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Teacher Effectiveness: Using Research to Improve Student Learning

Co-Sponsors:

- Edvance Research, Inc.
- Mid-Continent Comprehensive Center (MC3), University of Oklahoma/Outreach
- Minority Teacher Recruitment Center at the Oklahoma State Regents for Higher Education
- Oklahoma Business and Education Coalition

In collaboration with the Oklahoma Association of Colleges of Teacher Education (OACTE)

EDVANCE research INC.

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Teacher Effectiveness: Using Research to Improve Student Learning

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Dr. Phyllis Hudecki,

Oklahoma Secretary of Education

- Welcoming Remarks

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Dr. Lisa Holder,

Director, Minority Teacher Recruitment Center at the Oklahoma State Regents for Higher Education

- Introductions of Participants & Speakers

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Dr. Vicki Ferguson,

The University of Science and Arts of Oklahoma

Chair, Oklahoma Association of Colleges of Teacher Education

- Opportunities to Apply Research to Teacher Preparation Programs

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Dr. Dean Nafziger,

Edvance Research, Inc., Chief Executive Officer

- Research to Practice

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Who We Are

- Edvance Research, Inc.
  - Women & minority owned business, headquartered in San Antonio with offices in Austin.
  - Works to improve outcomes for students through building the capacity of educators and their school communities to conduct, understand, and use research in their practice.
- Primary Contracts
  - Regional Education Laboratory, Southwest – U.S. Dept Ed(REL Southwest)
  - Michael and Susan Dell Foundation
  - Texas Education Agency

www.edvanceresearch.com

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REL Southwest

- Funded by Institute of Education Sciences (IES) – U.S. Department of Education
- SW Region: Arkansas, Louisiana, New Mexico, Oklahoma, Texas
- REL Services:
  - Technical assistance
  - Fast Response research studies
  - Randomized control trials
  - Research sharing events with stakeholders
    - IES Practice Guides From What Works Clearinghouse

What are Practice Guides?

- Recommendations for addressing current challenges in education
- Practice Guide include:
  - Concrete how-to steps
  - Rating of strength of evidence
  - Solutions for common roadblocks
- Examples:
  - Organizing Instruction and Study to Improve Student Learning
  - Turning Around Chronically Low-Performing Schools
  - Helping Students Navigate the Path to College

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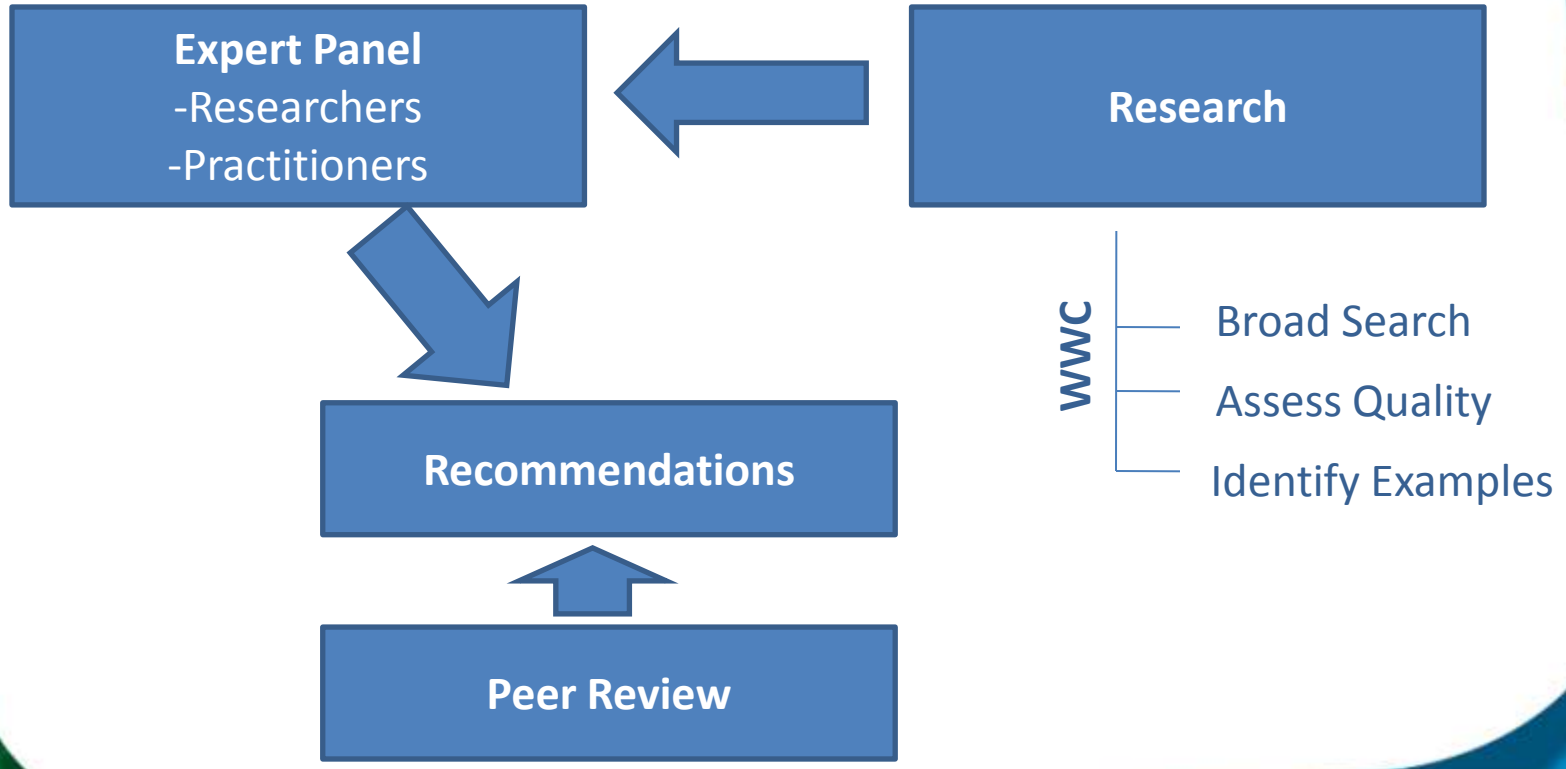
How Practice Guides are Developed



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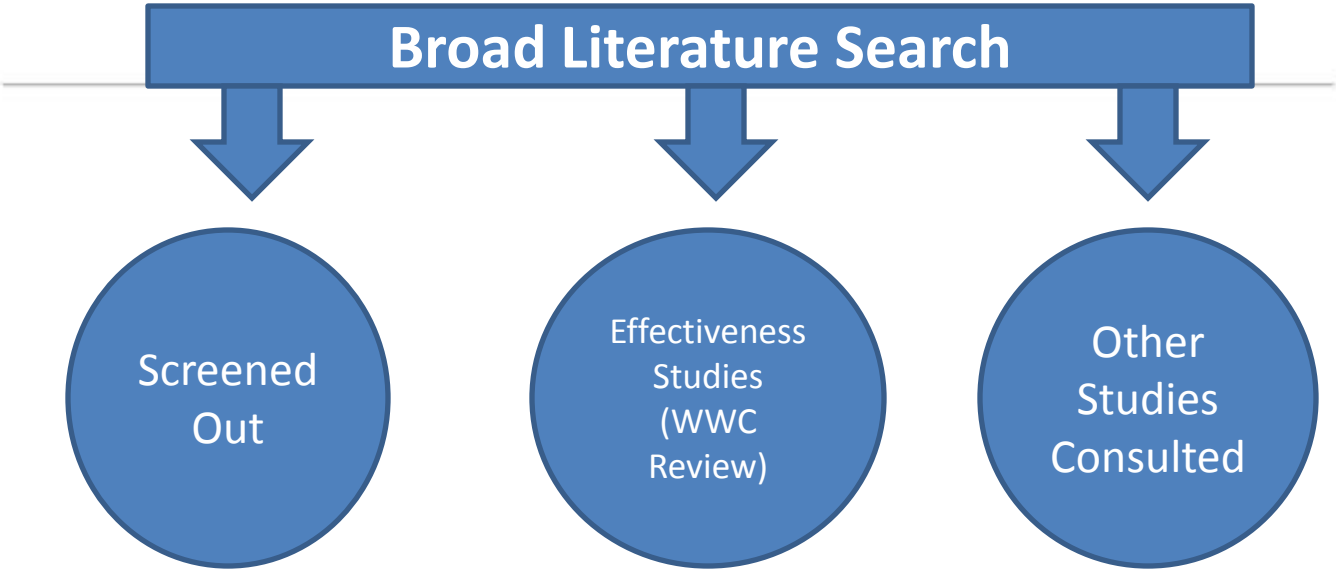

	Initial Search	After Screening	Effectiveness Studies	Met Standards
RTI-Math	801	350	115	40
Data Driven Decisions	2,853	495	64	24
Out of School Time	3,972	1,170	88	29

Levels of Evidence

- Strong: High confidence (multiple rigorous studies in a variety of contexts)
- Moderate: Some evidence (may not work in all settings)
- Low: Hasn't been proven with rigorous research (but panel still thinks it is important)

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Dr. Belinda Biscoe,

Director, Mid-Continent Comprehensive Center; Assistant Vice President, OUTREACH, University of Oklahoma

- Research to Practice

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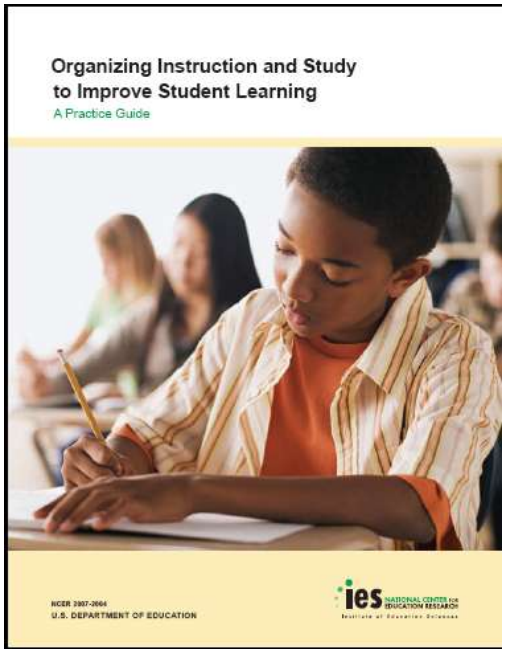
Dr. Harold (Hal) Pashler,

University of California at San Diego

Professor of Psychology and Cognitive Science

- Recent Research on Human Learning Sheds New Light on Effective Teaching Practices

Organizing Instruction and Study to Improve Student Learning



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Overview

- Overview of IES Practice Guides & our guide in particular
- Highlights from the 7 recommendations
- Additional Resources
- Summary

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Organizing Instruction and Study to Improve Student Learning

Practice Guide authors:

Hal Pashler (Chair), University of California, San Diego

Patrice M. Bain, Columbia Middle School, Illinois

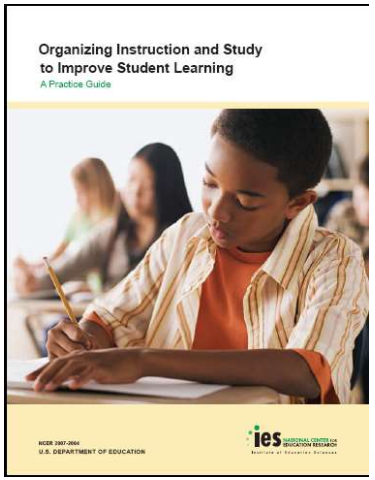
Brian A. Bottge, University of Wisconsin–Madison

Arthur Graesser, University of Memphis

Kenneth Koedinger, Carnegie Mellon University

Mark McDaniel, Washington University in St. Louis

Janet Metcalfe, Columbia University



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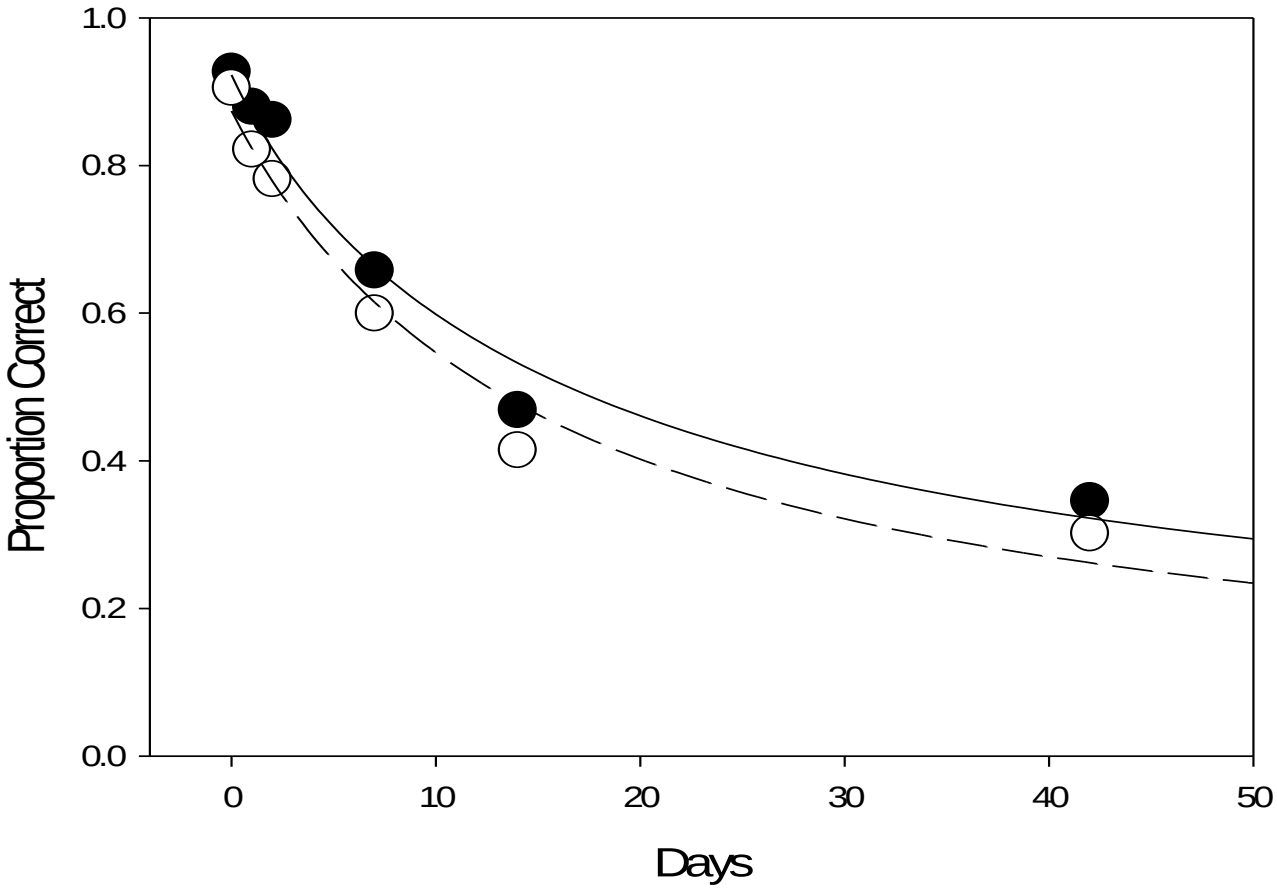
Focus of this Practice Guide

- Concrete principles of what to do and what not to do to maximize the efficiency of learning.
- "Micro-level" issues that often cut across different subject-matter categories (science, social studies, math…)
- Methods geared to promoting retention of information.

