Digital Tutoring and Accelerating Expertise in Information Technology:
Crossing the 2-Sigma Threshold and Beyond

National Initiative for Cybersecurity Education
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Topics

• Why tutoring?
  • Why computers?
• Can computers teach?
• About digital tutoring
• Do People Learn from Digital Tutors?
• The DARPA Digital Tutor
• Into the Future: ADL?
• Finale
Why (One-on-One) Tutoring?
The Last 50,000 years (or so) of Human Training and Education
“The principal consequence of individual differences is that every general law of teaching has to be applied with consideration of the particular person ... responses to any stimulus ... will vary with individual capacities, interests, and previous experience.”

E. L. Thorndike (1906)
“Whilst part of what we perceive comes through our senses from the object before us, another part (and it may be the larger part) always comes out of our mind”

William James (1890)
"The central assertion is that seeing, hearing, and remembering are all acts of construction, which may make more or less use of stimulus information depending on circumstances."

Ulric Neisser (1967)
We can’t afford a human tutor for every learner, but we may be able to afford a computer, or a cell phone, or ...
Why Is Tutoring So Effective?

- Individualization
- Interactivity/Immersion
Individualization & Classroom Instruction: Pace

- Ratio of time needed to build words from letters in kindergarten -- 13:1 (Suppes, 1964)

- Ratios of time needed to learn in grade 5 -- 3:1 and 5:1 (Gettinger & White, 1980)

- Ratios of time needed by hearing impaired and Native American students to reach mathematics objectives -- 4:1 (Suppes, Fletcher, & Zanotti, 1975, 1976)
## Interactivity/Immersion/”Flow”

### Classroom Instruction & Tutoring

### Number of Questions Asked Per Hour

<table>
<thead>
<tr>
<th></th>
<th>Traditional Classroom/Hr</th>
<th>Tutored Session/Hr</th>
</tr>
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<tbody>
<tr>
<td><strong>Student</strong></td>
<td>0.1</td>
<td>20-30</td>
</tr>
<tr>
<td><strong>Instructor</strong></td>
<td>3</td>
<td>120-150</td>
</tr>
</tbody>
</table>

(Graesser & Person, 1994)
Why Computers?
“Individualization is an educational imperative and an economic impossibility.” (Michael Scriven, 1975)
Enter the Computer: A Third Revolution in Learning?

- Revolution #1: Writing
  Content of learning made available anytime, anywhere

- Revolution #2: Books
  Affordable content of learning made available anytime, anywhere

- Revolution #3(?): Technology
  Affordable content and the interactions of learning made available anytime, anywhere

- On-demand learning is the common thread.
- We are returning to learning dialogues/conversations.
Primordial Beginnings (1960s)

- Illinois – PLATO
  let every Asimov arise (and use Plasma panels)
- MITRE/Texas/BYU – TICCIT
  from ISD to computer system design
- Stanford – Curriculum
  Drill and Practice and information structures (!)
- BBN & MIT - ICAI
  Feuerzeig -- mixed-initiative dialogue and information structures

Also: US Air Force, IBM Labs, Columbia, Penn State
Individualizing with Paper: Keller’s PSI

Instruction via modules

Pre-Test → Diagnose & Assess → Study Guide → Post-test

Also:
Postlethwait’s Audio-Tutorial Approach
Klausmeier’s Individually Guided Education
Bloom’s Learning for Mastery
And others …
In the multiplication $3 \times 4 = 12$, the number 12 is called a ______.

A. Factor  [Branch to remedial X1]
B. Quotient  [Branch to remedial X2]
C. Product  [Reinforce, go to next]
D. Power  [Branch to remedial X3]
In the multiplication $3 \times 4 = 12$, the number 12 is called a ______.

A. Factor [Branch to remedial X1]
B. Quotient [Branch to remedial X2]
C. Product [Reinforce, go to next]
D. Power [Branch to remedial X3]
Other Approaches:
E.g., Suppes’ Strands Approach

An excruciatingly detailed analysis of the subject matter, broken up into areas of activities (strands) followed by …

• Instruction based on student history and level of achievement
• Acceleration where appropriate
• Repeated practice where necessary
• A daily profile reporting each student’s progress to the student and classroom teacher
## Mathematics K-7 Strands

