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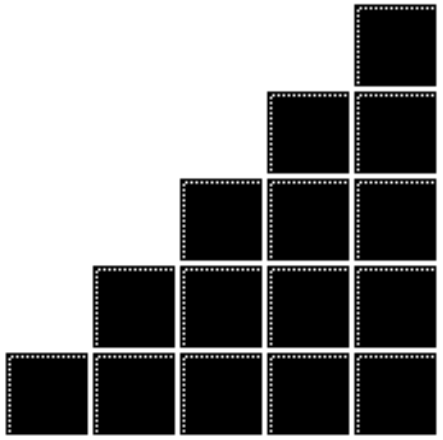
UNDERSTANDING OR MEMORIZATION: ARE WE TEACHING THE RIGHT THING?

Eric Mazur
Harvard University



Christopher Newport University
Newport News, VA
22 February 1999

❶ Problem

❷ Cause

❸ Remedy

PROBLEM? WHAT PROBLEM?

Traditional science education ineffective...

- lack of understanding
- frustration
- lack of basic knowledge

LACK OF UNDERSTANDING

LACK OF UNDERSTANDING

Well, "hot" is a relative term...

You see, given temperatures rise, regardless of mass.

Yeah, Galileo observed rising temperatures will decrease with the exposure of an endothermic source.

Endothermic?

True transparence will persist until this one irresistible calorie interacts, thus altering the system.

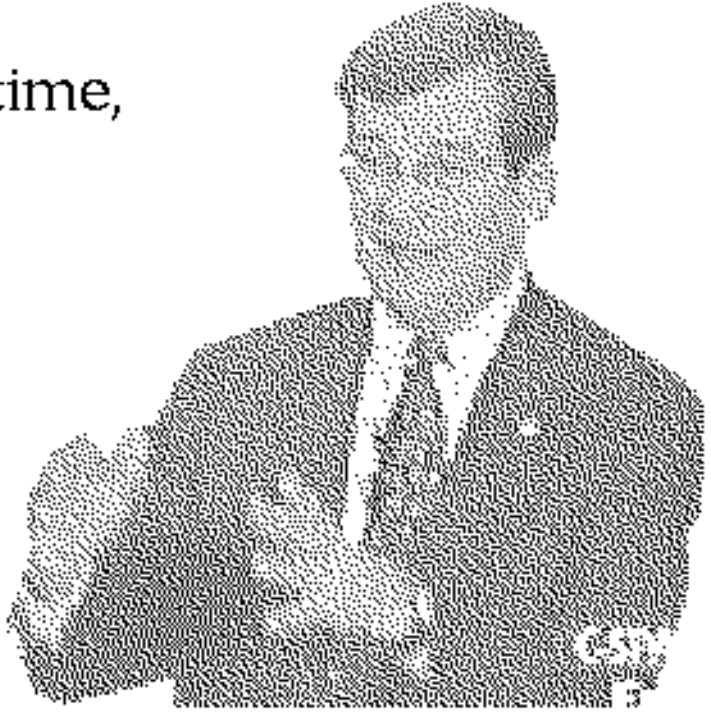
FRUSTRATION

FRUSTRATION

"I took four years of science and four years of math...

A waste of my time,
a waste of the teacher's time,
and a waste of space...

You know,
I took *physics*.
For *what*?"



FRUSTRATION

LACK OF BASIC KNOWLEDGE

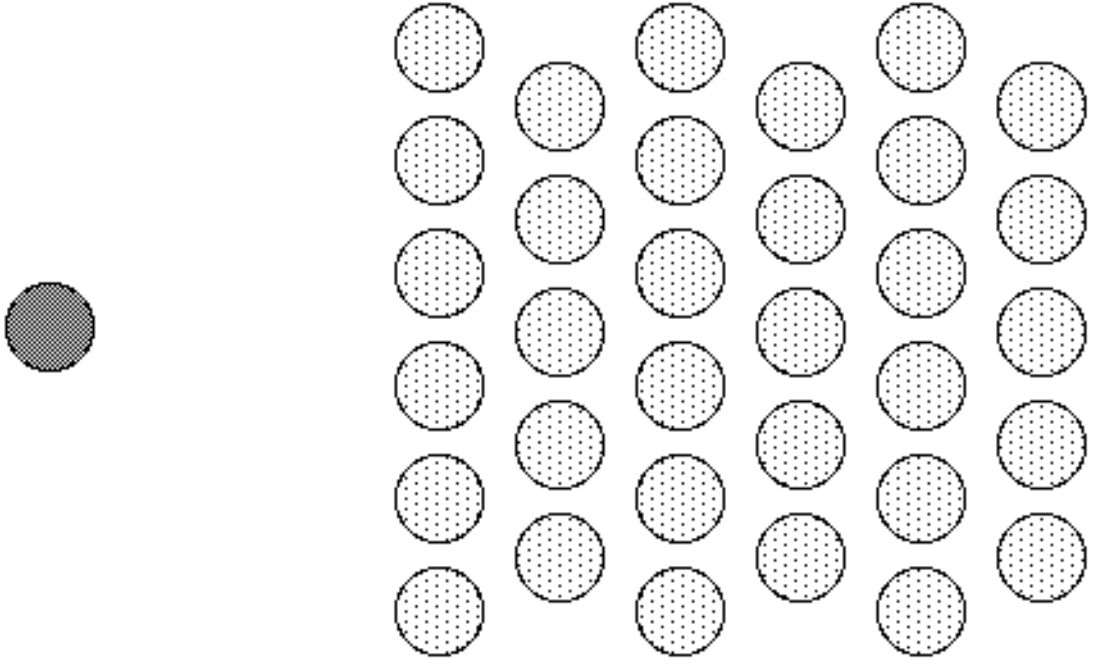
❶ Problem

❷ Cause

❸ Remedy

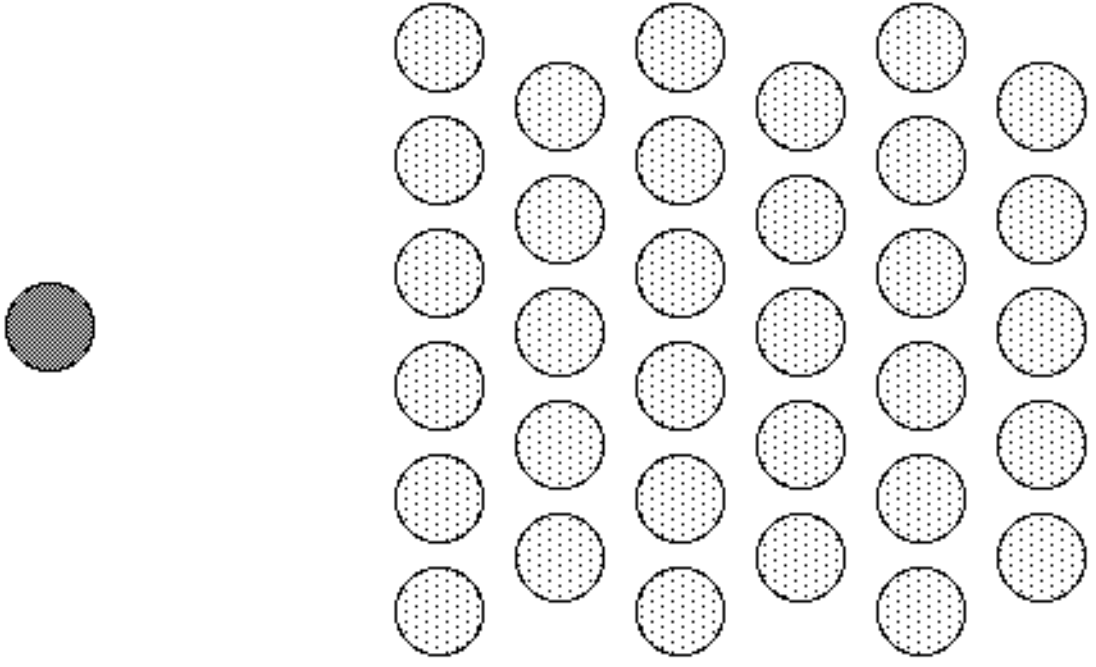
THE CAUSE

1. Lectures focus on transfer of information...



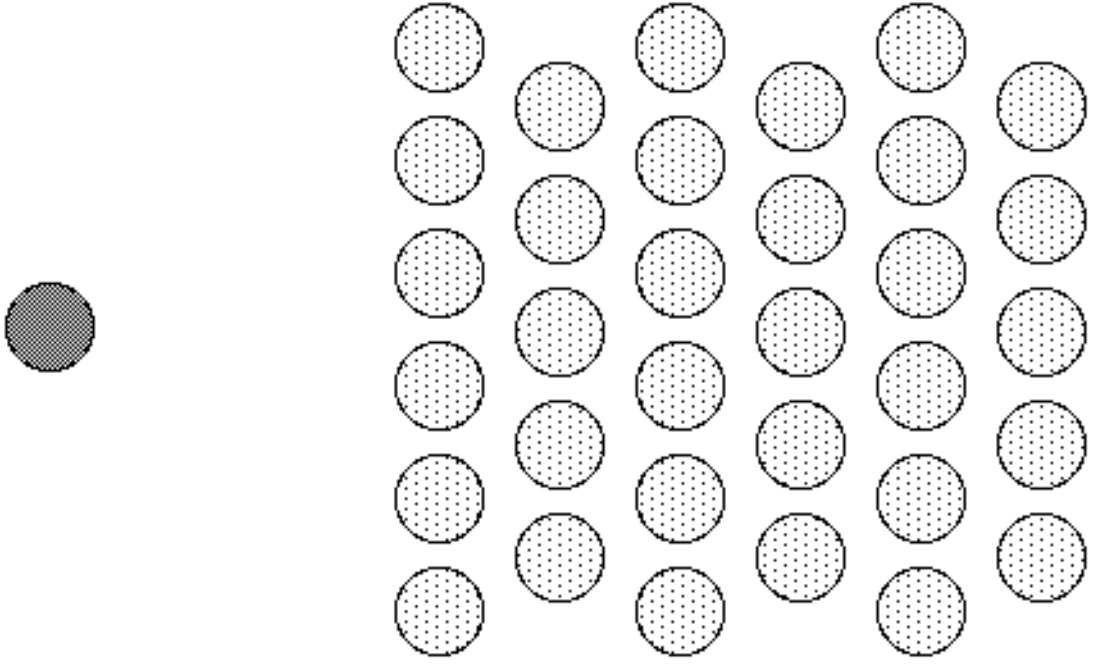
THE CAUSE

1. Lectures focus on transfer of information...



THE CAUSE

... but the information doesn't sink in!



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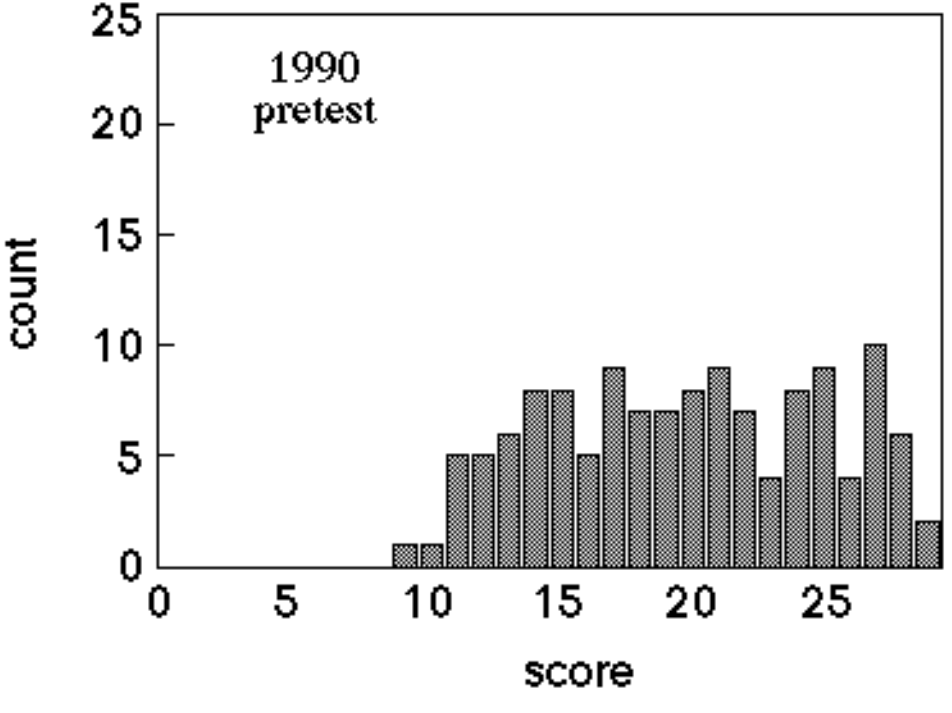
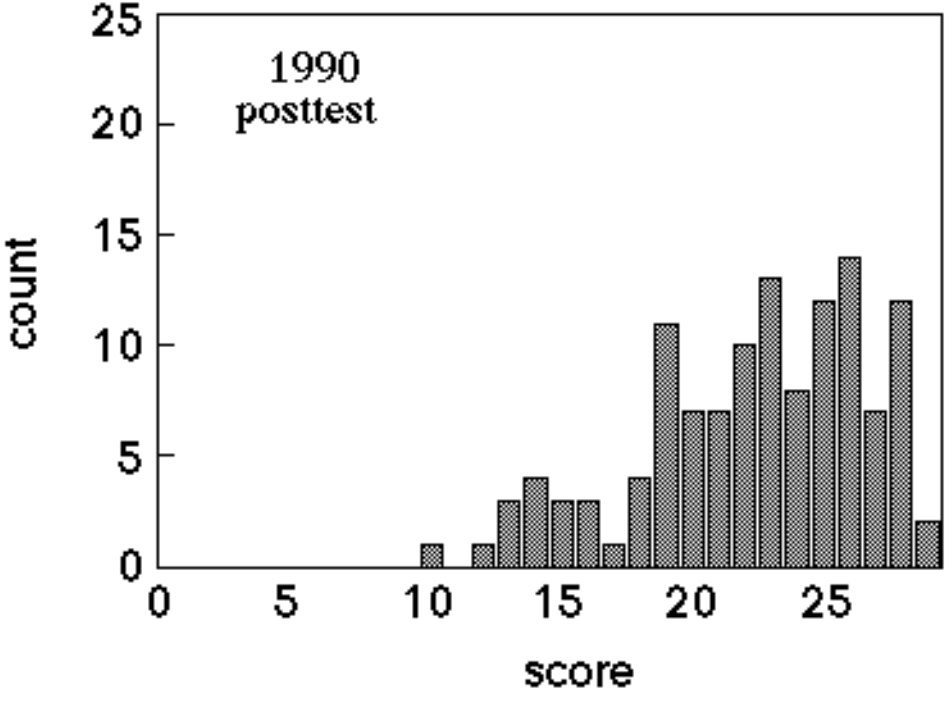


☞ Hestenes, *et al.*, TPT **30**, 141 (1992)