Reflects Background of Panel Members

- 5/7 are experimental cognitive psychologists with specialization in human memory and learning.
- Main activity in this field: running laboratory experiments in which people learn material and then get a delayed test of memory.

Typical Form of Human Forgetting Function



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Forgetting in Education: Ample Evidence for importance…

- Long-term follow-up on college, med school courses
  - Workplace training (e.g., MS Excel)
    - *(more speculatively) Studies showing dismal performance on basic factual information that was surely taught in all curricula (e.g., "where is Pacific Ocean?)".*

…but receives little discussion in education literature.

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Father Guido Sarducci

Pioneering Founder of the Five-Minute College

"People who went to college can tell you what they learned in just 5 minutes. So, at my college, students learn just the same stuff – all in 5 minutes."

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(One bit of Good News on Forgetting)

Even when a learner cannot recall information, they may have other benefits of learning:

Ability to recognize the information

"Savings": Ability to re-learn the information much more quickly

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Overview

- Goals of IES Practice Guides
- Highlights from the 7 recommendations
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Next

Two Recommendations focused on reducing forgetting:

Summary of Recommendations

Next

1. Space learning over time. (Moderate)
2. Interleave worked example solutions with problem-solving exercises. (Moderate)
3. Combine graphics with verbal descriptions. (Moderate)
4. Connect and integrate abstract and concrete representations of concepts. (Moderate)

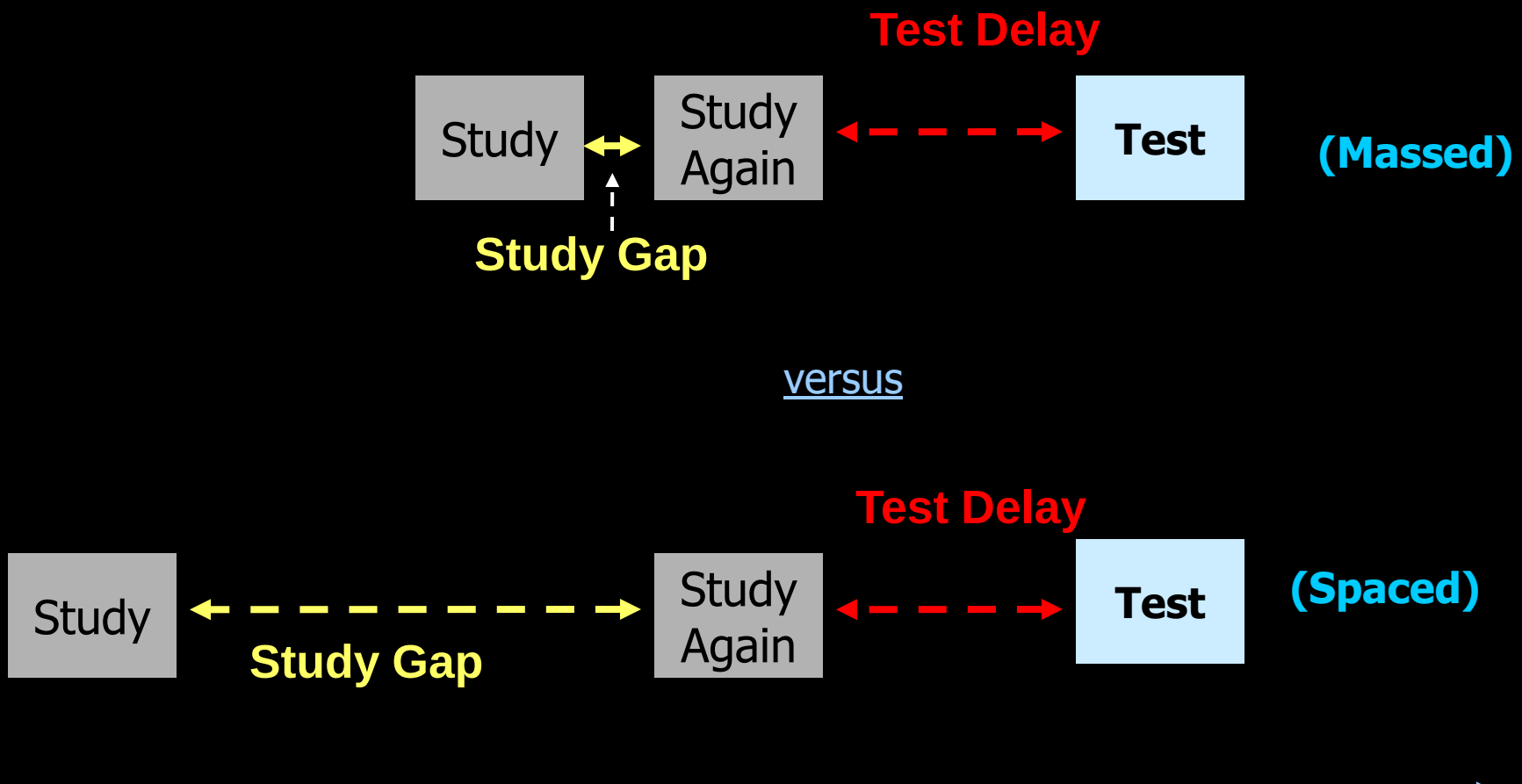
Two recommendations focused on reducing forgetting:

Summary of Recommendations, cont'd

Next

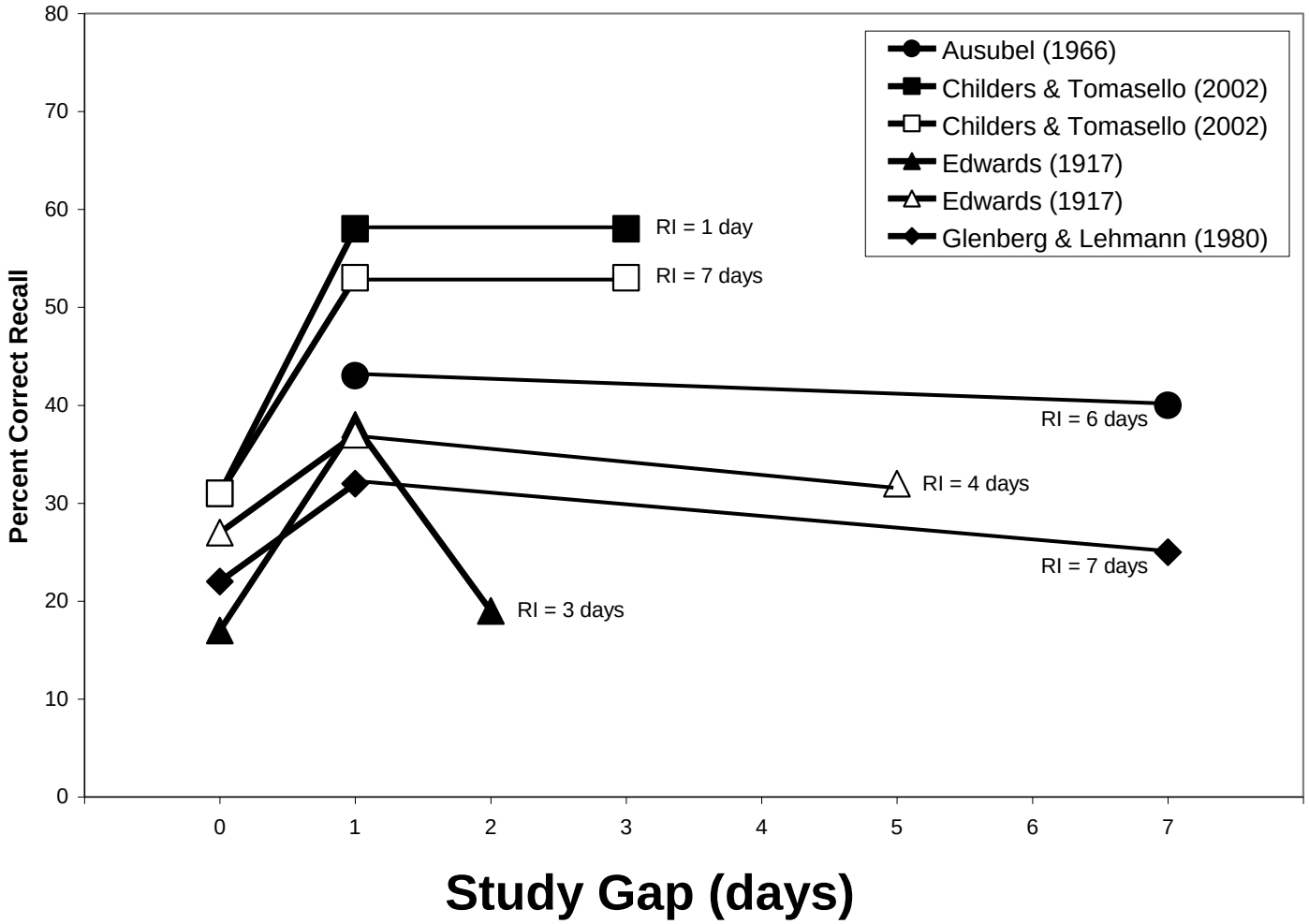
5. Use quizzing to (directly) promote learning.
    a) Use pre-questions. (Low)
    b) Use quizzes to re-expose students to key content. (Strong)
6. Help students allocate study time efficiently. (Low)
7. Ask deep explanatory questions. (Strong)

"Spacing Effect"



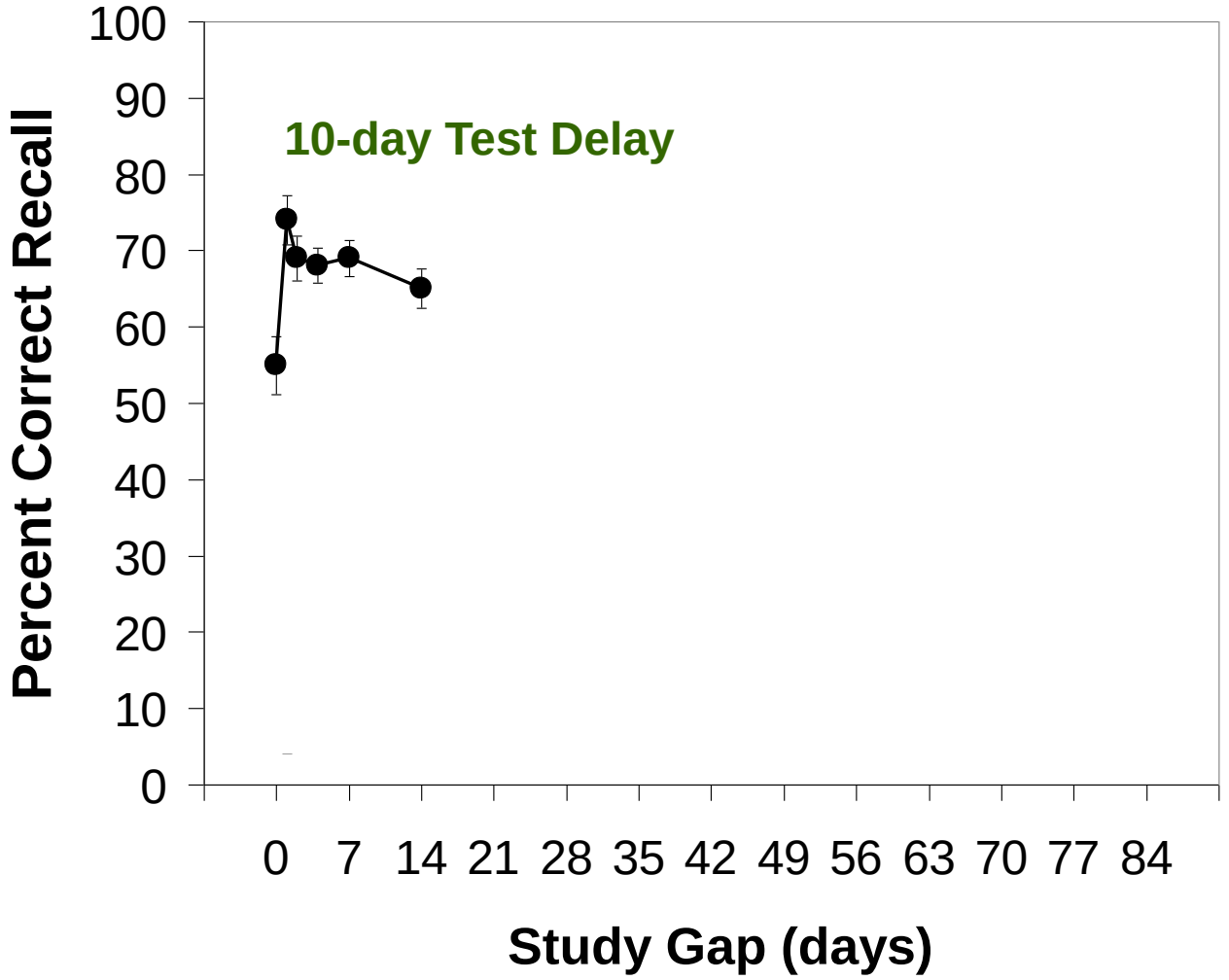
Origin: Ebbinghaus in 1880s

Hundreds of studies… but only a few with even a 1-day test delay!



Is a 1-day study gap best?

Data from 182 subjects tested for 3 sessions



Recent IES-sponsored Research

1. Examines long time intervals
2. Systematically varies test delay and study gap.
3. Equates study time in all conditions (to let us ask: how to get maximum bang for the buck?)