<table>
<thead>
<tr>
<th>Strand</th>
<th>Content</th>
<th>Grade level</th>
</tr>
</thead>
<tbody>
<tr>
<td>NUM</td>
<td>Number concepts</td>
<td>1.0-7.9</td>
</tr>
<tr>
<td>HAD</td>
<td>Horizontal addition</td>
<td>1.0-3.9</td>
</tr>
<tr>
<td>HSU</td>
<td>Horizontal subtraction</td>
<td>1.0-3.4</td>
</tr>
<tr>
<td>VAD</td>
<td>Vertical addition</td>
<td>1.0-5.9</td>
</tr>
<tr>
<td>VSU</td>
<td>Vertical subtraction</td>
<td>1.5-5.9</td>
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<tr>
<td>EQN</td>
<td>Equations</td>
<td>1.5-7.9</td>
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<tr>
<td>MEA</td>
<td>Measurement</td>
<td>1.5-7.9</td>
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<tr>
<td>HMU</td>
<td>Horizontal multiplication</td>
<td>2.5-5.4</td>
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<tr>
<td>LAW</td>
<td>Laws of arithmetic</td>
<td>3.0-7.9</td>
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<tr>
<td>VMU</td>
<td>Vertical multiplication</td>
<td>3.5-7.9</td>
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<tr>
<td>DIV</td>
<td>Division</td>
<td>3.5-7.9</td>
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<tr>
<td>FRA</td>
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<td>3.5-7.9</td>
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<td>DEC</td>
<td>Decimals</td>
<td>4.0-7.9</td>
</tr>
<tr>
<td>NEG</td>
<td>Negative numbers</td>
<td>6.0-7.9</td>
</tr>
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</table>
## Allocating Time and Effort to the Strands

<table>
<thead>
<tr>
<th>Strand</th>
<th>Half year</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
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<th>5.0</th>
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<td>5</td>
<td>7</td>
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<td>14</td>
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<td>PP</td>
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<td>12</td>
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<td>9</td>
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<td>VAD PT</td>
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<tr>
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<td>19</td>
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Note.—PT = proportion of time; PP = proportion of problems.
Allocating Time Among Students: Fun with Regression Equations

Linear:
\[ E(O_i) = b_0 + b_1 P_i + b_2 T_i \]

Linear with interaction:
\[ E(O_i) = b_0 + b_1 P_i + b_2 T_i + b_3 P_i T_i \]

Cobb-Douglas:
\[ E(\ln O_i) = b_0 + b_1 \ln P_i + b_2 \ln T_i \]

Exponential:
\[ E(\ln O_i) = b_0 + b_1 \ln P_i + b_2 \ln T_i + b_3 (\ln T_i)^2 + b_4 (\ln T_i)^3 \]

(O = outcome; P = pretreatment measure; T = time)
Can Computers Teach?
An Aside -- Effect Size

A descriptive (not inferential) statistic commonly used to estimate the magnitude of an effect (e.g., experimental treatment).

Cohen’s $d = \frac{\text{Mean Group 1} - \text{Mean of Group 2}}{\text{“Pooled” Standard Deviation}}$

<table>
<thead>
<tr>
<th>$d$</th>
<th>Magnitude</th>
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<tbody>
<tr>
<td>$&lt; 0.25$</td>
<td>Negligible</td>
</tr>
<tr>
<td>$&gt; 0.25$ to $0.40$</td>
<td>Small</td>
</tr>
<tr>
<td>$&gt; 0.40$ to $0.60$</td>
<td>Moderate</td>
</tr>
<tr>
<td>$&gt; 0.60$ to $0.80$</td>
<td>Large</td>
</tr>
<tr>
<td>$&gt; 0.80$</td>
<td>Very Large</td>
</tr>
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</table>
Learning Gains with Early (pre-1992) Computer-Assisted Instruction

- **Computer-Based Instruction (233 Studies)**: Effect Size (Cohen’s d) = 0.39
- **Interactive Multimedia Instruction (47 Studies)**: Effect Size (Cohen’s d) = 0.50
- **"Intelligent" Tutoring Systems (11 Studies)**: Effect Size (Cohen’s d) = 0.84

(Fletcher, 1997)
Costs to Increase Mathematics Achievement by One Sigma

(Fletcher, Hawley, & Piele, 1990)
Savings in DoD Skill Training With 30 Percent Reduced Training Time

Model from Angier & Fletcher, 1992
Are 30 Percent Time Savings Achievable?