THE CAUSE



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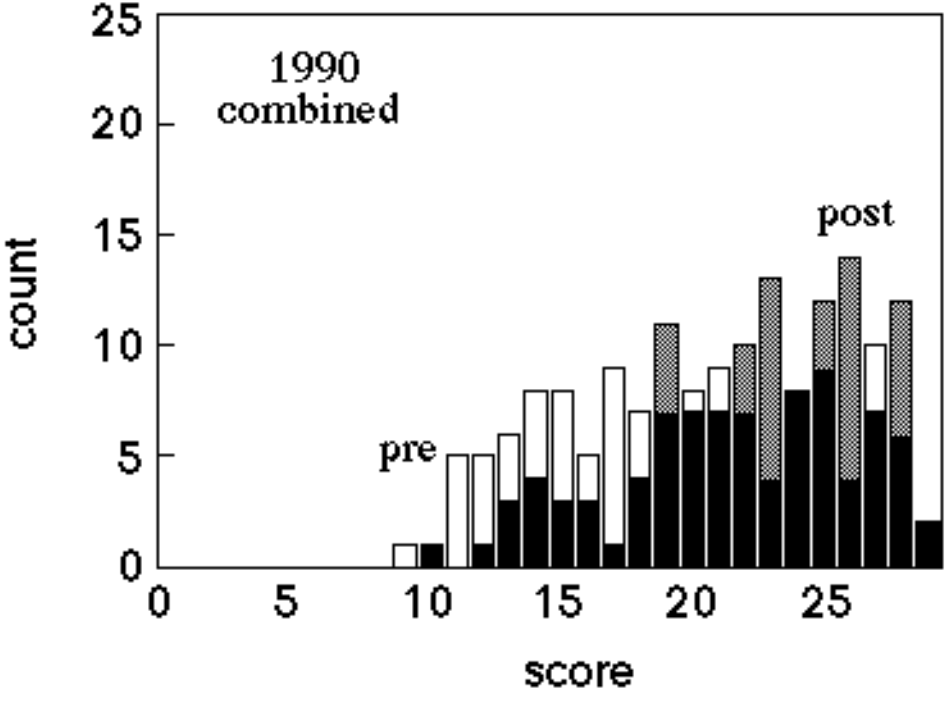

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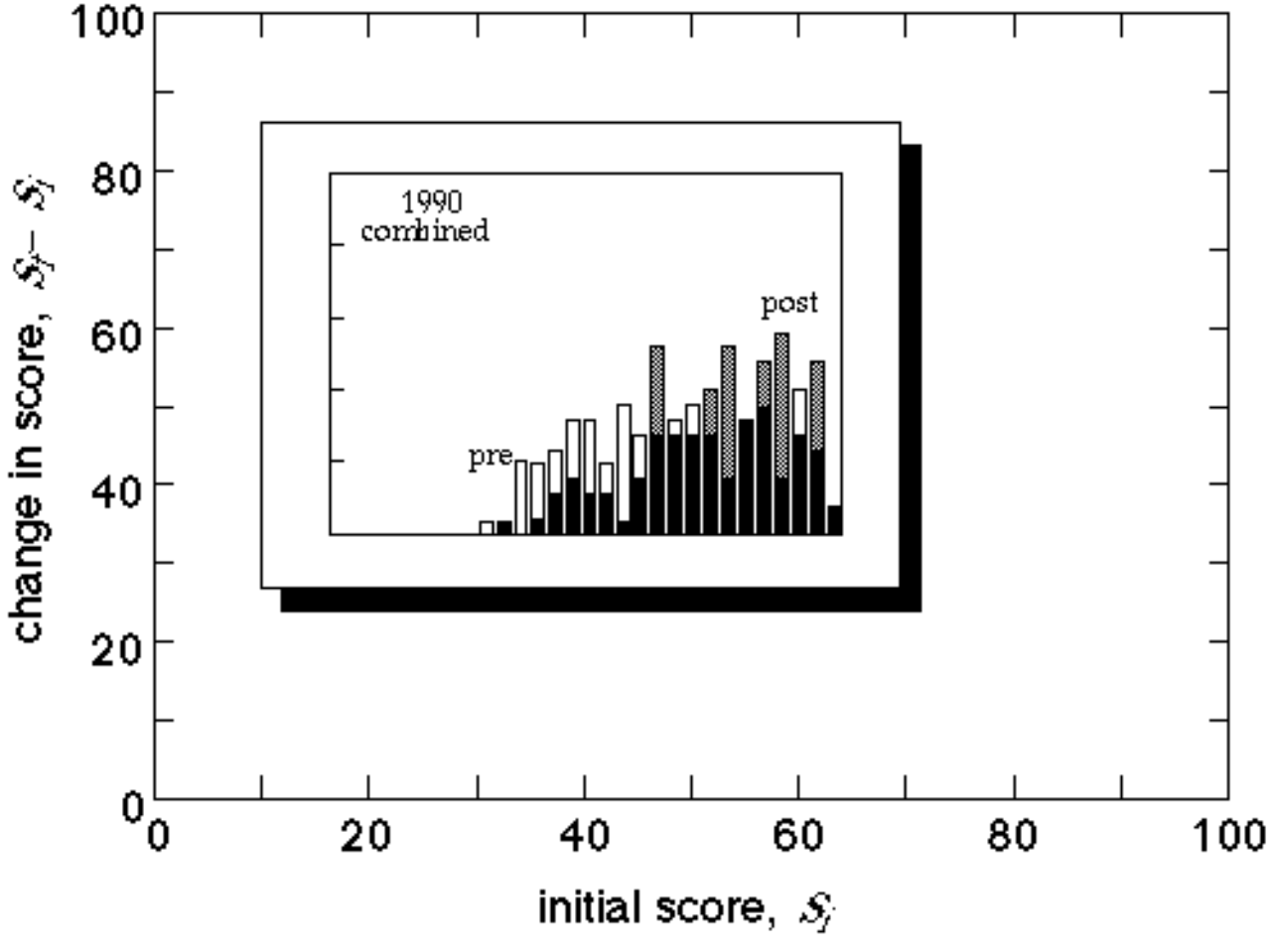
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change in score, $S_f - S_i$
initial score, S_i
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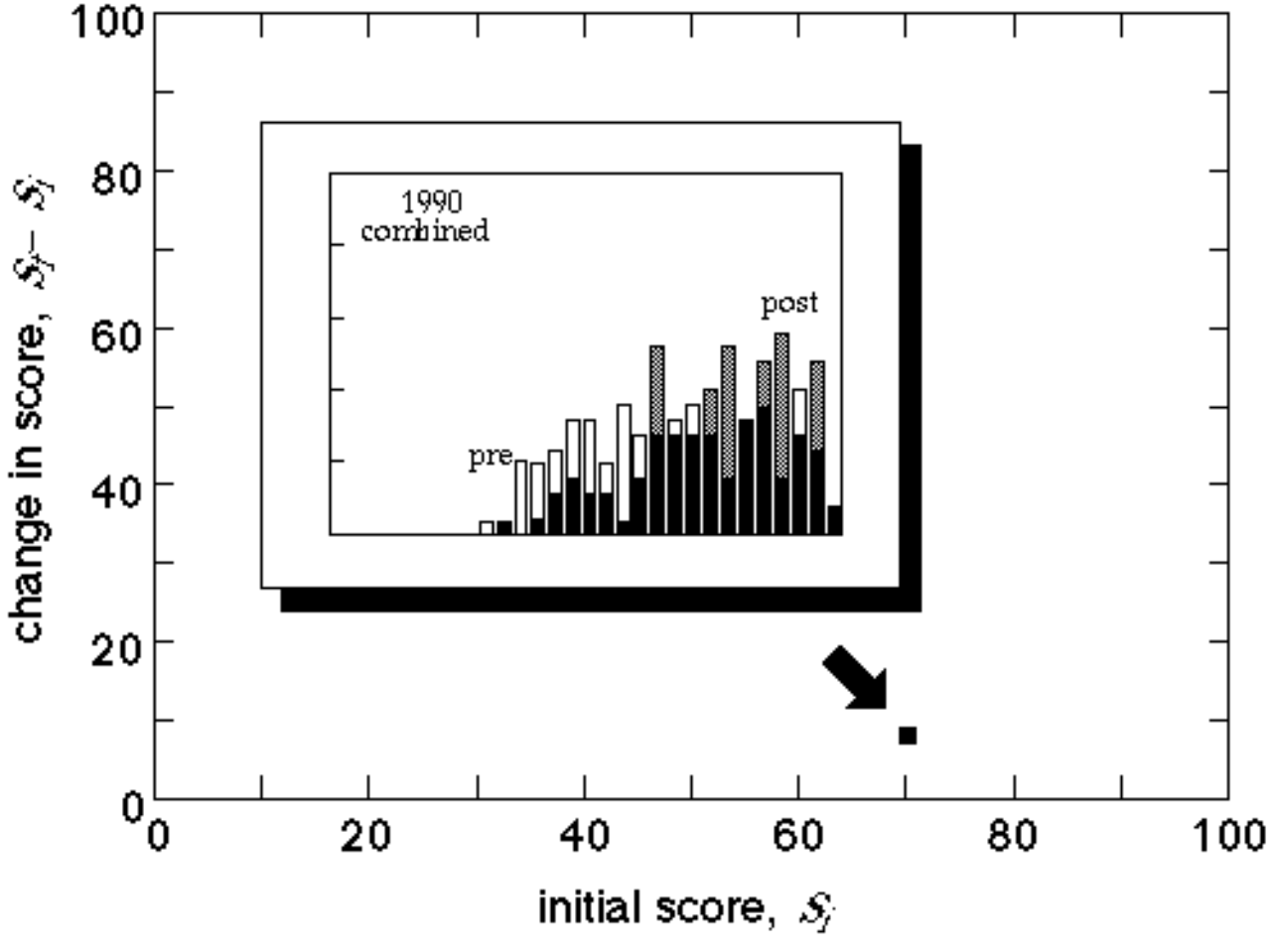
combined
post
pre

