Flipping the Script:
Innovating Large Undergraduate Lectures with Principles from Cognitive Science

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LearnLab
Pittsburgh Science of Learning Center

Problem

- Large lecture (n > 100) affords direct instruction w/ limited discussion
  - Less effective than other learning activities
    (Chi, 2009; Chi & Wiley, 2015)
- Challenge to keep students actively engaged and motivated
  (Leicht et al., 2013; Hake, 1998; Strayer, 2013)

Solution and Challenge

- Solution: Principles of cognitive science
  (Branford, Brown, & Cocking, 2000; Dunlosky et al., 2013)

  - Self-explanation, analogical comparison, and retrieval-practice

- Challenge

  - How to implement and integrate these principles into instruction for a large lecture course?
    - flipping class content and activity (e.g., Leicht et al., 2012)

  - Opportunity: Relatively little is known about how these principles impact student motivation (interest, goals, beliefs)
    (Belenky & Nokes-Malach, 2012; Zepeda et al., in press)

Cognitive Science Principles

- Self-explanation (Chi, 2000)
- Analogical comparison (Gick & Holyoak, 1983)
- Memory-retrieval practice (Karpicke & Roediger, 2006)

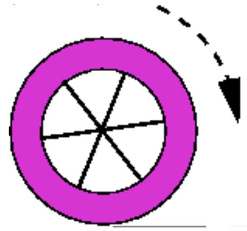
Self-Explanation

House
Isa: building
Parts: rooms and windows
Materials: wood, brick, stone
Function: human dwelling
Shape: rectilinear, triangular
Size: 100-10,000 sq ft.

- Explanation of worked examples or expository text
  (Chiu & Chi, 2014; Fonseca & Chi, 2011)
- Why?
  - Generating inferences from prior knowledge (Chi, 2000)
  - Helps to repair mental models (Chi, 2000)
  - Explanation helps identify sub-goals (Catrambone, 1996)
- Laboratory evidence across a number of domains: physics, biology, mathematics, electronics

Self-Explanation

The initial angular velocity of a wheel is π rad/s in a clockwise direction. If the wheel is speeding up with a constant angular acceleration of π/4 rad/s^2, what is the magnitude of the angular velocity of the wheel after 15 seconds?



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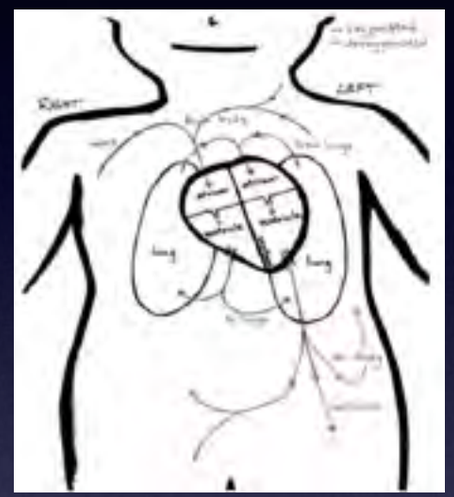

