

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

Goals of IES Practice Guides

- Department of Education, Institute for Education Sciences (IES)
 - Supports research on understanding student learning & improving education
 - Get *high quality* science into practice
- Panel goals
 - Extract best practice recommendations from the scientific literature
 - Report should provide honest assessment of strength of evidence for recommendations
 - External review of strength of recommendations

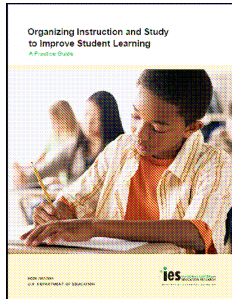
IES View of Credibility of Different Types of Evidence on Effectiveness of Instructional Methods

- Anecdote and Expert Opinion
 - *Little credibility*
- Studies observing practices and outcomes and correlating them
 - *Some value but relatively weak*
- Experimental studies randomly assigning learners to different instructional conditions, and measuring outcomes
 - *One and only "Gold Standard" for determining effectiveness*

Organizing Instruction and Study to Improve Student Learning

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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.

Focus of this Practice Guide, cont'd

- Ideas mostly derived from research in learning psychology and cognitive science
- Usually backed up by strong experimental research designs in well-controlled lab settings—but sometimes evidence for generalization to the classroom is weaker than one would like

Forgetting as a factor 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 probably included in all curricula (e.g., "where is Pacific Ocean?").

...but receives little discussion in education literature.

Two recommendations focused on reducing forgetting:

Summary of Recommendations

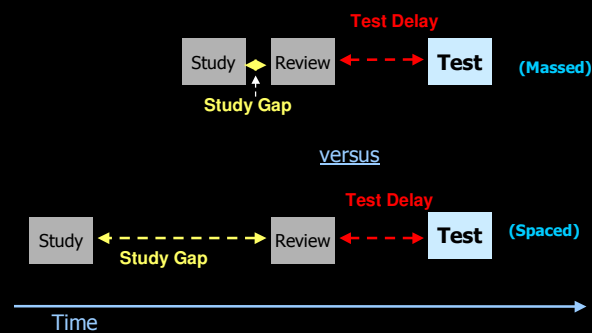
- 1. Space learning over time. (Moderate)
- 2. Interleave worked example solutions with problem-solving exercises. (Moderate)
- 3. Combine graphics with verbal descriptions. (Moderate)
- 4. Connect and integrate abstract and concrete representations of concepts. (Moderate)

Two recommendations focused on reducing forgetting:

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)

"Spacing Effect"



Studied by psychologists for > 100 years, but mostly looking at short retention intervals (hours or days).

Recent IES-sponsored research:

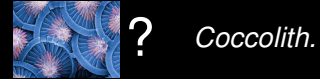
- 1. Examines long time intervals (months or >1 year)
- 2. Systematically varies study gap and test delay.
- 3. Holds study time constant in all conditions (to let us ask: how to get maximum bang for the buck?)

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

1. Learn a set of little-known facts (or little known object names)
2. Study gap = 0, 1, 7, 28, 84, or 168 days
3. Review the material presented in first session for a fixed amount of time
4. Test delay = 6 months
5. Take final test on the material

Learning Tasks

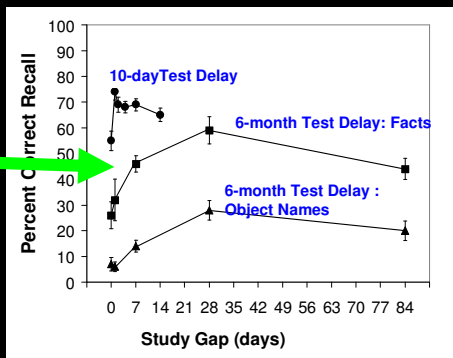
1. Learn names of little-known objects



2. Learn little-known facts

Who invented snow golf? *Rudyard Kipling.*

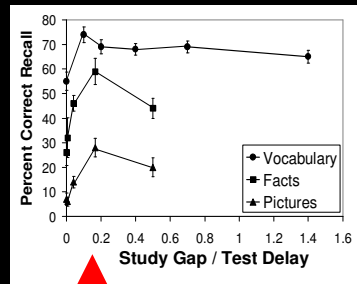
Final Test Performance



2- or 3-fold increases!

Cepeda et al., *Experimental Psychology*, 2009

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



Optimum gap = about 10% of test delay

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 10% of X !
- 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.

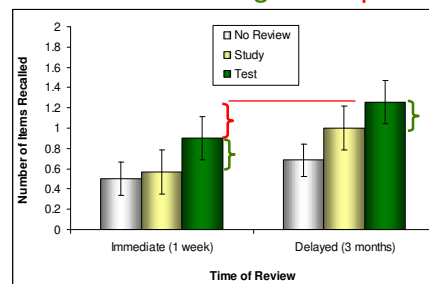
Results Show that Common Practices Create Perverse Incentives

- Suppose there is a single course exam on Feb 15, and students want 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.
- May not generalize to learning perceptual skills.

Recent Classroom Study on Benefits of Testing and Spacing



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
Study group = re-read facts
Immediate = Review 1 week after course
Delayed = Review 3 months after course
Final test 9 months later. Graph shows results

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

Recommendation 1. Space learning over time

- 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

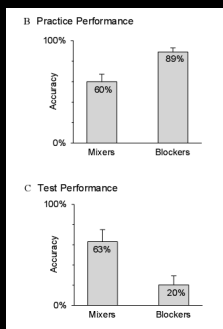
Relevance to Problem Sets in Math/Physics/Chemistry/etc

- 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
 - No training in figuring out "which method is relevant to solving this problem?"
 - But on final exam or in the real world, 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*):



HP Comments on Implementation

- Only a few textbooks make extensive use of mixed problems.
- Most have just a few “review questions” scattered throughout book.
- It is challenging for teachers to incorporate more long-gap review as we recommend:
 - Preparation becomes more taxing
 - Exposes the degree of forgetting that is occurring—may be demoralizing!

