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Digital Mentoring and Tutoring

Mad Scientist Learning in 2050

J. D. Fletcher

fletcher@ida.org
703-578-2837

Topics

- Training and Education
- Tutoring and Classroom Instruction
- Digital Tutoring
- The DARPA Digital Tutor
  - Navy Assessment
  - Veterans Assessment
- Into the Future (Madness exposed)
- Conclusions

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Training and Education

Education ~ Training

Education	Training
Life Objectives	Job Objectives
Negotiable Objectives (Personalization)	Fixed Objectives (Individualization)
Cost-Effectiveness	Return on Investment
An End in itself	Means to an end
Includes training	Includes education

These are differences in emphasis. Underlying approaches, techniques, technologies are the same.

(One-on-One) Tutoring and Classroom Instruction

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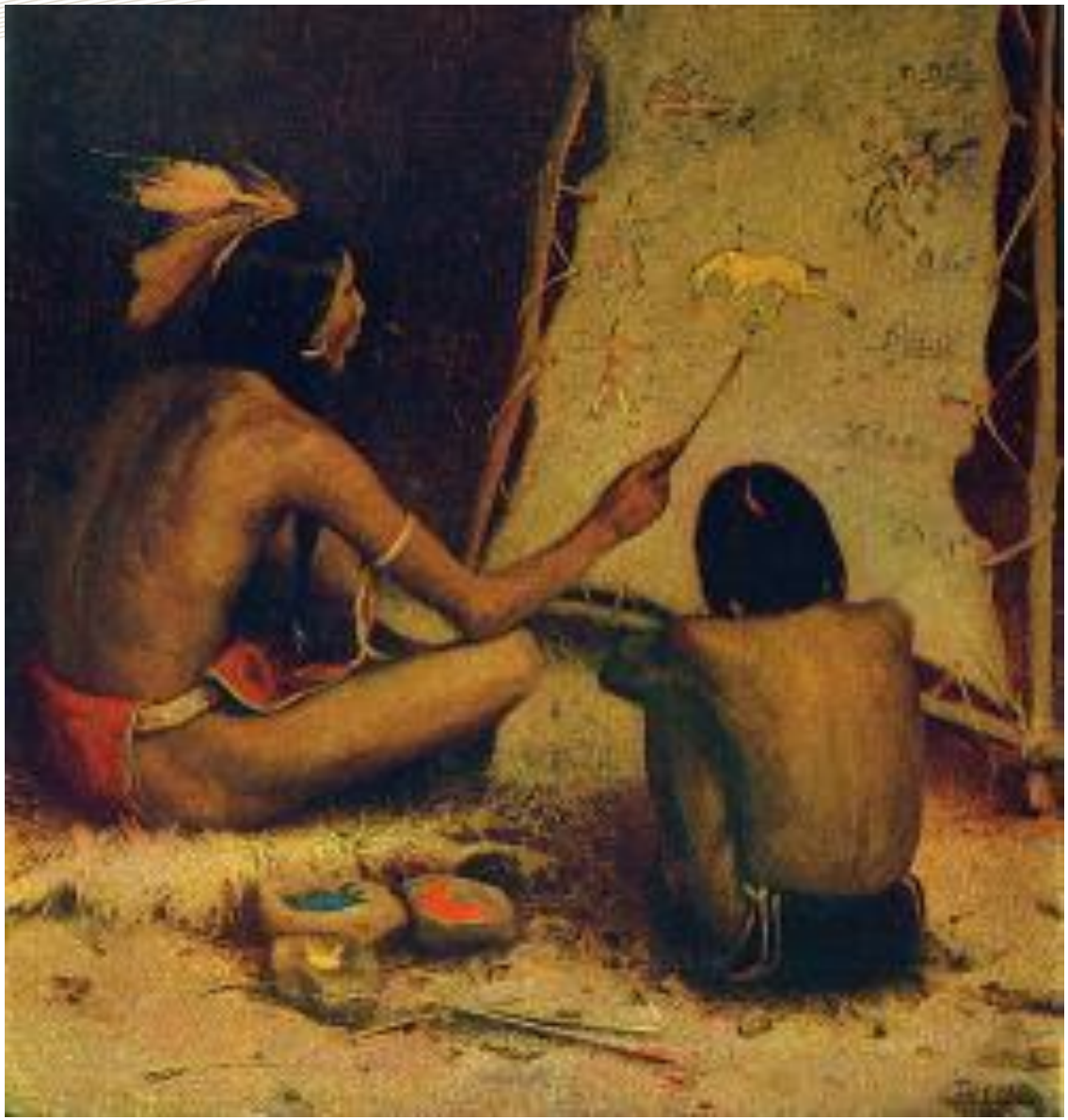
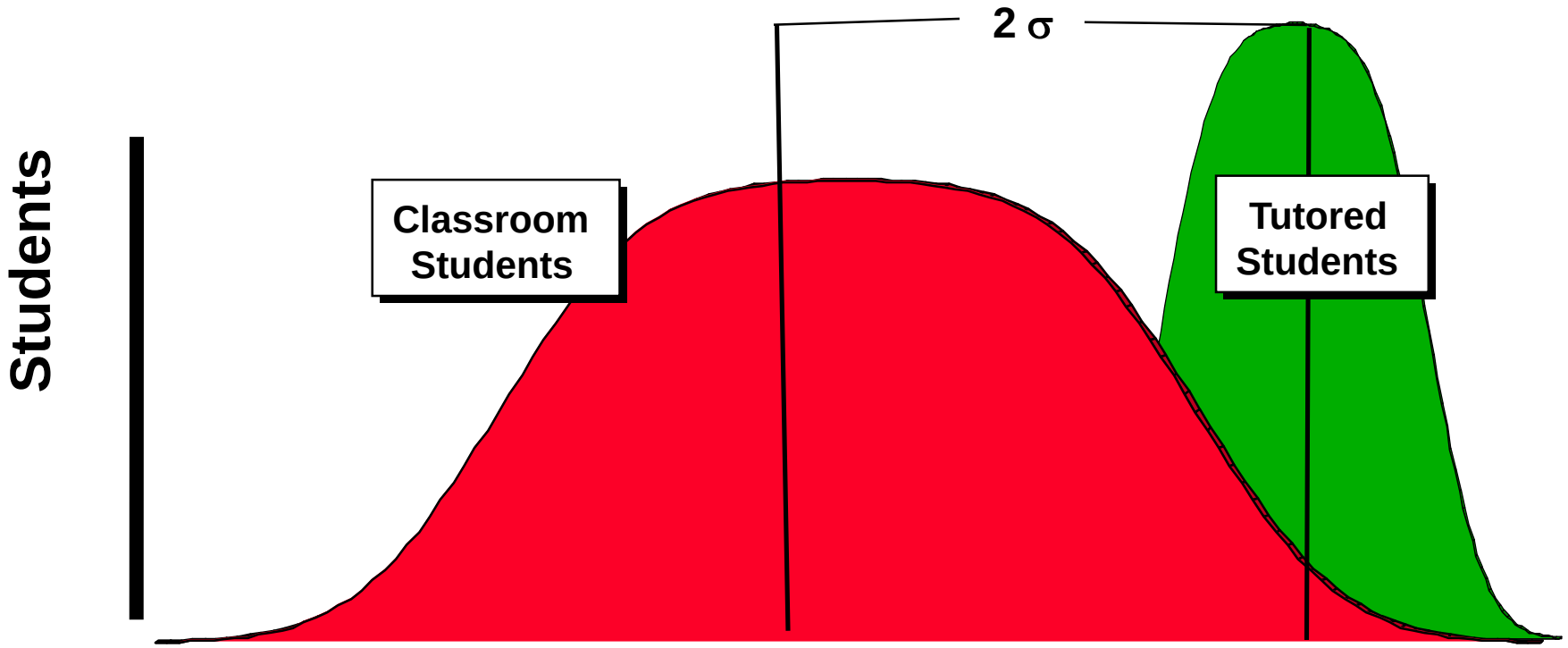
The Last 60,000 years (or so) of Human Training and Education