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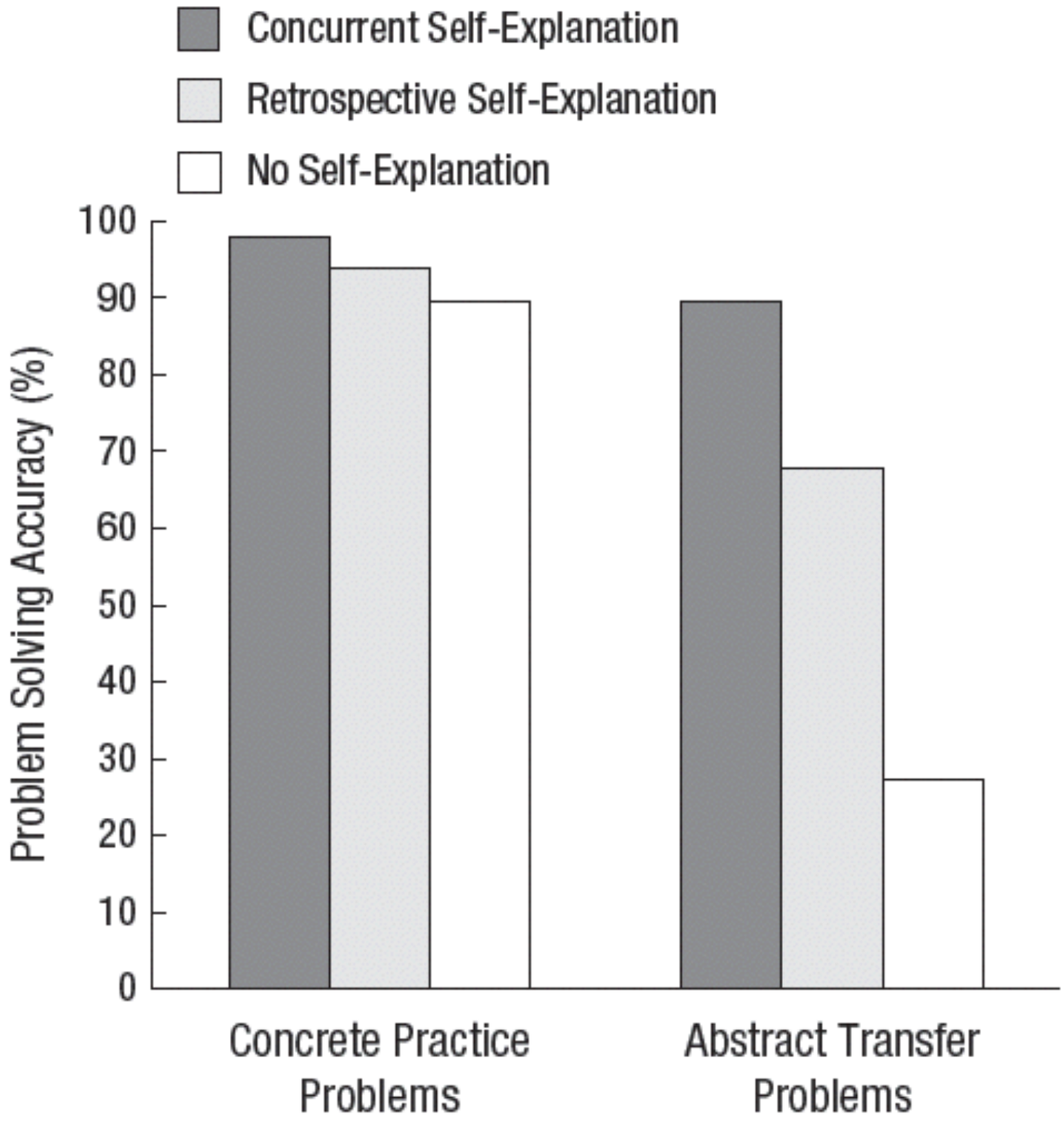
Concurrent Self-Explanation
Retrospective Self-Explanation
No Self-Explanation
Problem Solving Accuracy (%)
100
90
80
70
60
50
40
30
20
10
0
Concrete Practice Problems
Abstract Transfer Problems

Berry, 1983

Analogy

- Analogies can facilitate learning and problem solving
  (Gentner, Holyoak, & Kokinov, 2001)
- Why?
- Facilitates abstraction, acquisition of a problem schema, and a focus on the underlying concept
  (e.g., Gick & Holyoak, 1983; Nokes-Malach at el al., 2013)

What is similar across the problems?

House
Isa: building
Parts: rooms and windows
Materials: wood, brick, stone
Function: human dwelling
Shape: rectilinear, triangular
Size: 100-10,000 sq ft.

John's house is a building where he lives that consists of 10 rooms and 20 windows. It is made of wood and brick. It is a large rectangle and is approximately 9,000 sq. feet.

Sarah's House is a building where she and her family lives that consists of 5 rooms and 9 windows. It is made of brick and stone. It is a large rectangle and is approximately 3,450 sq. feet.

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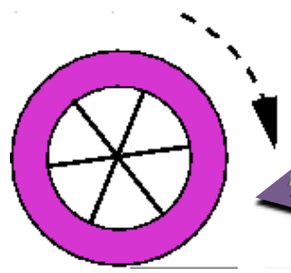
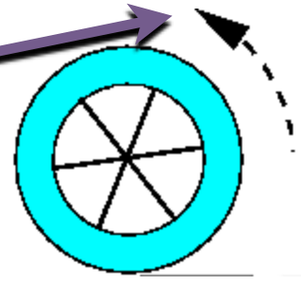


The magnitude of the initial angular velocity of a wheel rotating counterclockwise is π rad/s. If the wheel is slowing down with an average angular acceleration of π /6 rad/s^2, how long does it take to stop?