THE CAUSE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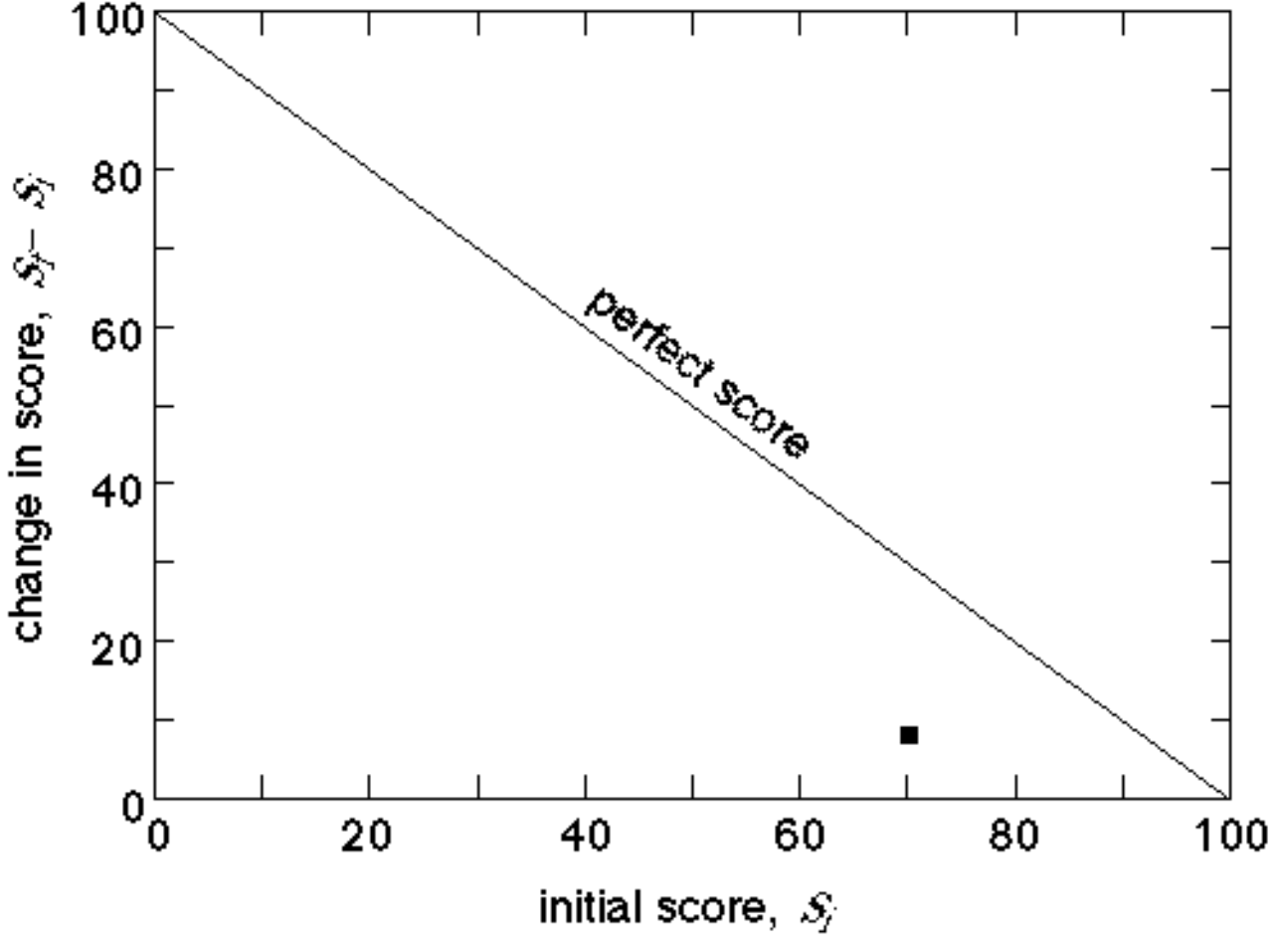
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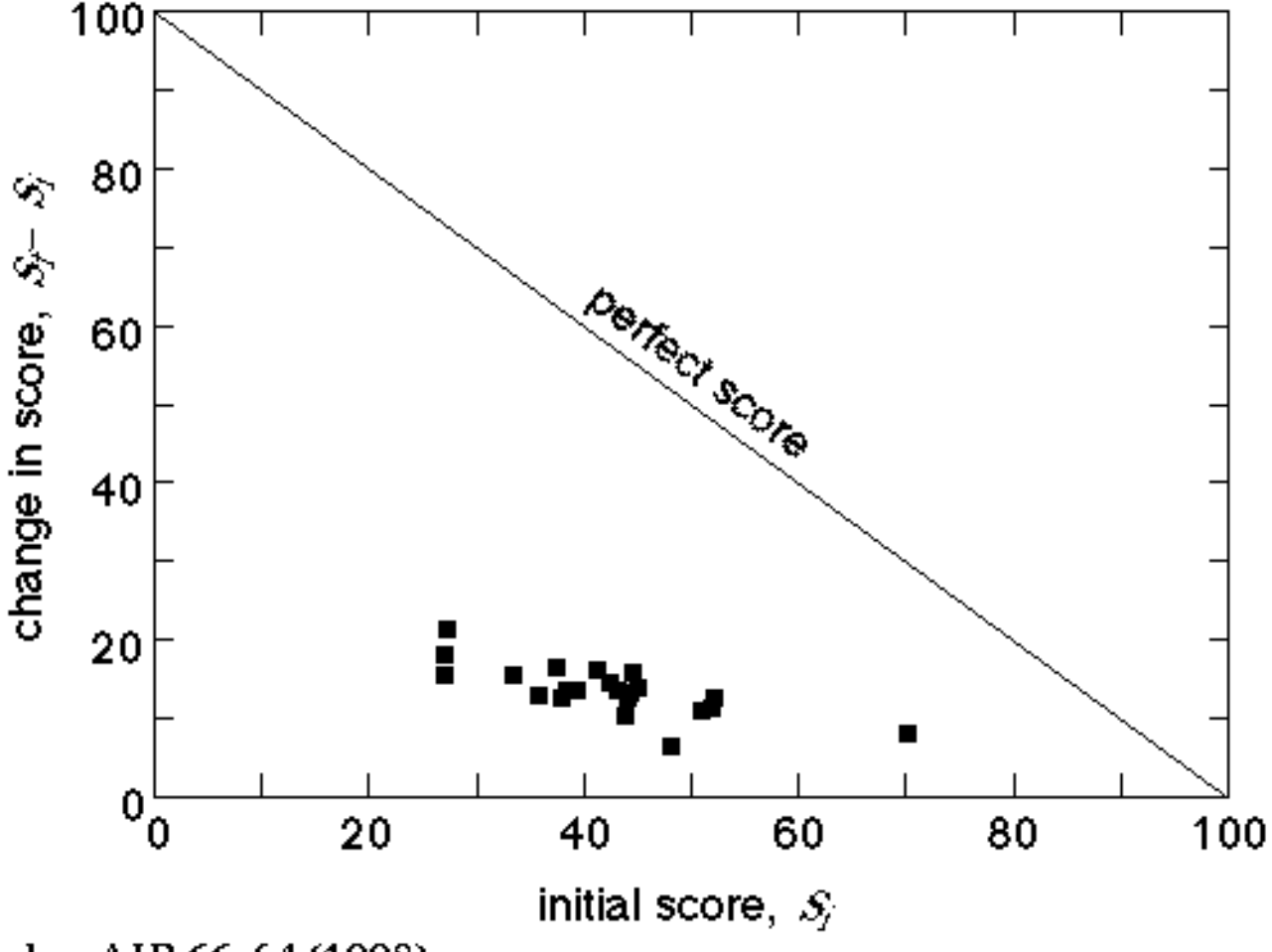
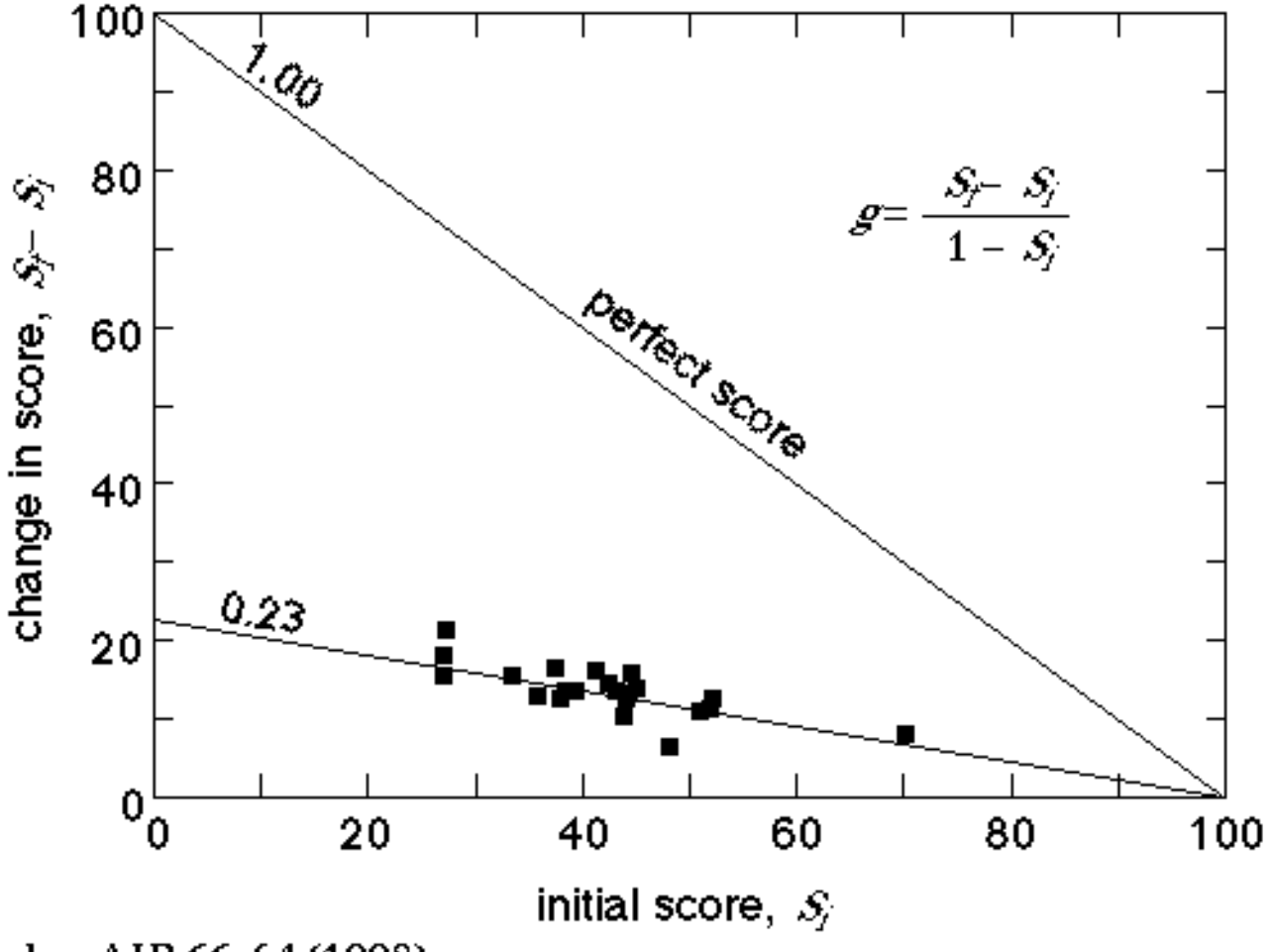
initial score, S_i
perfect score

THE CAUSE



☞ Hake, AJP **66**, 64 (1998)

THE CAUSE



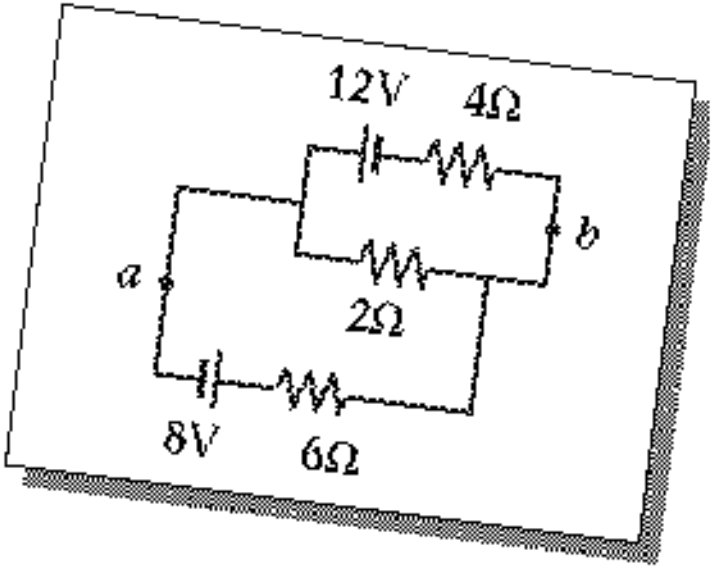
☞ Hake, AJP **66**, 64 (1998)

2. Conventional problems reinforce bad study habits

Calculate:

(*a*) the current in the 2-Ω resistor, and

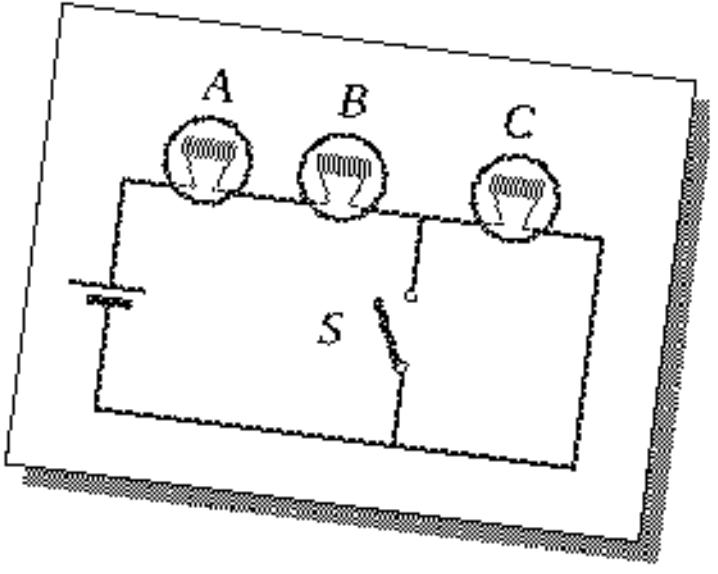
(*b*) the potential difference between points *a* and *b*.



Are basic principles understood?

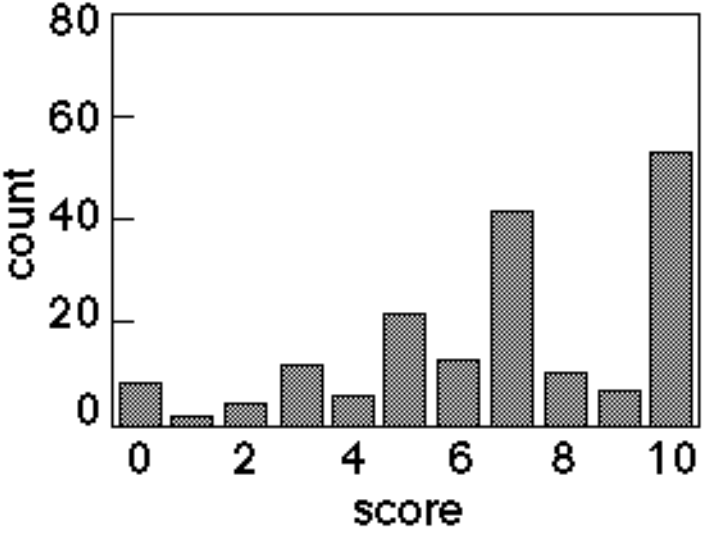
When S is closed, what happens to the:

(a) intensities of A and B?
(b) intensity of C?
(c) current through battery?
(d) voltage drop across A, B, and C?
(e) total power dissipated?