<table>
<thead>
<tr>
<th>Studies</th>
<th>Percent Time Savings</th>
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</thead>
<tbody>
<tr>
<td>Kulik Adult Education (1994) (15 Studies)</td>
<td>0.31</td>
</tr>
<tr>
<td>Johnston &amp; Fletcher (1995) (12 Studies)</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>0.54</td>
</tr>
</tbody>
</table>
About Digital Tutoring
A Role for Digital Tutoring

Learning Content
- Abstracted Concepts
- Adaptive Procedures
- Simple Concepts
- Simple Procedures
- Facts

Learning Objectives
- Remember
- Apply
- Understand
- Analyze
- Evaluate
- Create

Digital Tutoring Territory

Drill and Practice

(Framework courtesy of Anderson & Krathwohl, 2001)
Primordial ITS (nee ICAI) motivation

Two findings from early (1960s- early 1970s) research:

- Computers can teach effectively.
- Anticipating and then dealing with all possible states of the learner is time-consuming and difficult (i.e., costly) -- and incomplete).

A thought:

- Perhaps computers can do some of this ‘authoring’ themselves, i.e., they might generate instruction:
  - In real time
  - On demand
  - As tutorial dialogue
What Do We Mean by Digital Tutoring?

Two main differences (Carbonell, 1970):

- Based on information structures rather than ad-hoc frames
- Mixed-initiative dialogue

Requires:

- Explicit models of the subject matter
- Dynamically evolving model of the learner
- Tutorial strategies, based on learning objectives and evolving state of the learner
Mentor: Begin the physical examination.
Student: PHYSICAL EXAM

M: Fine, what in particular would you like to know?
S: RESPIRATORY RATE

M: It is common practice to begin an examination by checking the patient’s general appearance.
S: GENERAL APPEARANCE

M: Acutely prostrated, lying in bed on his right side ....

S: LABORATORY REPORTS
M: Finish the physical exam first.
S: CONTACT WITH BIRDS
M: None, except the patient has a pet canary

S: PSITTACOSSIS
M: There's insufficient evidence for any conclusive diagnosis at this time. Show a little more restraint please.

S: PULSE?
M: 100 a minute. Occasional extra systole.

S: TEMPERATURE?
M: 103

S: PNEUMOCOCCAL PNEUMONIA.
M: Stop guessing and continue with the examination.

(Feurzeig, 1969)
A Dialogue from Sophie

Student: What is the base emitter voltage of the voltage limiting transistor?

SOPHIE: The base emitter voltage of Q5 is -.037 volts.

Student: What about for the current limiting transistor?

SOPHIE: The base emitter voltage of Q8 is .349 volts.

Student: What should it be?

SOPHIE: In a working circuit, the base emitter voltage of Q8 is .593 volts.

Student: Replace Q8.

SOPHIE: I am going to ask you some questions about how Q8 is faulted. Are any junctions shorted?

•

•

(Brown, Burton, & DeKleer, 1982)
<table>
<thead>
<tr>
<th><strong>Early ICAI/ITS Systems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MENTOR</strong></td>
</tr>
<tr>
<td><strong>SCHOLAR</strong></td>
</tr>
<tr>
<td><strong>WHY</strong></td>
</tr>
<tr>
<td><strong>SOPHIE</strong></td>
</tr>
<tr>
<td><strong>WEST</strong></td>
</tr>
<tr>
<td><strong>BUGGY</strong></td>
</tr>
<tr>
<td><strong>WUSOR</strong></td>
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<tr>
<td><strong>EXCHECK</strong></td>
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<tr>
<td><strong>BIP</strong></td>
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<tr>
<td><strong>SPADE</strong></td>
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<tr>
<td><strong>ALGEBRA</strong></td>
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<tr>
<td><strong>LMS</strong></td>
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<tr>
<td><strong>QUADRATIC</strong></td>
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<tr>
<td><strong>GUIDON</strong></td>
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<tr>
<td><strong>MENO</strong></td>
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<tr>
<td><strong>STEAMER</strong></td>
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</table>
Do People Learn from Digital Tutors?
VanLehn (2011):

- 27 Evaluations
  - Effect size of 0.59 overall
  - Effect size of 0.76 for step-based tutoring
  - Effect size of 0.40 for substep-based tutoring

Kulik/Fletcher (2012):

- 45 “Systems Evaluations”
  - Effect size of 0.63 overall
  - Effect size of 0.86 for 39 properly aligned studies
Where Is Digital Tutoring Best Applied?