E. L. Thorndike (1906)

“The principal consequence of individual differences is that every general law of teaching has to be applied with consideration of the particular person.”

One-on-One Tutoring vrs. Classrooms



(Bloom, 1984)

Cohen, Kulik, & Kulik (1982):

52 studies; ES = 0.40; range -0.03 – +2.3; ES for 16 studies > 0.5

Why Is Tutoring Effective?

- Interactivity/Immersion
- Individualization

Interactivity/Immersion/"Flow" in Classroom Instruction & Tutoring

Number of Questions Asked Per Hour

	Traditional Classroom/Hr	Tutored Session/Hr
Student	0.1	20-30
Instructor	3	120-150

(Graesser & Person, 1994)

Need for Individualization: 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)
- Ratio of time needed by college undergraduates to learn LISP -- 7:1 (Corbett, 1998)

“Individualization is an educational imperative and an economic impossibility.”
(Michael Scriven, 1975)

Enter the Computer:
A Third Revolution in Learning?

- **(Phonetic) Writing (~3000 BC)**

Learning content available anytime, anywhere

- **Books (1000 or 1400 AD)**

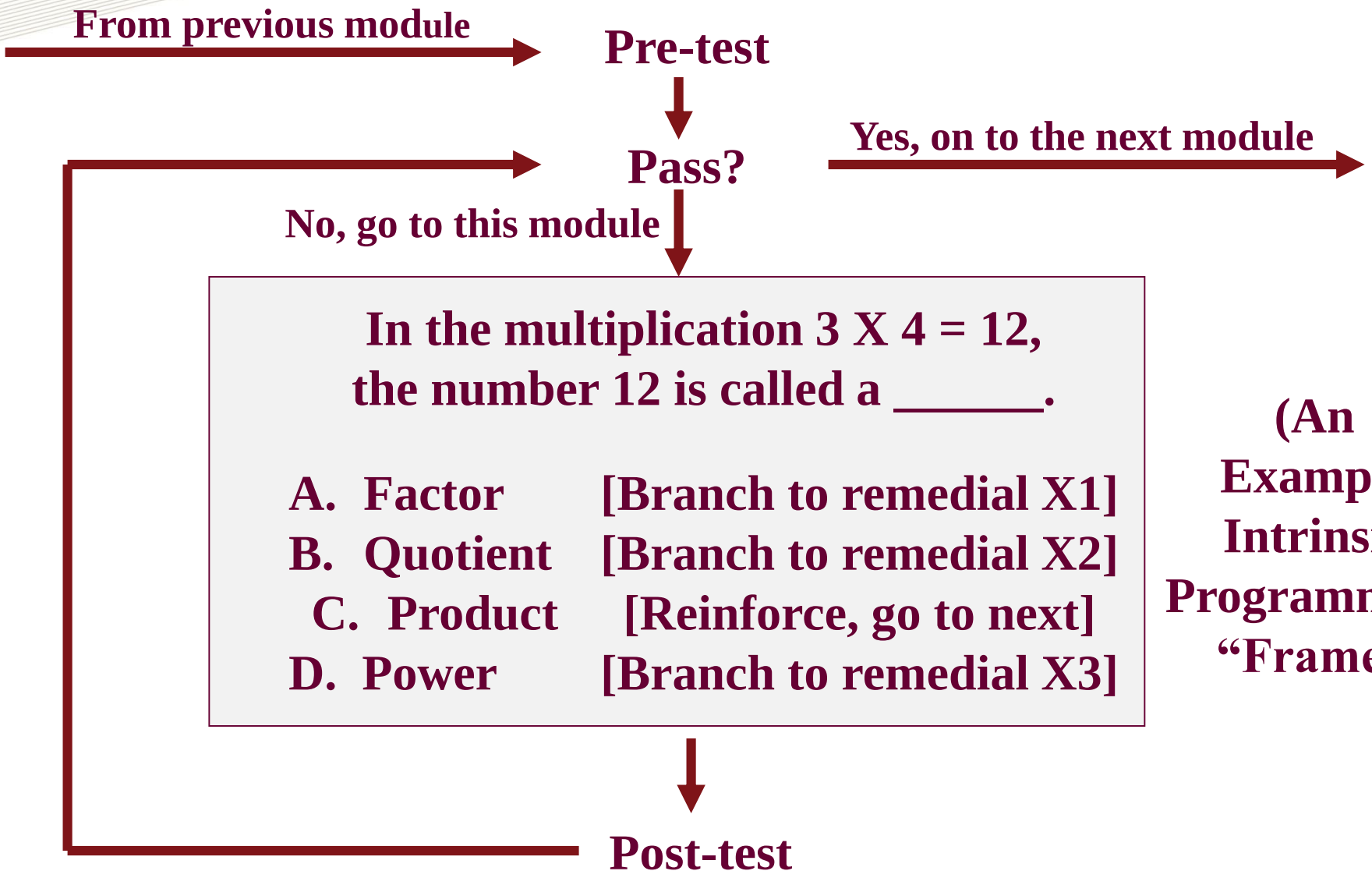
Affordable content of learning made available anytime, anywhere