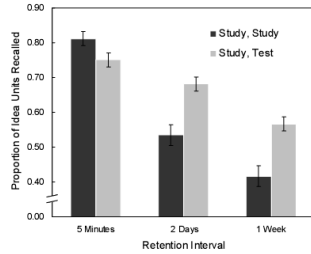
Recommendation 5: Use Quizzing to Promote Learning

- 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 (while the student is actually doing the quiz!).

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

Roediger & Karpicke (2006, *Psych Science*)

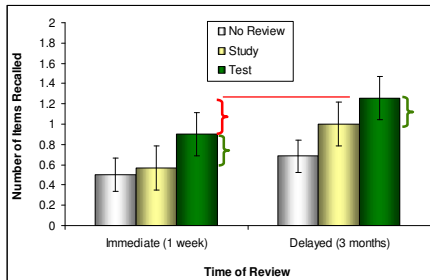
- Read prose passage; then spend 7 minutes
(a) studying or (b) getting a test (no feedback)



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.

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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

HP Comments on Implementation

- Again, conventional textbook style does not make it easy!
- At college level, curriculum makes almost no use of this principle, but (it seems to me) better students often discover and use it themselves.
- At high school level, it may be useful to help students to recognize importance of retrieval in their own studying.

Two recommendations focused on facilitating comprehension and transfer:

Summary of Recommendations

1. Space learning over time. (Moderate)
- Next → 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

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6. Help students allocate study time efficiently. (Low)
- Next → 7. Ask deep explanatory questions. (Strong)

Optimal Arrangement of Problems in Math and Science Instruction

Q: Which is better for student learning?

- A. Homework includes solutions to half the problems
- B. Homework requires student to solve all the problems

A: Homework includes solutions to half the problems

Why?

--Initial instruction and examples on new concepts and skills often does not provide enough information for students to construct accurate knowledge.

--Moving too quickly to problem solving leads students to engage in shallow strategies, like guessing rather than thinking.

--Forgetting takes place even between class time and evening homework time.

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

- When teaching math or science, interleave worked example solutions & problem-solving exercises, i.e., alternate between problems with a given solution & problems that students solve

Rec. 7. Explanations

Q: Which is better for student learning?

- A. Explain steps in worked out examples
- B. Ask students to explain steps in worked out examples

Example: Students watch videos of a physics instructor solving problems who either explains each step or asks students to explain to themselves

A: Ask students to explain steps in worked out examples

Why?

--When students attempt to explain they usually go beyond the explicit material and link the material back to prior instruction or to personal knowledge and experiences.

-- Testing effect may facilitate retention.

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

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)

Questioning Strategies & Examples

- Encourage students to “think aloud” to explain their understanding as they study
- Ask questions that elicit explanations
 - For example, in biology ask:
 - “How do bees pollinate flowers?” or “Why will the destruction of bees threaten life on planet earth?”
 - Not shallow questions with quick short-answers:
 - “What organism pollinates flowers?” or “How many types of bees are there?”

Explanation Treatment Condition (in computer tutor)

External Angle of Parallel Lines

Given: $DR \perp EC$. If the measure of angle SRB is a right angle, find the measure of angle SRN .

Reasons:

- m<SRB 90 Reason: given
- m<OSC 90 Reason: int. angles same side
- m<OSR 45 Reason: angle bisection
- m<ESR 135 Reason: angle addition
- m<SRN Reason: _____

Messages

Some reasons dealing with parallel lines are highlighted in the Glossary. Which of these reasons is appropriate? You can click on each reason in the Glossary to find out more.

Glossary

- Converse of Isosceles Triangle (Theorem)
- Isosceles Right Triangle
- Triangle Sum (Theorem)
- Linear Pair
- Linear Trio
- Parallel Lines --- Corr. Angles Are Cong.
- Parallel Lines --- Alt. Int. Angles Are C.
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Example: l_1 and l_2 are parallel lines, intersected by transversal T . $\angle 1$ and $\angle 2$ are alternate interior angles. If $m\angle 1$ is 37° , then $m\angle 2$ is also 37° .

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

External Angle of Parallel Lines

Given: $DR \perp EC$. If the measure of angle SRB is a right angle, find the measure of angle SRN .

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- m<SRN

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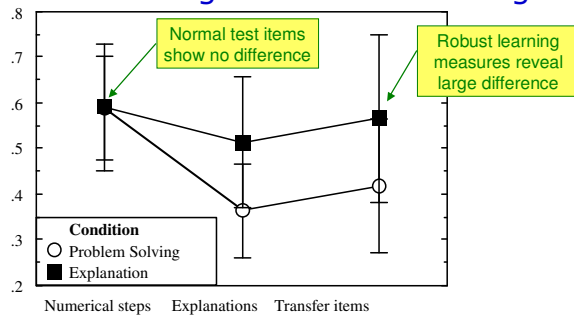
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Self-explanation improves understanding => *robust learning*



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

A very concrete recommendation:

Summary of Recommendations

1. Space learning over time. (Moderate)
2. Interleave worked example solutions with problem-solving exercises. (Moderate)
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Next