<table>
<thead>
<tr>
<th>Reference</th>
<th>Effect Sizes for Deep Learning</th>
<th>Effect Sizes for Shallow Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person, Bautista, Graesser, &amp; Mathews (2001)</td>
<td>0.34</td>
<td>0.00</td>
</tr>
<tr>
<td>Graesser, Moreno, Marineau, Adcock, Olney, &amp; Person (2003)</td>
<td>0.30</td>
<td>0.03</td>
</tr>
<tr>
<td>VanLehn, Lynch, Schulze, Shapiro, Shelby, Taylor, &amp; Wintersgill (2005)</td>
<td>0.95</td>
<td>–0.08</td>
</tr>
<tr>
<td>Overall</td>
<td>0.62</td>
<td>–0.02</td>
</tr>
</tbody>
</table>
The DARPA Digital Tutor (DT)
The DARPA Challenge

16 weeks of tutoring to produce graduates who are superior in knowledge and practical skills to technicians with many years of experience.
Context for the Digital Tutor (DT)

- A product of DARPA’s Training Superiority and Education Dominance programs (DARWARS, Ambush!, Tactical Language and Cultural Training, …)
- Focused on accelerating expertise
- Provides 16 weeks covering “A” school and some “C” school training for USN Information Systems Technology (IT) rating
- Approach is to capture procedures and practices of expert one-on-one tutors
  - Spiral curriculum focused on concepts
  - Hands-on work with IT systems
Basic Approach for the Digital Tutor

- Borrows ideas from intelligent tutoring technology and constructivist notions, but aspires to be rigidly neither:
  - Its strategy is eclectic and pragmatic
  - Its validation is job performance

- Its approach is to:
  - Capture procedures and practices of subject matter experts who are also expert one-on-one tutors
  - Emphasize active (situated, authentic) problem solving to develop higher order concepts
The DARPA IT Tutor

Why Information Technology?

• An operationally critical competency
• Current training in sore need of improvement (agreement across all echelons)
• An Incredibly Complex Task
Design Features: Strategies

• Thorough front end analysis to determine objectives for expertise

• Modeled on human tutors who were expert in subject elements and 1-1 tutoring

• Spiral curriculum with focus on problem solving

• Not dependent on expert solutions

• Focus on conceptual understanding

• Use Drill and Practice to teach the basics
Design Features: Tactics

- No hints
- Never solve the problem for the learner
- Build on what the learner knows to resolve impasses
- Always question a successful solution
- Frequently question a successful step
Five Assessments

- July-August 2009 – IWAR 1 – 1 week DT + 15 weeks of human tutoring
- April 2010 – 4 weeks then available of the DT
- November 2010 – 8 weeks then available of the DT
- March-April 2012 – IWAR 2 – 16 weeks – First version of a fully completed DT

NB:
- Assessments focused on job performance
- The usual tests of statistical significance
- Effect size measured by Cohen’s d
What are we looking for?
Kirkpatrick’s Four Levels of Evaluation

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Evaluation</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Surveys</td>
<td>Impressions and opinions</td>
</tr>
<tr>
<td>2</td>
<td>Outcomes</td>
<td>Were the objectives achieved?</td>
</tr>
<tr>
<td>3</td>
<td>Transfer</td>
<td>Is the unit more effective?</td>
</tr>
<tr>
<td>4</td>
<td>Benefits</td>
<td>Is the enterprise more effective?</td>
</tr>
</tbody>
</table>

*(Did we do things right?)*

*(Did we do the right things?)*
Comparison:

- 1 week of DT + 15 weeks of 1:1 (*human*) tutoring (N = 12)
  & Fleet ITs with 4-18 years Navy IT experience (N = 12)

Measures:

- 139-item Written Knowledge Test
- Practical Troubleshooting Exercises (2.5 days)
- System Building Exercise (6 hours)
- (Also Dockside and Deployed observations)
Phase 1 IWAR

Results:

• Written Knowledge Test
  DT > Fleet ITs \( (d = 1.02)^a \)

• Written Knowledge Test 1-Week DT portion
  DT > Fleet ITs \( (d = 1.73)^a \)

• Practical Troubleshooting Exercises
  DT > Fleet ITs \( (99 \text{ vrs } 79 \text{ solved})^a \)