Cepeda et al. (2009) Study of Spacing with 6-month test delay

1. Study some material for the first time

2. Study gap = 0, 1, 7, 28, 84, or 168 days

3. Study the same material for a second time

4. Test delay = 6 months

5. Take final test on the material

Cepeda et al. (2009) Study of Spacing with 6-month test delay, cont'd

Tasks

1. Learn names of little-known objects

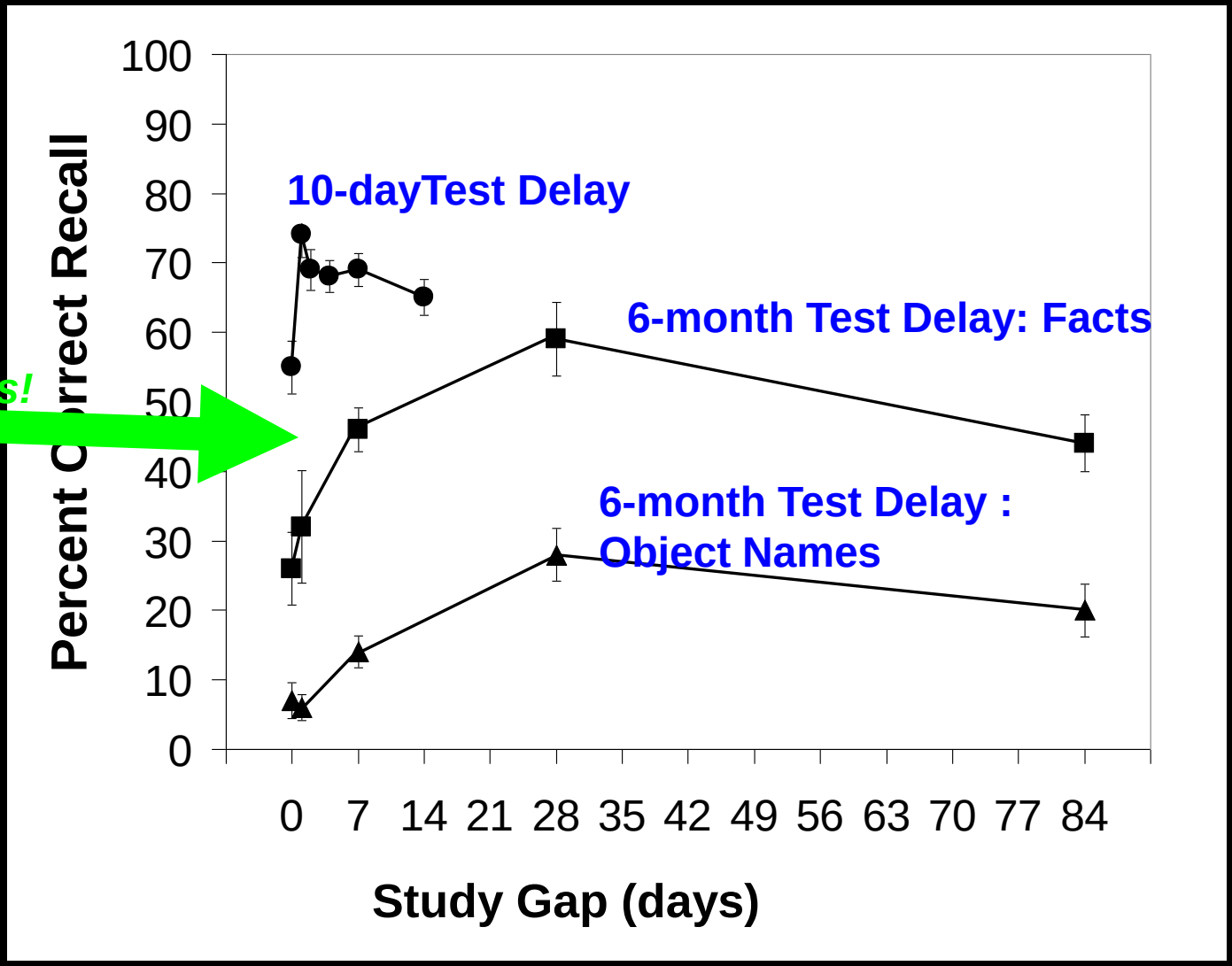
? *Coccolith.*

2. Learn little-known facts

Who invented snow golf? *Rudyard Kipling.*

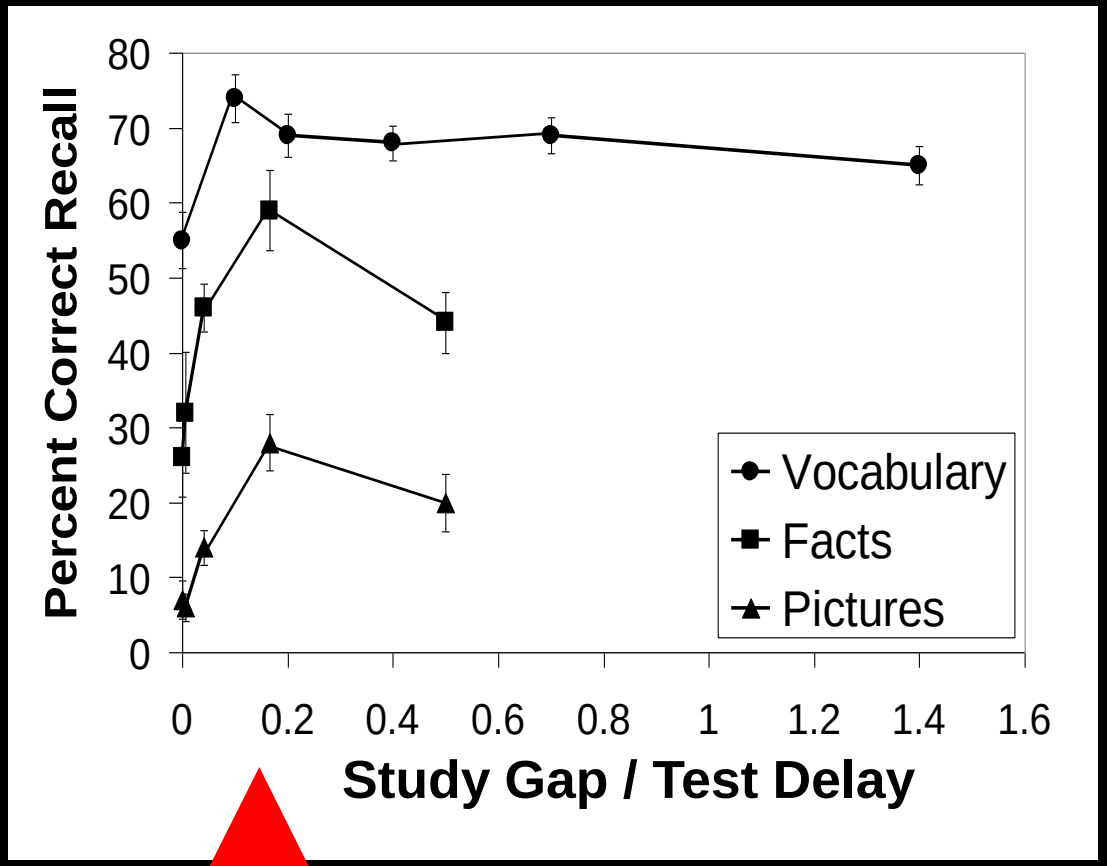
Final Test Performance

2- or 3-fold increases!

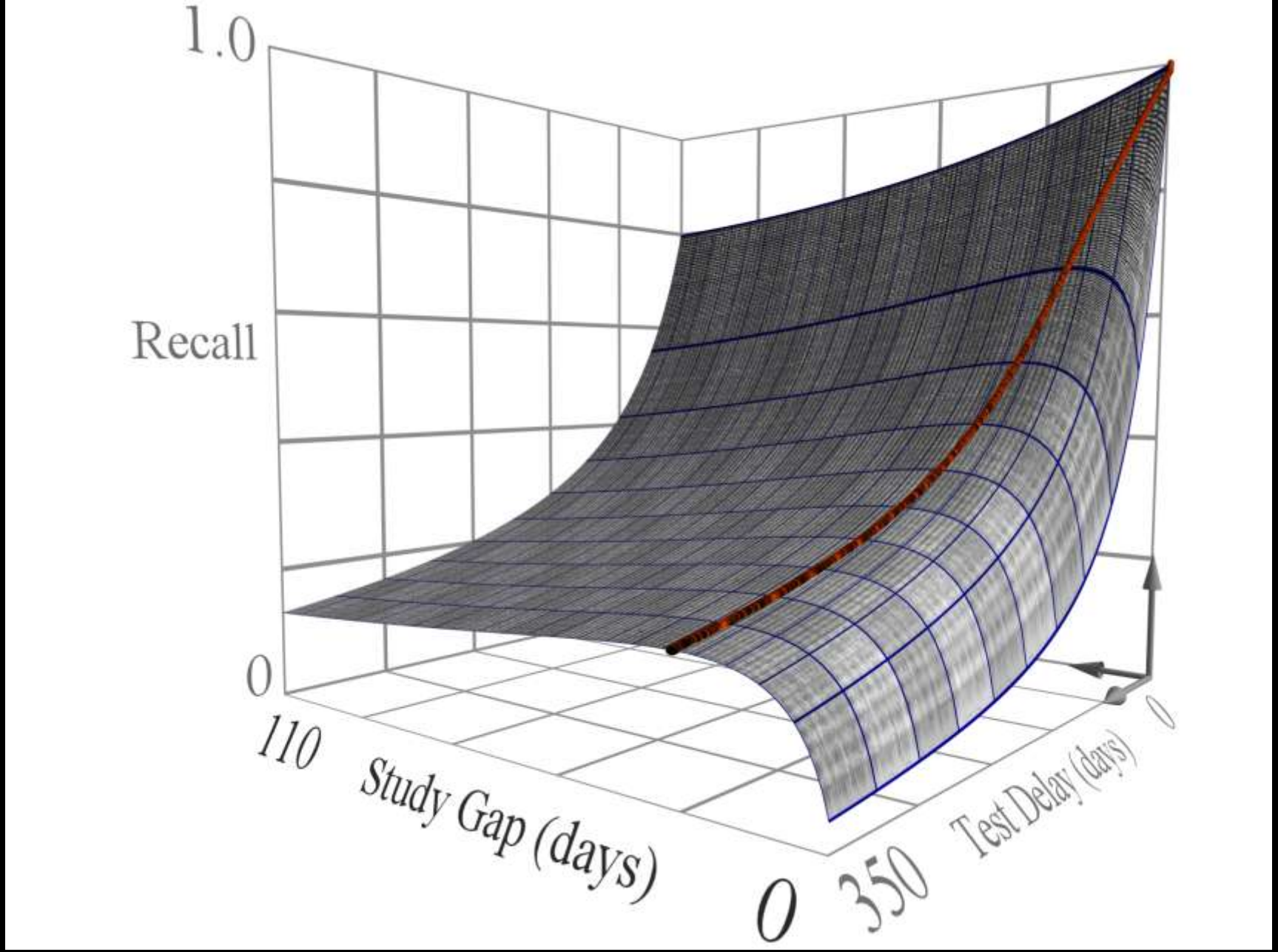


Cepeda et al., *Experimental Psychology,* 2009

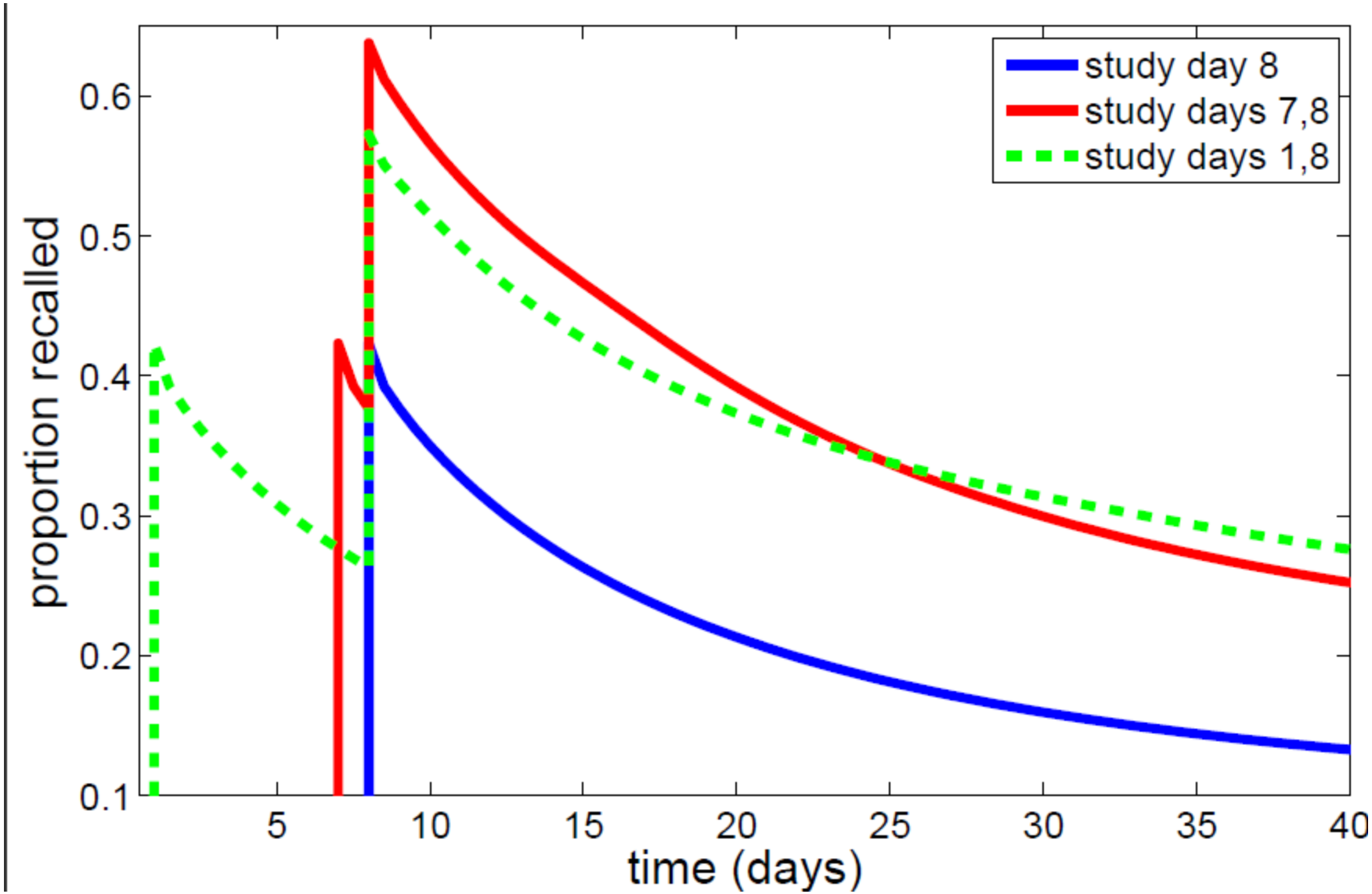
Same 3 graphs plotted in terms of study gap/test delay



Optimum gap = 10 – 20% of test delay



Cepeda, Vul, Rohrer, Wixted, & Pashler (*Psychological Science, 2009*)



Implications

- If you want to retain something for a period of time X, and you are able to study it twice, arrange to have the time between study approximately = X/10!
- Therefore, if you want to remember something for many years, make sure you study it twice with at least six months separating these study events.

