How can laboratory research in cognitive and developmental psychology contribute to science education (and vice versa)?

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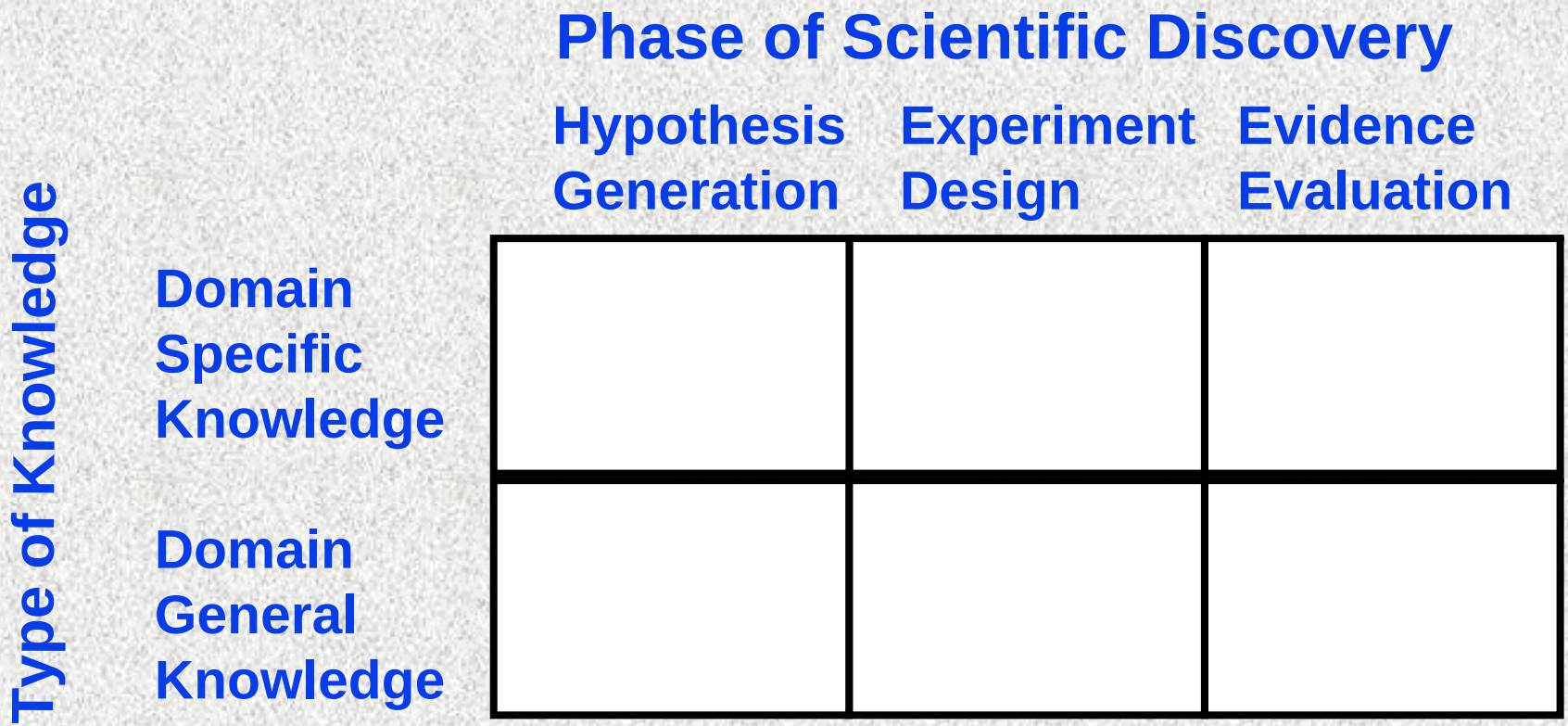
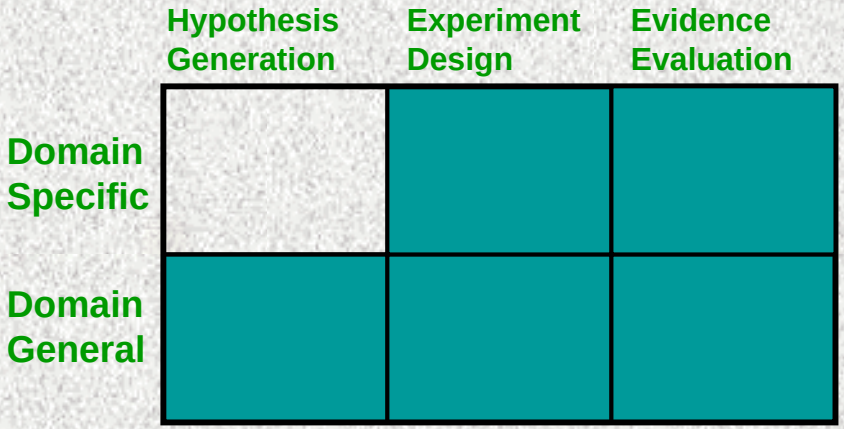
Outline

- Psychological investigations of scientific thinking in children
  - Paradigm
  - Findings
- Tensions between
  - basic versus applied
  - engineering vs science
- An example from my lab
- Establishing a unique paradigm for Science Education

Types of Psychological Research on Scientific Thinking



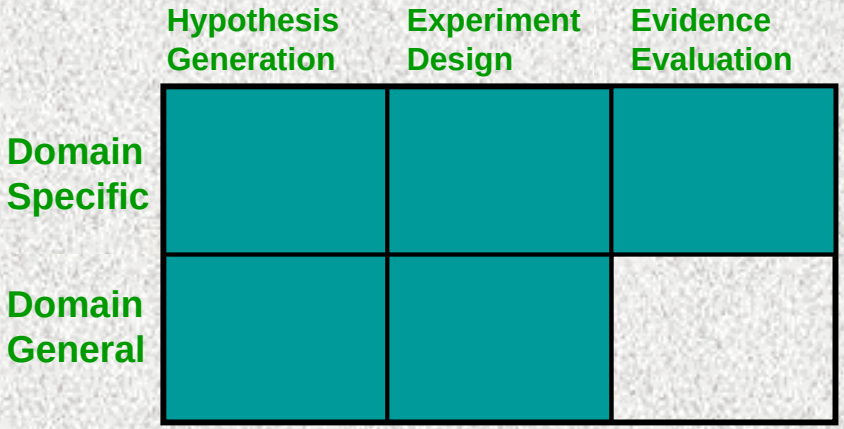


Domain-Specific Hypothesis Generation

What do children know about different physical domains?

Theories of Motion

Heat & Temperature



Domain-General Evidence Evaluation:

What do children know about the relation between:

- covariation & causality?
- knowing & guessing?

What has research on children's scientific thinking revealed?

1. Children develop "theories" about the natural world long before they enter school.

2. Deeply entrenched misconceptions:

- **Momentum and Force**
- **Heat & Temperature**
- **Mass & Density**
- **Solar system**
- **Animacy (What's alive?)**
- **Theory of Mind (how other's think)**

What has research on children's scientific thinking revealed?