• System Building Exercises:
  Fleet > DT \( (113 \text{ vrs } 84 \text{ objectives met}) \)

\(^a(p < 0.01)\)
Comparison:
  • 4 weeks of then available DT (N = 20)
    & 16 week Integrated Learning Environment (ILE)
    CBT graduates (N = 31)
    & School Instructors (N = 10)

Measure:
  152-item written knowledge test covering IT material

Results:
  DT ~ ILE (d = 2.81)a
  DT ~ Instructors (d = 1.26)a
  Instructors ~ ILE (d = 1.25)a

a(p < 0.01)
Comparison:

- 8 weeks of the available DT (N = 20)
  & 16 week Integrated Learning Environment (ILE) 
    CBT graduates (N = 18)
  & 19 week IT of the Future (IToF) graduates (N = 20)
  & School Instructors (N = 10)

Measures:

- 293-item written knowledge test covering DT material
- 4 hours practical trouble shooting exercises
- 2 hours packet tracing exercises
- Oral exams (about 30 minutes) of 7 DT and 6 IToF students
November 2010 Results

• Written Knowledge test
  DT & ILE  \((d = 4.68)\)
  DT & IToF \((d = 1.95)\)
  DT & Instructors \((d = 1.35)\)

• Practical exercises
  DT & IToF \((d = 1.90)\)

• Packet Tracing Exercises
  DT & IToF \((d = 0.74)\) (Un-Weighted)
  DT & IToF \((d = 1.00)\) (Weighted)

\(^a(p < 0.01)\)
Comparison Groups:

- 16 weeks of the completed DT (N = 12)
- 35 weeks of IT Training Continuum (ITTC) (N = 12)
- Fleet ITs (N = 12) 9.6 Years average IT Experience

Measures:

- 6 hours of problem solving (troubleshooting) exercises
- 272-item written knowledge test
- 3 hours of security exercises
- 6 hours of a system design and develop exercise
- 20-30 minute individual interviews
IWAR 2 Troubleshooting Exercises

Solution Quality Scores

<table>
<thead>
<tr>
<th></th>
<th>Occur by Chance</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT 3.78 (1.91) &gt; Fleet 2.00 (2.26)</td>
<td>p &lt; 0.0001</td>
<td>0.85</td>
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<tr>
<td>DT 3.78 (1.91) &gt; ITTC 1.41 (2.09)</td>
<td>p &lt; 0.0001</td>
<td>1.13</td>
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</table>
DT students attempted more problems at every difficulty level with greater probability of success.
Uncorrected Harmful Changes in Troubleshooting

<table>
<thead>
<tr>
<th></th>
<th>Number of Harmful Step Errors</th>
<th>Probability of Uncorrected Harmful Change</th>
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<tbody>
<tr>
<td></td>
<td>DT</td>
<td>Fleet</td>
</tr>
<tr>
<td>20</td>
<td>41</td>
<td>29</td>
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</table>

|                      | p = .14 SD_p = .35            | p = .41 SD_p = 0.49                     | p = .33 SD_p = .47                       |

<table>
<thead>
<tr>
<th></th>
<th>Occur by Chance</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>DT &gt; Fleet</td>
<td>p &lt; 0.0001</td>
<td>-0.61</td>
</tr>
<tr>
<td>DT &gt; ITTC</td>
<td>p &lt; 0.01</td>
<td>-0.44</td>
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</table>
Knowledge Test Scores

<table>
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<tbody>
<tr>
<td>DT &gt; Fleet</td>
<td>$p &lt; 0.0001$</td>
<td>4.30</td>
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<tr>
<td>DT &gt; ITTC</td>
<td>$p &lt; 0.0001$</td>
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<tr>
<td>Performance Measure</td>
<td>DT &gt; Fleet?</td>
<td>Occur by Chance</td>
</tr>
<tr>
<td>------------------------------------------------</td>
<td>-------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Problem Solving (PS) Total</td>
<td>+</td>
<td>p &lt; .0001</td>
</tr>
<tr>
<td>PS (Fewer) Harmful Actions</td>
<td>+</td>
<td>p &lt; .0001</td>
</tr>
<tr>
<td>PS (Fewer) Unnecessary Actions</td>
<td>+</td>
<td>p &lt; .0001</td>
</tr>
<tr>
<td>Individual Interviews</td>
<td>+</td>
<td>p &lt; 0.01</td>
</tr>
<tr>
<td>Security Exercise</td>
<td>-</td>
<td>N.S.</td>
</tr>
<tr>
<td>Network Design &amp; Development</td>
<td>+</td>
<td>N.S.</td>
</tr>
<tr>
<td>Knowledge Test Total Score</td>
<td>+</td>
<td>p &lt; 0.0001</td>
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</table>
## IWAR 2 Results Summary DT & ITTC