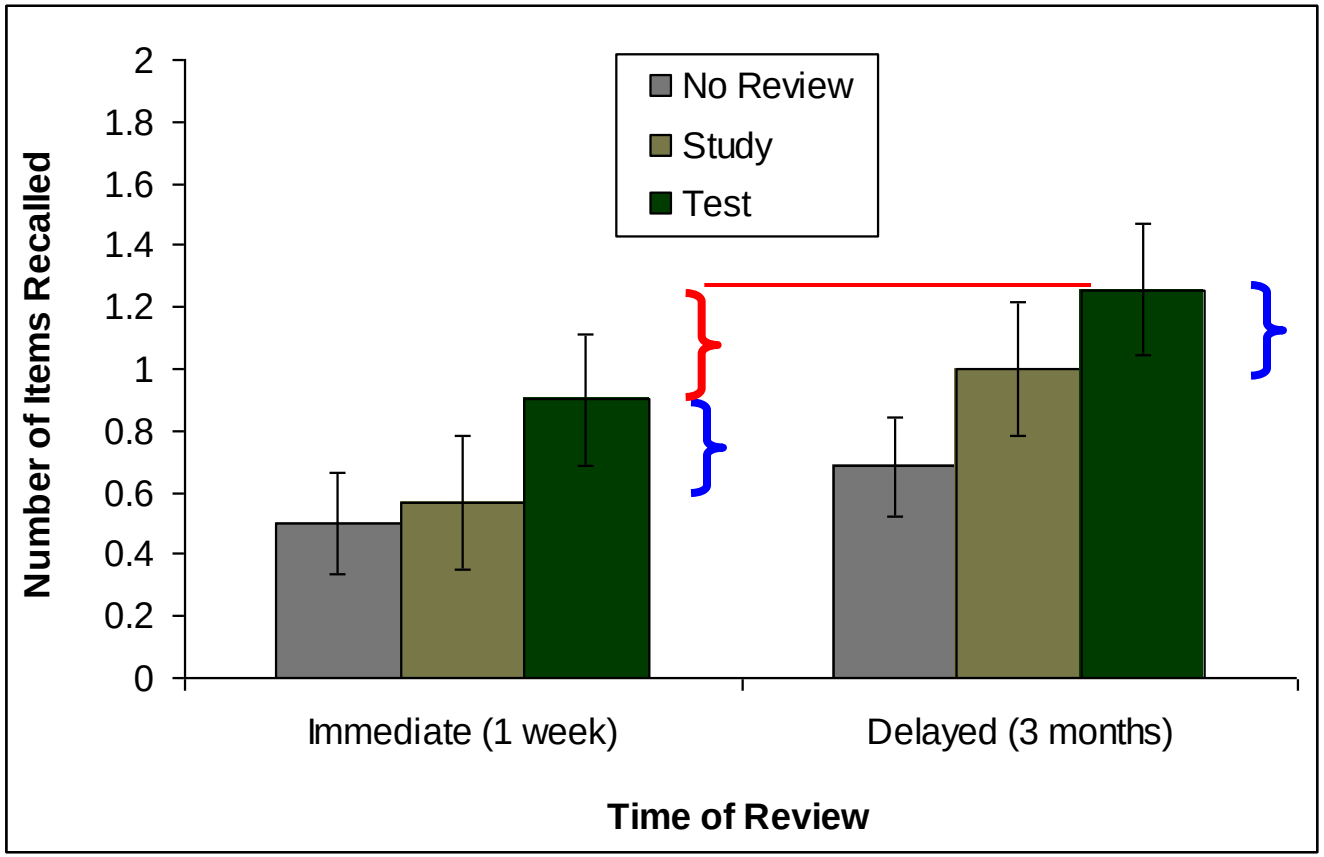
Sad Consequence of Spacing: Perverse Incentives in Standard Practices

- Suppose student has exam on material on Feb 15, and wants to budget enough time to read the material twice. When should s/he study in order to **maximize** performance on exam?
- Answer: Do all study on Feb 14 (ie cram).
- What is the **worst** thing a student could do in terms of what s/he will remember years later?
- Answer: Do all study on Feb 14 (ie cram).

Generalizability of Results

- Generalizes to classroom learning of factual material
- Generalizes to children and adults (possibly not toddlers, however).
- Seems to generalize to learning connected body of facts, not just isolated facts.
- Generalizes to math learning.
- May not generalize to learning perceptual skills.

Benefits of Testing (and Spacing) in Review of Classroom Material



8th graders reviewed facts from U. S. history class like "In what year were all women allowed to vote in the U.S.?"

Answer is? 1920

Test group = answered test questions
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Immediate = Review 1 week after course
Delayed = Review 3 months after course

Final test 9 months later: Graph shows results

Carpenter, Pashler, & Cepeda (2008). *Applied Cognitive Psychology*

Rec. 1. Space learning over time

- Recommendation
  - To help students remember key facts, concepts, and knowledge … arrange for students to be exposed to key course concepts on *at least two occasions—separated by several weeks or months*.

Relevance to familiar problems in classroom (1):

- 7th grade teacher: Didn't they teach … in 6th grade?!
- What's going on? Why are such complaints so common?
- Students forget! And especially so if 6th grade lessons were "massed" in one lesson or chpt
- Help the teacher in the next grade
  => space practice!
  - Have less repetition within a lesson/chapter, more "mixed review" in later lessons

Relevance to familiar problems in classroom (2):

- Students seem to understand & perform well in class in fall & winter
- But come standardized test time in spring …
- Poof! Understanding has disappeared
- Again, *forgetting* may be the culprit*
  - Students did understand, but they did not get enough *spaced* repetition to remember in long term

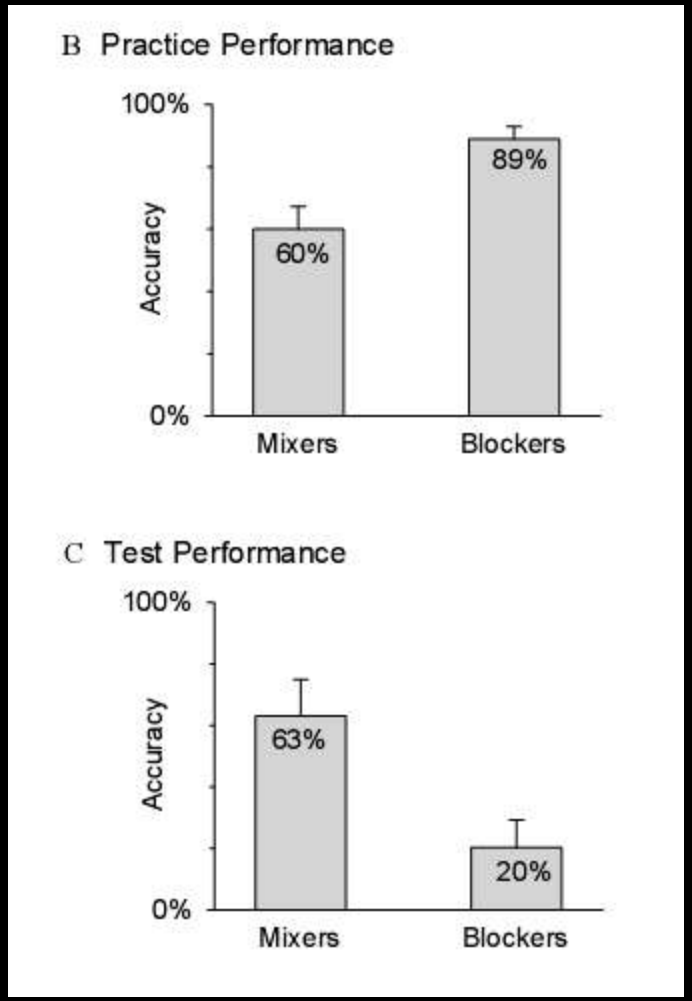
Spacing and Problem Sets in Math/Physics/Chemistry/etc

- Standard textbook design:
  - Chapter 1
  - Problems on Chapter 1
  - Chapter 2
  - Problems on Chapter 2
  - Etc.
- Consequences:
  - Little spacing for the learning relevant to each chapter
  - Student receives no training in determining "which method is relevant to solving this problem?"
  - But on final exam, high stakes tests, or the real world, the problems will not come with labels telling what solution method to use!

Doug Rohrer and Kelli Taylor (USF):

"Shuffling of Mathematics Practice Problems Improves Learning"

(in press, *Instructional Science*):



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HP Comments on Implementation

- Many challenges for teachers in incorporating more review of material covered much earlier in class:

  -- Preparation becomes more taxing

  -- Exposes the degree of forgetting that is occurring—may be demoralizing!

- For interleaving problems in math/science, only a very few textbooks provide this in the book.

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Rec. 5: Use Quizzing* to Promote Learning

*(much broader, really)

What is the purpose of tests in education?

1. Assess learning.
2. Provide incentive for student to study.
3. Provide incentive for teachers & administrators to teach effectively.

***4. Directly promote learning (<u>while the student is actually doing the quiz!</u>).

An Old Idea

"Exercise in repeatedly recalling a thing strengthens the memory."

(Aristotle, 4th century B.C., *De Memoria et Reminiscentia)*

"If you read a piece of text through twenty times, you will not learn it by heart so easily as if you read it ten times while attempting to recite from time to time and consulting the text when your memory fails."

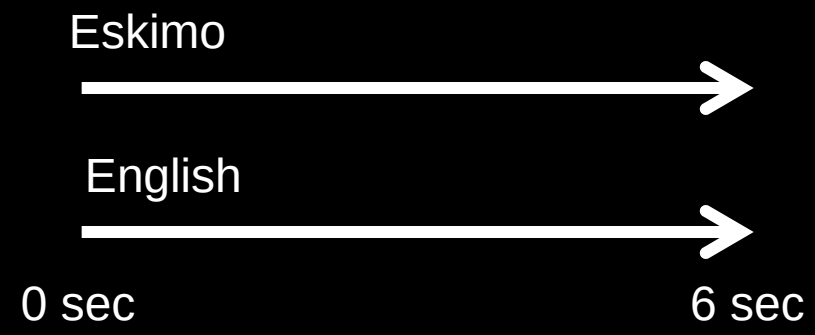
(Sir Francis Bacon, 1620, *Novum organum)*

"A curious peculiarity of our memory is that things are impressed better by active than by passive repetition. I mean that in learning (by heart, for example), when we almost know the piece, it pays better to wait and recollect by an effort from within, than to look at the book again. If we recover the words in the former way, we shall probably know them the next time round; if in the latter way, we shall very likely need the book once more."

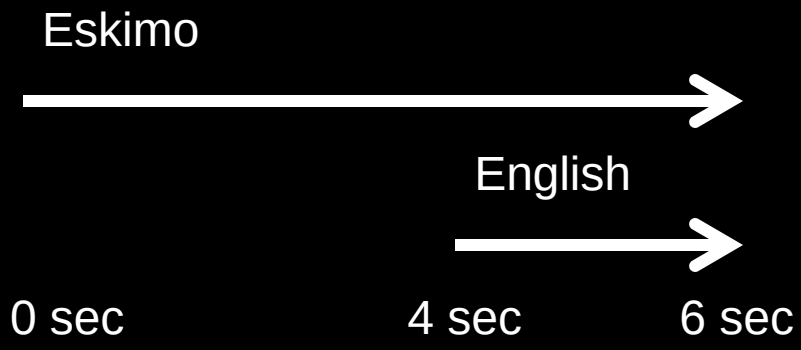
(William James, 1890, *Principles of Psychology)*

It works even when retrieval demand means less exposure to the answer!

Pure Study Condition



Test/Study Condition



** ~ 20% better on final test

Carrier & Pashler (1992)

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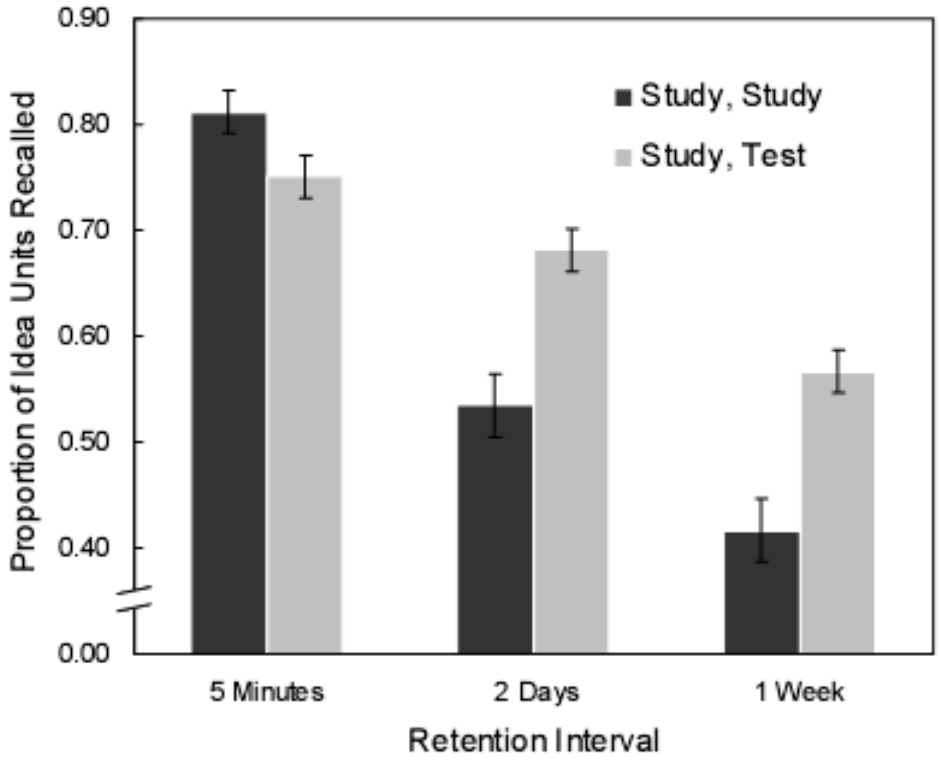
Recent Finding: Learning from quizzing actually slows rate of forgetting!

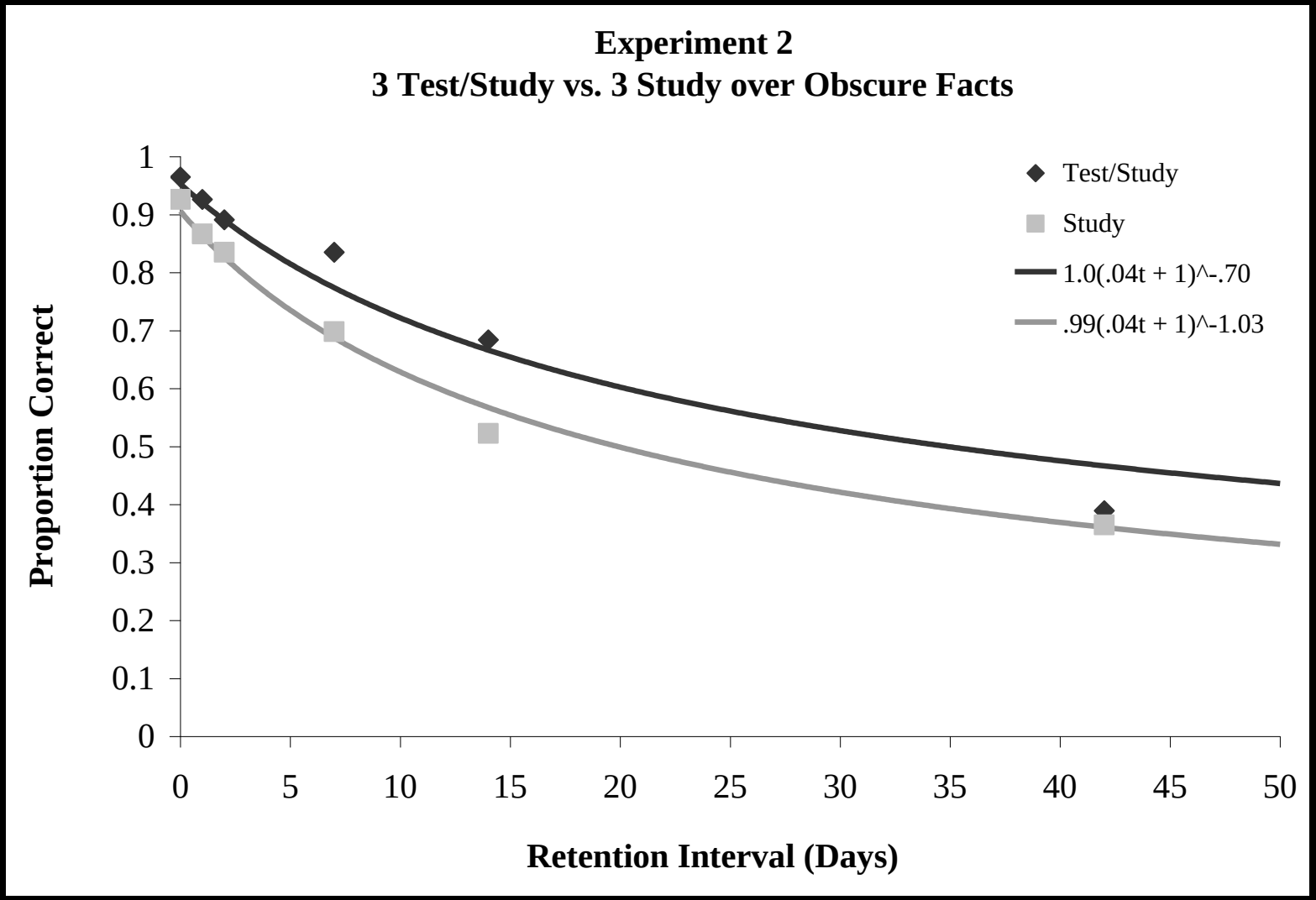
Roediger & Karpicke (2006, *Psych Science)*

- Read prose passage; then spend 7 minutes

(a) studying or (b) getting a test (no feedback)



Carpenter, Pashler, Wixted, & Vul (2008, *Memory & Cognition*)



Generalizability of Results

- Children as well as adults (Spitzer)
- Visual/spatial learning (e.g., Carpenter & Pashler, 2008)
- Recall test, fill-in-blank test, & (sometimes) multiple choice test.
- Classroom as well as lab.