3. Children acquire new reasoning processes slowly, along multiple paths.

4. Sets of partially correct strategies:

- **simple arithmetic**
- **evaluating evidence**
- **naïve physics**

5. Knowledge is organized around prior conceptions (or mis-conceptions).

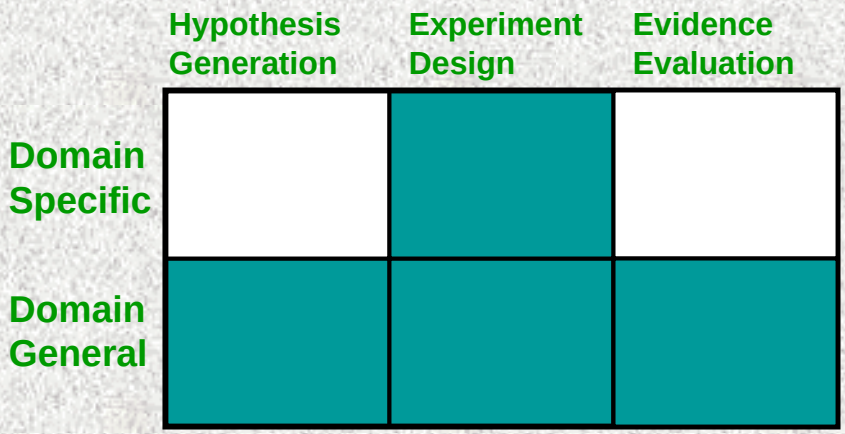
What has research on children's scientific thinking revealed?

6. Experts use prior knowledge for efficient and rapid encoding of new information

7. Expertise is domain-limited.

8. Analogy is a powerful heuristic for solving problems and learning new material.

Psychologist's reaction to studies of isolated cell or cells: Great Stuff!



Teacher's response: Who cares?

But real teachers teaching real science can't isolate the cells!

Example: 4th grade classroom lesson on what determines a pendulum's period?

	Hypothesis Generation	Experiment Design	Evidence Evaluation
Domain Specific	Length? Initial force? Mass?	Select length, mass, force, etc.	•Counting •Timing •Measuring
Domain General	Asking good questions	•Vary one thing •Keep others the same	•Recording data •Making Tables •Averages

Conflicting goals and constraints:

Psychologists need to isolate theoretically motivated variables.

Educators need to weave many aspects of Science into classroom lessons.

We have a lot of knowledge about cognition.

How to use it for improving instruction in science?

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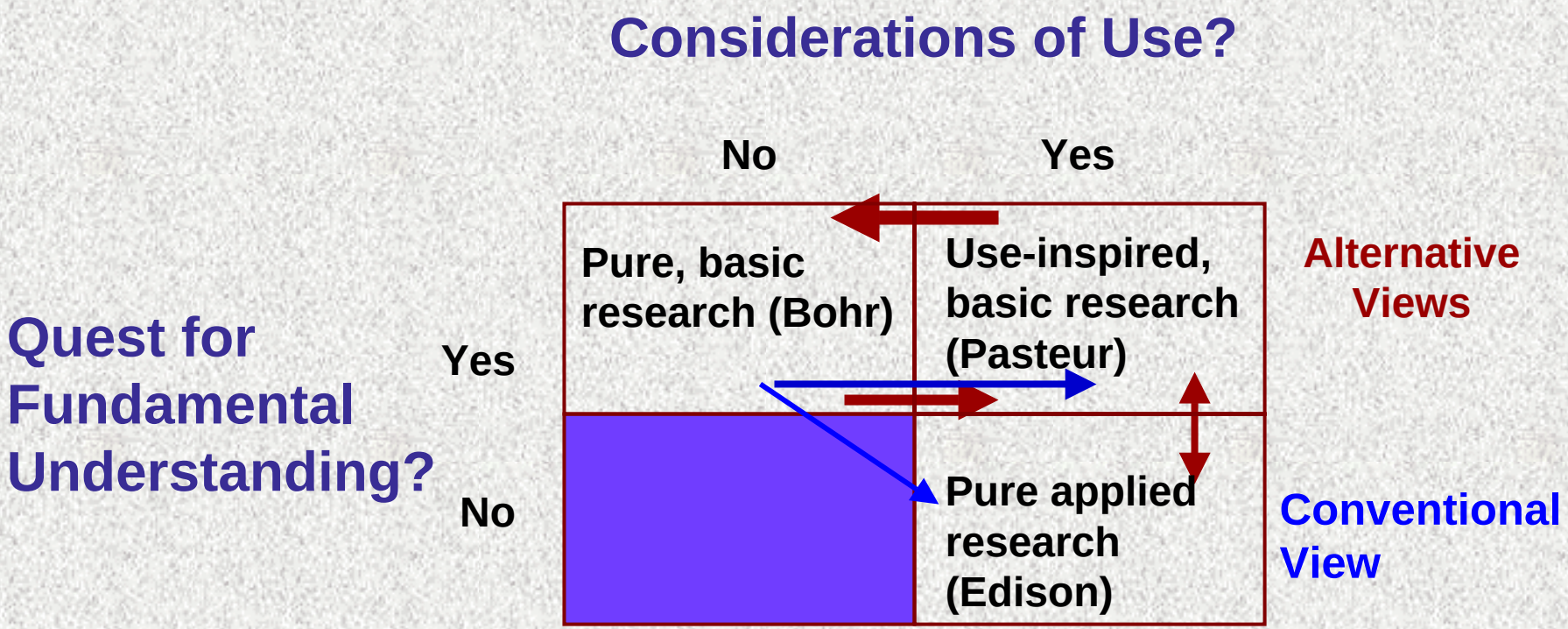
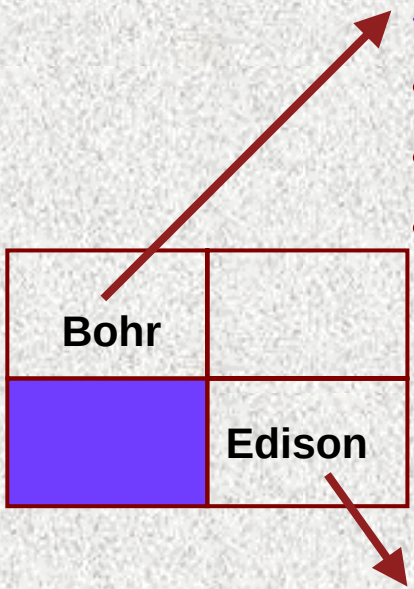
Stokes, Donald (1997) Pasteur's Quadrant: Basic Science and Technological Innovation.



