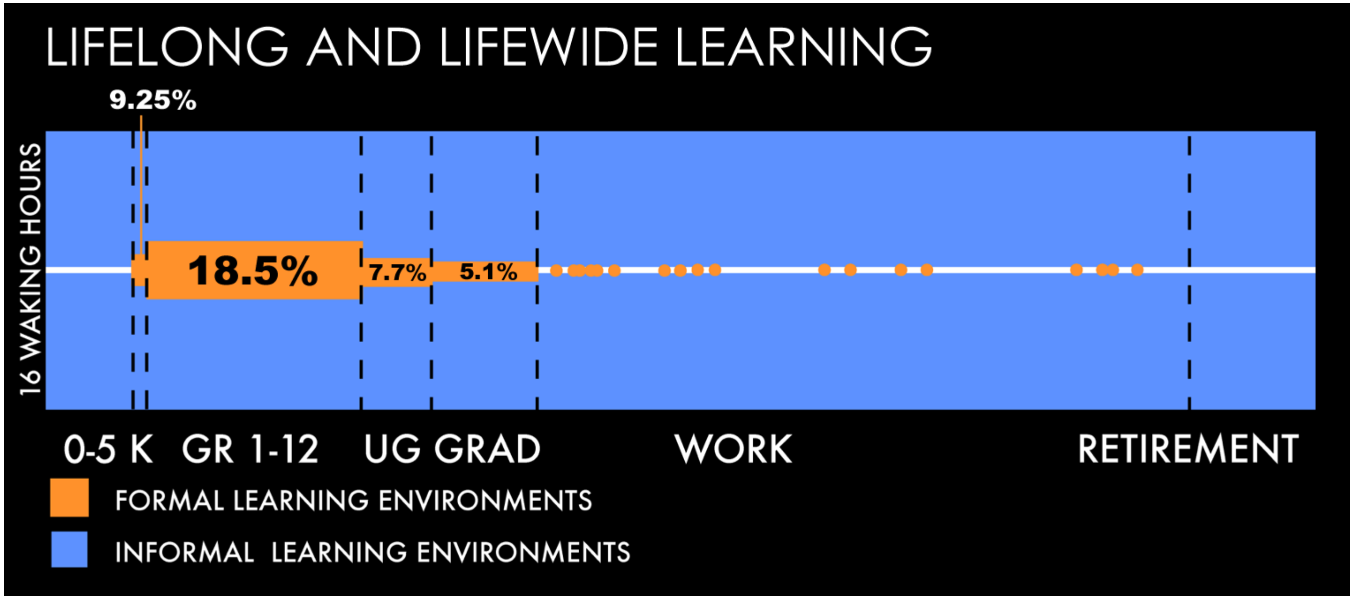
Definitions and purpose of paper

- Technology-enhanced learning (TEL) will be characterized by seamless learning spaces
- One-to-one means one device per learner
- Examine how to “cross the chasm” from early adopters to adoption-based research overcoming digital divide
- Explore opportunities, challenges and risks associated with going to scale with 1:1 TEL

Seamless learning: TEL next phase

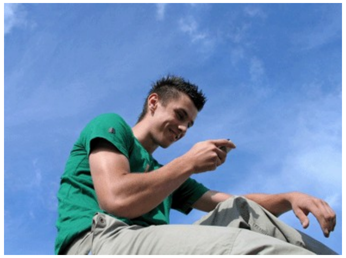
- Seamless learning implies that a student can learn whenever they are curious in a variety of scenarios and that they can switch from one scenario to another easily and quickly using the personal device as a mediator.
- *Scenarios* include: learning individually, with another student, a small group, or a large online community, with possible involvement of teachers, mentors, parents, librarians, workplace professionals, and members of other supportive communities, face-to-face or at a distance in places such as classroom, campus, home, workplace, zoo, park, and outdoors.
- Exploration of the seamless learning space provides potential to extend formal learning time from classroom into informal spaces, to embrace opportunities for out-of-school learning driven by the personal interests of students - may involve interacting with an online learning community, visiting museums, participating in community projects, or other venues.

How can we productively blend Formal and Informal learning?



Greater potential than realized for harvesting "funds of knowledge" from people's learning experiences outside of classrooms - and supporting *bridging* across informal and formal learning.