What kind of tests work?

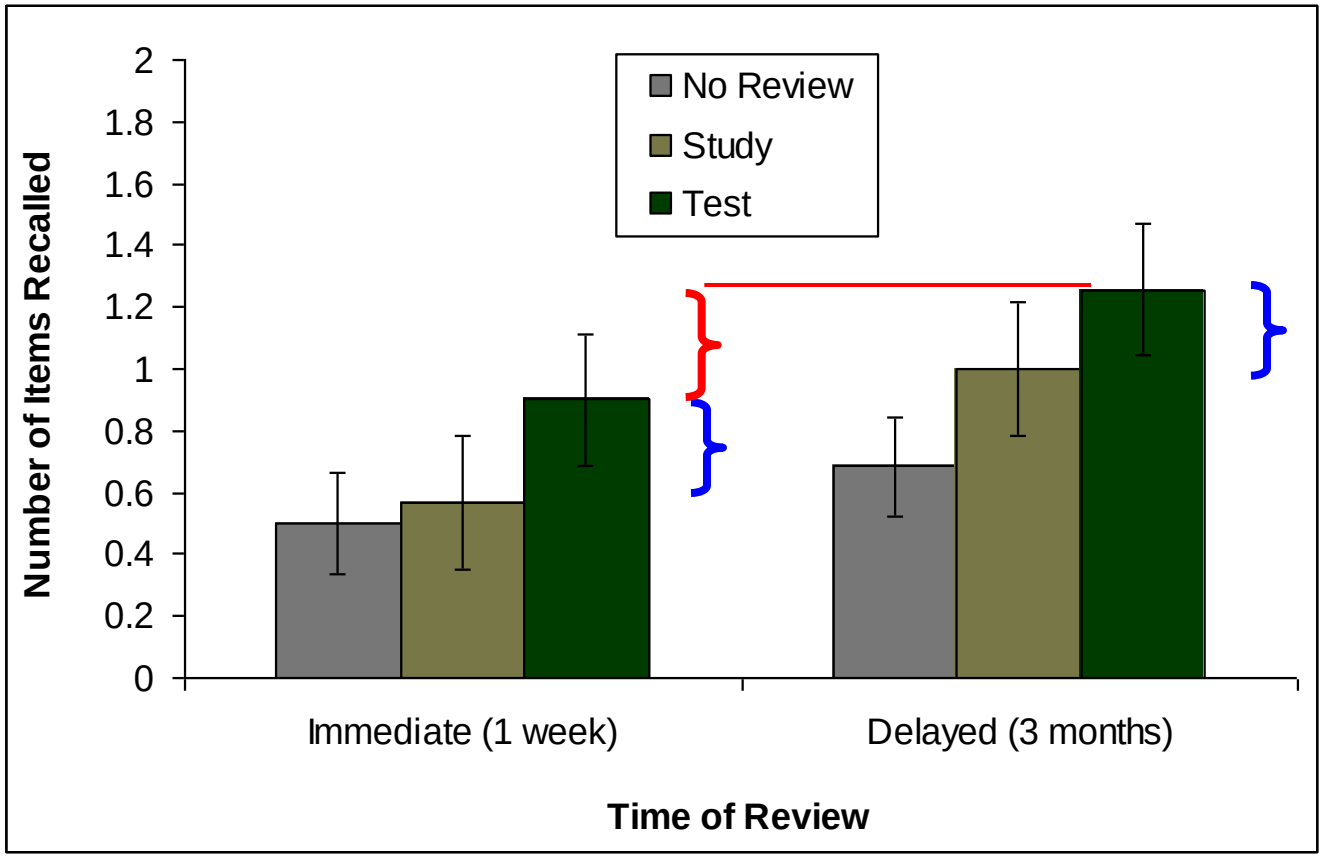
- Recall (essay, short-answer) ++
- Multiple-Choice: only a little bits
  - Even if criterial test is MC!

(Kang, McDermott, & Roediger, 2007)

Other Recent Findings

- *Repeated* retrieval practice amplifies the benefit (ideally with reasonable spacing).
- To maximize the benefit of testing, feedback should be provided when initial test performance is low (low accuracy level and no feedback is often an inferior learning condition!)
- Benefits hold up on Transfer Tests, as well as recall tests.

Benefits of Testing (and Spacing) in Review of Classroom Material



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Carpenter, Pashler, & Cepeda (2008). *Applied Cognitive Psychology*

Rec. 5. Use quizzing to promote learning

- 5a. Use “pre-questions” to activate prior knowledge & create a need for information provided in lecture (weak)

- 5b. Use quizzes to re-expose students to key content (strong)

Examples of quizzes to re-expose & enhance memory

- Ways to implement:
  - Give students closed-book quizzes between initial exposure & final assessment
  - Either formal quizzes or informal testing situations, such as playing a Jeopardy-like game
  - Many educational websites allow instructors to create test questions with answers for online study

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Unproven hunch: Students May Benefit from Knowing that Retrieval Practice Effect Exists!

- In college, lecture/textbook instruction does not facilitate retrieval practice, but (anecdotally) it seems that better students often discover and use it themselves.

- Is it useful to help students to recognize importance of retrieval practice in their own studying?

Two recommendations focused on facilitating comprehension and transfer:

Summary of Recommendations

Next

1. Space learning over time. (Moderate)
2. Interleave worked example solutions with problem-solving exercises. (Moderate)
3. Combine graphics with verbal descriptions. (Moderate)
4. Connect and integrate abstract and concrete representations of concepts. (Moderate)

Two recommendations focused on facilitating comprehension and transfer:

Summary of Recommendations, cont'd

5. Use quizzing to (directly) promote learning.
   a. Use pre-questions. (Low)
   b. Use quizzes to re-expose students to key content. (Strong)
6. Help students allocate study time efficiently. (Low)
7. Ask deep explanatory questions. (Strong)

Next

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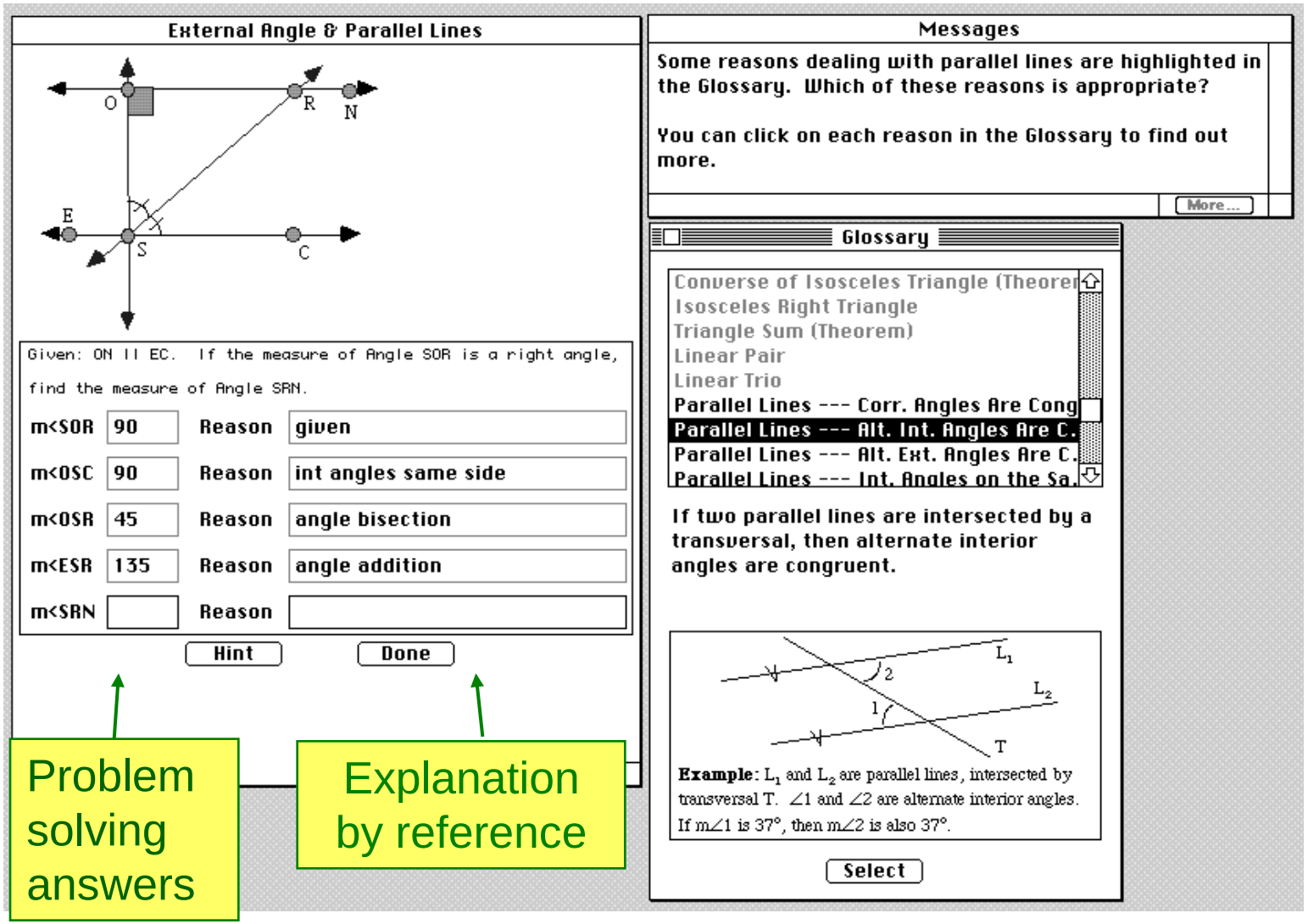
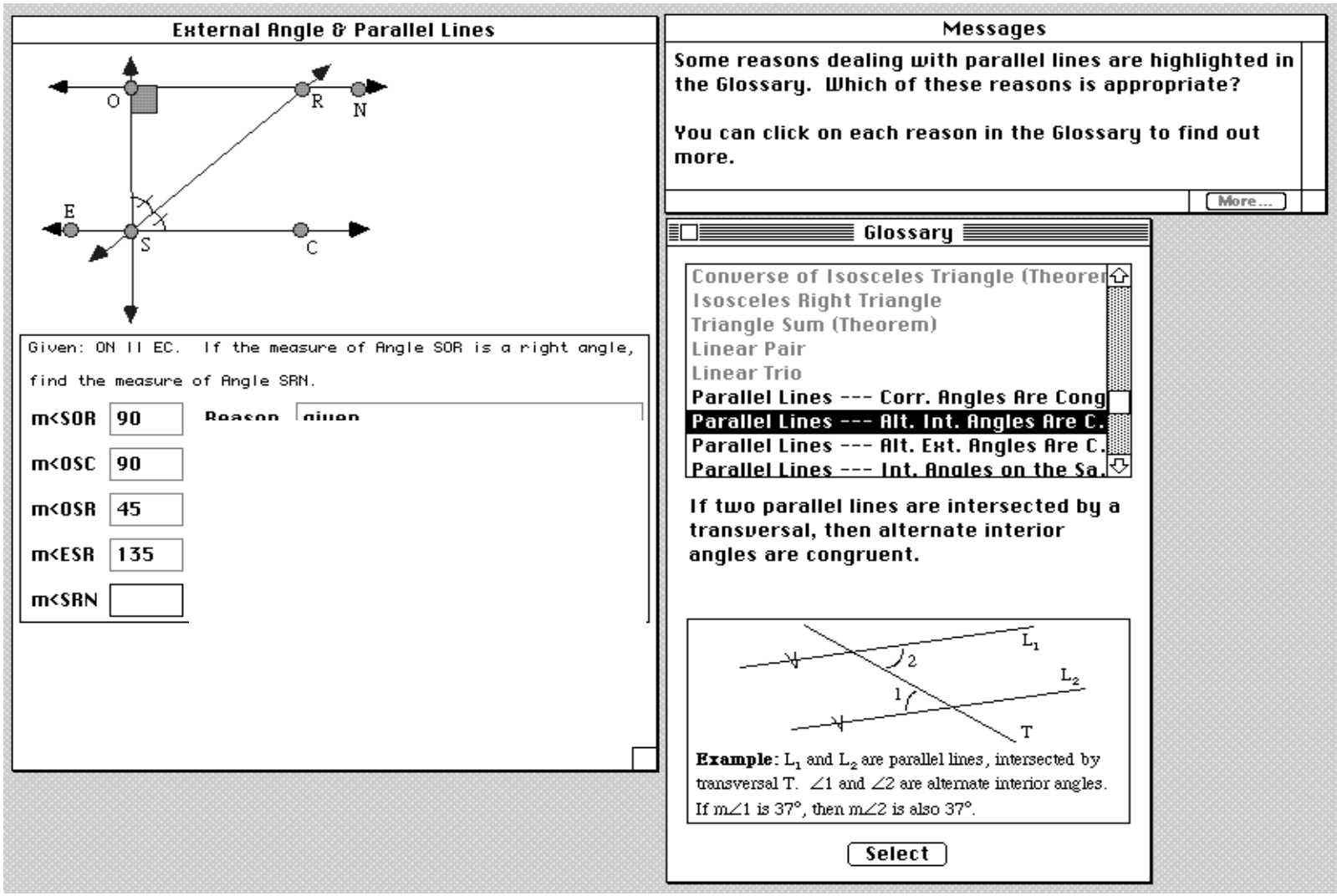
We've already seen that learning of facts is better strengthened by quizzing that requires the learner to produce the fact, rather than re-presenting the fact to the learner.

- Can questioning focused on "deeper" structures facilitate better understanding and promote transfer (solving new problems)?