“Engineering” vs “Science” in science education



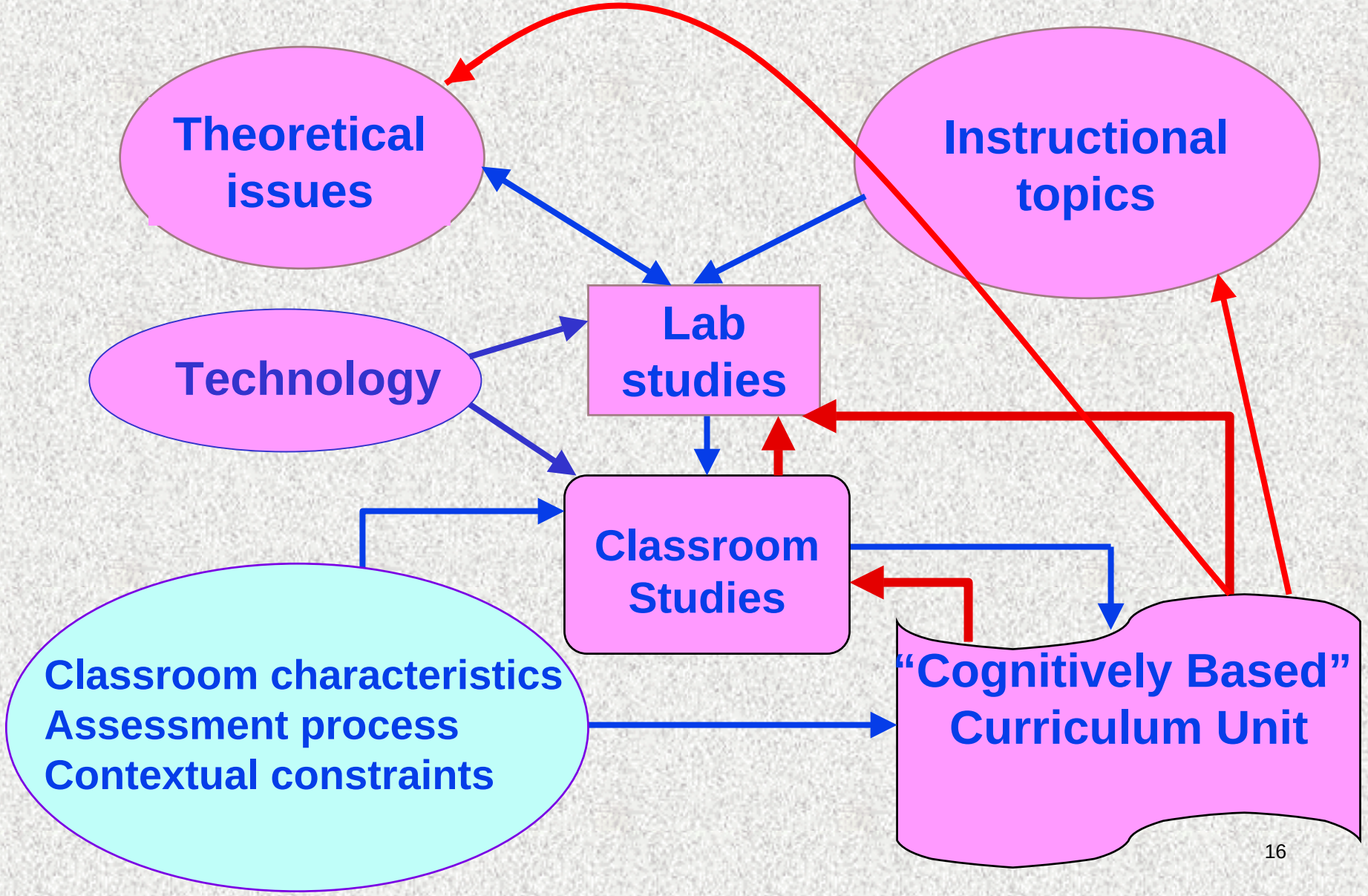
Science of Educational Research:

- Goal: new knowledge about learning & its causes.
- Mantra: “What is the mechanism?”
- Procedures:
  - systematic, theoretically motivated;
  - “clean” treatments
    - controlled experiments, randomization;
    - pre tests & post tests; etc.

Engineering of Educational Outcomes:

- Goal: new effects, improved learning.
- Mantra: “Make it work!”
- Procedures:
  - Application of new, empirically verified, techniques
  - some theory, some hunch,
  - multiple changes, complex, uncontrolled interactions, etc.

From basic to applied research in instruction



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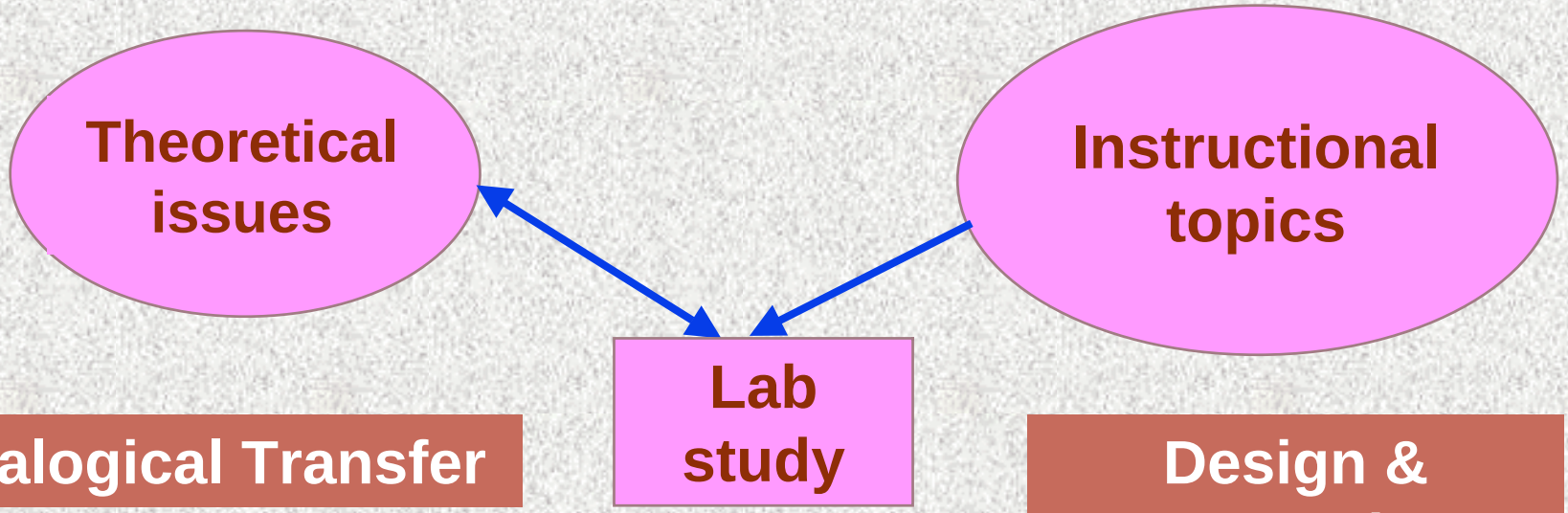
Recent & Current Collaborators:

Zhe Chen
Milena Nigam
Brad Morris
Amy Masnick
Lara Triona
Junlei Li

Research Questions:

- **Psychological: can elementary school kids understand the logic and procedures underlying the control of variables strategy (CVS)?**
- **Educational: can children be taught how to design unconfounded experiments?**
- **Instructional: how does direct instruction compare with discovery learning in this domain?**

Lab study: CVS Training[1]



- Analogical Transfer
- Discovery Learning
- Direct Instruction

- Design & Recognize "Good" Experiments
- Control of Variables Strategy

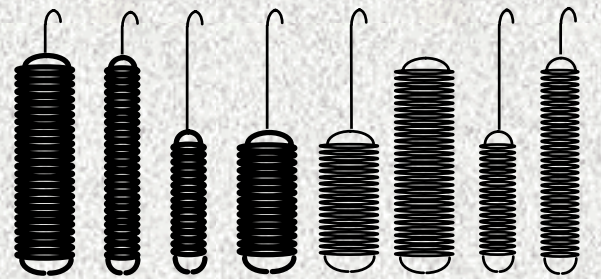
THE SPRINGS DOMAIN

Question: how do different attributes of springs determine how far a spring will stretch?