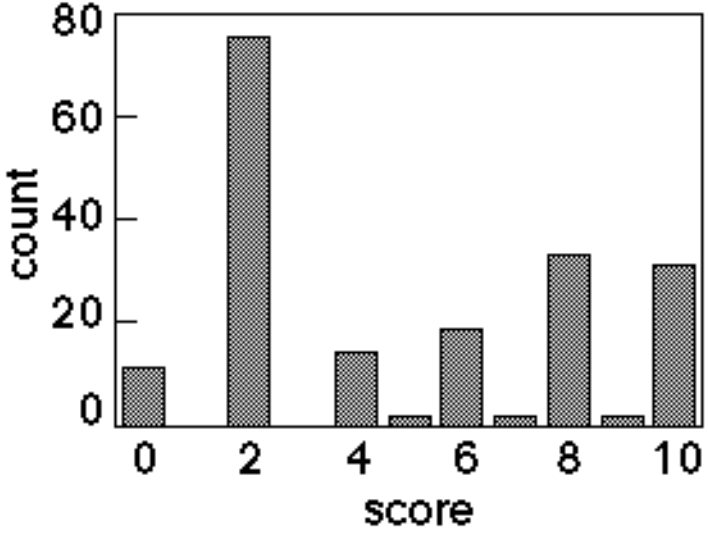


THE CAUSE

conventional



conceptual



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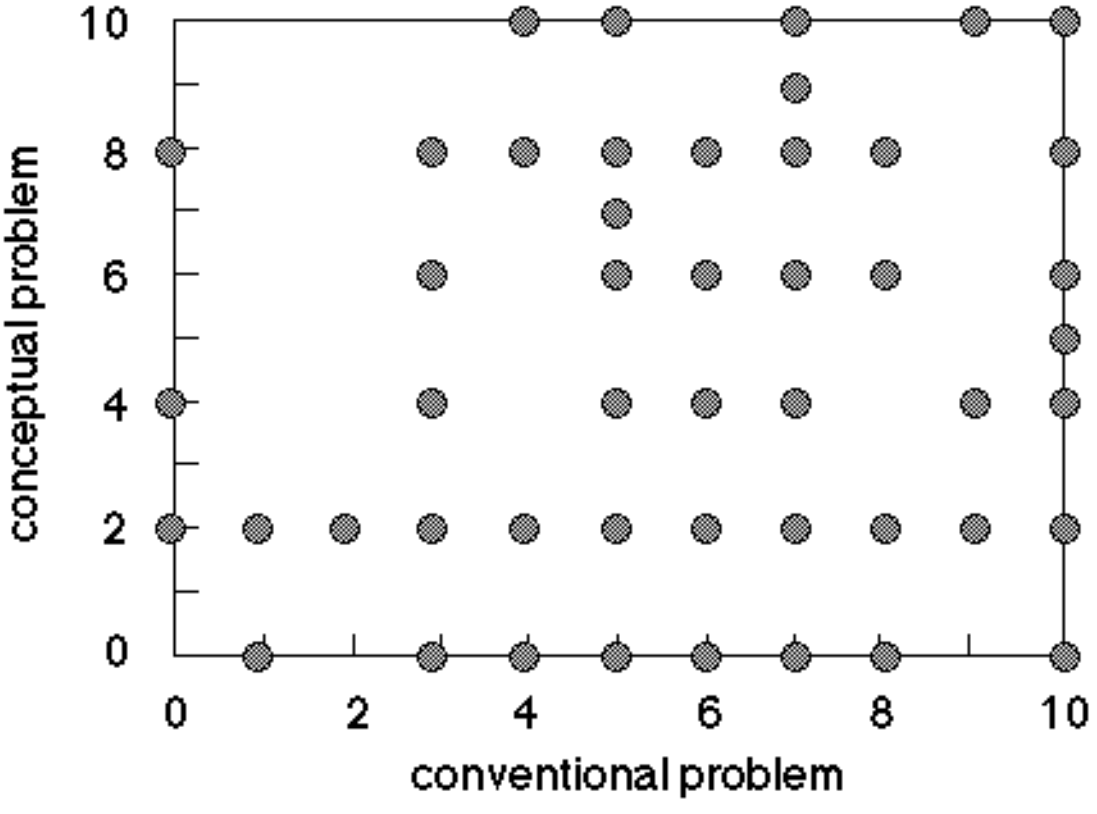
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2
0
conceptual problem
0
2
4
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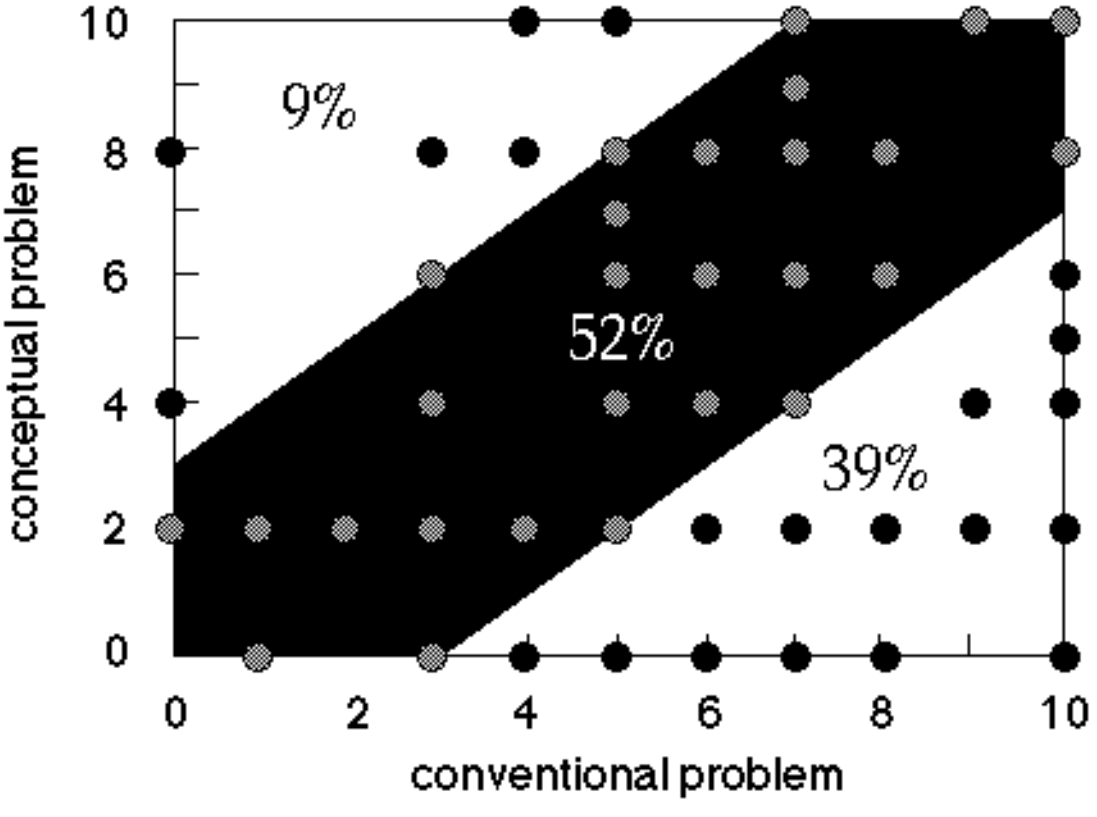
8
10
conventional problem

THE CAUSE


10
8
6
4
2
0
conceptual problem
9%
52%
39%
0
2
4
6
8
10
conventional problem

❶ Problem

❷ Cause

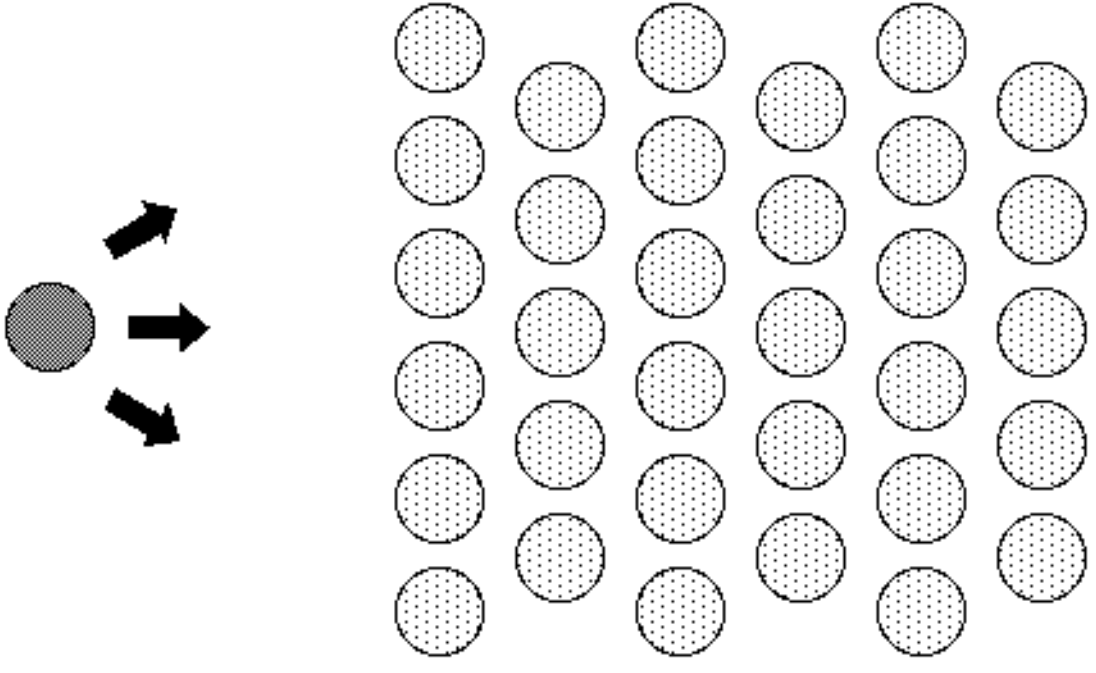
❸ Remedy

PEER INSTRUCTION

Give students more responsibility for learning!

PEER INSTRUCTION

1. Recognize the inefficacy of the lecture method!



PEER INSTRUCTION

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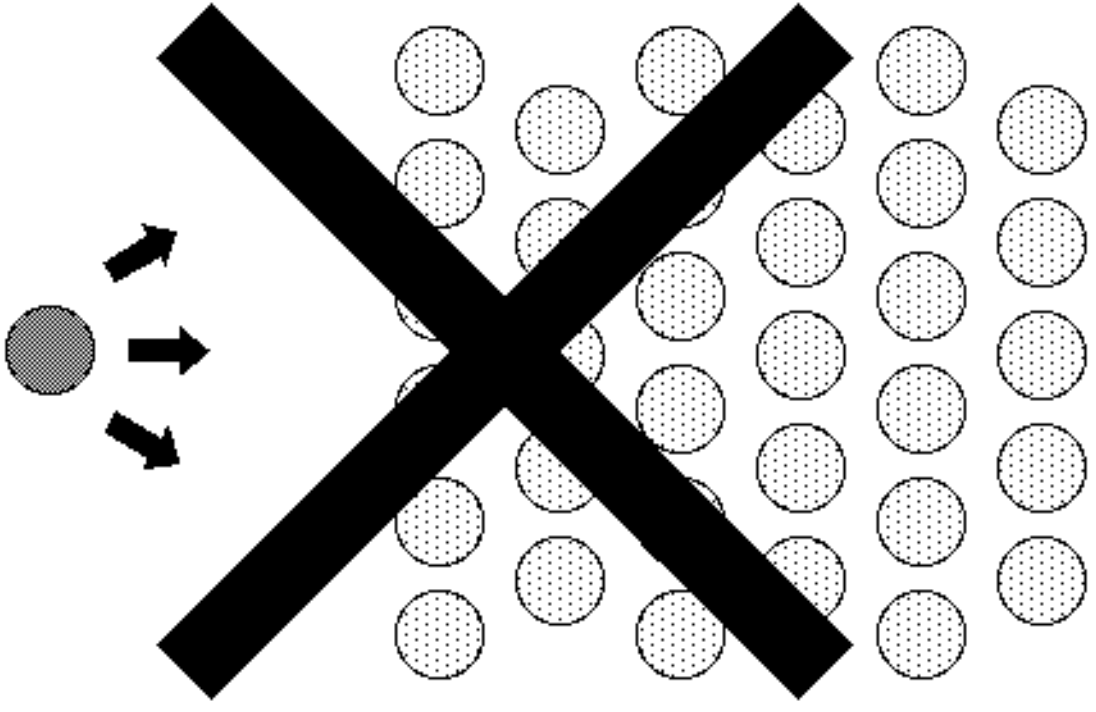
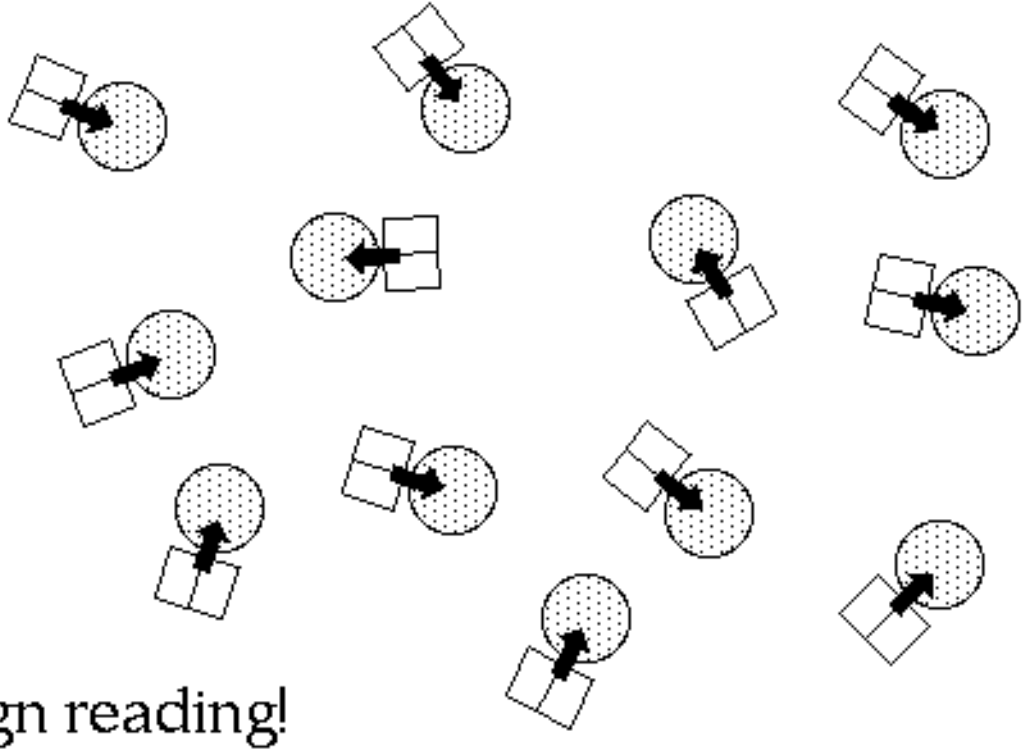


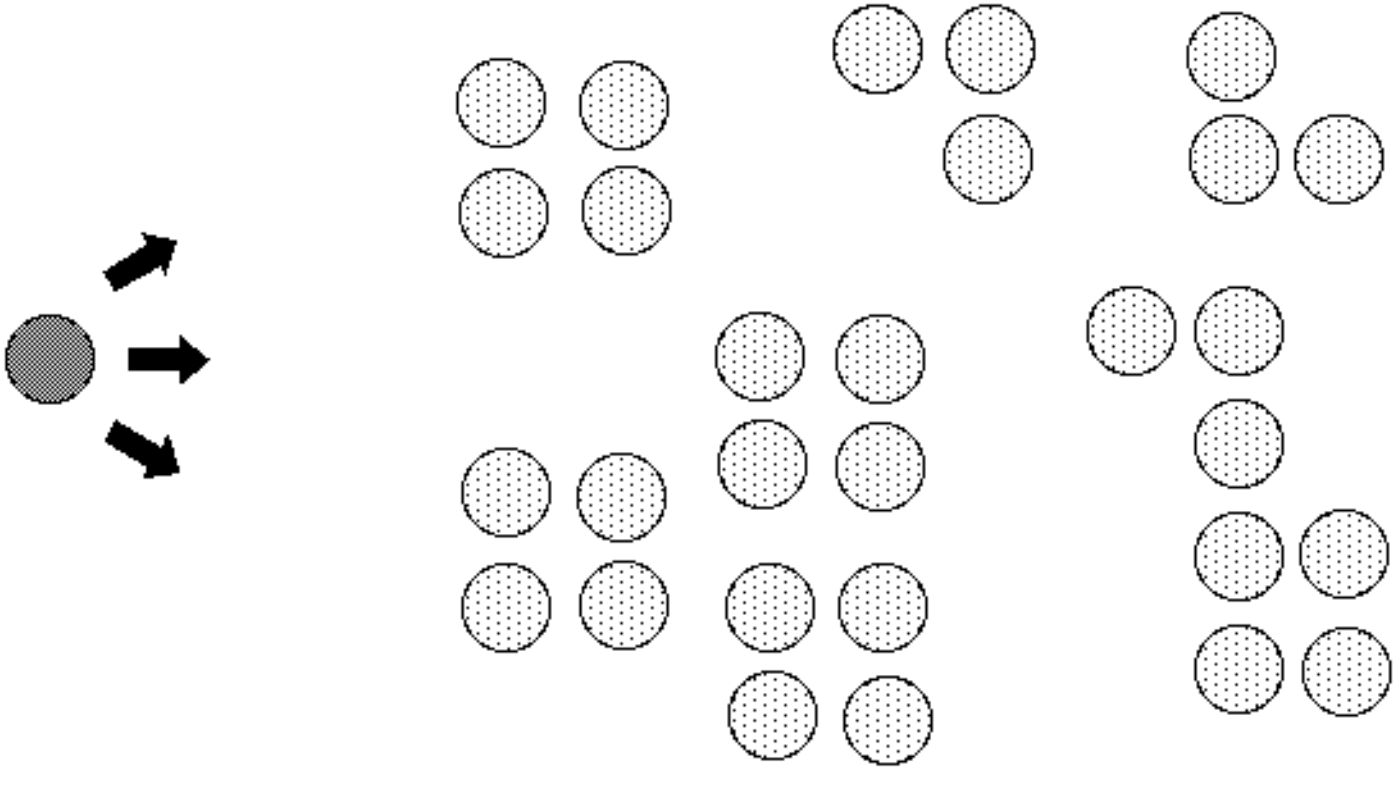
2. Move first exposure to material **out of classroom**