For design - must consider the activities and life experiences of the learner *throughout the day* as our units of learning design.



Overview

- What is TEL?
- Collaborative and social learning TEL promotes
- Research agenda
- Toward adoption based research
- South Africa example
- Risks and downsides

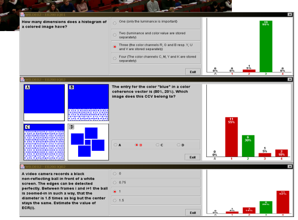
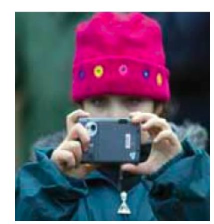
What is TEL?

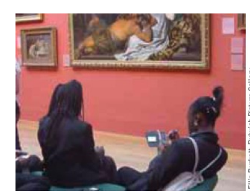
- Digital technology-enhanced learning
- Incorporating:
  - CAI
  - Educational technology, educational computing
  - Information and communication technology (ICT) in education
  - E-learning, distributed learning, asynchronous learning, networked learning

Values of 1:1 for diverse learner needs: Augmenting activity spaces

- *Ready-to-hand*: Travels with the learner across learning settings for daily uses integral to life
- A *communication* engine and portal for connecting the home & community with learning resources and schooling
- Overcome digital divide - *Socially inclusive* - tool for full participation in class interactions
- *Geo-localizing* generic text-based education - Device for capturing 'in the field' media and data and sharing ideas relating to learning & educational topics





Collaborative and social learning TEL promotes

- Contrast to ITS optimization of delivery of instruction through 1:1 learning by doing and knowledge modeling and tracing
- Collaborative and cooperative learning, learning by participation and discourse in communities of practice
- Knowledge building communities as a social learning approach (Scardamalia & Bereiter)
    - Aim: enculturate youth into a knowledge-creating culture where sustained idea improvement is the norm.
    - Through links across virtual communities and to the rich resources of the Internet, students join the worldwide community of knowledge builders.

Research agenda

- Learning scenarios in TEL space - how to combine and evolve new synergies?
- How should individual and social learning be orchestrated?
- How do individual intelligent tutoring techniques and computer-supported collaborative learning methodologies complement each other?
- How can home based informal learning be combined seamlessly with formal education?

Research questions

- How to reconcile the networked learning youth engage in as technology-fluent, powerful multimedia communicators outside school, when they are forbidden to use mobiles in school?
- How can learning leverage the virtual and physical world at once (and minimize cognitive overload)?
- How might instructional supports and devices be designed to switch between scenarios or settings with different configurations?
- How do we achieve a technical level of semantic interoperability to allow intelligent learning software components to be easily exchanged and re-used?
- How to create new designed-for-learning environments by redesigning physical sites such as historical places, community centers, and other public spaces?
- What are new digital-divide & equity issues when 1:1 computing is realized?
- How to design TEL to minimize risk and protect privacy as personal data, school performance, and other social information become more available?

Five years of international mobile learning research conferences

mLearn melbourne 2007

- Kaleidscope workshop: Beyond Mobile Learning: Innovating Rather Than Replicating Existing Learning Scenarios, January 21-23, Villars, Switzerland http://craftwww.epfl .ch/events/alpine/programme/programme_w2.html
- 3nd IEEE International Workshop on PervasivE Learning(PerEL 2007), March 26-30, 2007 in New York, USA *http://wwwra.informatik.uni-rostock.de/perel07/*
- 2nd International Conference on Interactive Mobile and Computer aided Learning: eLearning, mLearning and virtual and remote labs, Amman, Jordan, 18-20 April 2007 http://www.imcl-conference.org/
- PERVASIVE LEARNING 2007: DESIGN CHALLENGES AND REQUIREMENTSA Workshop at the PERVASIVE 2007 Sunday, 13 May 2007, Toronto, Canada http://www.massey.ac. nz/~hryu/CFP_Pervasive_Learning.html
- IADIS International Conference Mobile Learning 2007, Lisbon, Portugal, 5 – 7 July 2007 *http://www. mlearning-conf.org/*
- 7th IEEE International Conference on Advanced Learning Technologies, Niigata, JapanJuly 18-20, 2007. (ICALT has several tracks on mobile learning) *http://www.ask4research.info/icalt/2007/*
- 6th International Conference on Mobile Learning, Melbourne, Australia, 16-19 October 2007 *http://www.mlearn2007.org/*
- Handheld Learning 2007, Central Hall Westminster, London, October 10-12th 2007, *http://www.handheldlearning2007.com/*
- International Workshop on Mobile and Ubiquitous Learning Environments (MULE)in conjunction to ICCE 2007, 5-6 November, 2007, Hiroshima, Japan http://www-yano.is.tokushima-u.ac.jp/ogata/MULE2007.htm
- 5th IEEE International Conference on Wireless, Mobile and Ubiquitous Technologies in Education (WMUTE2008), March 23-26, Beijing, China .http://www.wmute2008.org/