- **Computer Technology (~1960 AD)**

Affordable content and tutorial interactions of learning made available anytime, anywhere

- **On-demand learning is the common thread.**
- **We are returning to learning dialogues/conversations.**

Individualizing with Computers: PSI (Keller) & Intrinsic Programming (Crowder)



(An Example Intrinsic Programming "Frame")

Digital Tutoring

Early Motivation for Digital Tutoring

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 impossible.**

A thought:

- **Perhaps computers can do some of this_ ‘authoring’ for us, 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):

- Dialogue via "Information structures", not pre-specified frames
- Mixed-initiative dialogue

Requires:

- Explicit models of the subject matter
- Dynamically evolving model of the learner
- Tutorial strategies, based on learning objectives and model of the learner

Can We Generate Dialogues? Mentor (1)

Mentor: Begin the physical examination.
Student: PHYSICAL EXAM

Mentor: Fine, what in particular would you like to know?
Student: RESPIRTORY RATE

Mentor: It is common practice to begin an examination by checking the patient's general appearance.
Student: GENERAL APPEARANCE

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

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Student: LABORATORY REPORTS
Mentor: Finish the physical exam first.

Tutoring in Mentor (2)

Student: CONTACT WITH BIRDS
Mentor: None, except the patient has a pet canary

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

Student: PULSE?
Mentor: 100 a minute. Occasional extra systole.

Student: TEMPERATURE?
Mentor: 103

Student: PNEUMOCOCCAL PNEUMONIA.
Mentor: Stop guessing and continue with the examination.

(Feurzeig, 1969)

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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?

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(Brown, Burton, & DeKleer, 1982)

Early ICAI/ITS Systems

MENTOR	Medical Diagnosis	Feurzeig, 1967
SCHOLAR	South America geography	Carbonell, 1970
WHY	Causes of rainfall	Stevens, et. al. 1982
SOPHIE	Electronic troubleshooting	Brown, et al., 1982
WEST	Arithmetic expressions	Burton & Brown, 1979
BUGGY	Subtraction	Brown & Burton, 1978
WUSOR	Logical relations	Goldstein, 1982
EXCHECK	Logic and set theory	Suppes, 1982
BIP	BASIC programming	Barr, et al., 1976
SPADE	LOGO programming	Miller, 1982
ALGEBRA	Algebra word problems	Lantz, et al., 1983
LMS	Algebraic procedures	Sleeman, 1982
QUADRATIC	Quadratic equations	O'Shea, 1982
GUIDON	Infectious diseases	Clancey, 1982
MENO	PASCAL programming	Soloway, et al., 1983
STEAMER	Steam propulsion (USN)	Williams, et al., 1981

Effect Size Interpretation [a]

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

$$\text{Effect Size} = \frac{\text{Mean Group 1} - \text{Mean of Group 2}}{\text{Standard Deviation}}$$

Effect Size	Interpretation	Rough Percentiles
< 0.25	Negligible [b]	0 – 59th
< 0.40	Small	60th–65th
< 0.60	Moderate	66th–73rd
< 0.80	Large	74th–79th
> 1.00	Very Large	80th and up
> 2.00	Bloom's Challenge	98th and up

[a] Extended from suggestions by Cohen (1988)

[b] What Works Clearinghouse (2010)

Does Digital Tutoring Work?