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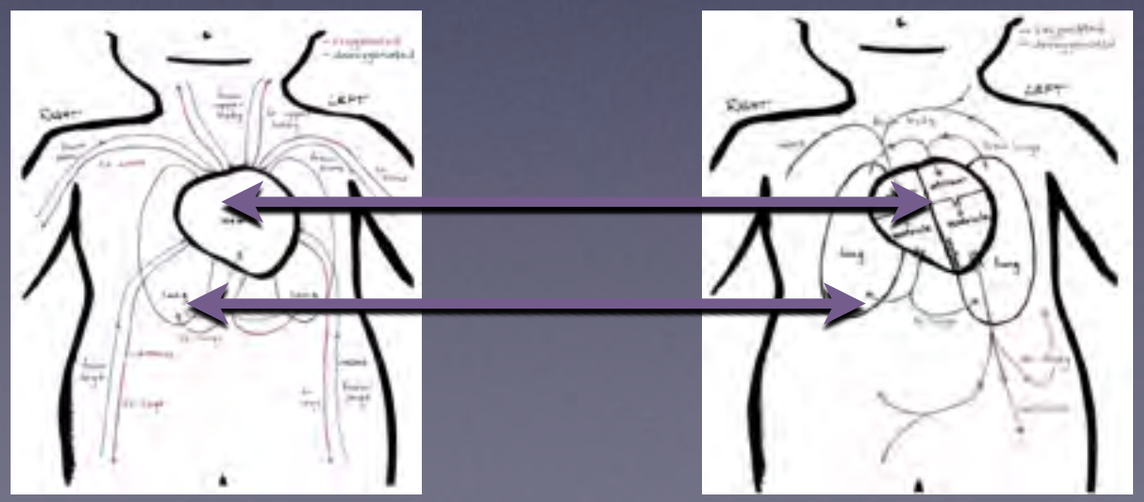