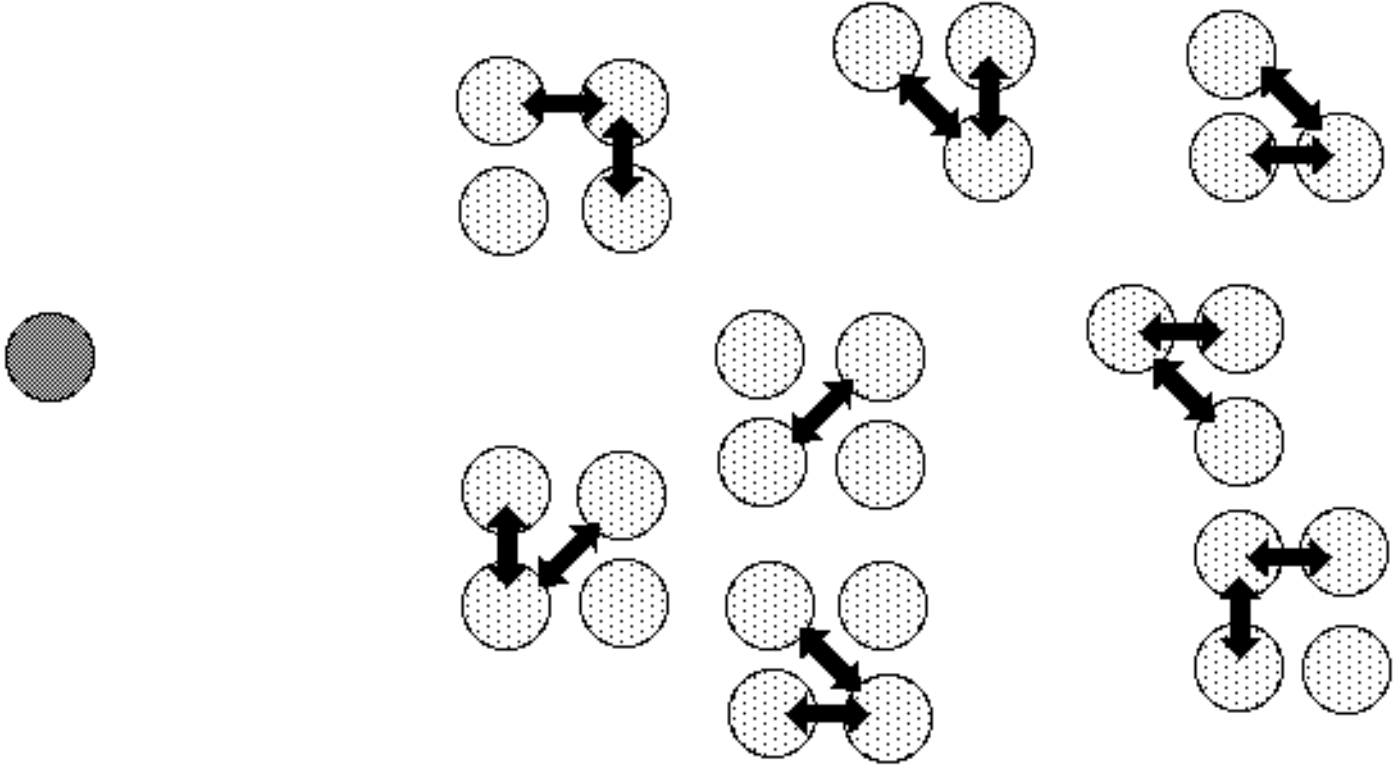
...assign reading!

3. Use class to deepen and broaden understanding

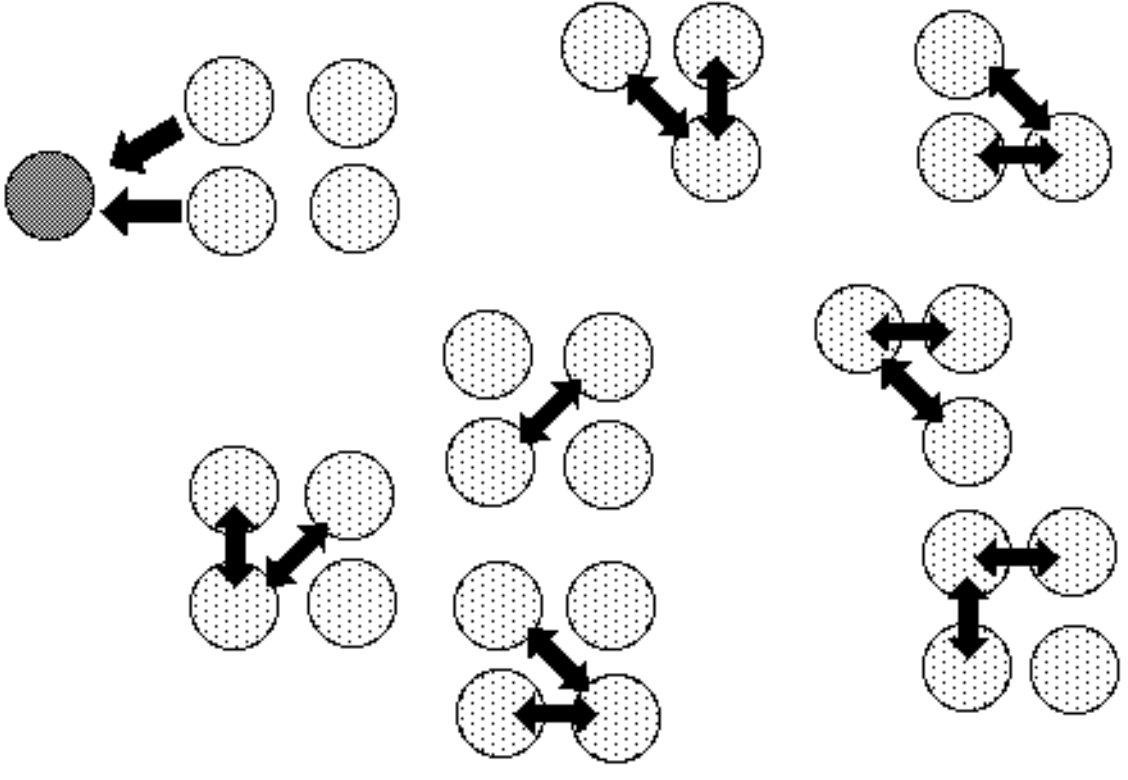
... by transferring some **additional** information ...



... and by giving students opportunities to **think**.



Better yet: **Learn** from your students ...



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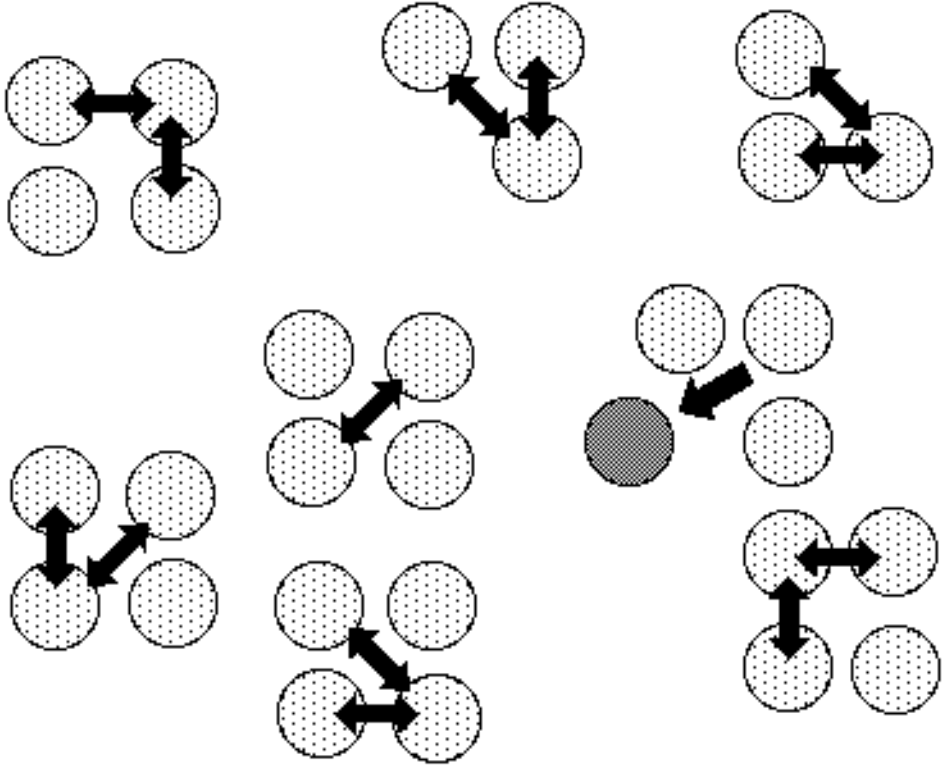

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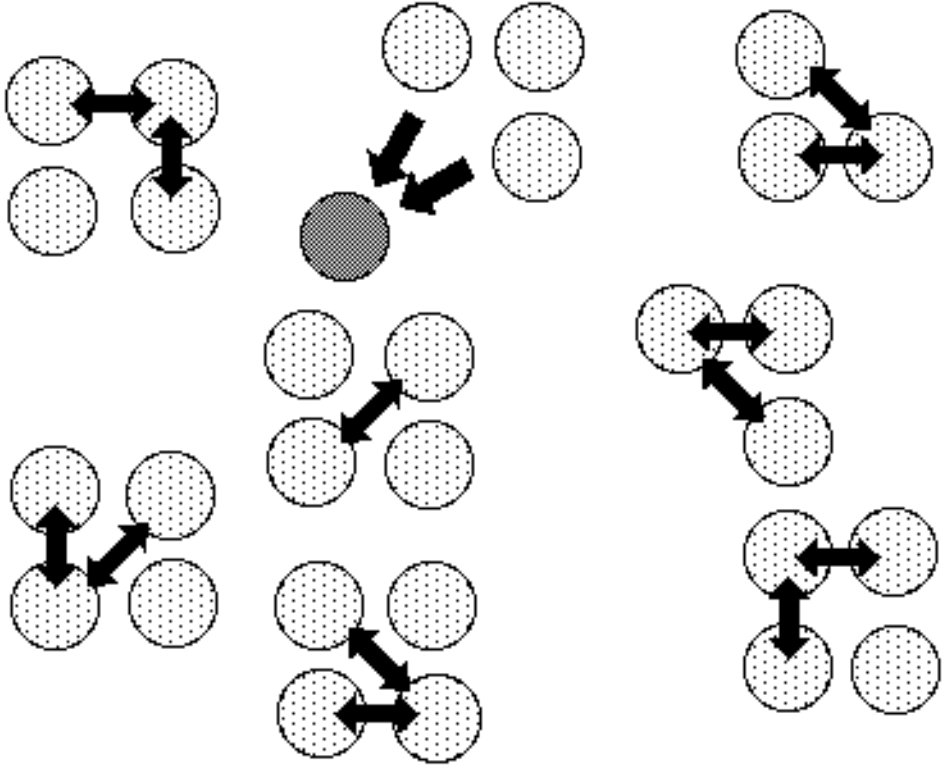
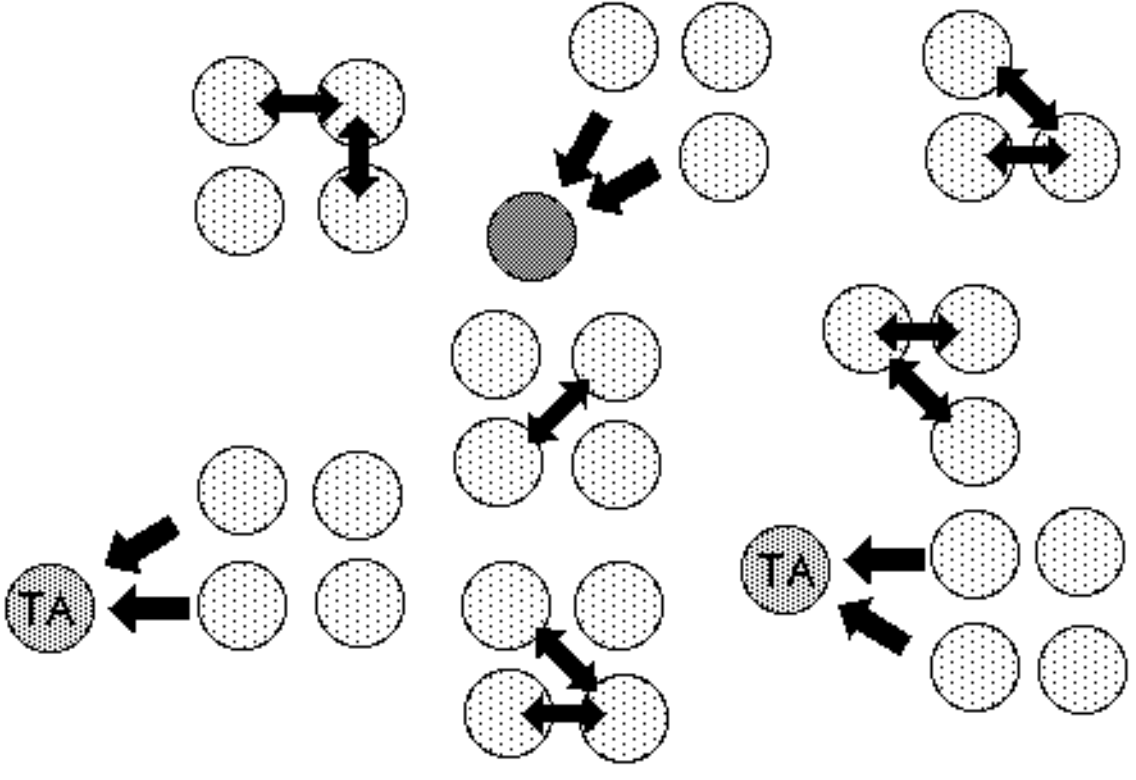


... bring in your **Teaching Assistants** too...!