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 sub-step-based tutoring**

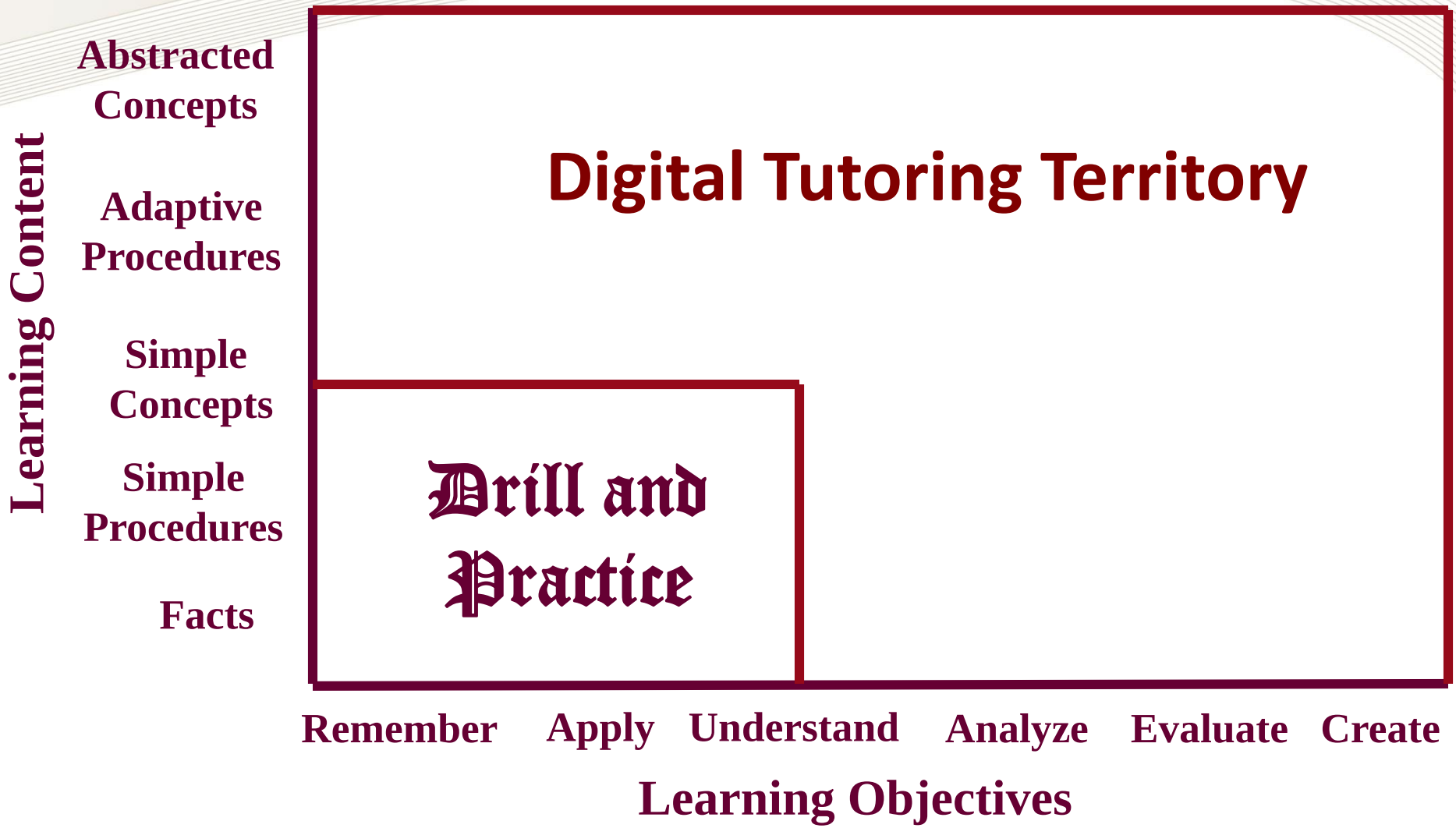
Kulik/Fletcher (2012):

- **45 Evaluations**
  - **Effect size of 0.60 overall**
  - **Effect size of 0.75 for 39 properly aligned studies**

Where Is Digital Tutoring Best Applied?

Reference	Effect Sizes for Deep Learning	Effect Sizes for Shallow Learning
Person, Bautista, Graesser, & Mathews (2001)	0.34	0.00
Graesser, Moreno, Marineau, Adcock, Olney, & Person (2003)	0.30	0.03
VanLehn, Lynch, Schulze, Shapiro, Shelby, Taylor, & Wintersgill (2005)	0.95	–0.08
Overall	0.62	–0.02

The Role for Digital Tutoring



(Framework courtesy of Anderson & Krathwohl, 2001)

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The DARPA Digital Tutor (DT)

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A DARPA Challenge

16 weeks to produce graduates who are superior in knowledge and practical skills to technicians with many years of experience.

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The DARPA IT Tutor

Why Information Technology?

- An operationally critical competency
- Current training in great need of improvement (agreement across all echelons)
- A Critical, Complex Task

IDA Basic Approach for the Digital Tutor

- **Borrows ideas from elsewhere, but empirically flexible:**
  - **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 <u>also</u> expert one-on-one tutors**
  - **Emphasize active (situated, authentic) problem solving to develop concepts**

IDA Development Approach: Strategy

- Thorough front end analysis to determine objectives for expertise
- Modeled on human tutors who are expert in specific IT topics and 1-1 tutoring
- Focus on problem solving (Navy trouble reports)
- Focus on higher order concepts underlying problem solving processes and solutions
- Integration with human mentors

Design Features: Operational

- Active, constant interaction with learners
- Problem solving in authentic environments
- Constant, ‘stealthy’, diagnostic assessment
- Frequent insistence on learners’ reflection and explanations of what went right and what did not
- Information structures shadow the learner by generating solutions in real time (not prescribed expert solution paths)

Design Features: Tactics

- No hints
- Never solve the problem for the learner
- Build on what the learner knows to resolve impasses
- Review both successful and unsuccessful actions
- Whenever possible, let the learner discover his/her errors

In Brief, No Magic Sauce

Known, but high-quality ingredients applied in proportions determined by systematic trial and error.