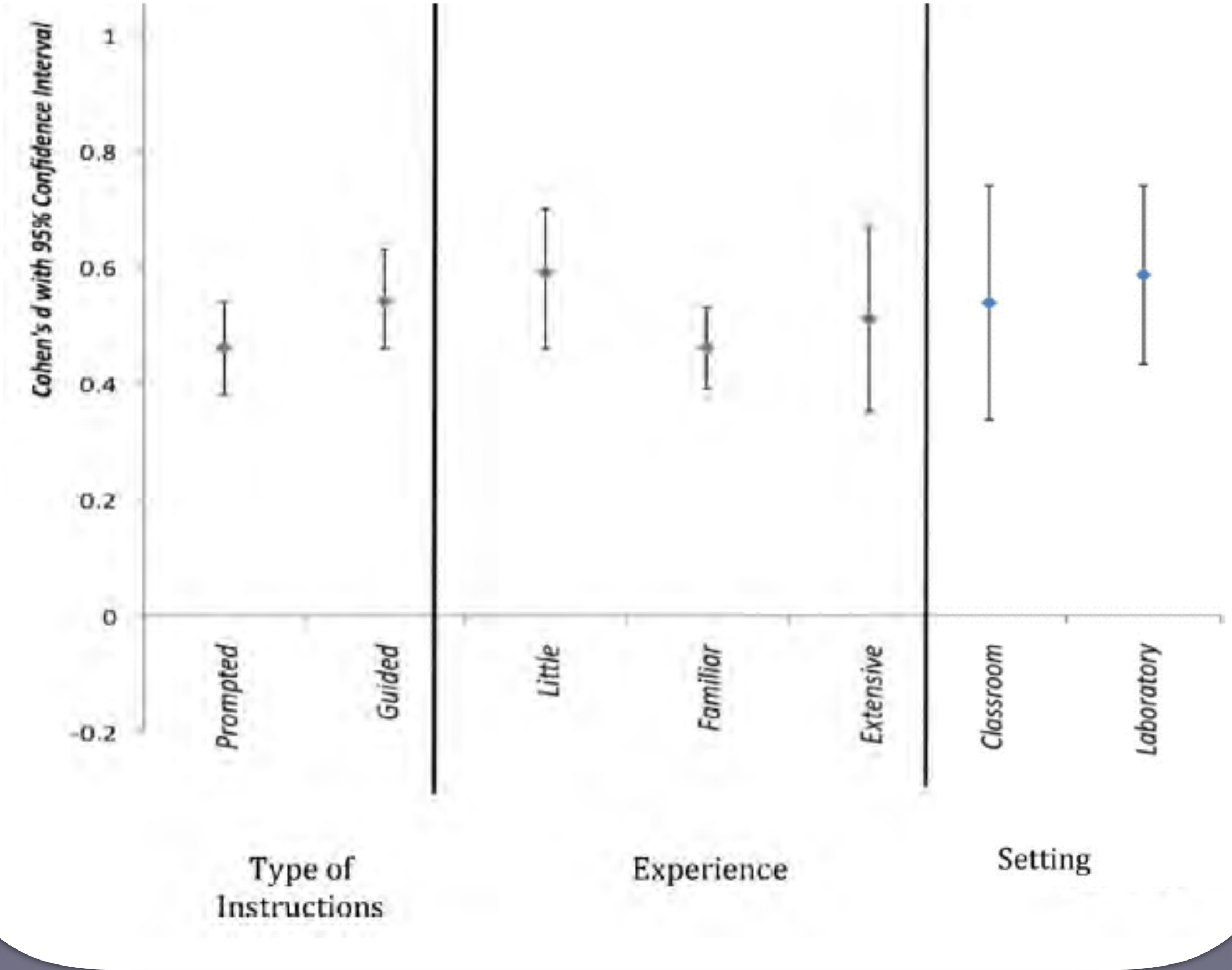
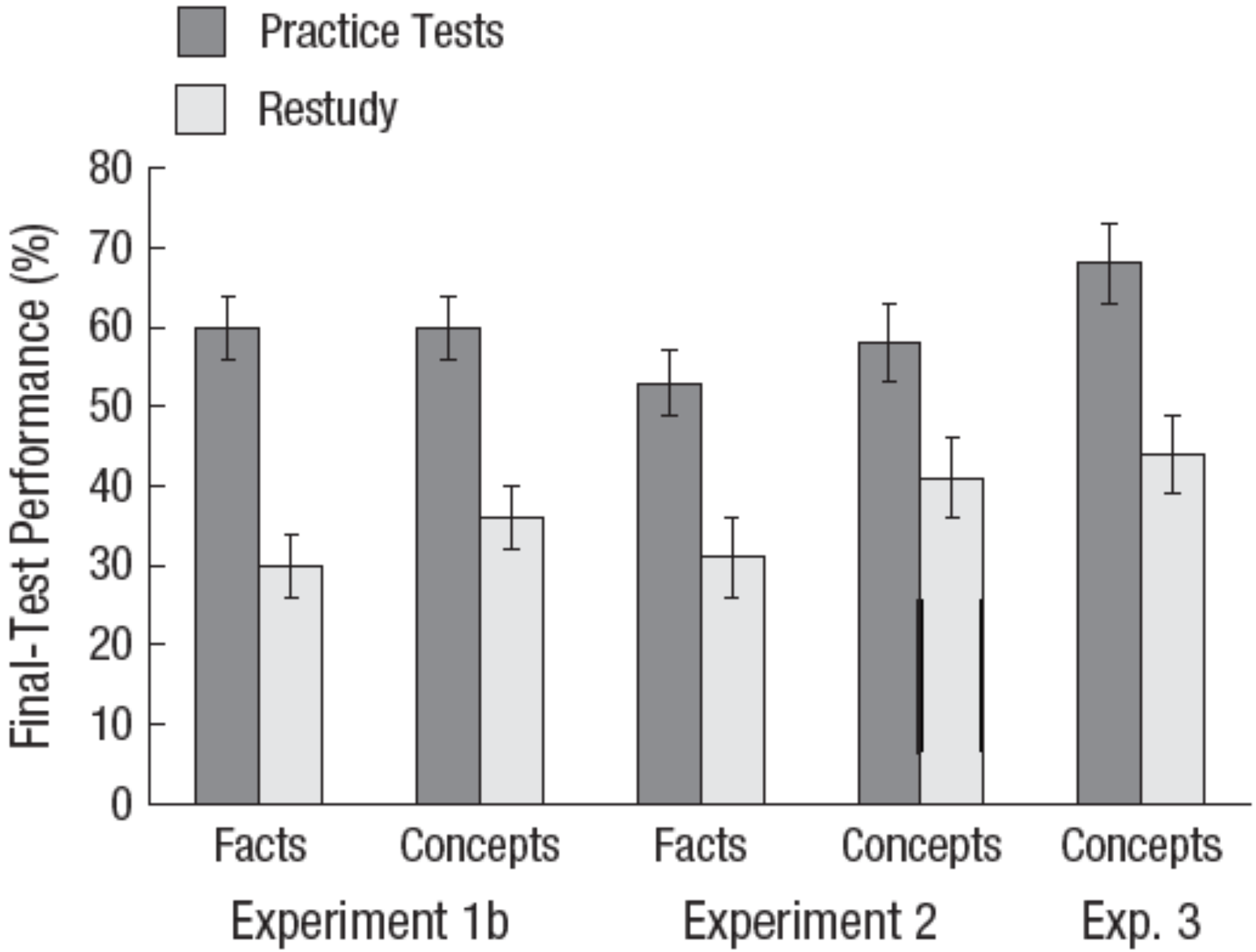