SETUP:

8 springs: 2 lengths x 2 widths x 2 wire sizes

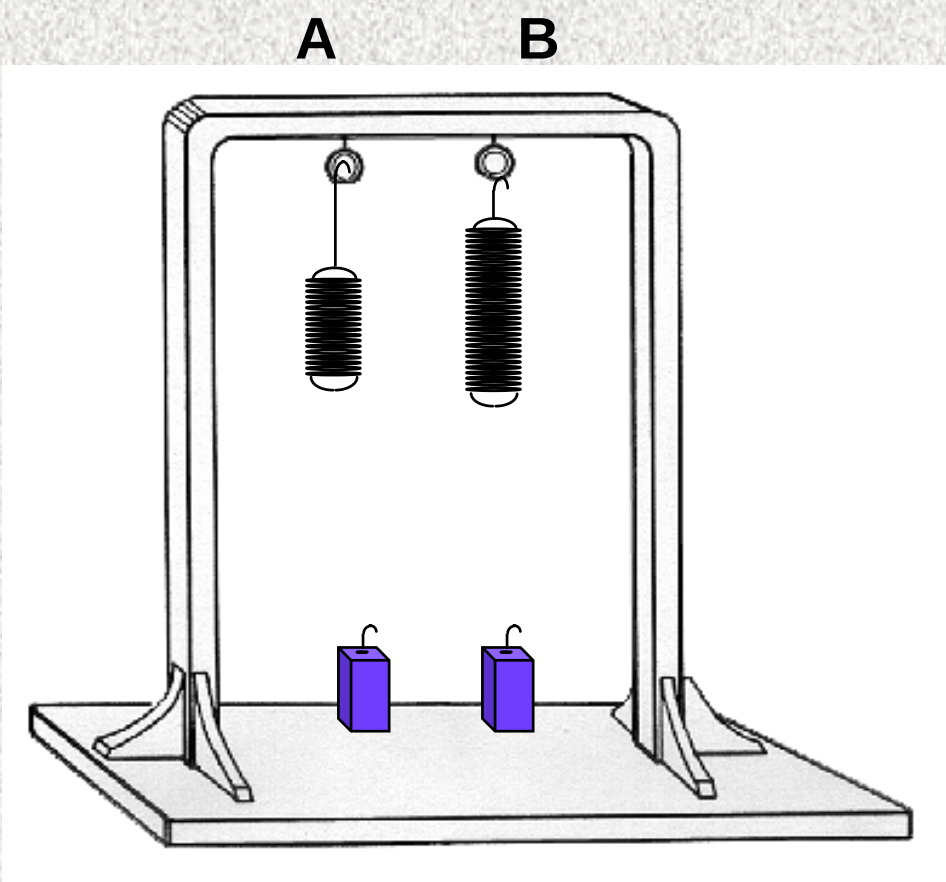
- **Select two springs**
- **Select two weights**



EXECUTION

- **Hang springs on rack hooks**
- **Hang weights on springs.**
- **Compare amount of stretching.**

SPRINGS: an unconfounded test for length



	A	B
Length:	short	long
Width:	wide	wide
Wire:	thin	thin
Weight:	light	light

RAMPS: A multiply confounded test

A

Surface: smooth
Run: short
Steepness: high
Ball: golf

B

Surface: rough
Run: long
Steepness: low
Ball: rubber

THREE TYPES OF TRAINING

***Direct, didactic*: Provide both explicit instructions *and* probe questions.**

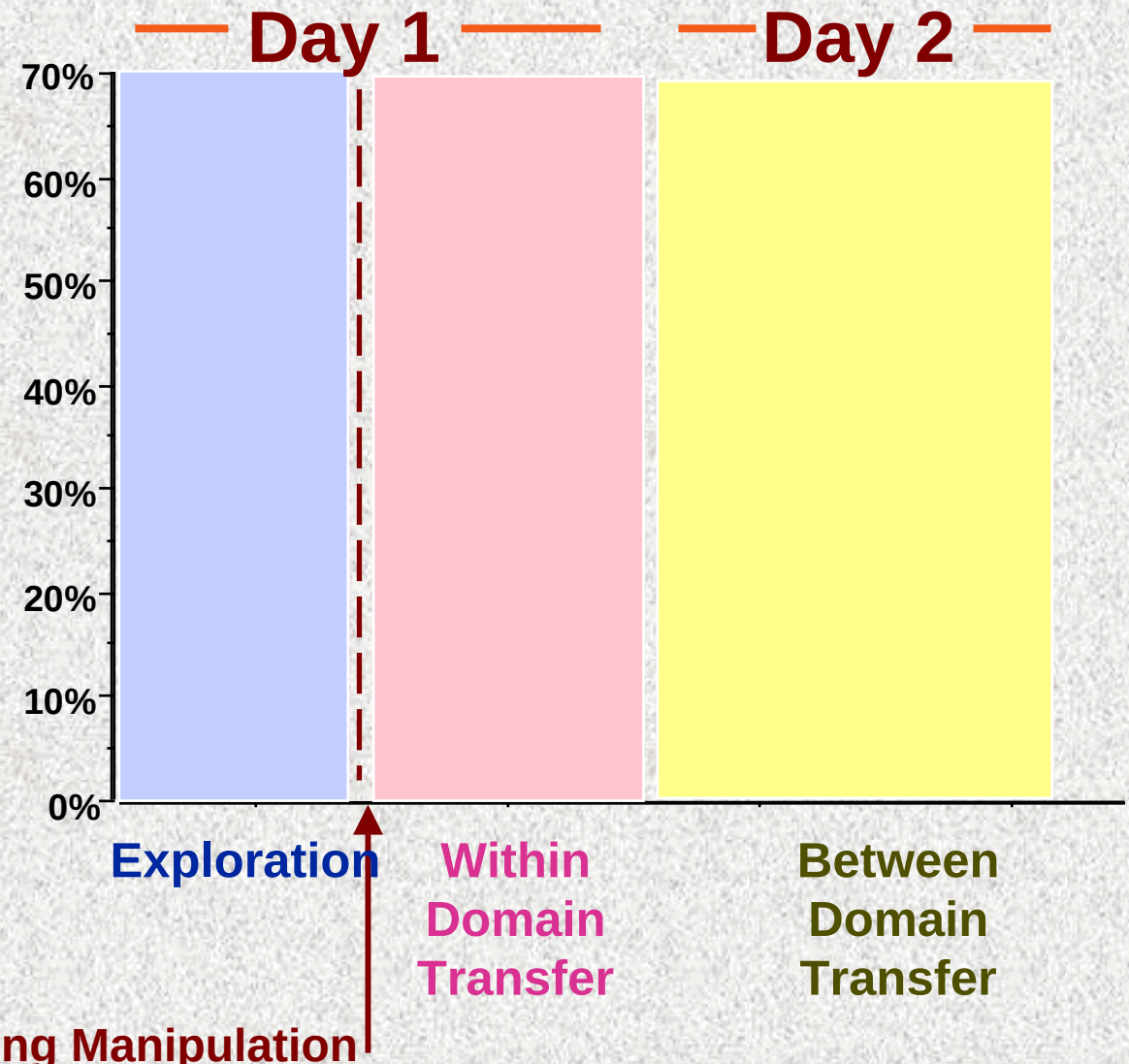
***Socratic*: Provide only probe questions on each trial.**