Did it work?
Navy Assessment

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Groups and Measures

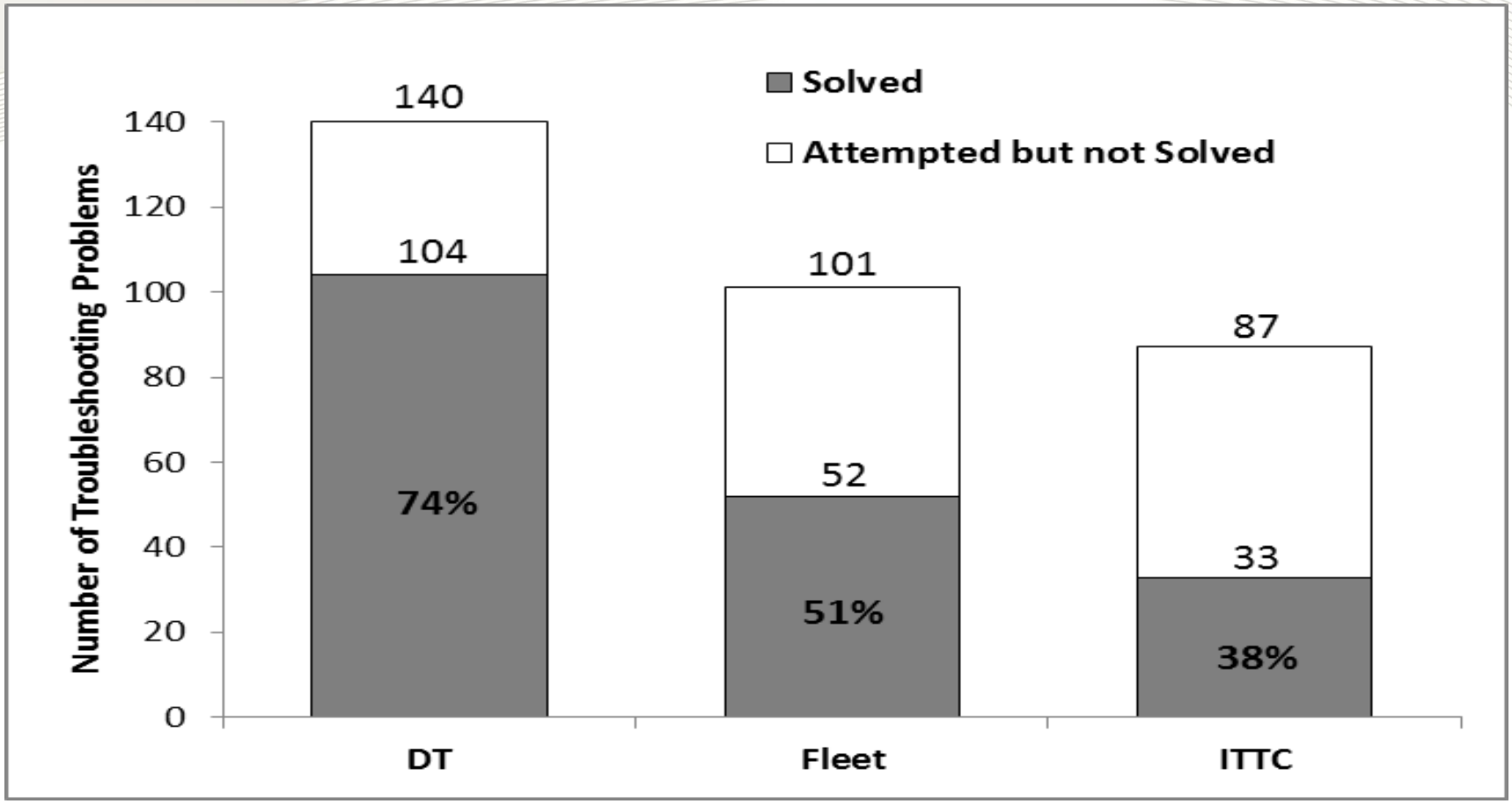
Comparison Groups:

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

Measures:

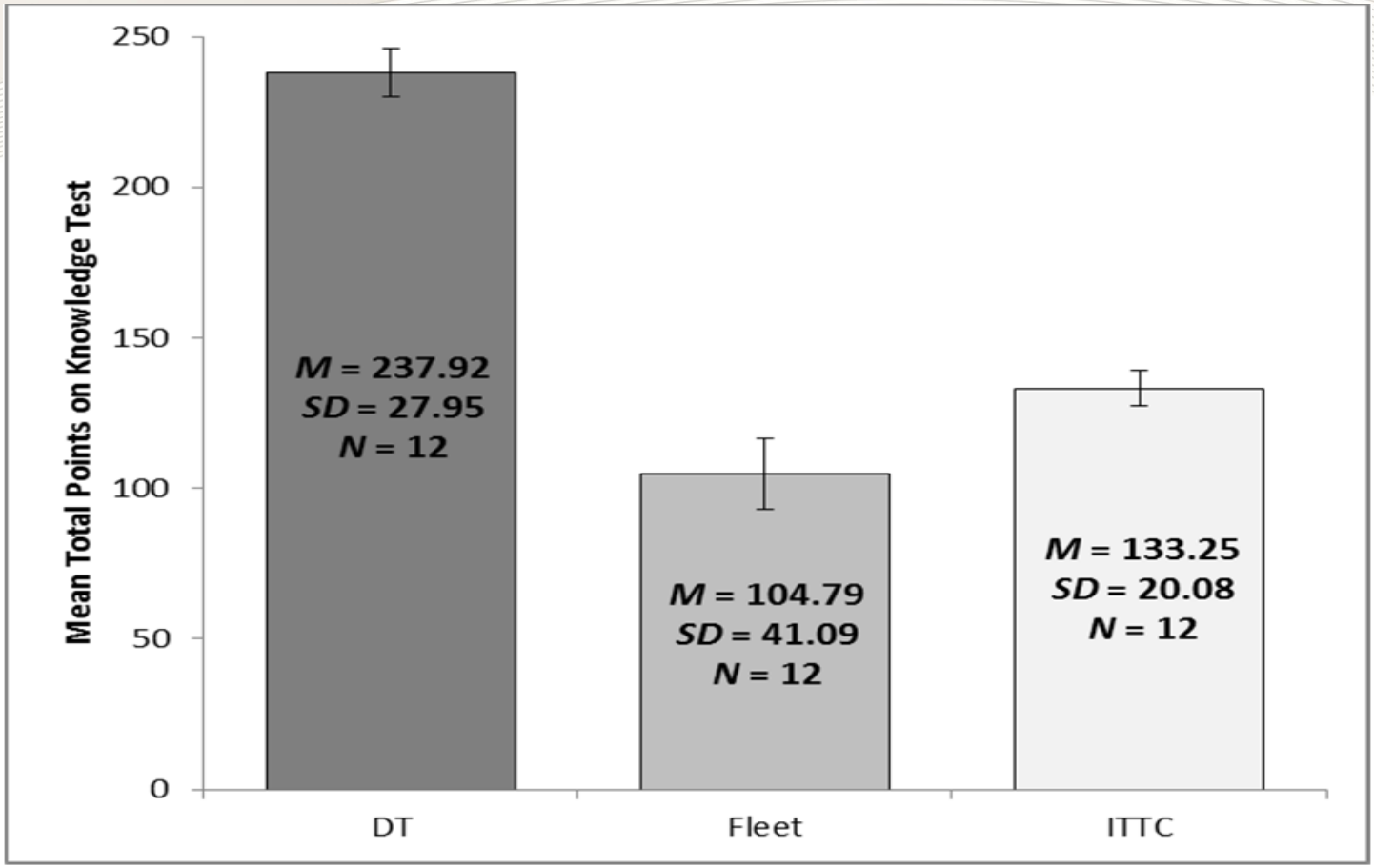
- 6 hours of problem solving (troubleshooting) exercises
- 272-item written knowledge test
- 3 hours of security exercises
- 6 hours of a system design and develop exercise
- 20-30 minute individual interviews

Findings: Troubleshooting Exercises



Solution Quality Total Scores (4 teams)		
	Occur by Chance	g
DT 132.38 (8.29) > Fleet 70.00 (16.32)	p < 0.0001	4.19
DT 132.38 (8.29) > ITTC 49.5 (9.72)	p < 0.0001	7.98

Knowledge Test Scores



Knowledge Test Scores (12 per group)		
	Occur by Chance	g
DT 237.92 (27.95) > Fleet 104.79 (41.09)	p < 0.0001	3.66
DT 237.92 (27.95) > ITTC 133.25 (20.08)	p < 0.0001	4.15

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So What?
ROI from Accelerated Learning

Training Option	Year											
	1	2	3	4	5	6	7	8	9	10	11	12
"A" School	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7	A OJT/7
"A" School plus Digital Tutor	A OJT/7 DTD	A OJT/7 DTD	A OJT/7 DTD	A OJT/7 DTD	-- OJT/7 DTI	-- OJT/6 DTO	-- OJT/5 DTO	-- OJT/4 DTO	-- OJT/3 DTO	-- OJT/2 DTO	-- OJT/1 DTO	-- -- DTO

12-Year NPV ROI (3,076.2 – 1,563.6) = $1,512.6M

Did it Work Outside the Navy? Veterans Assessment

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The Veterans Project

Objective: Assess use of DARPA Digital Tutor to prepare veterans for civilian IT employment.

- 18 week course – 2390 applicants
- 5 cohorts of 20 Veterans each
- 97 Finished (No academic dropouts)

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Qualification Requirements

- Honorable Discharge
- Meet Army and Navy qualification for IT training
- Completed application
  - Three questionnaires
  - Some phone interviews
  - Submission of ASVAB scores