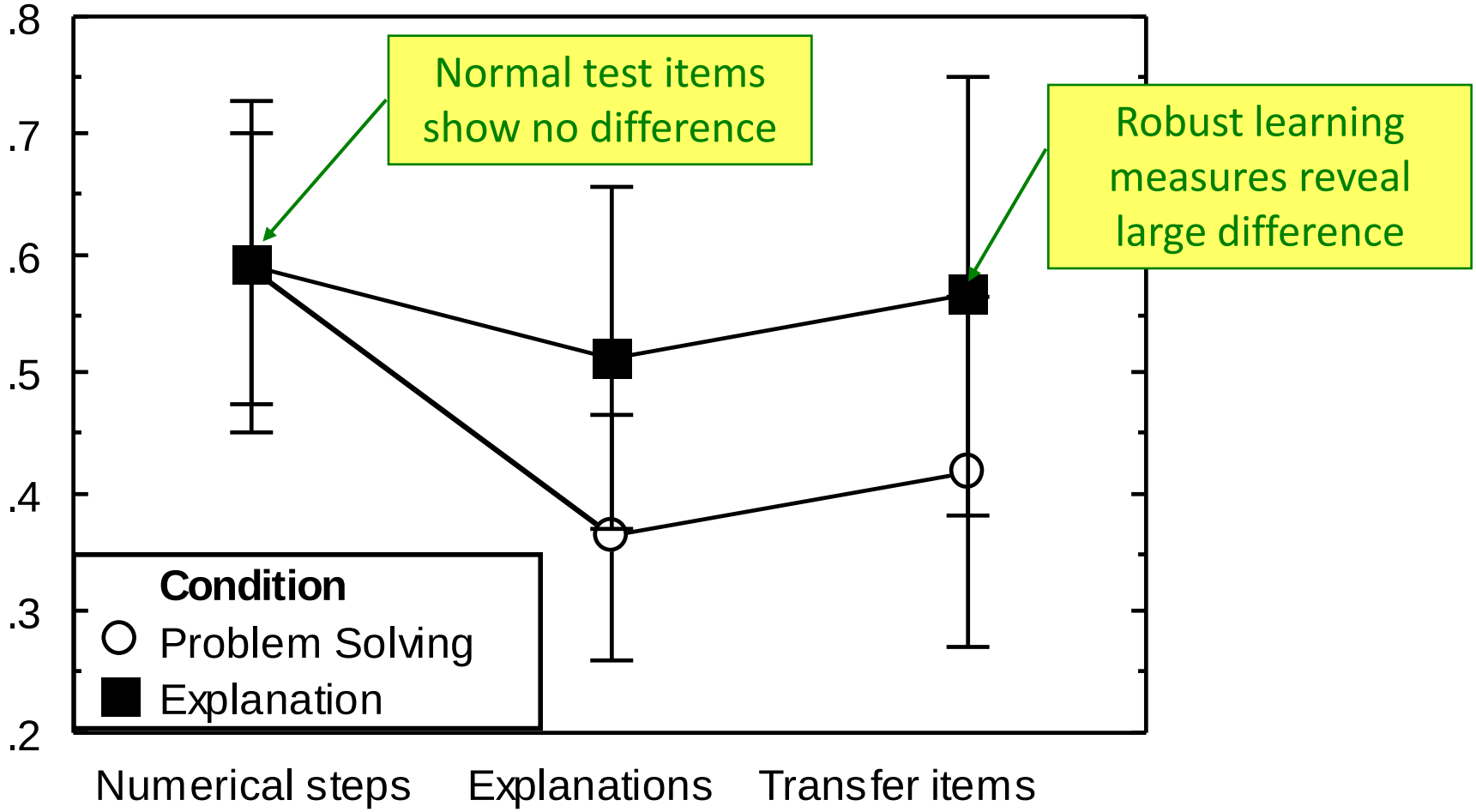
Explanation Treatment Condition (in computer tutor)



Problem Solving Condition (Control: Computer Tutor as it was)



Self-explanation improves understanding => robust learning



Aleven & Koedinger (2002). An effective metacognitive strategy: Learning by doing and explaining with a computer-based Cognitive Tutor. *Cognitive Science.*

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Evidence for use of deep questions to build explanations & deep understanding

- More than 10 studies in K12
- More than 10 studies in college courses
- Many lab experiments
- References
  - Beck, McKeown, Hamilton, et al. (1997); Craig, Sullins, Witherspoon, et al. (2006); Driscoll, Craig, Gholson, et al. (2003); Gholson & Craig (2006); King (1992; 1994); Wisher & Graesser (2007)
  - Review in Rosenshine, Meister, & Chapman (1996)

Rec. 7. Ask deep explanatory questions

- Recommendation
  - After initial instruction, ask students questions that require deep explanations of key concepts
  - Deep explanations get at how things work, at underlying plans & justifications
    - Ask why, why-not, how, what-if, how does X compare to Y, and what is the evidence for X?
  - When: During classroom instruction, class discussion, independent study
- Example of kinds of explanations
  - causes & consequences of historical events
  - motivations of people involved in historical events
  - scientific evidence for particular theories
  - justifications for steps in math procedure

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Case Study for Heavy Use of Retrieval Practice: Waterford High School, Waterford, CA

2001: lowest-performing school in county, API = 475

2008: API = 808 (fastest API growth in State of California, and top in County)

2009 Modesto Bee story: *"From Worst to First"*

- Roughly equal improvement in all demographic groups (and socioeconomically disadvantaged in 2008 far outperformed non-disadvantaged in 2003)

Waterford High 2006

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Key Ingredients As Reported by School Leadership

- Focus on more effective use of normal instruction time (not after-school programs, family interventions, etc.)

- Big emphasis on maximizing effective “time on task”.

- Continual questioning of students throughout class time with random students called upon to answer each question.

(Slide Provided by Will Frey, Teaching Coach, Waterford H.S.)

Quizzing AKA Checking for Understanding

- Teach for a short period of time
- If it's worth teaching, it's worth checking for understanding
  - Ask the question before calling on the student
  - Think time
  - Non volunteers first
    - Randomizer / Whiteboard / Choral / Hand signal

In Math and Science Instruction

Standard Homework Assignment:

List of problems for students to solve, possibly with final answers to some of them.

Is this the most effective kind of homework assignment?

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Example of a study favoring alternating problems/worked examples:

Sweller and Cooper (1985) Study

- 8th and 9th grade algebra students
- First got general introduction to a particular algebraic concept.
- Control group: Solve 8 problems
- Interleaving group:
  - Solve, Read worked problem, Solve, Read worked problem, etc.
- Interleaving group took less time, but did better on delayed test.

Example of a study favoring alternating problems/worked examples:

Trafton and Reiser (1993) Study

- Undergraduates taking first programming class
- Control group: Saw 6 worked examples, then solved 6 practice problems.
- Interleaving group did 12 alternating:
  - Solve, Read worked problem, Solve, Read worked problem, etc.
- Interleaving group did substantially better on later measure of learning.

Rec. 2. Interleave worked example solutions with problem-solving exercises

- Recommendation

  When teaching math or science, interleave worked example solutions & problem-solving exercises

  Alternate between problems with a given solution & problems that students solve

- Evidence
  - Lab experiments
    Catrambone (1996; 1998); Cooper & Sweller (1987); Kalyuga, Chandler, & Sweller (2001); Kalyuga, Chandler, Tuovinen, et al. (2001); Paas & van Merriënboer (1994); Renkl (1997; 2002); Renkl, Atkinson, & Große (2004); Renkl, Atkinson, Maier, et al, (2002); Renkl, Stark, Gruber, et al. (1998); Schwonke, Wittmer, Aleven, et al. (2007); Schworm & Renkl (2002); Sweller (1999); Sweller & Cooper (1985); Trafton & Reiser (1993).
  - Classroom experiments, K12 & college
    McLaren, Lim, Gagnon, et al. (2006); Ward & Sweller (1990); Zhu & Simon (1987)
  - Variety of content domains in math, science, & technology.

A very concrete recommendation:

Summary of Recommendations

1. Space learning over time. (Moderate)
2. Interleave worked example solutions with problem-solving exercises. (Moderate)
3. Combine graphics with verbal descriptions. (Moderate)
4. Connect and integrate abstract and concrete representations of concepts. (Moderate)

Next

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Rec. 3. In presenting materials that lend themselves to graphical illustration (e.g., science, math):

- Always seek to combine verbal and graphical material (regardless of student's "learning style"!).
- Always place verbal material very close to corresponding elements in illustration—do not assume that student will draw the right connection.
- Do not aim for photorealism or (irrelevant) attention-grabbing.
- OK to leave out irrelevant detail.

Summary

- 7 recommendations
  - Spacing, Examples, Testing, Explanations
- Common theme:
  - "Engagement with material" is not enough": optimal instruction requires that learner be led to *generate* content.
  - Generation of information that is "too easy" (eg at short temporal spacing) produces only temporary learning.
  - But… demands for generation that produce low success rate in context where corrective feedback is absent can be counterproductive.
- Find out more: http://dww.ed.gov

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Thank you for your attention!

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Dr. Mitchell J. Nathan,

University of Wisconsin – Madison
Professor of Educational Psychology in the Learning Sciences Graduate Program

- Taking the Research to the Classroom: Reframing the Challenges

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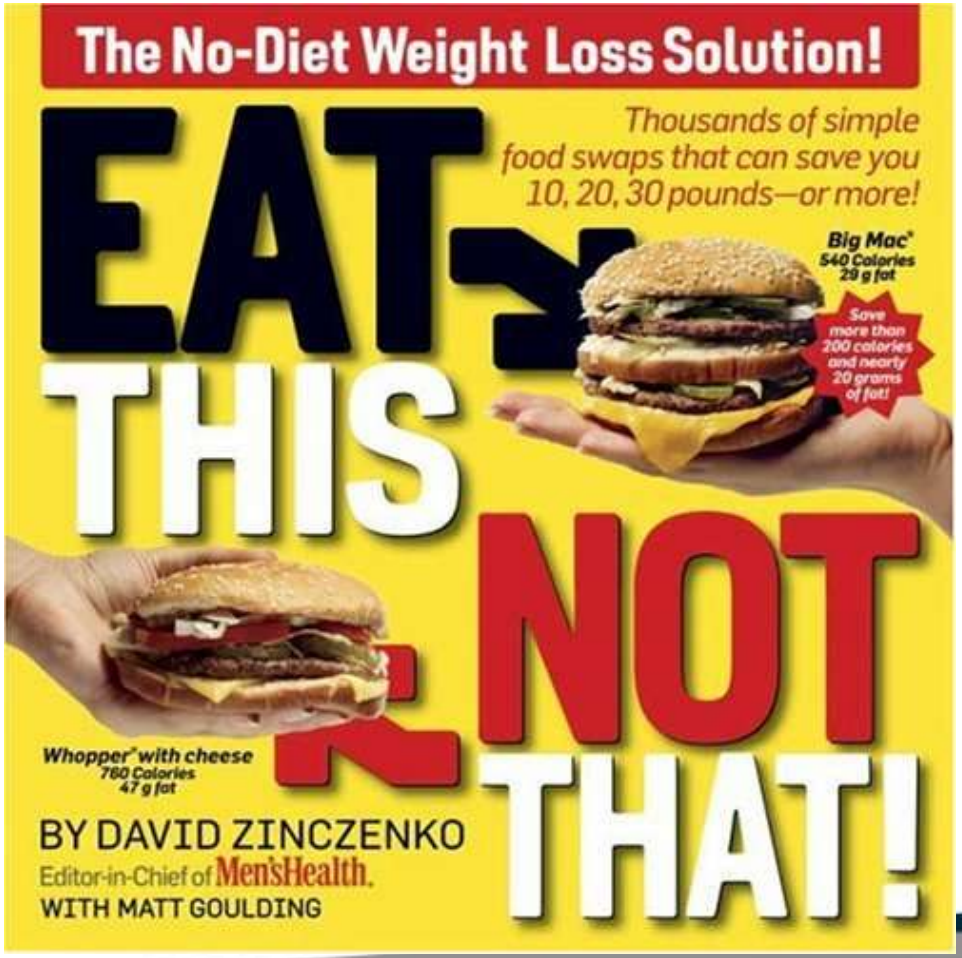

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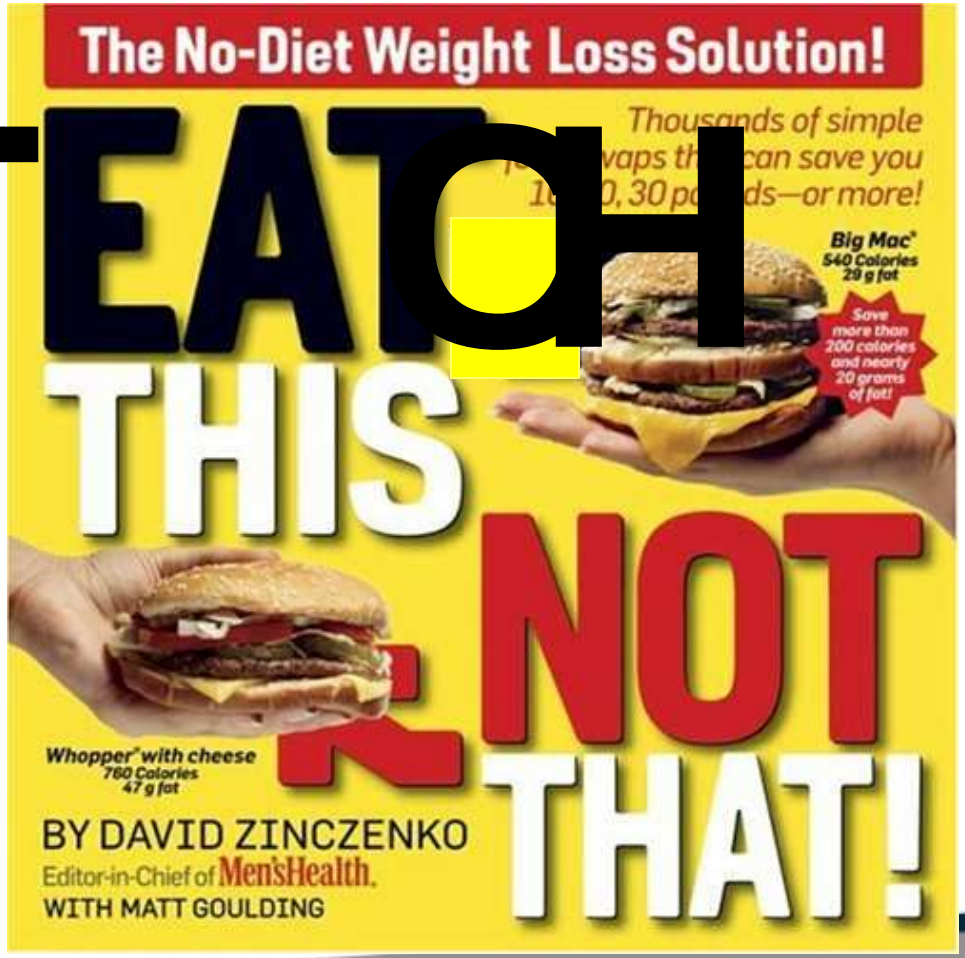
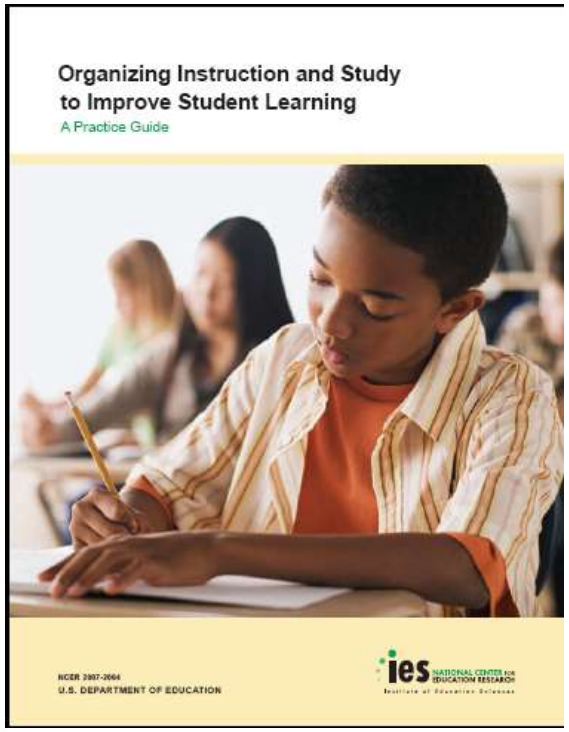


TEACH THIS NOT THAT!