Toward adoption based research of TEL

- Challenges of educational reforms
- Technology innovation and diffusion processes take decades (Rogers, 1995)
  - Innovators
  - Early adopters
  - Early majority
  - Late majority
  - Laggards

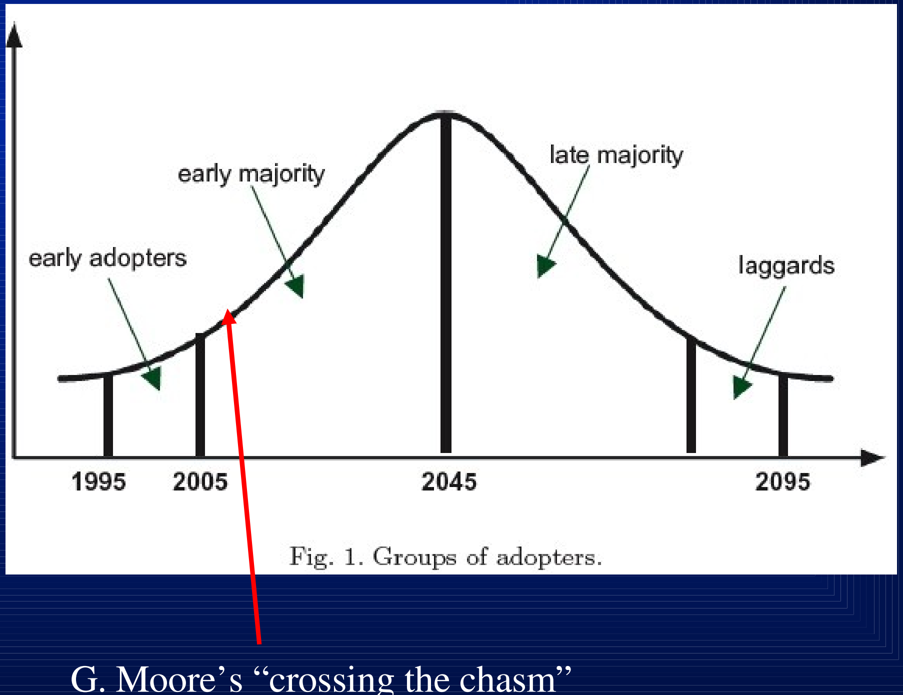


Fig. 1. Groups of adopters.

Note: Timeline looks overly pessimistic to me

South Africa example

- Leapfrogging internet land-line access
- In 2007, wireless mobiles in S. Africa have 90% penetration, yet only 10% of population within 1-hr walk to an Internet access point
- While other African nations are not as saturated with mobile access the same leapfrogging phenomena is playing out
  - Sub-Saharan Africa 2007 figure is 18.3% mobile vs. 1.7% landline access
  - North Africa 2007 figure: 53% mobile vs 12% land

Downside risks

- Blending informal and formal environments with pervasive computing as a threat to a balanced life
- Challenging data security, integrity, and privacy issues
- Being co-opted into the industry logic of a persistent digital divide

Towards global research collaboration

- Formation of G1:1 (2002) - many international workshops and proceedings since then
- Three key strands of work
  - Scenario-based planning
  - Global network of testbeds (a school, a college, an informal learning site such as a museum, or a company for on-job training, which has a strong institutional support and continuously collaborating with a one-to-one research team for a long period)
  - Component exchange community
- Please join this global community enterprise to investigate 1:1 Technology Enhanced Learning and cross the chasm of adoption!

For further information:

www.cra.org/reports/cyberinfrastructure.pdf