Alfieri, Nokes-Malach, & Schunn, 2013



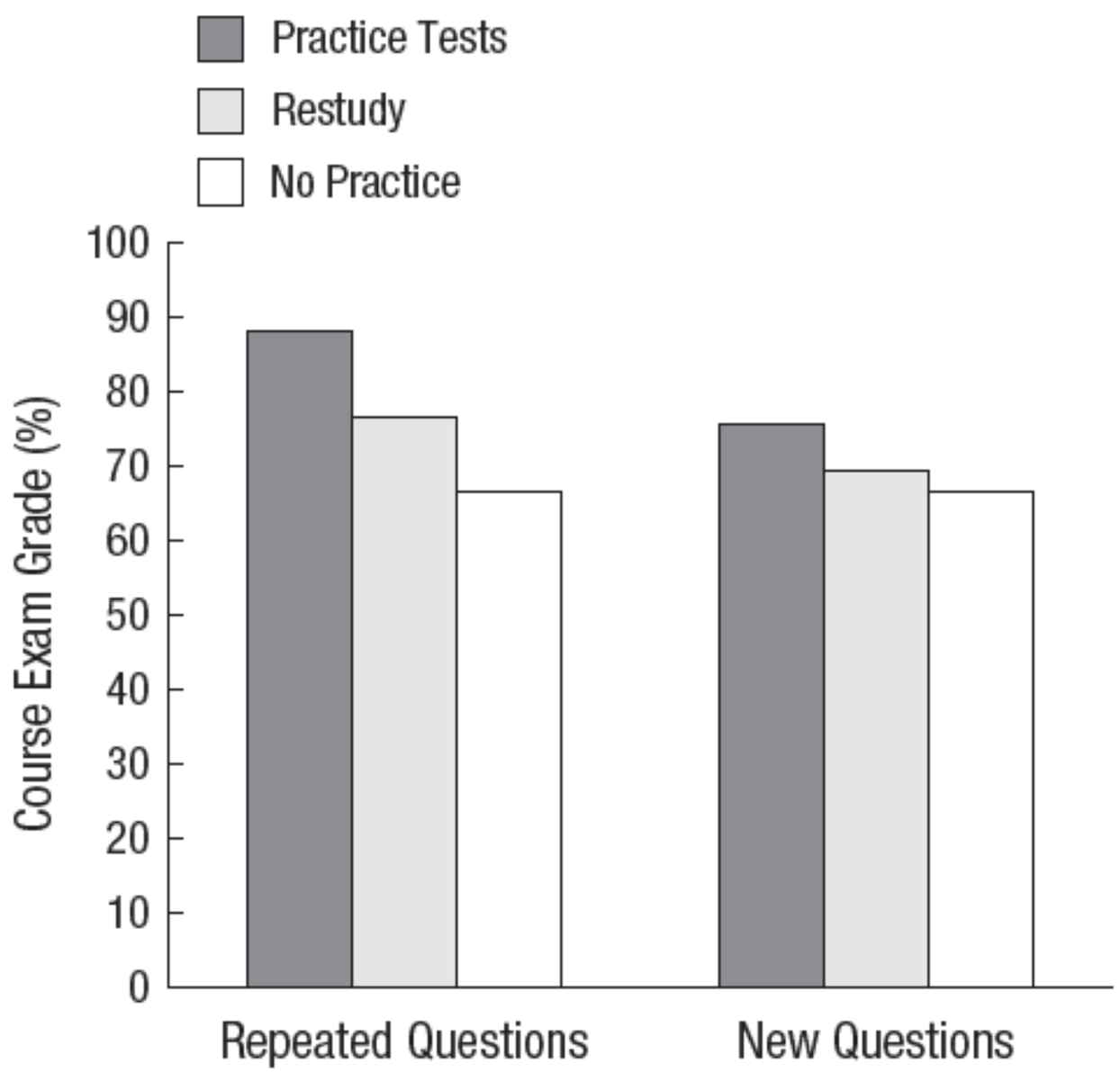
Retrieval practice

- Testing that is completed as a formative assessment
- Many studies have shown that it improves learning and retention compared to restudy (Karpicke & Roediger, 2006)
- Why?
  - Direct effects: generative versus passive; elaborative retrieval processes (activates related info); organization of retrieval
  - Indirect effects: figure out what one does not know, opportunity for future study


Practice Tests
Restudy
Final-Test Performance (%)
80
70
60
50
40
30
20
10
0
Facts
Concepts
Facts
Concepts
Concepts
Experiment 1b
Experiment 2
Exp. 3