Recommendations



Pashler et al. 2007

- Space learning over time
- Interleave worked examples and problems
- Combine graphics with verbal descriptions
- Connect abstract and concrete representations
- Quizzing
- Efficient use of study time
- Ask/answer deep questions

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Main Points

1. Actionable recommendations
2. Select & combine recommendations
3. “Illusion of Cognitive Compliance”
4. Intended v. enacted curriculum

Actionable recommendations

Skills & effort:

- Interpret for specific curriculum content;
- analysis & coding;
- plan & implement;
- monitoring (snow days)
- possible re-planning & re-implementation
- Qs: Student absences?

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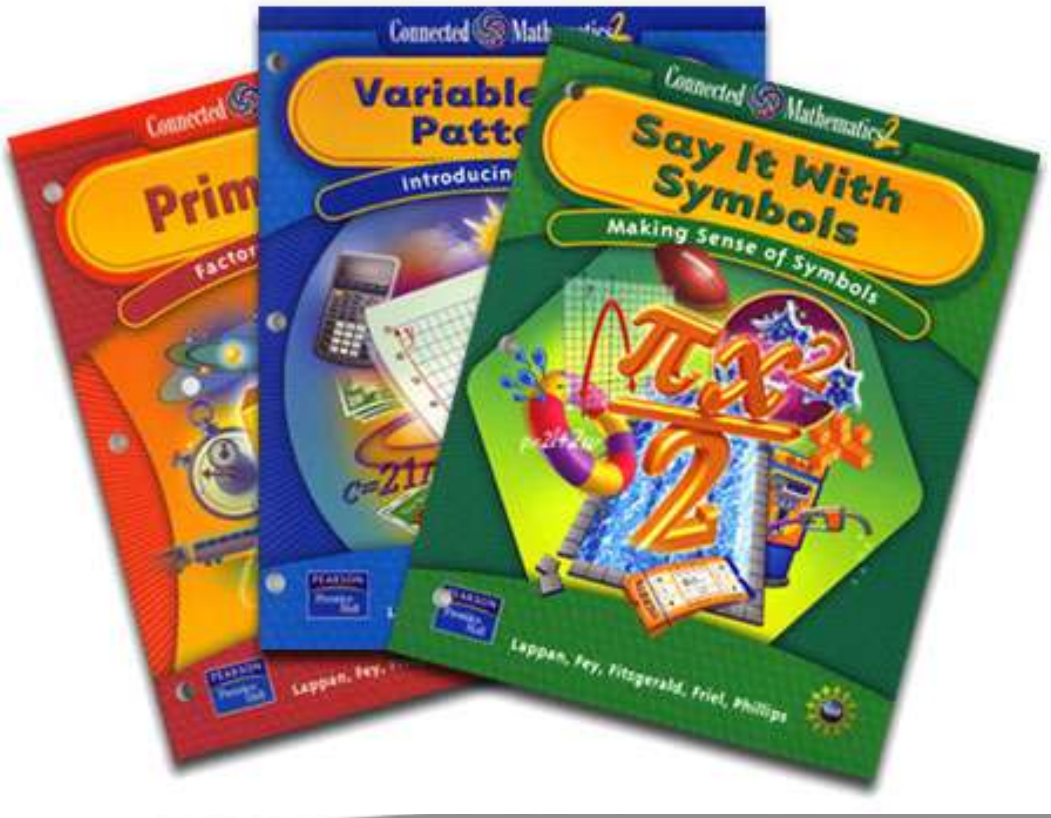
Connected Mathematics CMP



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CMP Authors

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Content & Curriculum

- 6th *Bits & Pieces 1, 2 & 3*
- 8th *Say it with Symbols*
- Problem based: active and collaborative
- Investigations
- Applications - Connections- Extensions (ACE)
- Mathematical Reflections

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Applying the Recommendations

NATIONAL RESEARCH & DEVELOPMENT CENTER ON
COGNITION & MATHEMATICS INSTRUCTION

- Spacing effect
- Integrating visual and verbal
- Interleaving worked examples
- Quizzing effect

http://www.iesmathcenter.org

ies INSTITUTE OF EDUCATION SCIENCES
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Spacing of Practice, Assessment and Feedback

- Jim Pellegrino
- Susan Goldman
- Kevin Dietz
- Deena Soffer

- Math Advisors:
  - Janet Beissinger
  - Diane Briars
  - Alison Castro Superfine
  - Mara Martinez

- Neil Heffernan
- Cristina Heffernan
- David Magid
- Matt Dailey
- Yutao Wang
- Undergraduate Research Team

Space Learning Over Time

- Practice
  - Recall; apply facts, & concepts at multiple points in time increases retention
- Distributed practice
  - Reinforces connections
  - Provides multiple routes for retrieval

Space Learning Over Time

Apply to a curriculum

1. Unit of analysis
2. Target skills
3. Content analysis each item:
   a. Skills (knowledge), context, procedure, response
   b. When was skill last practiced (mastered)?
4. Bookkeeping
5. Scheduling & revisions (Dynamic)

Space Learning Over Time

Open Questions:

- Multiple skills?
- Student differences?

Hard to implement consistently outside of a computer based learning environment

Unit (Book Number)	Investi	Lesson	Component	Item	Skills	Context	Procedure	Response	Mastered Lesson	Mastered Lag	Last Practiced	Practice Lag
2	4	3	E	35	ordering fractions	number line	draw; compute	numeric; number line	6.2.2.5	8	6.2.4.1.31	2
2	4	3	E	36	ordering fractions	number line	draw; compute	numeric; number line	6.2.2.5	8	6.2.4.1.31	2
2	4	3	E	37	Fraction of	diagram	solve; explain	numeric; text	6.2.1.4	13	6.2.4.1.1a	2

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Combine Visual & Verbal

University of Wisconsin

- Mitchell J. Nathan
- Martha W. Alibali
- Jennifer L. Cooper
- Virginia Clinton
- Pooja G. Sidney
- Undergraduates
  - Crescentia Stegner-Frietag
  - Xiaohui (Evie) Jiang

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Combine Visual & Verbal

"… recommend that teachers combine graphical presentations (e.g., graphs, figures) that illustrate key processes and concepts with verbal descriptions of those processes and concepts"

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Combine Visual & Verbal

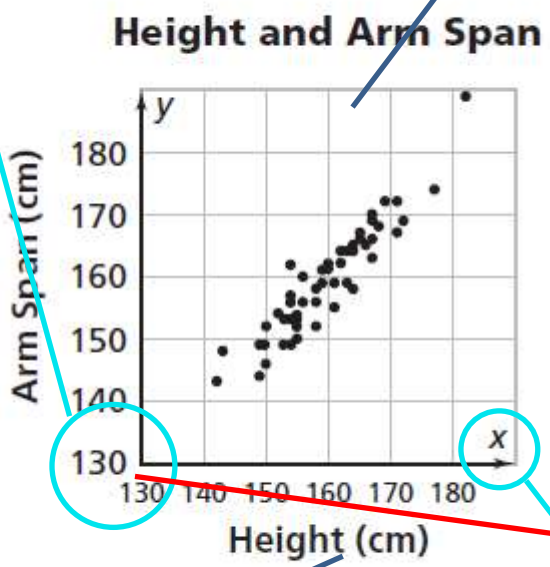
- Evidence:
  - Scientific processes; math representations (e.g., number line)
- Design Principles:
  - Improve integration of graphics and verbal representations, based on evidence
  - Remove 'seductive' details

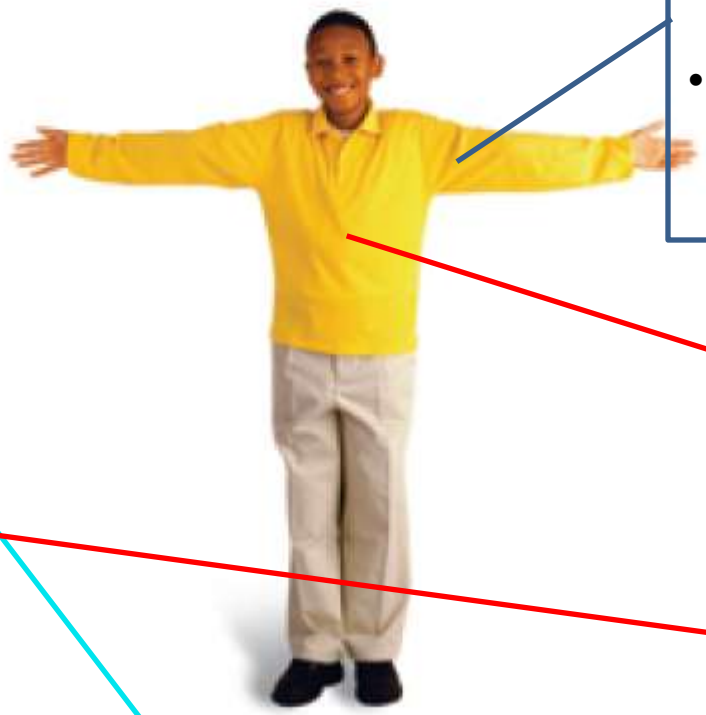
Graph
- Scatterplot
- Has graph title and axis labels
- Quadrant 1 (partial)
- Coordinate grid background
- Information essential to problem

Possible Confusion: Both axes start at 130, without indicating a break.

Illustration
- Illustrates Context
- Math Relevance Possible
- Complementary information (also described in text)

In *Data About Us*, a group of 54 sixth-grade students measured their arm spans and their heights. Their data are shown in the scatter plot.





Modification: Overlay diagram with variables showing arm span and height

Modification: Reset origin at (0,0)

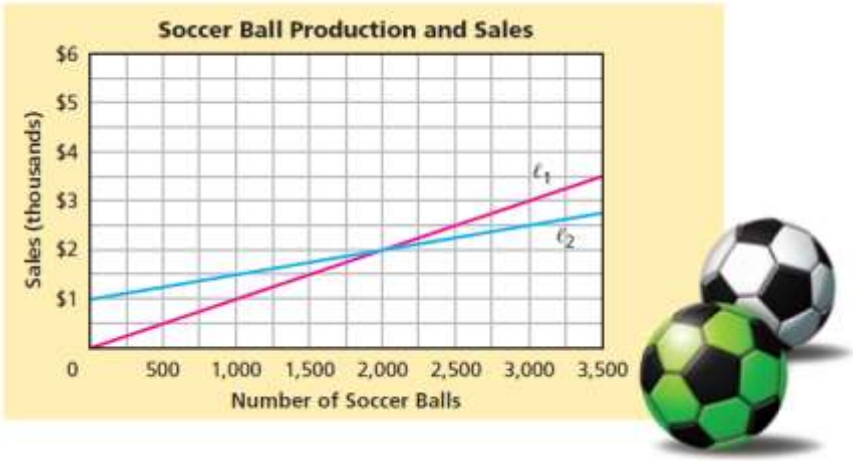
- Two continuous variables (measurement data, units given)
- Functional relationship

Possible Confusion: Why are there labels of "x" and "y" accompanying the variable labels?