PEER INSTRUCTION

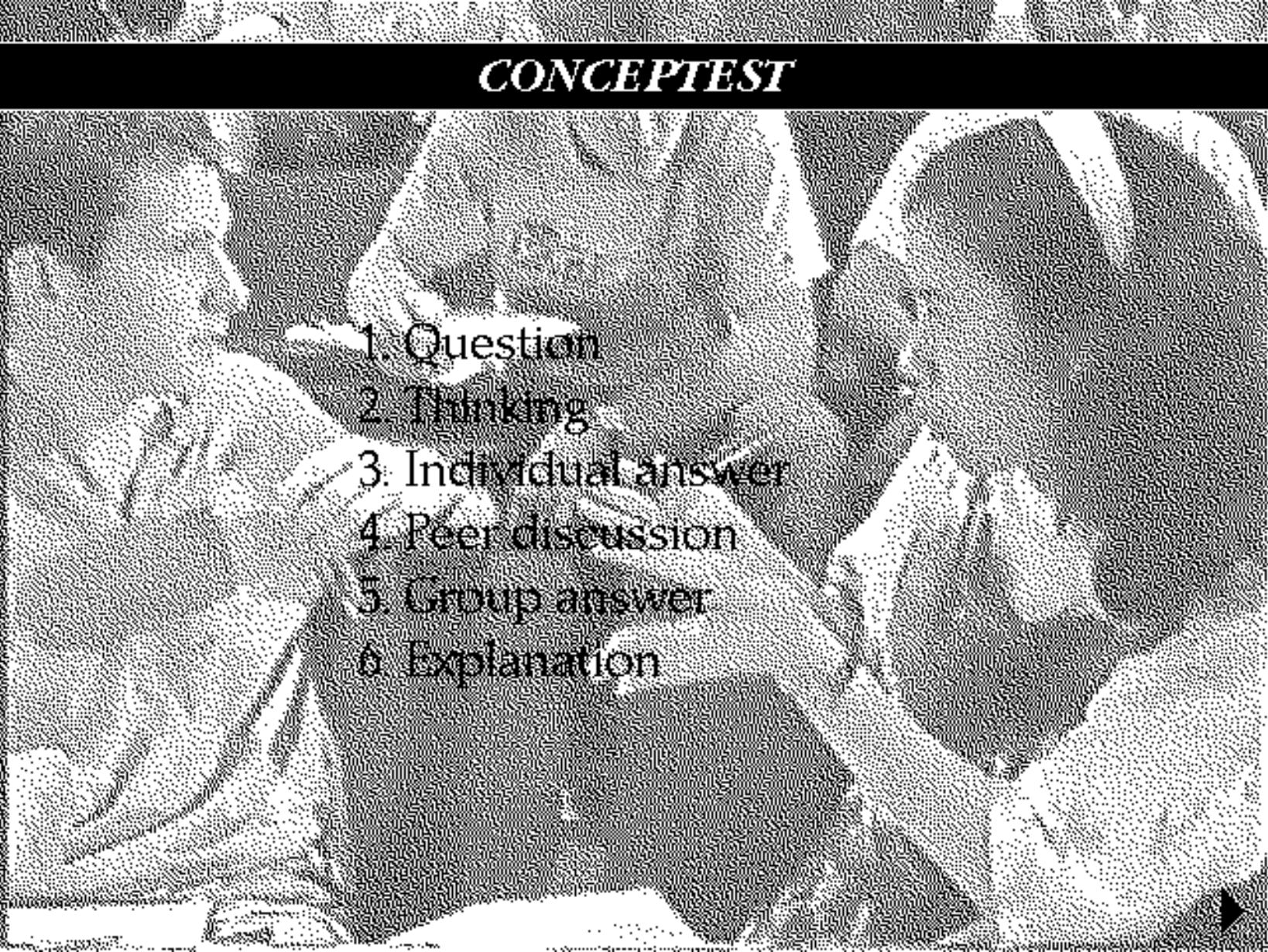
Main features:

- Pre-class reading
- In class: depth, not coverage
- ConcepTests

CONCEPTEST

1. Question
2. Thinking
3. Individual answer
4. Peer discussion
5. Group answer
6. Explanation

CONCEPTEST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2. Thinking
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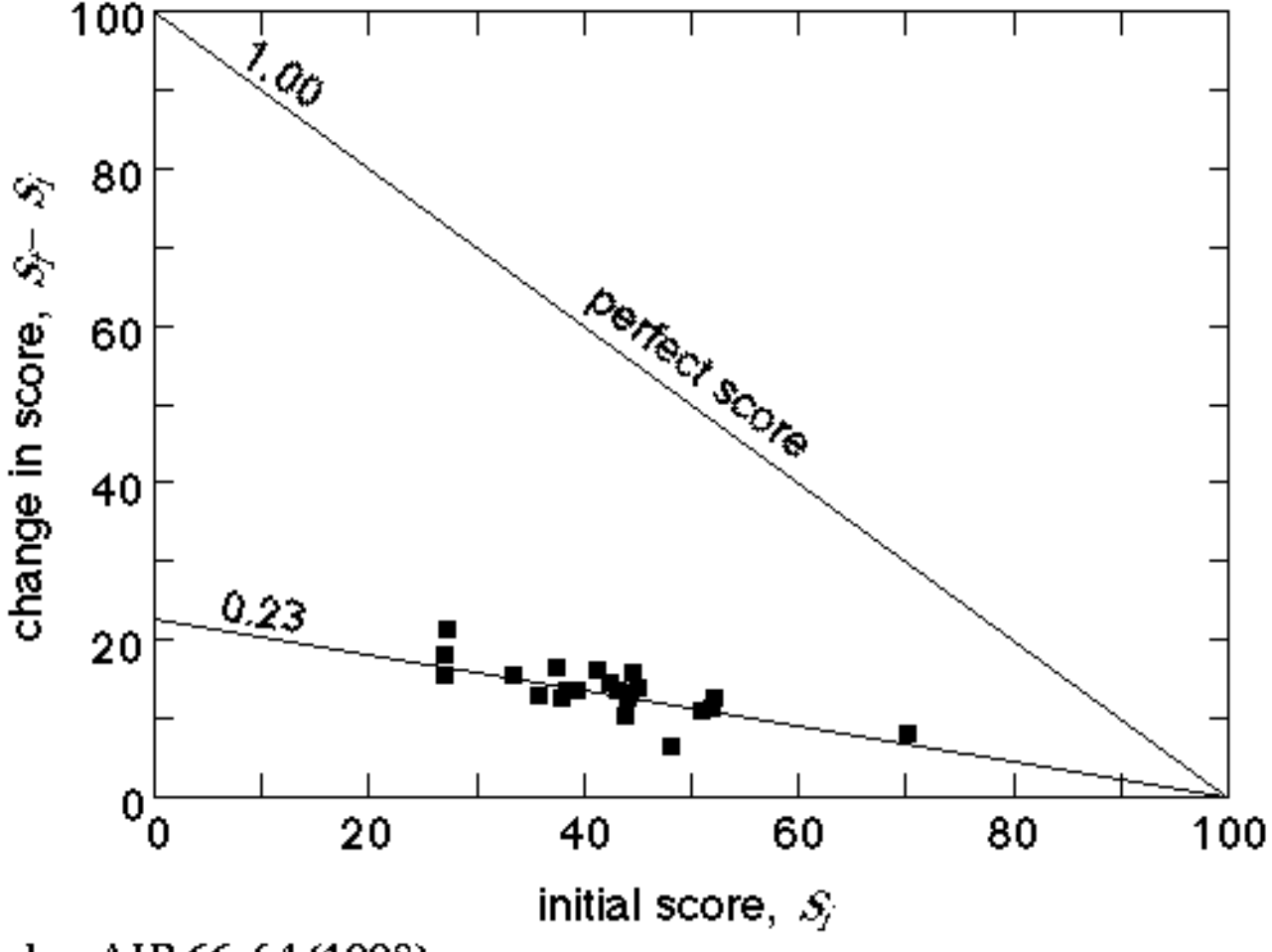
6. Explanation

CONCEPTEST

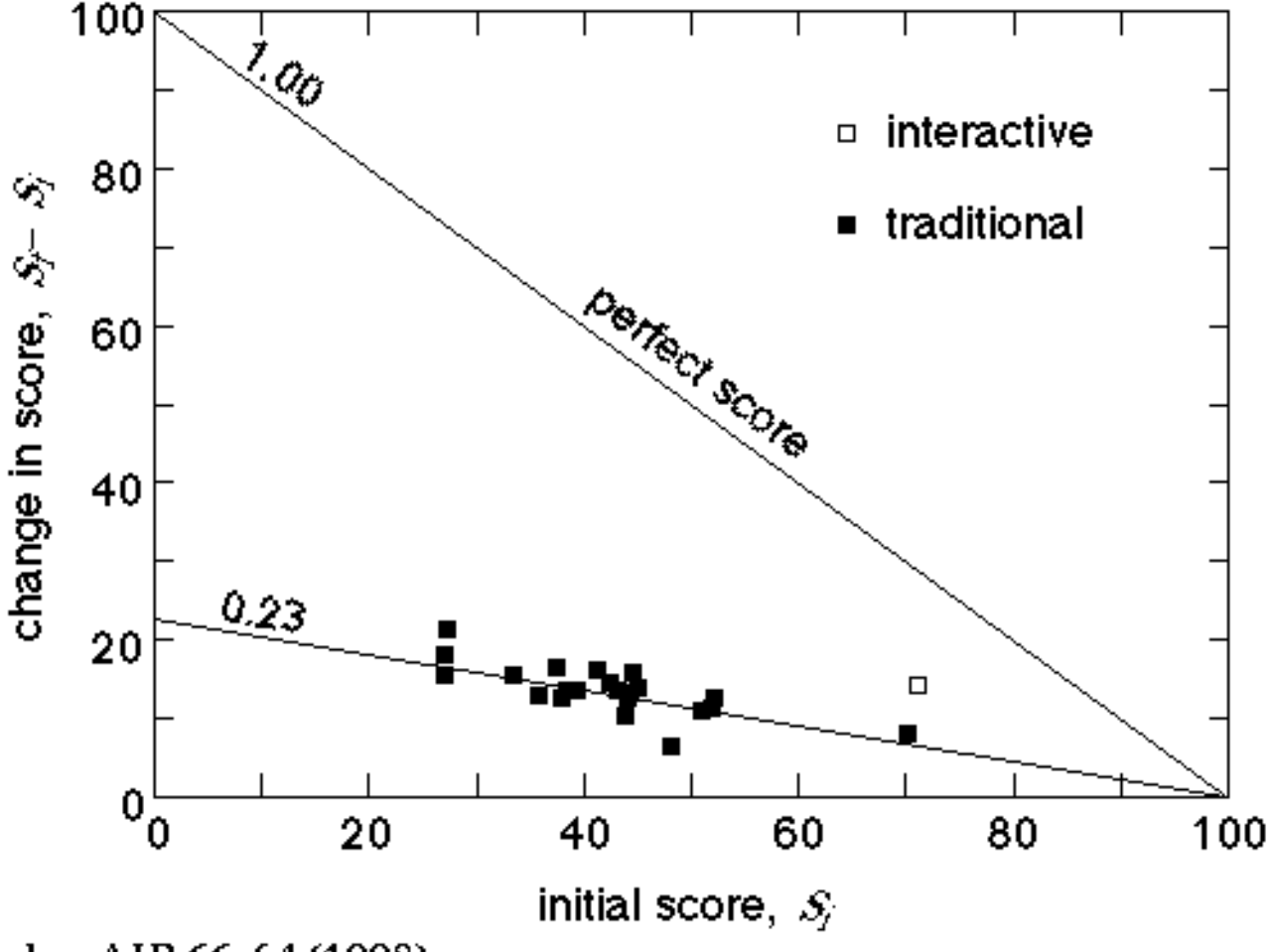
1. Results
2. Student reactions

RESULTS



☞ Hake, AJP **66**, 64 (1998)

RESULTS



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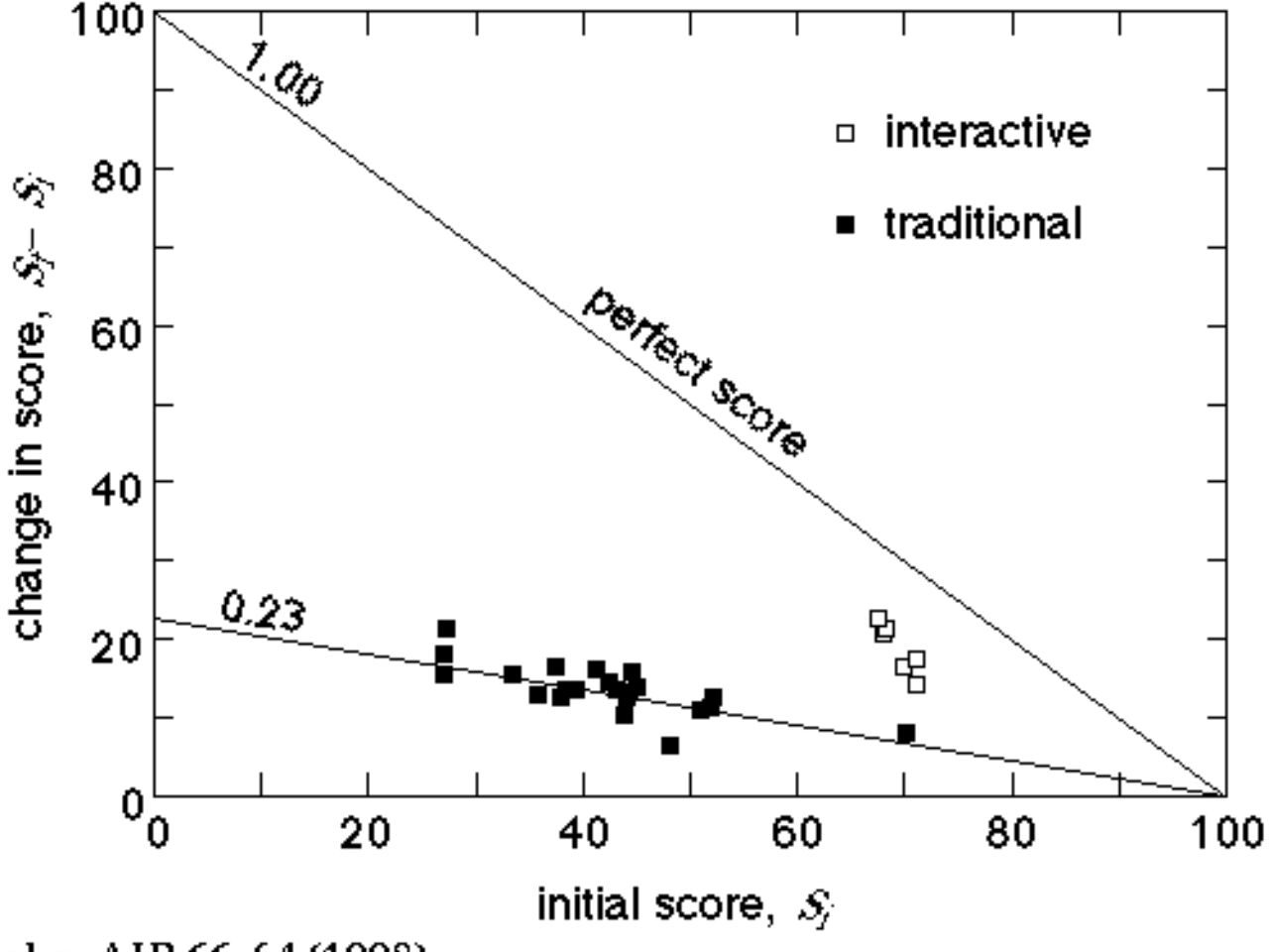