Butler, 2010

Classroom results



McDaniel, Wildman, & Anderson, 2012

Solution and Challenge

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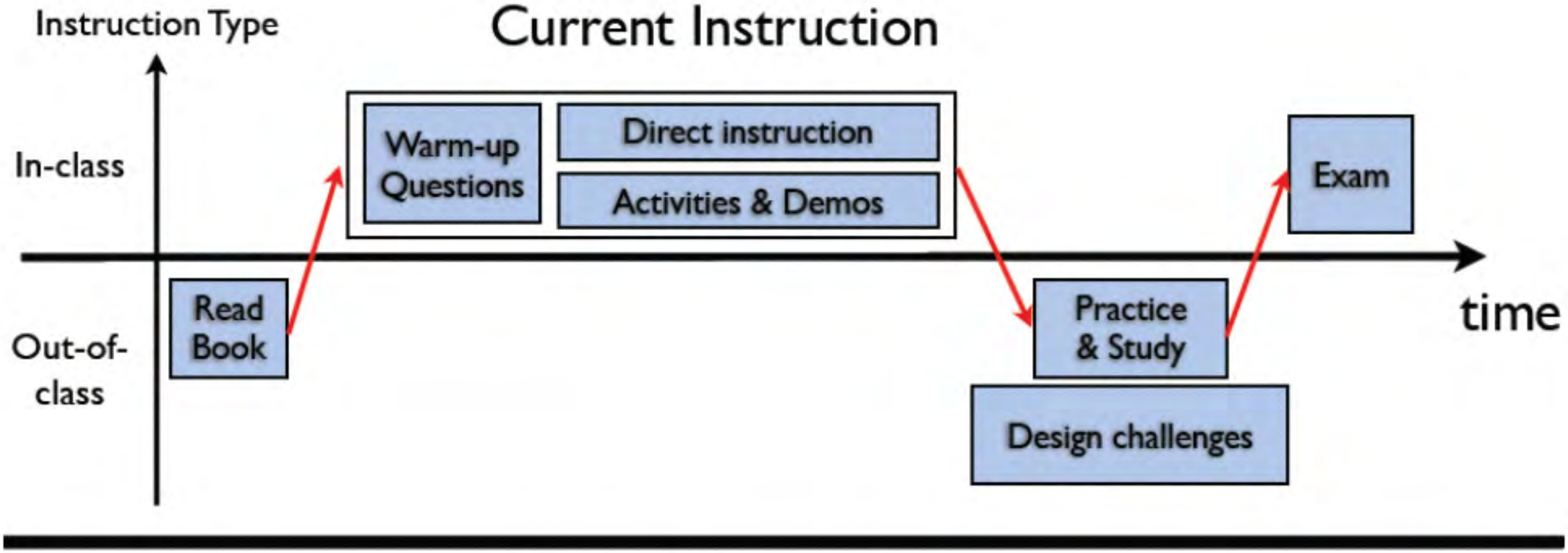
Current Class

- 422 Cognitive Psychology

  Science of the mind: perception, attention, memory, language, concepts, problem solving, expertise, creativity, etc.

- One of five psychology core courses
- 200 students
  - About even split between sophomore, junior, and senior
- ~ 65/35 split between Major and Non-majors