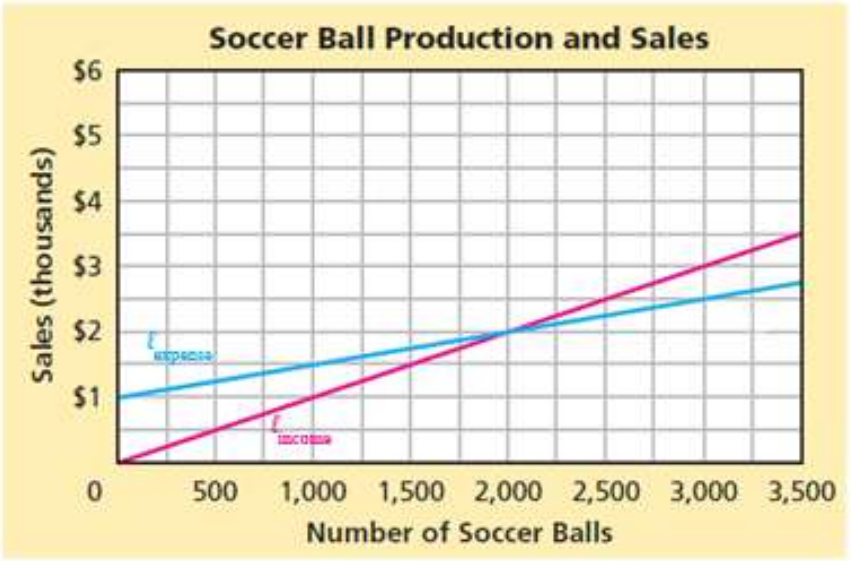
Combine Visual & Verbal

- Support integration of representations

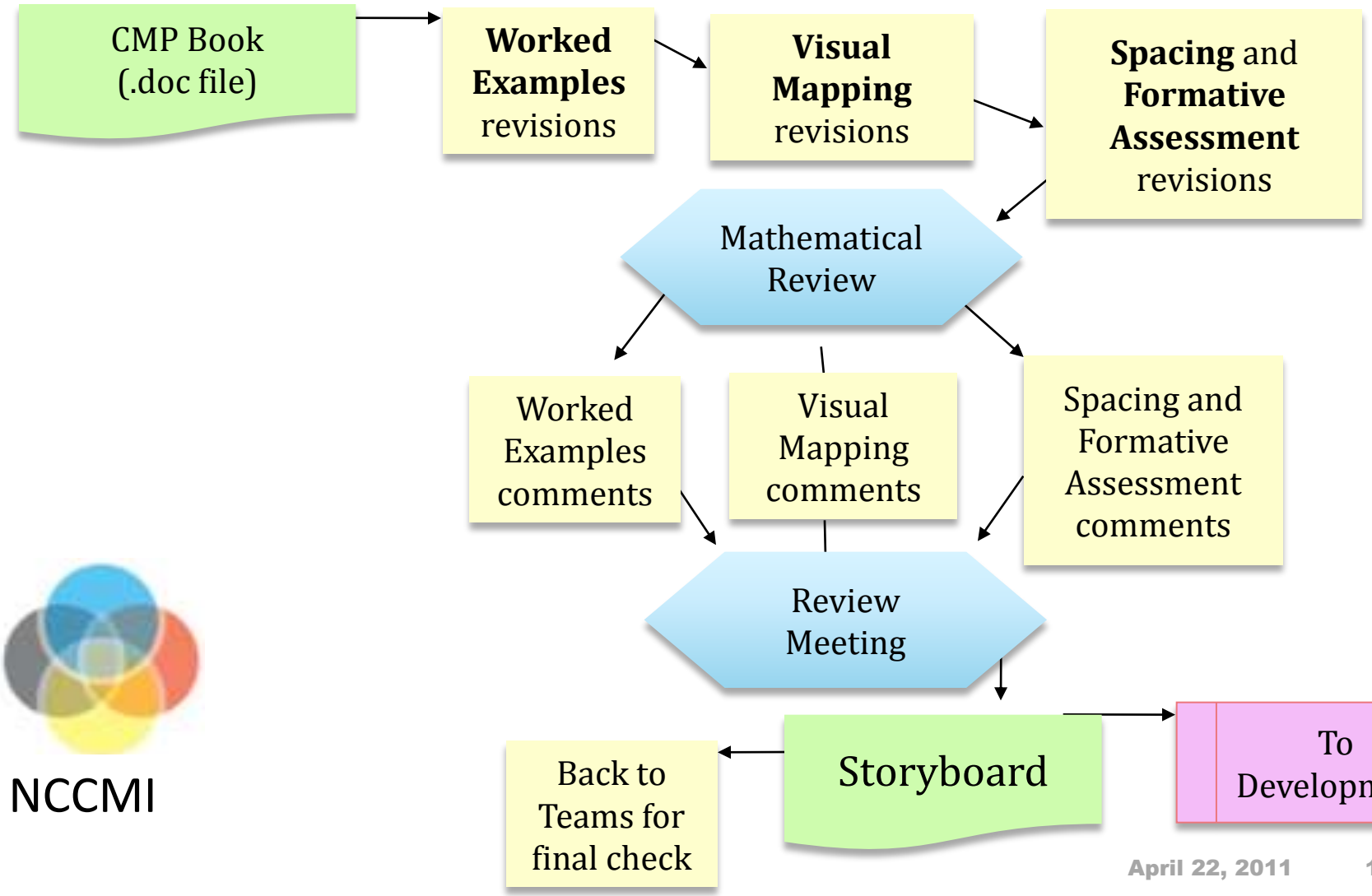
In the following graph, line ℓ_1 represents the income for selling n soccer balls. Line ℓ_2 represents the expenses of manufacturing n soccer balls.



In the following graph, line $\ell_{expense}$ represents the expenses of manufacturing n soccer balls. Line ℓ_{income} represents the income for selling n soccer balls.



Integrated Modification Process



NCCMI

"Illusion of Cognitive Compliance"

Students

- Falsely favor short practice intervals (Dunlosky & Rawson)
- Overconfidence in learning
  - "Feeling of knowing" (Thiede et al.)
- Study time
  - Distractions

"Illusion of Cognitive Compliance"

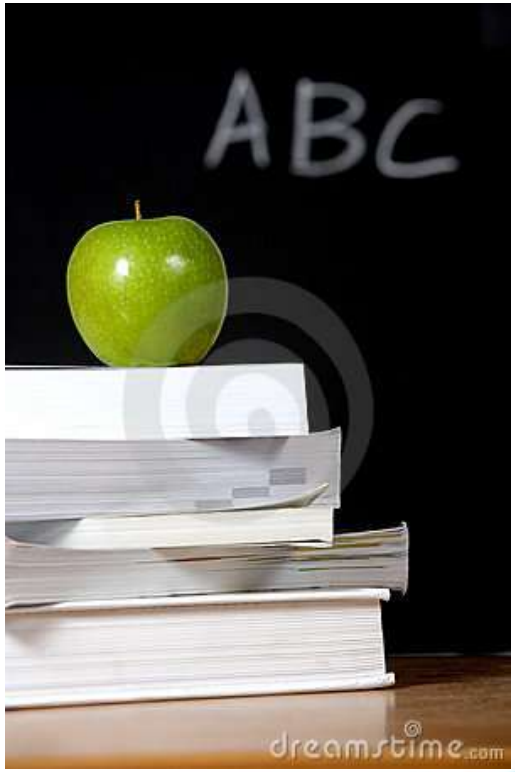
Teachers

- "I do that!"
- Recommendations are sufficiently vague
- Exposed to rhetoric of reform rather than implementations
- Little data on ICC and how it affects adoption of new practices

"Illusion of Cognitive Compliance"

Curriculum Developers

- Visual-Verbal: Use of images with words
- Spacing: Spiral curriculum
- Use of worked examples



Enacted Curriculum

- Intended curriculum
- Variability of instruction, instructors
- Discourse-based, problem-based instruction
- Beyond fidelity of established factors

Next Steps

- Need an empirical vs. normative theory of instruction
- How do teachers interpret & implement recommendations?
- Meta-principles for selecting and combining recommendations
- Evidence-based teacher professional development

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The Study of Instruction

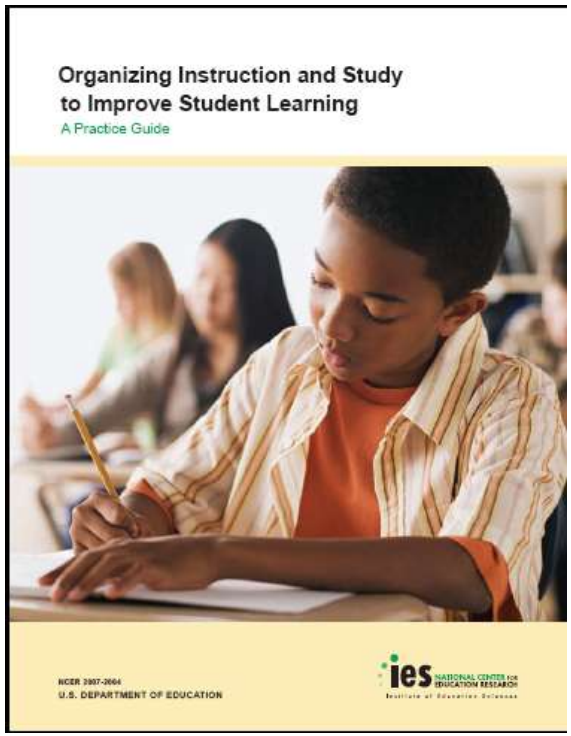
- A cognitive science of learning, but not of teaching
- Relation of knowledge and instruction
- Apply to curricula
- Variability among students

Scaling Down: From Classroom to Lab (and back again!)

10^{-2} s down	10^{-2} to 10 s	10^{2} to 10^{4} s Mins to Hours	10^{4} s to 10^{6} s Hours to Days –
Neural, Biological & Chemical	**Cognitive**	**Rational**	**Social-cultural-historical**

Nathan & Alibali 2010 *WIRes*.

Conclusions



- Progress on specifying the conditions for learning
- Place it in broad educational context
- Scientifically based theories of teacher knowledge and classroom practice

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Thank you

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Worked Examples

- Temple University
  - Julie L. Booth
  - Allison Talbot
  - Melissa Oyer
  - Celeste Malone
  - Miriam Gates
- Carnegie Mellon University
  - Kenneth R. Koedinger
  - Mimi McLaughlin

Worked Example Strategies

- Interleaving WEs with problem solving
  - More effective
  - More efficient
- Include Correct WEs
  - Provide fully worked-out example the first time a new problem type is introduced

Worked Example Strategies

- Prompt self-explanations
- Guide
  - attention to key features that demonstrate *when* procedures are effective
  - explanations to *why* procedures are effective

(Aleven & Koedinger, 2002; Chi, 2000)

Worked Example Strategies

- Include *incorrect* WEs
  - focus on why some procedures are *not* appropriate

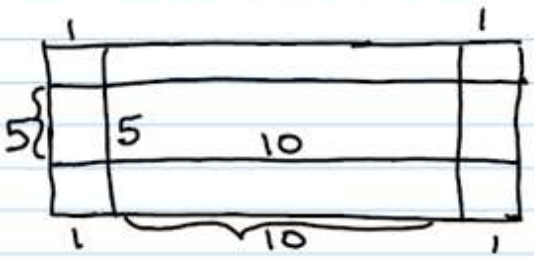
Rittle-Johnson (2006)

Worked Examples

1.

a. How many 1-foot-square border tiles do you need to surround a pool that is 10 feet long and 5 feet wide?

Adriana solved this problem in a correct way. Look at her work, and then answer the question below.



$P = 10 + 10 + 5 + 5 + 4$

$P = 34$

Question: Why are there two 5s and two 10s?

Booth & Koedinger (2008)

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Faded Worked Examples

b. Write an equation for the number of border tiles needed to surround a pool *L* feet long and *W* feet wide.

Ben started to solve this problem, but got stuck. Look at his work and fill in the blank.

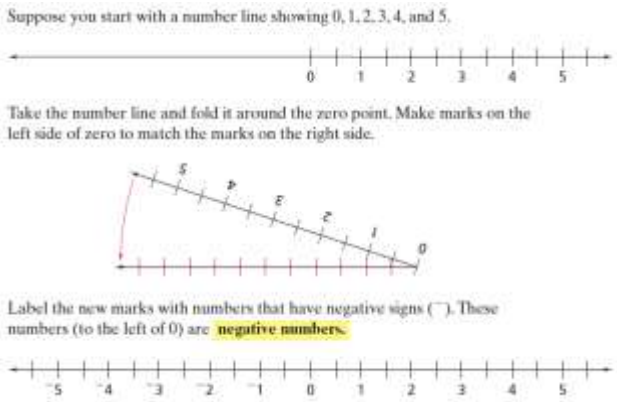
$N = L + L + W + W + \_\_$

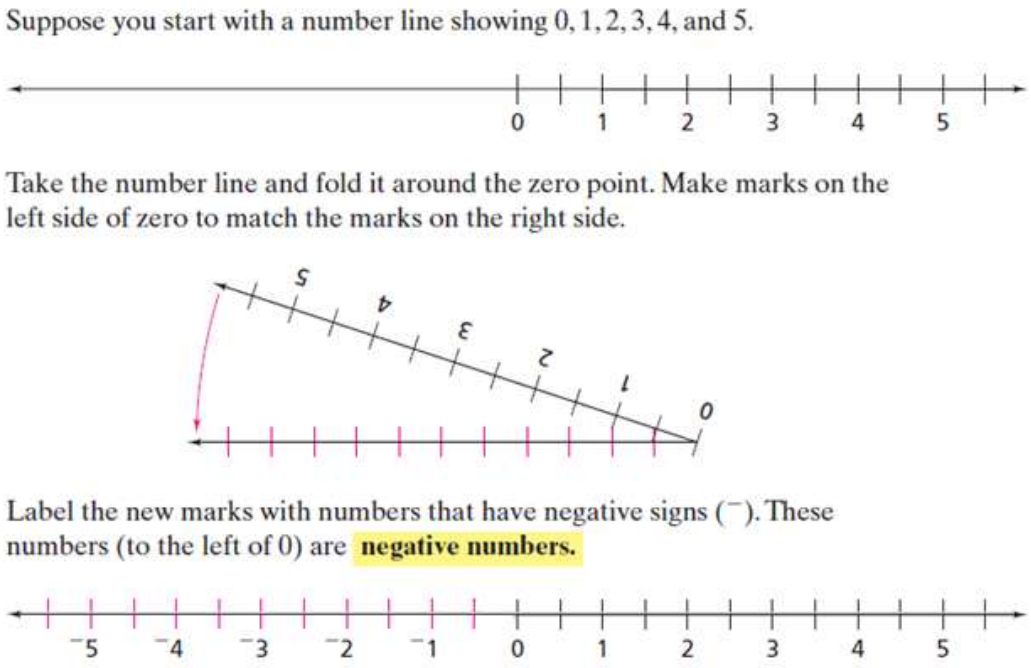
c. Write a different but equivalent equation for the number of tiles needed in part (b). Explain why your equations are equivalent.

Booth & Koedinger (2008)

Combine Visual & Verbal

- Support integration of representations

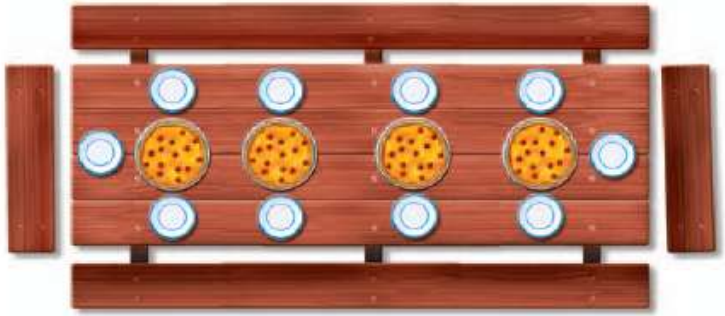


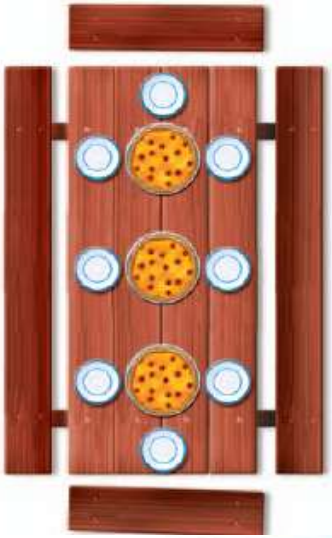


Combine Visual & Verbal

- Increase spatial contiguity
- Reduce impact of 'seductive' details

The camp dining room has two kinds of tables. A large table seats ten people. A small table seats eight people. On pizza night, the students serving dinner put four pizzas on each large table and three pizzas on each small table.

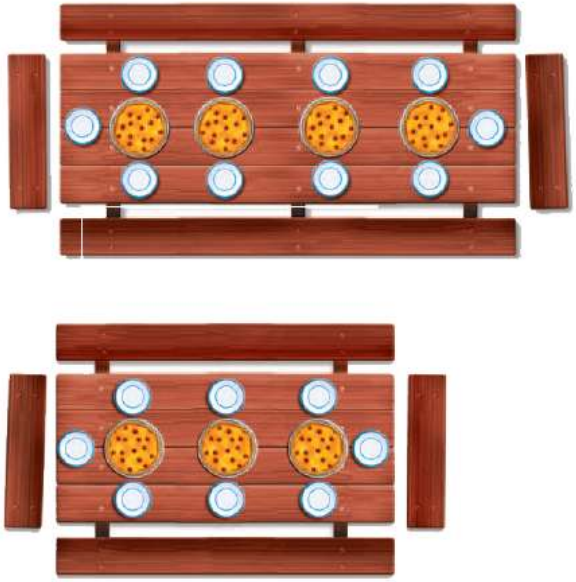




Visual – Verbal Mapping: Example

The camp dining room has two kinds of tables. A large table seats ten people. A small table seats eight people. On pizza night, the students serving dinner put four pizzas on each large table and three pizzas on each small table.

- Increase spatial contiguity
- Reduce impact of 'seductive' details



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Questions & Answers

Group Discussion

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Where Do We Go From Here?

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Closing Remarks

Please complete the evaluation