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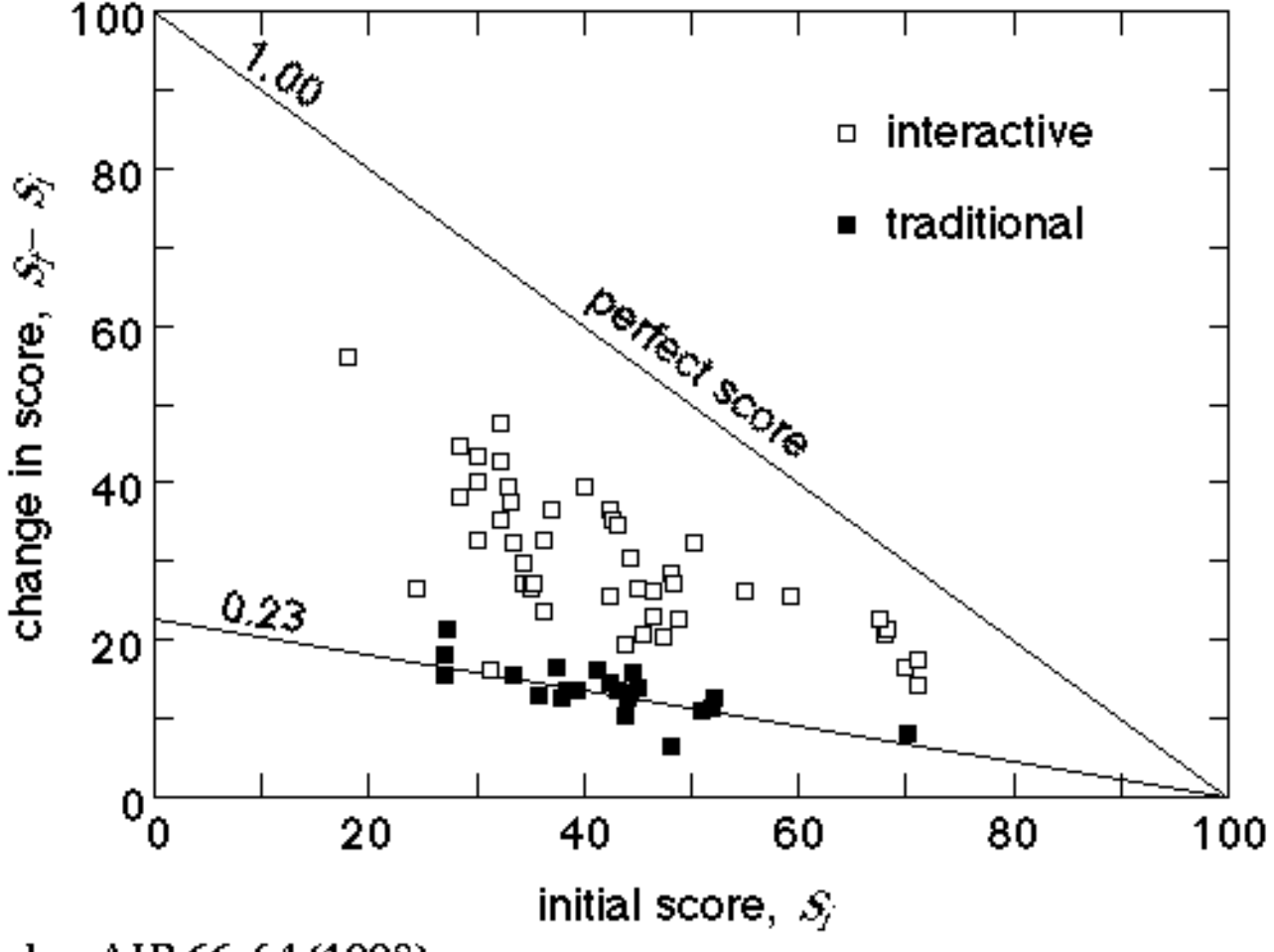

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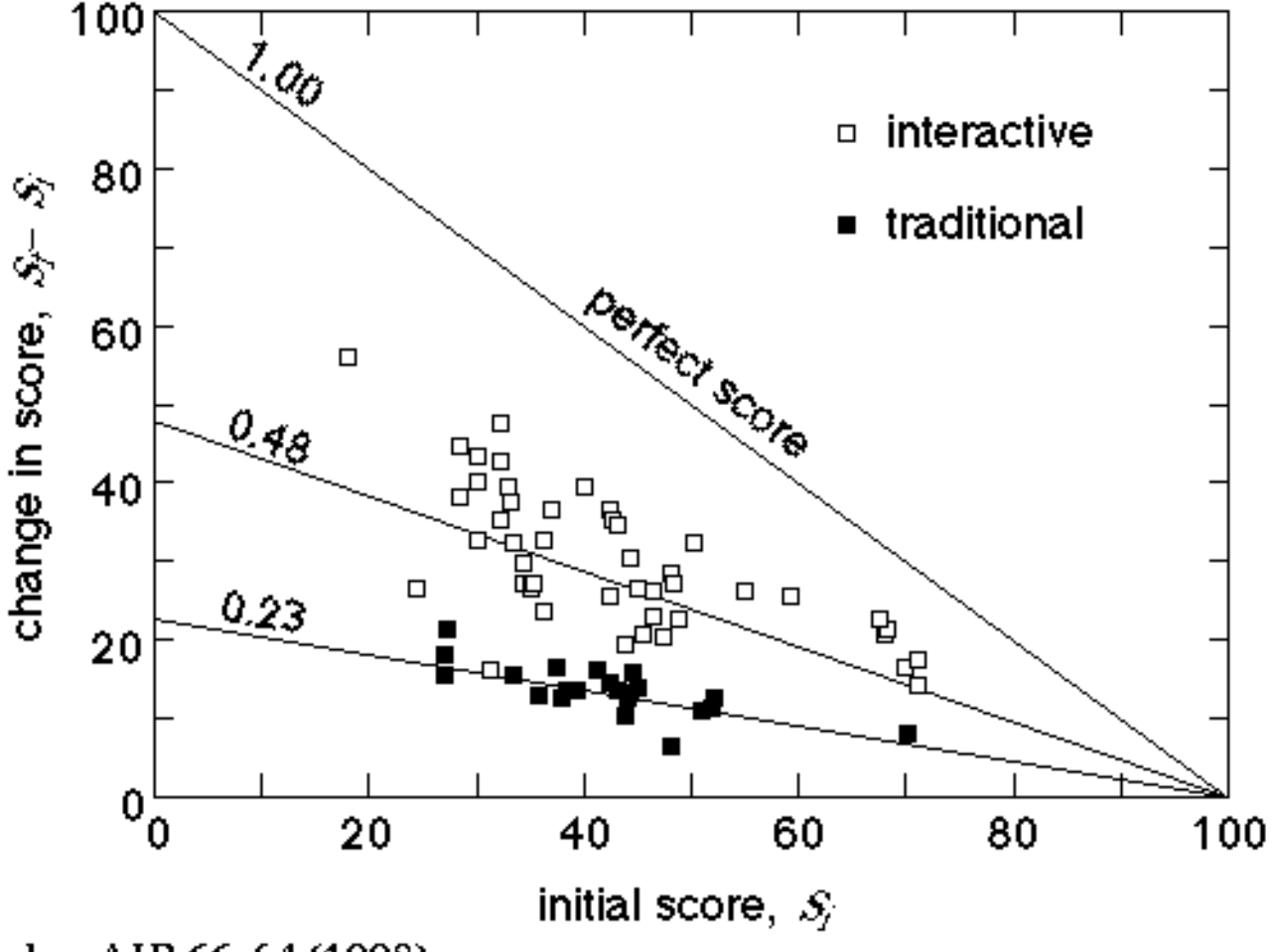
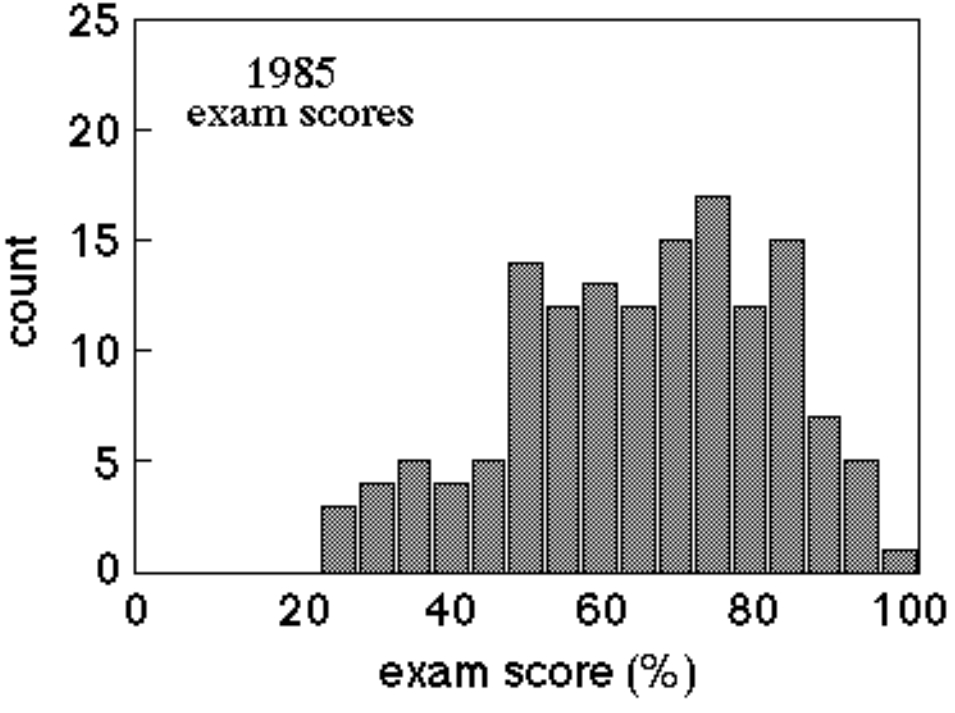


☞ Hake, AJP **66**, 64 (1998)

RESULTS

What about problem solving...?

RESULTS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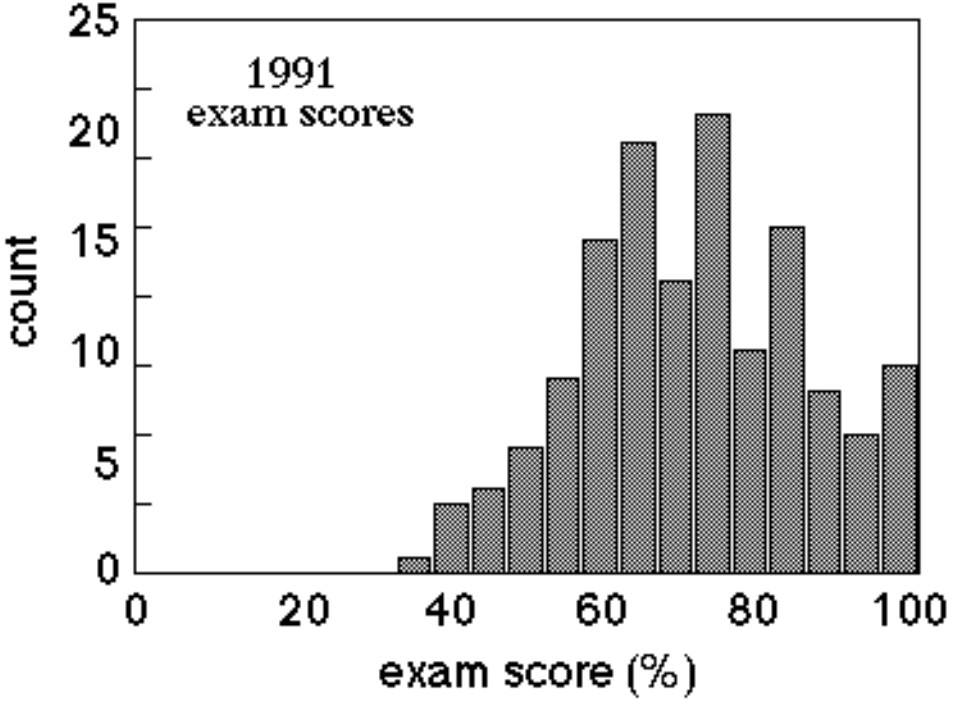
exam scores
count
exam score (%)
0
5
10
15
20
25
0
20
40
60
80
100

RESULTS


1991
exam scores
count
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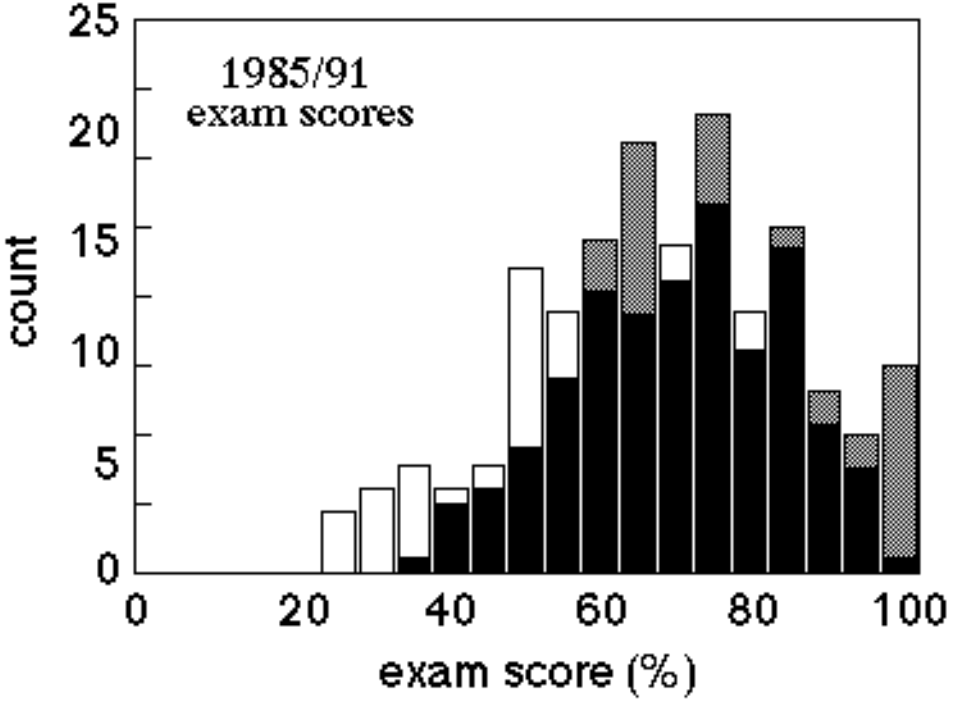
80
100
exam score (%)

RESULTS


1985/91
exam scores
count
exam score (%)
0
5
10
15
20
25
0
20
40
60
80
100

RESULTS

So, better understanding leads to better problem solving ...

RESULTS

So, better understanding leads to better problem solving ...

(but "good" problem solving doesn't always indicate understanding!)

1. Results
2. Student reactions

STUDENT REACTIONS

Why does it work?