Current Instruction



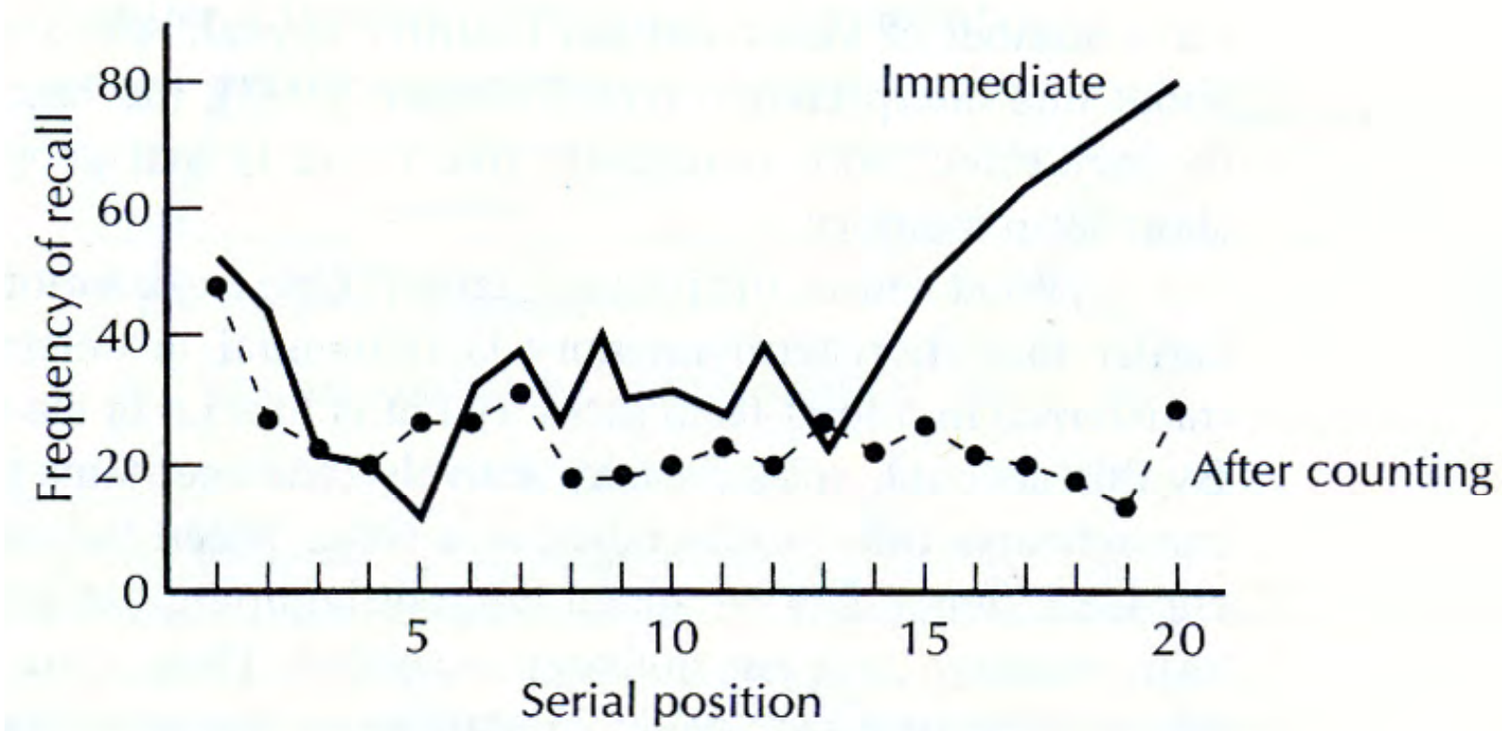
In-class activity
Let’s try a free recall task

- I will read off 21 words
- When I finish (not before start writing)

How many correct in each group of three?

- Fox, dish, tree
- Shirt, screen, board
- Book, cup, lamp
- Car, hat, leg
- Nail, key, ball
- Head, bike, pen
- Spoon, cat, rose

Serial Position Effect

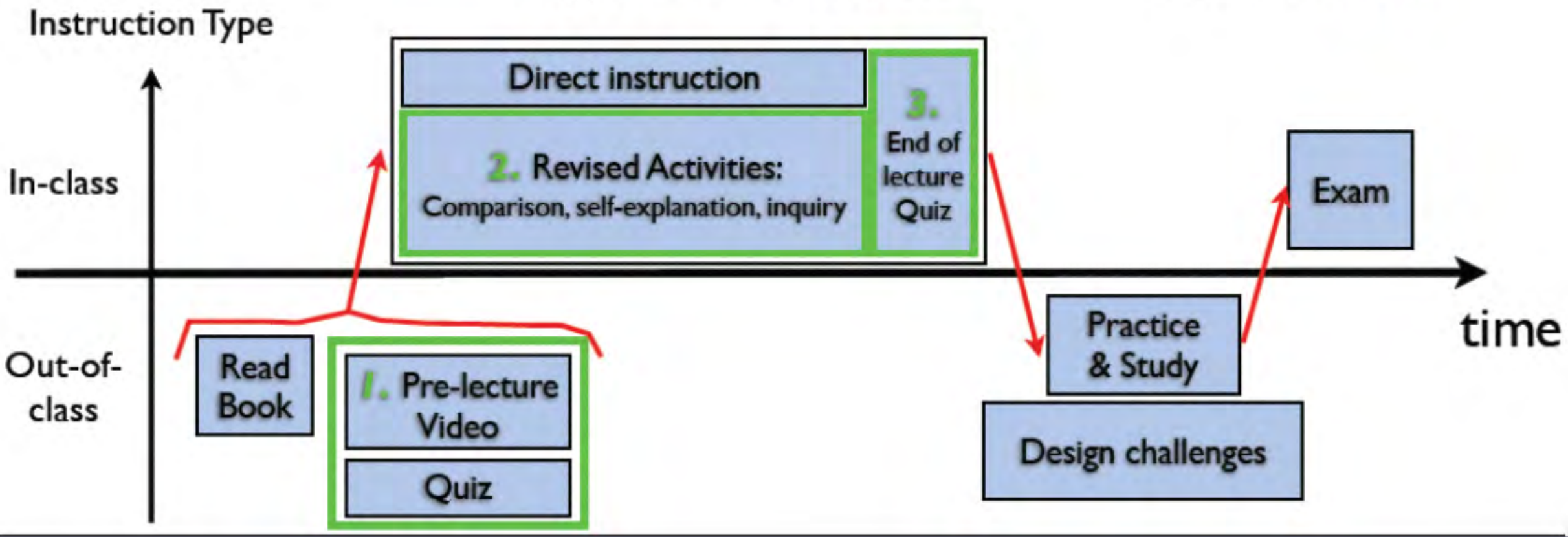


Serial position functions for free recall tests given immediately after the presentation of a 20-word list as compared to a test given after a 30-second delay, during which subjects were counting backward.