***Discovery*: Provide only hands-on experience. (No instruction, no questions)**

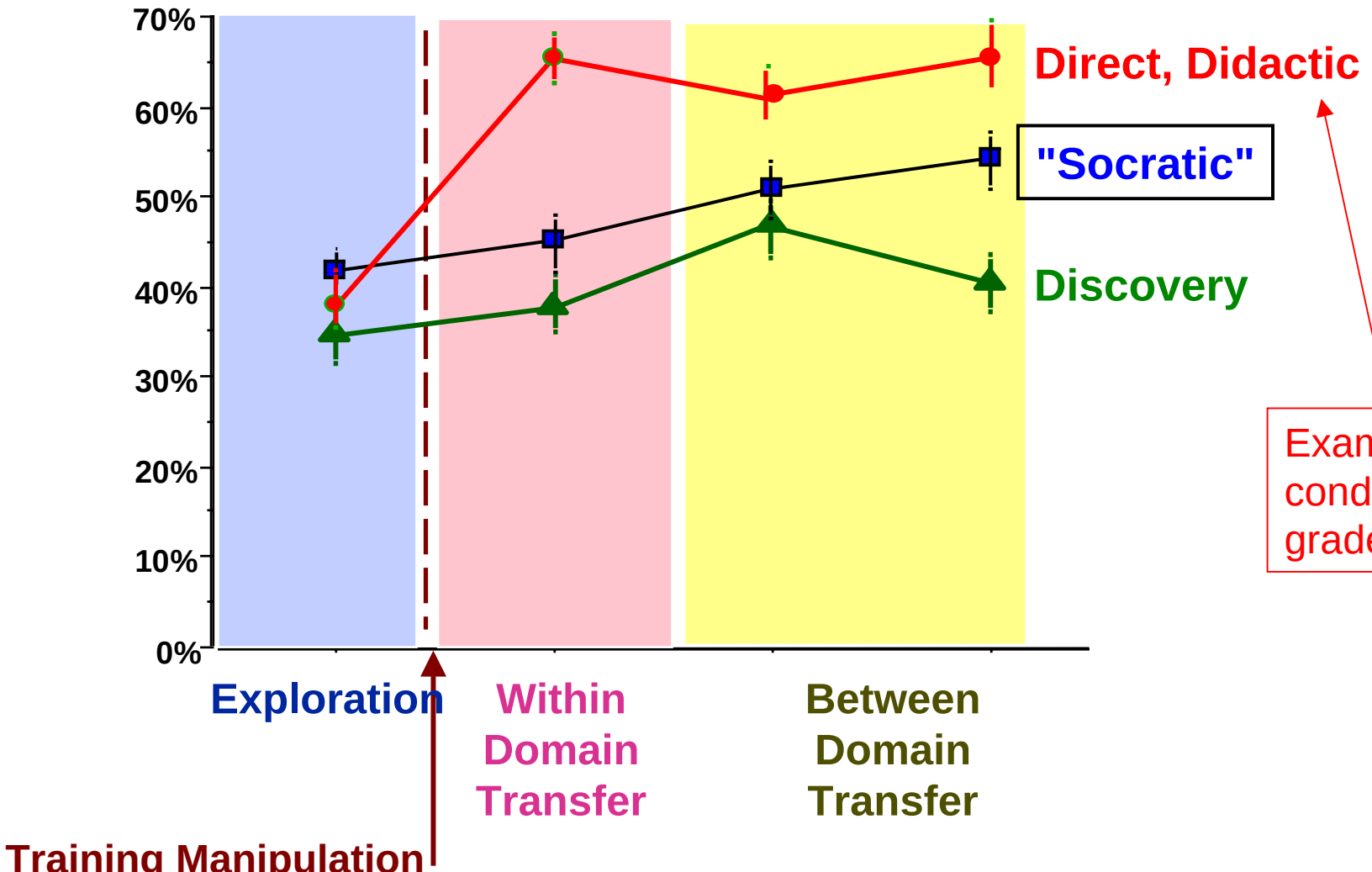
Direct Instruction

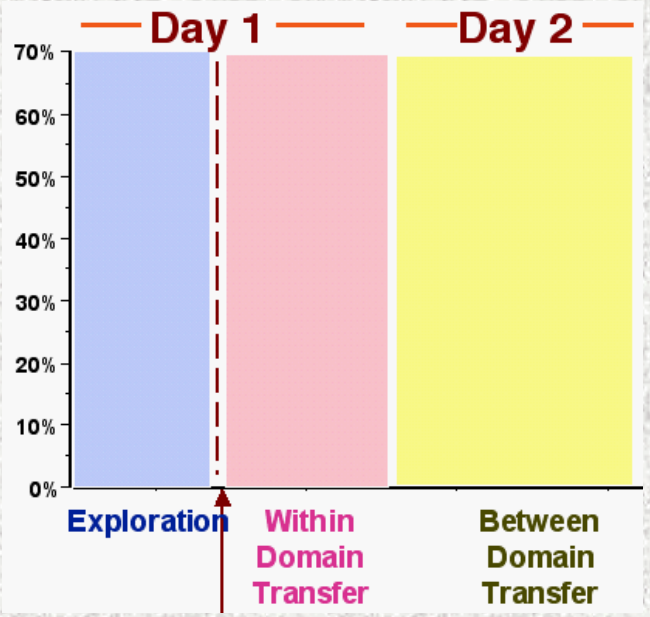
- Present good and bad examples
  - Set up apparatus
  - Run experiment
  - Observe outcome
- Ask: good or bad? Why?
- Can you tell for sure?
- Why? What did you learn?
- Explain why good or bad.