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>DT &gt; ITTC?</th>
<th>Occur by Chance</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem Solving (PS) Total</td>
<td>+</td>
<td>p &lt; .0001</td>
<td>Very Large (1.13)</td>
</tr>
<tr>
<td>PS (Fewer) Harmful Actions</td>
<td>+</td>
<td>p &lt; 0.01</td>
<td>Medium (-0.44)</td>
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<tr>
<td>PS (Fewer) Unnecessary Actions</td>
<td>+</td>
<td>p &lt; .0001</td>
<td>Medium (-0.62)</td>
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<tr>
<td>Oral Review</td>
<td>+</td>
<td>p &lt; 0.05</td>
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<td>Security Exercise</td>
<td>-</td>
<td>N.S.</td>
<td>Negligible (-0.03)</td>
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<td>Network Design &amp; Development</td>
<td>+</td>
<td>p &lt; 0.01</td>
<td>Very Large (1.41)</td>
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<tr>
<td>Knowledge Test Total Score</td>
<td>+</td>
<td>p &lt; 0.0001</td>
<td>Very Large (2.63)</td>
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So What?

Cost of the Digital Tutor = $40-50M
<table>
<thead>
<tr>
<th>Option</th>
<th>Year</th>
<th>Cost Difference ($M)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
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<tbody>
<tr>
<td>&quot;A&quot; School</td>
<td>1</td>
<td>($12.5)</td>
<td>A+ 7 OJT</td>
<td>A+ 7 OJT</td>
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<td>Tutor</td>
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<td>($12.5)</td>
<td>($12.5)</td>
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<td>$319.2</td>
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<tr>
<td>Cost Difference</td>
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<tr>
<td>($M)</td>
<td>3</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>$19.8</td>
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<td>12-Year ROI (3,076.2 – 1,563.6)</td>
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<td>12-Year ROI</td>
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<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>$19.8</td>
<td>$72.2</td>
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<td>$319.2</td>
<td>$368.7</td>
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<tr>
<td>(3,076.2 – 1,563.6)</td>
<td>5</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>($12.5)</td>
<td>$19.8</td>
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<td>= $1,512.6M</td>
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</tbody>
</table>
Into the Future: ADL?
A thought:
The future is already here, but unrecognized and unevenly distributed.
The Past as Prologue: The ADL Vision

Intelligent Tutoring Systems
Moore’s Law
Global Information Grid
Natural Language Interaction
Electronic Performance Aids
Distributed Learning Capabilities
Object Oriented Applications
Hand-Held Computers
Simulations and Games
Etc.

Personal Learning Associates
Hence, the ADL Vision

Shareable instructional objects from across the World Wide Web

Assembled in real-time, on-demand

To provide learning and assistance anytime, anywhere via guided dialogues
Eventually …

• Anywhere, Anytime Learning Integrated with Performance/Decision Aiding (Integrating the supply and demand side of learning)

• Fewer Lessons, More Learning (Learning as conversation)

• Fewer Tests -- More Assessment (‘stealth assessment’) (Continuous, Unobtrusive)

• Personal Learning Associates (‘distributed’) (In classrooms and out – anytime, anywhere)

Instruction (and Performance/Decision Aiding) as Individualized Tutorial Conversation
In Conclusion …
Implications

• The fiscal folly of inadequate residential training.

• Training and education are investments not expenses.

• Increase amount (and depth) learned over reducing time to learn.

• We can greatly accelerate the acquisition of expertise – and should – the Digital Tutor is not the only example (e.g., Sherlock, IMAT).

• We can similarly accelerate acquisition of basic skills – (e.g., reading studies, math).

• Spend the money -- ROI is relatively insensitive to development costs at scale.
The difficult, intransigent issues may be organizational, administrative, and structural. Not technological.
Finally …

- Digital Tutoring can accelerate the development of targeted problem solving expertise

- Digital Tutors are expensive to build

- We should build them anyway, because of large:
  - Monetary Return on Investment
  - Operational Return on Investment
Thank you!