Source: Postman & Phillips, 1965.

Flipped Instruction

Major Revisions



Example revised activity

If the balloons popped, the sound would not be able to carry. Everything would be too far away from the correct floor. A closed window would also prevent the sound. This is because most buildings tend to be well insulated. The whole operation depends on a steady flow of electricity. A break in the middle of the wire would also cause problems. Of course, the fellow could shout. But the human voice is not loud enough to carry that far. An additional problem is that the string could break on the instrument. Then there could be no accompaniment to the message. It is clear that the best situation would involve less distance. Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong.

Activity adapted from Schwartz & Bransford, 1998

In the first experiment, 8 college students read the passage with 13 sentences. These participants were told that they would be tested for their memory of what they had read. Four of the participants were in the *immediate recall* condition. Immediately after reading the passage, the participants were told to write down everything they could remember from the passage. The other 4 participants were in the *delayed recall* condition. After they read the passage, they had to count back from 100 by 3s (e.g., 100, 97, 94 …). After this delay, these 4 participants were also instructed to write down everything they could recall from the passage. Here is what they remembered.

Immediate recall condition.

Participant 1: With face to face contact, the least number of things could go wrong. Then there would be fewer potential problems. If the balloons popped, the sound would not be able to carry. The human voice is not loud enough to carry. A closed window would also prevent the sound from carrying.

Participant 2: With face to face contact, the least number of things could go wrong. It is clear the best situation would involve less distance. If the balloons popped, the sound would not be able to carry. The whole operation depended on a steady flow of electricity.

Participant 3: With face to face contact, the least number of things could go

carry. A string could break on the instrument. Most buildings tend to be well-insulated.

Participant 4: Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong. If the balloons popped, the sound would not carry. Then there could be no accompaniment to the message. A break in the wire would cause problems.

Delayed recall condition.

Participant 5: If the balloons popped, the sound would not be able to carry. Everything would be too far away from the correct floor. It depends on a steady flow of electricity.

Participant 6: If the balloons popped, the sound would not be able to carry. Of course, the fellow could shout.

Participant 7: A closed window would prevent the sound from carrying. If the balloon popped, the sound would not carry. With face to face contact, the least number of things could go wrong. The human voice is not loud enough to carry that far.

Participant 8: If the balloons popped, the sound would not be able to carry. Everything would be too far from the correct floor. There would be no accompaniment to the message.

Analogy and Explanation

Immediate recall condition. ⟷ *Delayed recall condition.*

Participant 1: With face to face contact, the least number of things could go wrong. Then there would be fewer potential problems. If the balloons popped, the sound would not be able to carry. The human voice is not loud enough to carry. A closed window would also prevent the sound from carrying.

Participant 2: With face to face contact, the least number of things could go wrong. It is clear the best situation would involve less distance. If the balloons popped, the sound would not be able to carry. The whole operation depended on a steady flow of electricity.

Participant 3: With face to face contact, the least number of things could go wrong. If the balloons popped, the sound would not be able to carry. A string could break on the instrument. Most buildings tend to be well-insulated.

Participant 4: Then there would be fewer potential problems. With face to face contact, the least number of things could go wrong. If the balloons popped, the sound would not carry. Then there could be no accompaniment to the message. A break in the wire would cause problems.

Participant 5: If the balloons popped, the sound would not be able to carry. Everything would be too far away from the correct floor. It depends on a steady flow of electricity.

Participant 6: If the balloons popped, the sound would not be able to carry. Of course, the fellow could shout.

Participant 7: A closed window would prevent the sound from carrying. If the balloon popped, the sound would not carry. With face to face contact, the least number of things could go wrong. The human voice is not loud enough to carry that far.

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Assessment

- Learning
  - 3 Exams (35 multiple choice question)
  - Design Challenges
  - Quizzes
  - Inquiry activity (pattern finding, hypothesis generation)
  - Surveys: study skills (cognitive and meta-cognitive)

- Motivation and Engagement
  - Surveys: interest, self-efficacy, achievement goals, theory of intelligence, persistence, and sense of belonging
  - Course web use
  - Attendance; office hours utilization; questions during lecture and via email

Thank you

Questions?

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