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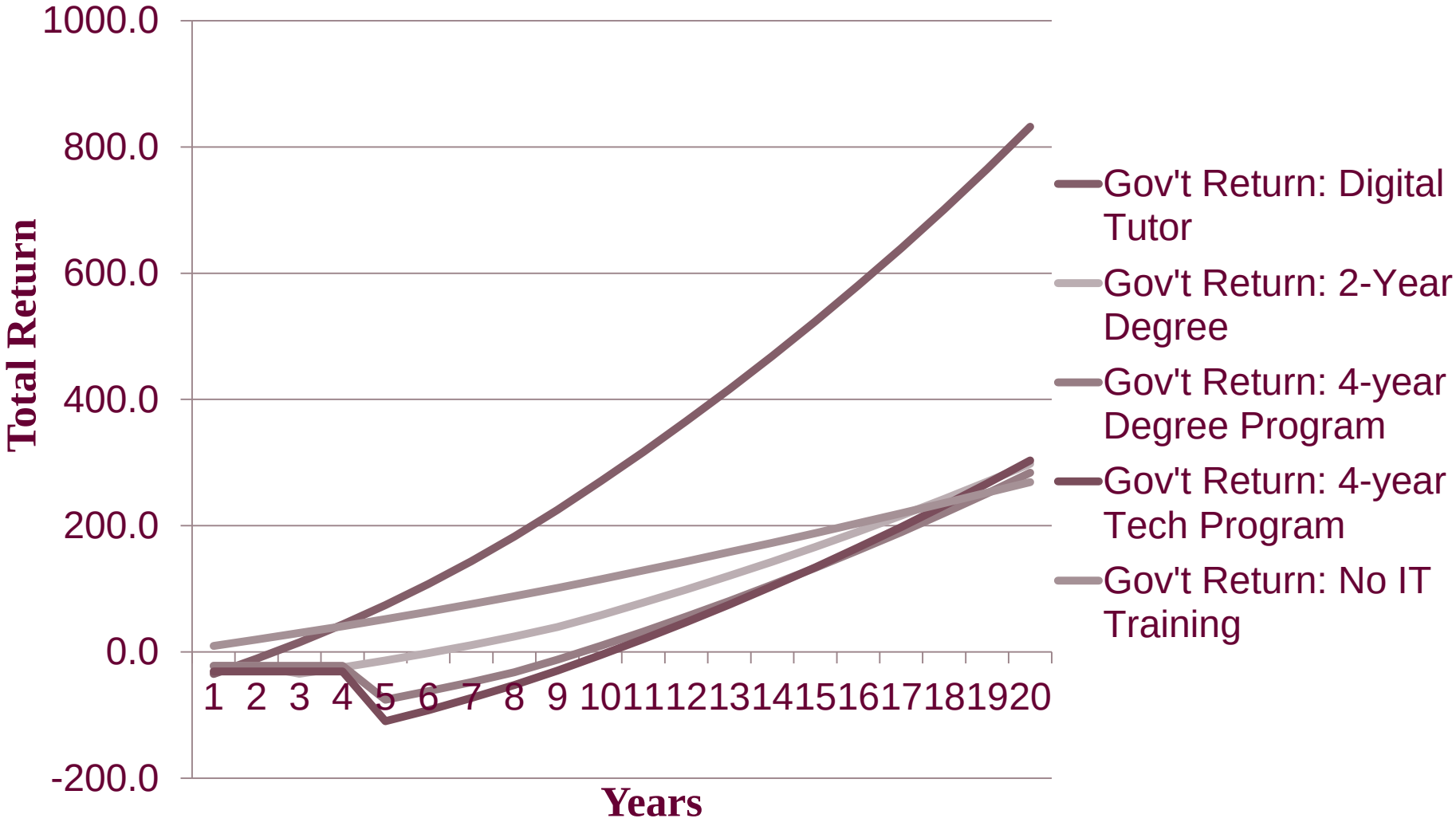
Veterans' Demographic Data

Average Age	30.5
IT Experience	8%
Male	91%
Military IT Training	4%
Married	29%
HS/GED Degree Only	45%
Employed	17%
Employed Full Time	11%
Average AFQT	87.1
Honorable Discharge	100%

Results

- 100 Began, 97 Completed
- No Academic Dropouts
- Job seekers confirmed employed: 97%
- Average annual salary $73K (highest, $144)

20-Year Incremental Revenue for the Government ($000)



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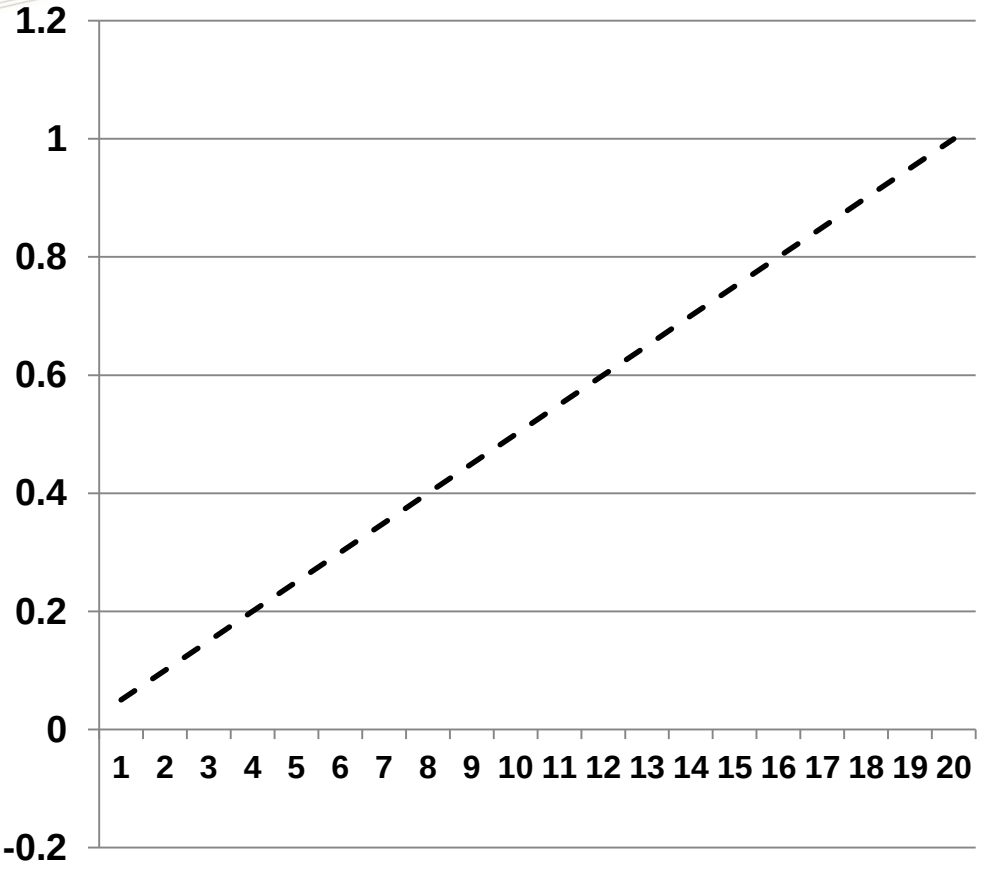
Equity of Learning