Phases


Day 1
Day 2
70%
60%
50%
40%
30%
20%
10%
0%
Exploration
Within Domain Transfer
Between Domain Transfer
Training Manipulation

Results

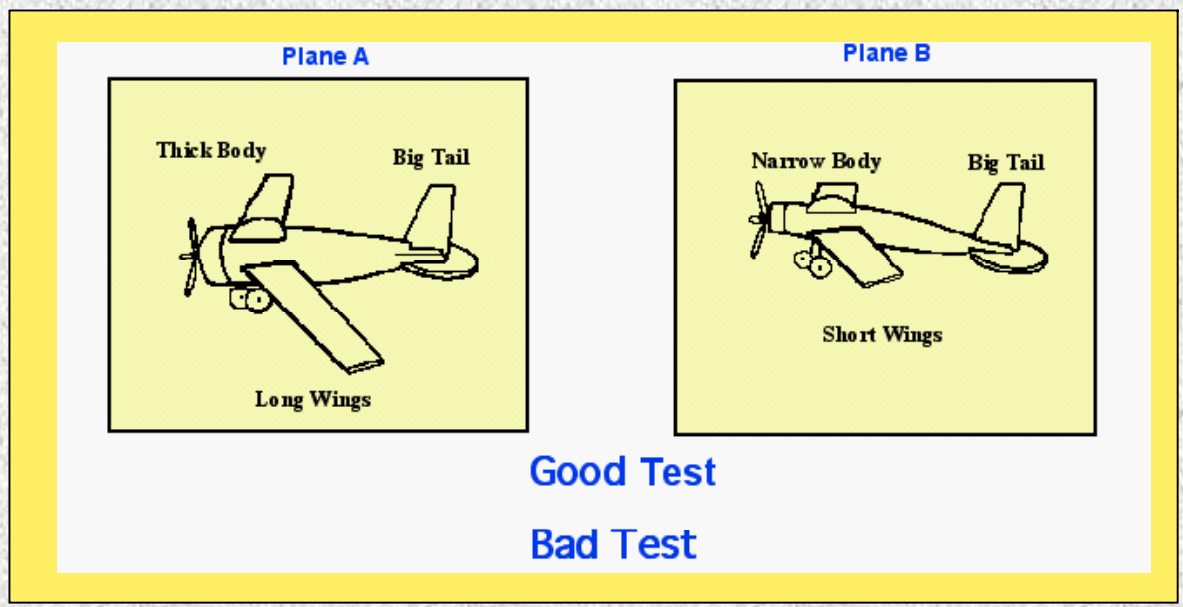

70%
60%
50%
40%
30%
20%
10%
0%
Direct, Didactic
"Socratic"
Discovery
Exploration
Within Domain Transfer
Between Domain Transfer
Training Manipulation
Examine this condition by grade



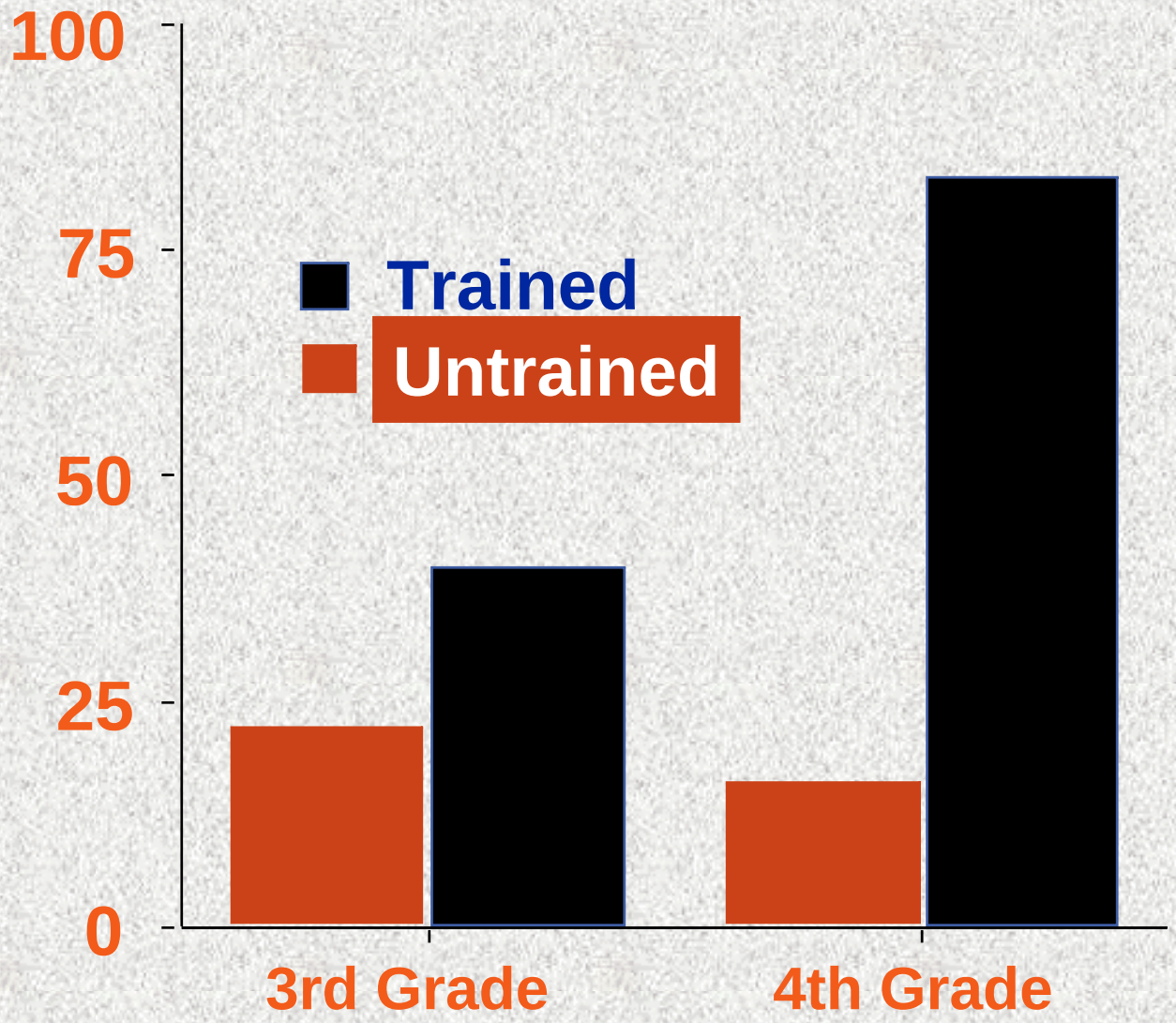
Remote Transfer:

7 months later,

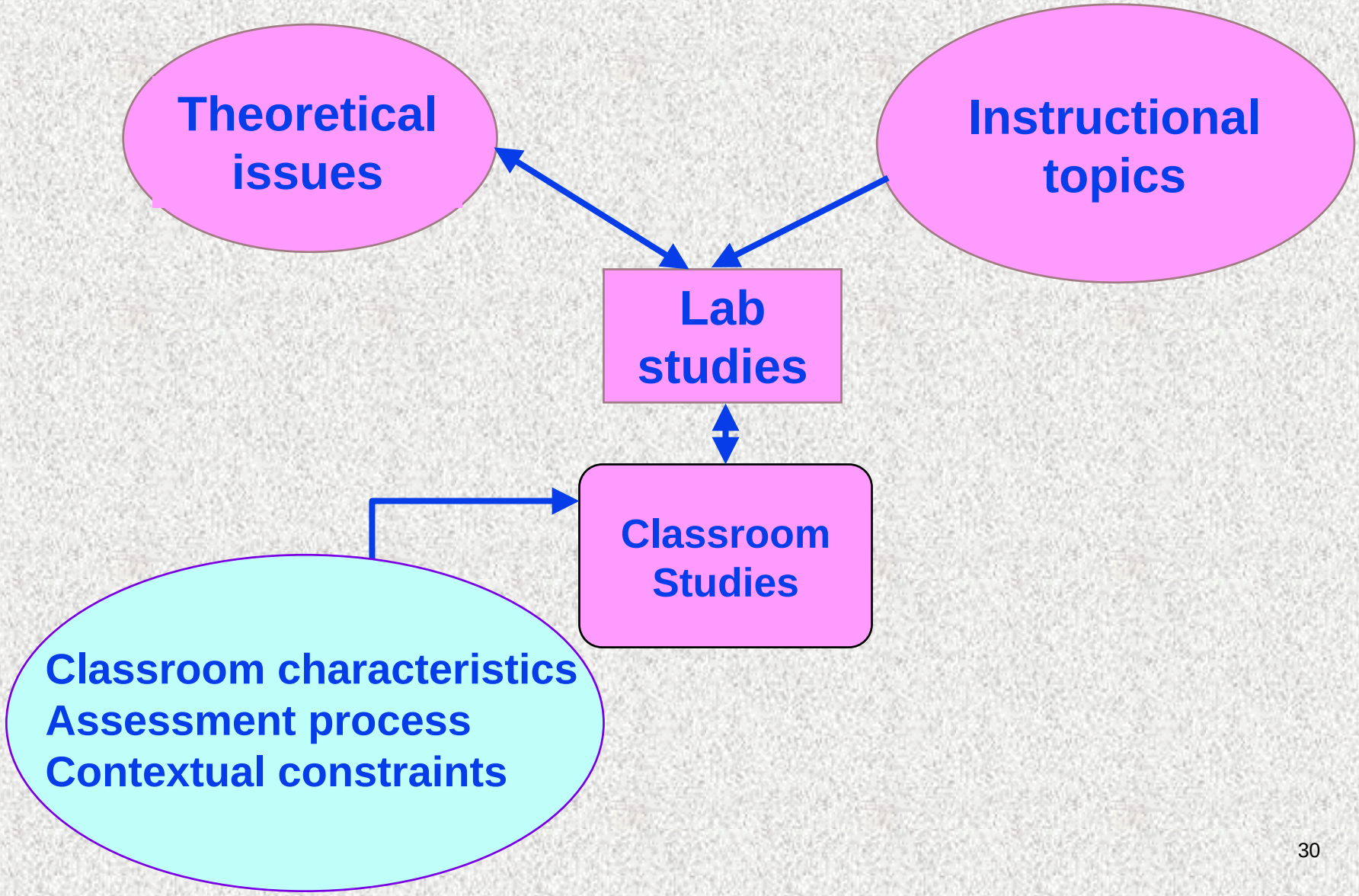
15 of these types of problems:



% OF CHILDREN GETTING 13 of 15 CORRECT ON REMOTE (7 month delay) POSTTEST



From Basic to Applied



What to hold and what to fold?

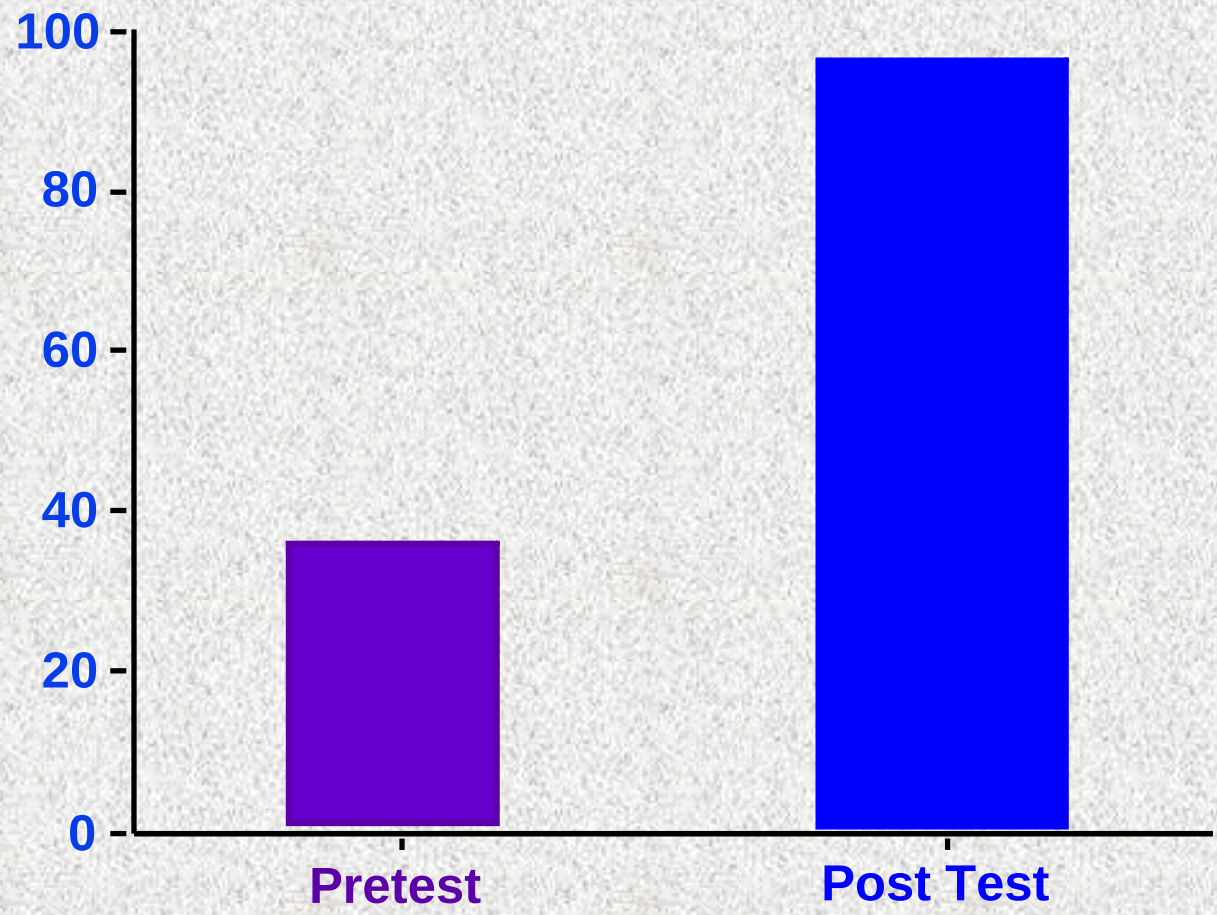
- **Pedagogy:**
  - Same goal – teach CVS
  - Same type of instruction: direct instruction
- **Assessment:**
  - Same as laboratory
  - Plus, some new assessments in classroom
- **Context (many differences):**
  - Scheduling
  - Student/teacher ratio
  - Group work
  - Record keeping
  - Error and multiple trials

Participants in Classroom Study

- 77 4th graders from 4 classrooms in two different schools
- 2 different science teachers
- Neither school had participated in earlier “lab” study

Results of classroom Study

Percent of unconfounded designs



Classroom results (continued)

Individual students classified as "Experts" (8 of 9 correct)

Pretest:

5% classified as Expert

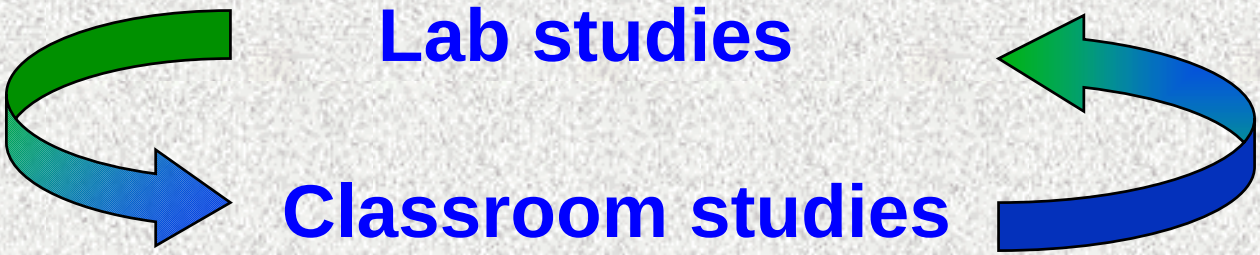
Posttest:

91% classified as Expert

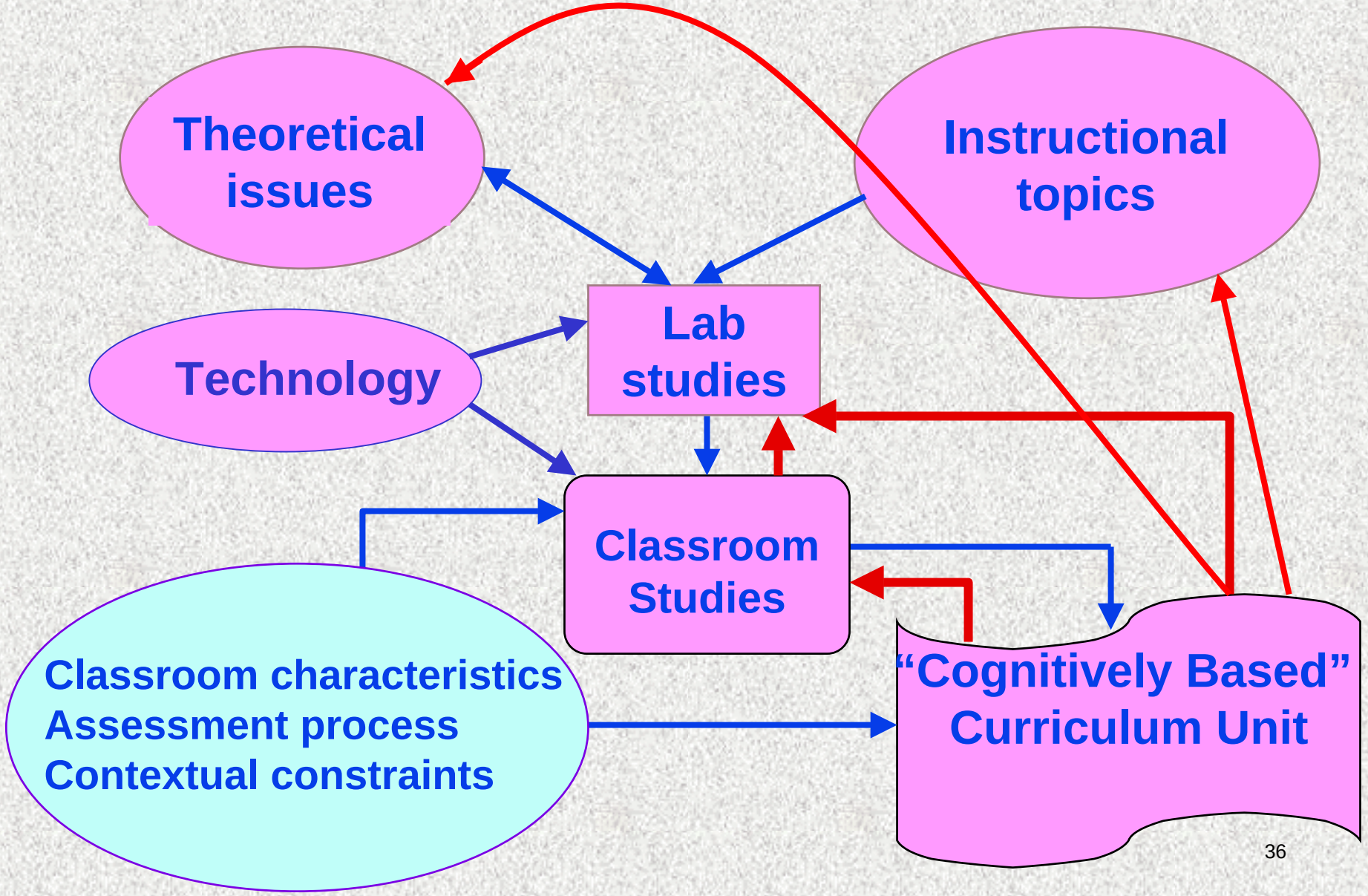
Mutually informative approaches[1]

- Lab studies can be extrapolated to classroom practice

- Classroom studies can raise new basic issues



What about the red arrows??



New Issues raised by classroom study

Subsequently investigated in further laboratory studies

- The medium and the message?
- Authenticity and far transfer?
- Children's understanding of error and variability?

- *(additional slides for each of these studies, if time for elaboration)*

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Suggestions for a science of science education

- Beware “approaches”
- Go forth and multiply
- Honor thy failures
- Research as problem solving

Approach Avoidance

- **Not useful: Educational practice derived from"approaches"**
  - **Piaget, Vygotsky, Constructivist, Situated, Information Processing, Hands on vs hands-off, etc.**
  - **Specifying a "Newtonian Approach" doesn't get you to Mars.**
  - **A prescription that says "use germ theory" doesn't help a pharmacist much.**
- **Definitions matter!**
  - **"Discovery", "Direct", "Socratic": labels are just packaging.**
  - **Key to science is *Operational definition*: what was done?**
- **Details matter!**
  - **Space shuttle launches:**
    - **O-rings: How cold is too cold?**
    - **Foam chunks: How big too big?**
  - **Teacher training:**
    - **What knowledge; which skills; what kind of experience?**

Needed: large number of specific, but robust, findings

"Once we have dozens or hundreds of randomized or carefully matched experiments going on each year on all aspects of educational practice, we will begin to make steady, irreversible progress" (Robert Slavin, 2002)

- "Progress"? For sure.
- "Irreversible"? Perhaps.
- "Hundreds of studies"? At the least.

What works, AND what doesn't work, AND what doesn't seem to matter one way or the other

- Important to focus on success
- Equally important to focus on "failure"
- Scientific discovery is a type of problem solving (Klahr, 2000)
  - Requires "search"
    - For hypotheses
    - For experiments
    - For evaluation of experimental outcomes
  - As in any problem solving: failures are *informative*, not useless!

No magic bullet

- **Medical model (often touted)**
  - **But: no universal "wellness pill" or "generic health procedure"**
  - **Medical research is highly specific and detailed, and extrapolations to practice based on many replicated studies.**
- **In Education:**
  - **Research to practice link must be specific and detailed and theory-based and engineered**
  - **Practice to research link must be nurtured (as in Medicine)**

Thank you