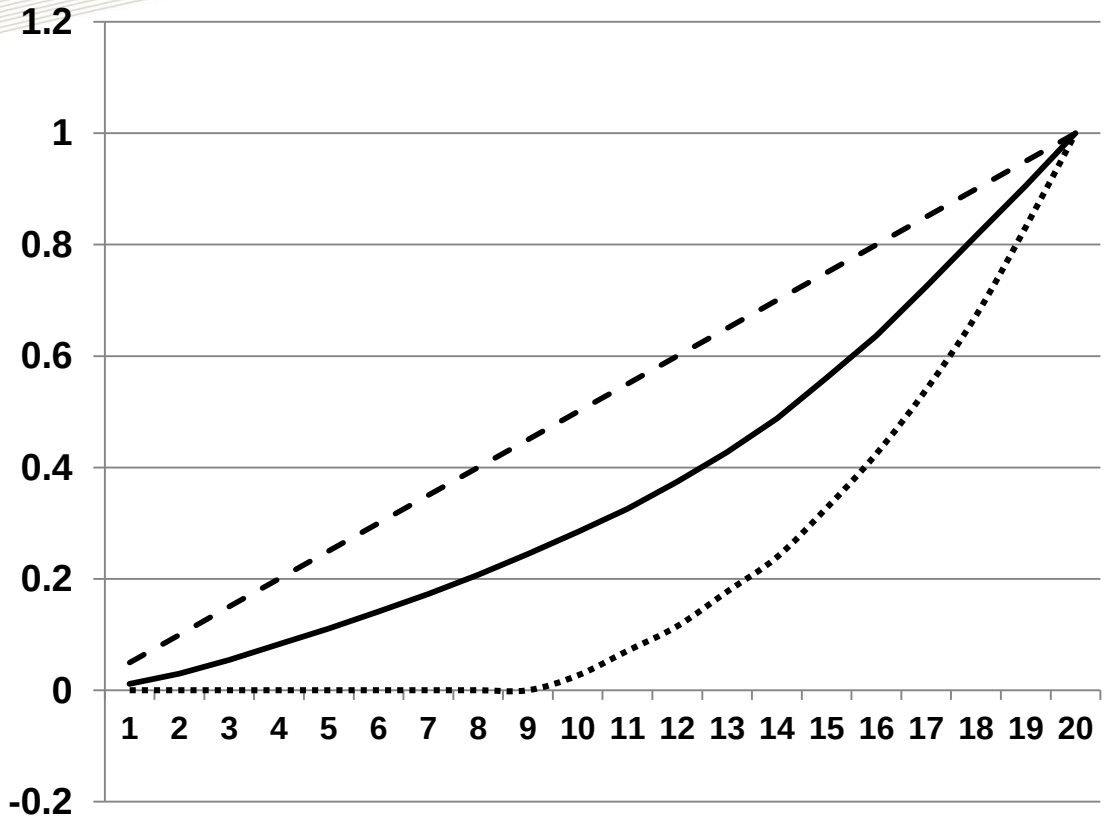
- Economists use Lorenz curves and Gini coefficients to assess equitable distribution of income.
- What happens if we apply the same technique to learning?

Perfect (Gini) Equality



If perfect equality, Gini Coefficient = 0; If perfect inequality, Gini = 1.00

IDA | Lorenz Curve for the Digital Tutor



Gini Coefficients: Tutoring (0.47); Classroom (0.69)

Replicates Jamison, Fletcher, Suppes, Atkinson (1976)

The Issues: Should We . . .

(1) Enhance Learning

or

Validate Theory

(2) Maximize Effect
(Accelerate Expertise)

or

Minimize Cost
(Hold Expertise Constant)

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Findings …

- **Digital Tutoring can substantially accelerate the acquisition of expertise for all learners**
- **Digital tutoring represents a major monetary and operational opportunity to improve training efficiency and mission effectiveness.**
- **We know enough about the Digital Tutor design to replicate it in other areas at much less cost, but it must be done right**

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Madly Into the Future: Ubiquitous, Distributed Learning?

The ADL Vision

Server

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

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Eventually …

- **Anywhere, Anytime Learning Integrated with Performance/Decision Aiding (Integrating the supply and demand side of learning)**
- **Individualized Learning-- A Response to Thorndike (Learning as tutorial conversation)**
- **More Precise Assessment of Learning (Continuous, Unobtrusive, 'stealth' assessment)**
- **Personal Learning Associates (Distributed in classrooms and out – anytime, anywhere)**

Instruction (and Performance/Decision Aiding) as Individualized Tutorial Conversation

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In Conclusion . . .

- **The Challenge/Issue**

  DoD Classroom-oriented technical training is expensive and requires additional on-the-job training to develop readiness-level expertise.

- **Opportunity**

  Digital Tutoring can produce technical expertise in the same time now used for classroom training.

- **Benefit**

  Less time to train, fewer technicians needed to meet readiness requirements.

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A Final Thought …

The difficult, intransigent issues may be cultural, organizational, administrative, and structural. Not technological.

Questions? Comments? Objections? Complaints? Thank you!