Students:

- gets them thinking
- helps uncover misunderstandings
- boosts confidence

Faculty:

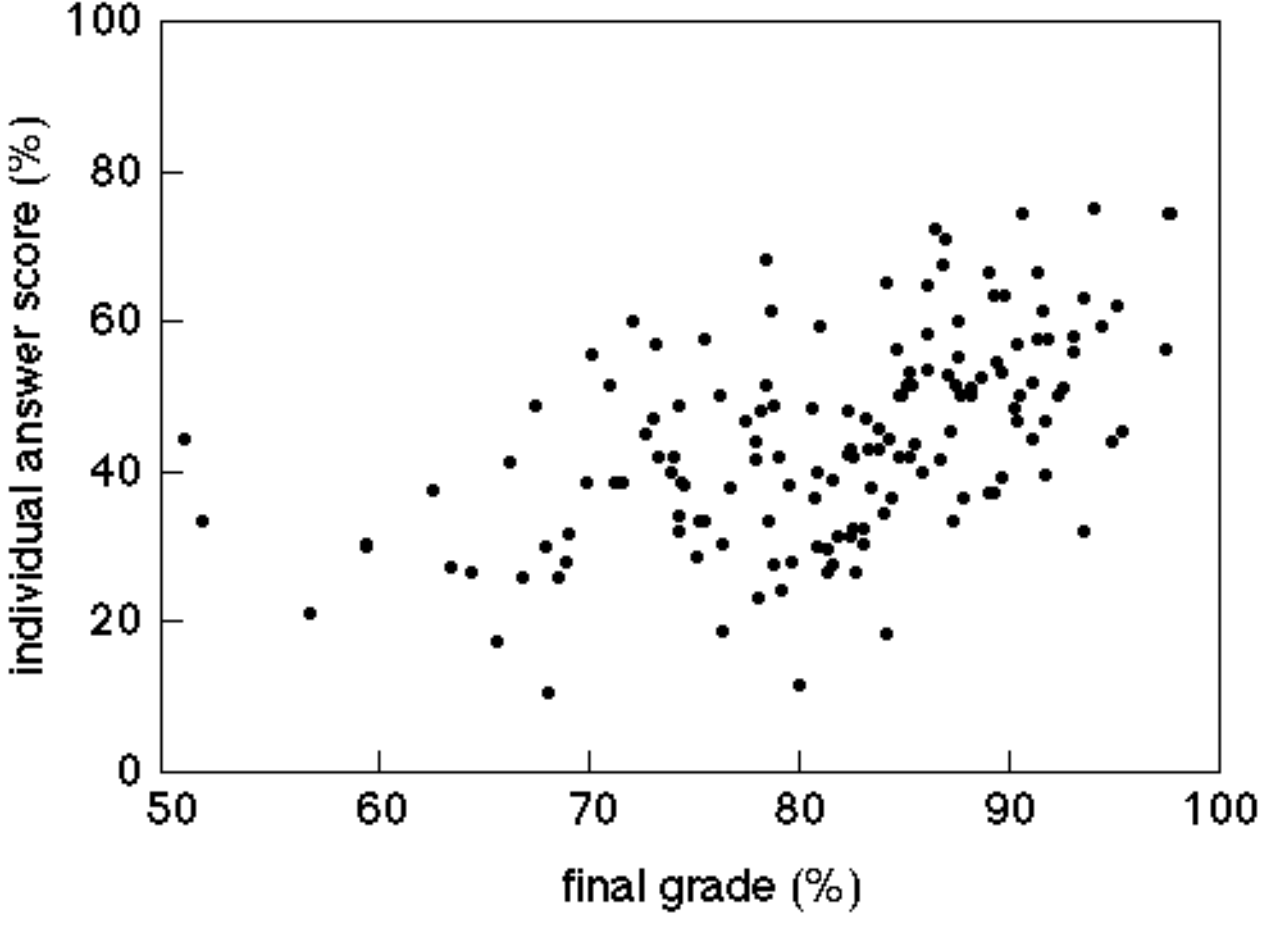
- change of format, not content
- with existing questions, little effort
- adaptable

Catherine Crouch (Harvard)
Deborah Alpert (Harvard)
Michael Aziz (Harvard)
William Paul (Harvard)
Tim Bozik (Prentice Hall)
David Hestenes (ASU)

Additional information:

http://galileo.harvard.edu

WHO BENEFITS?



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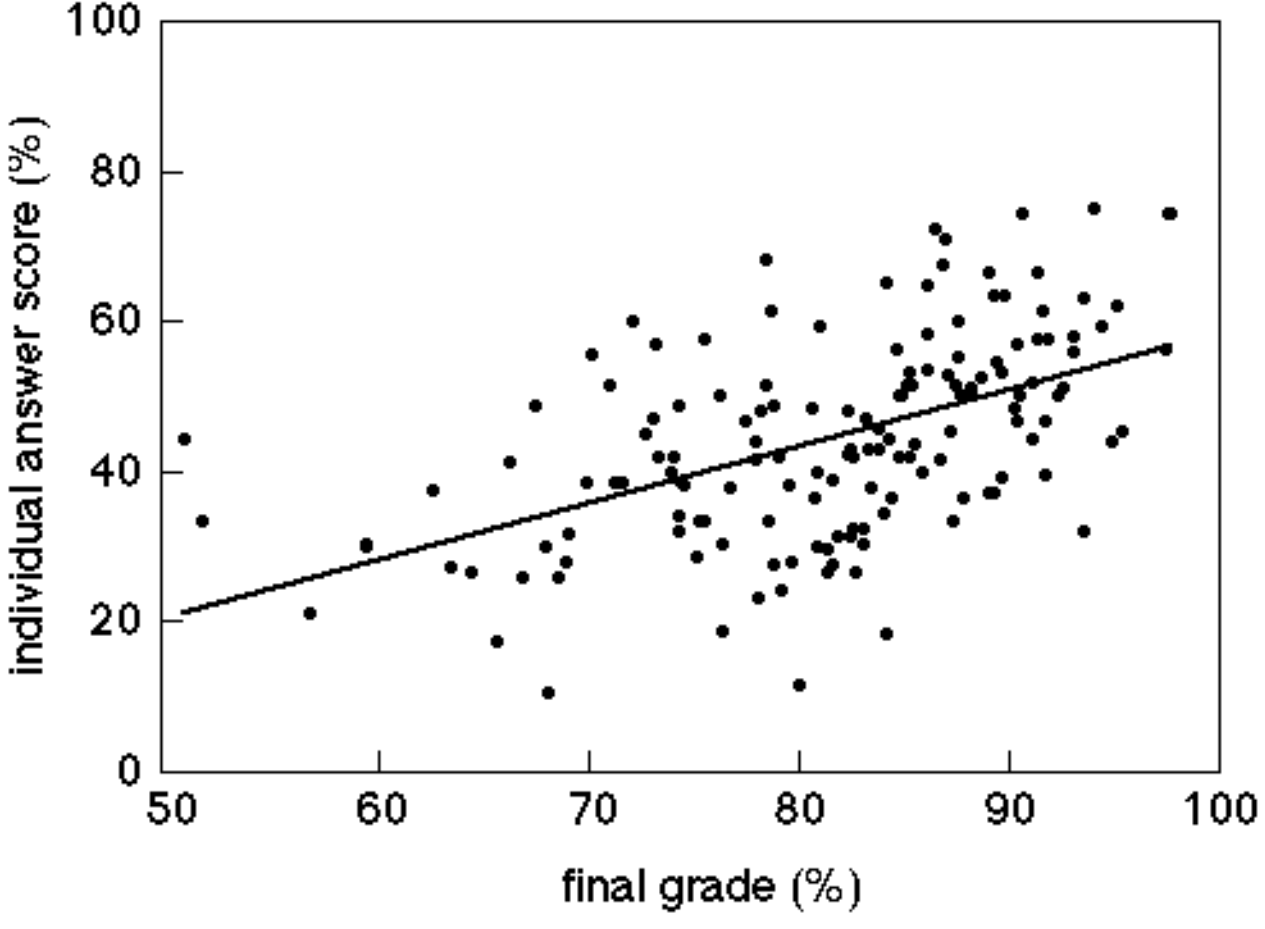

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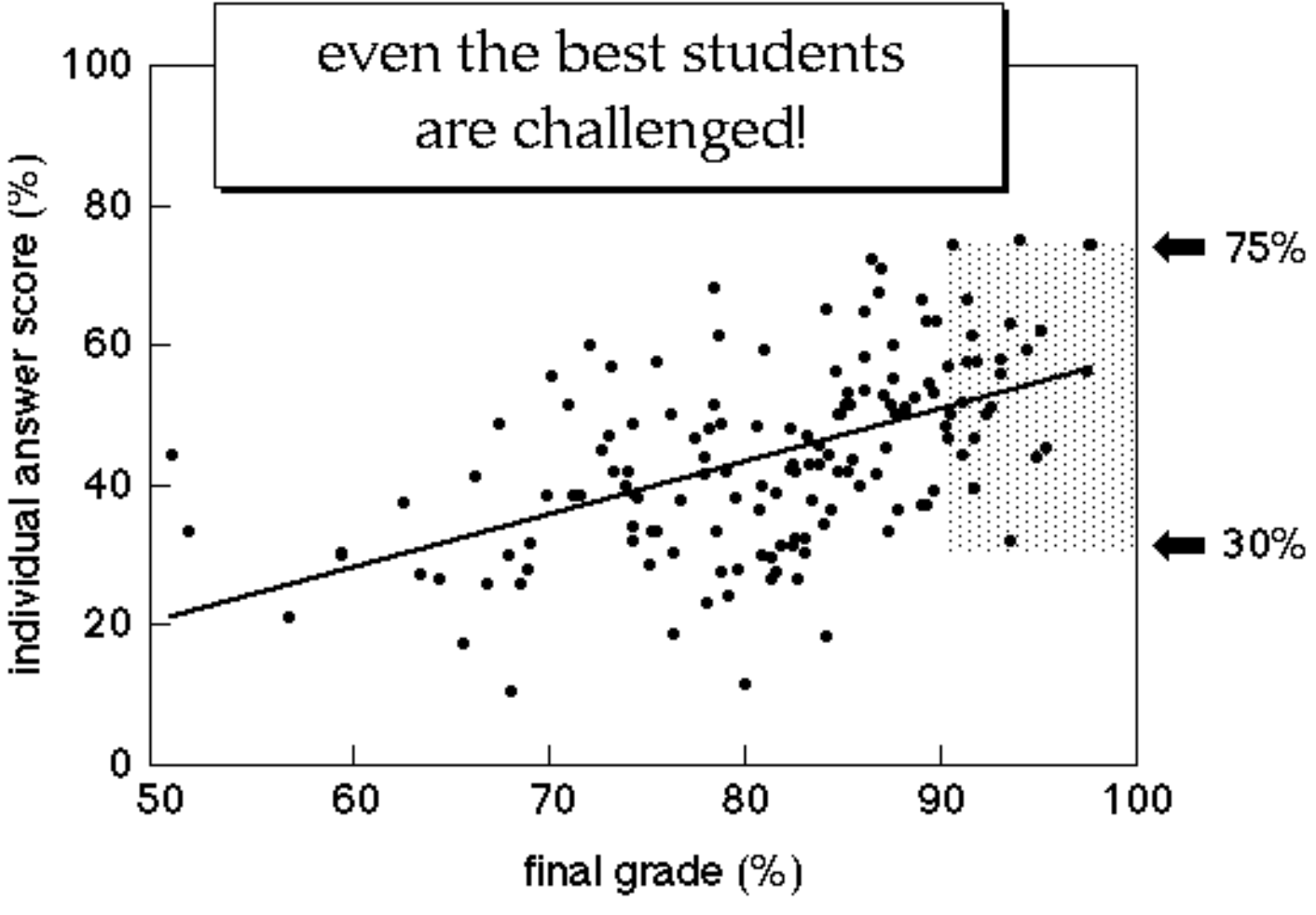

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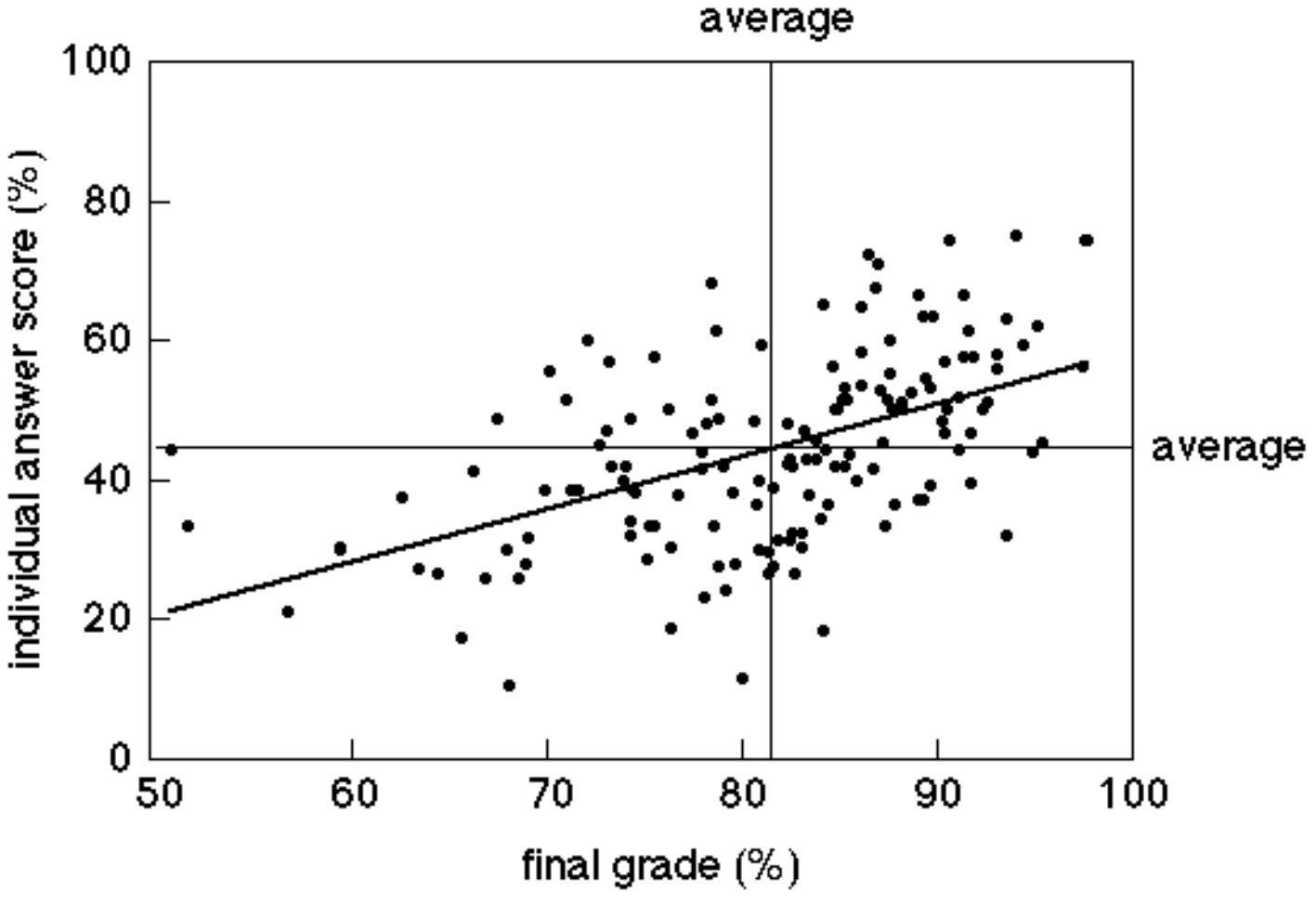

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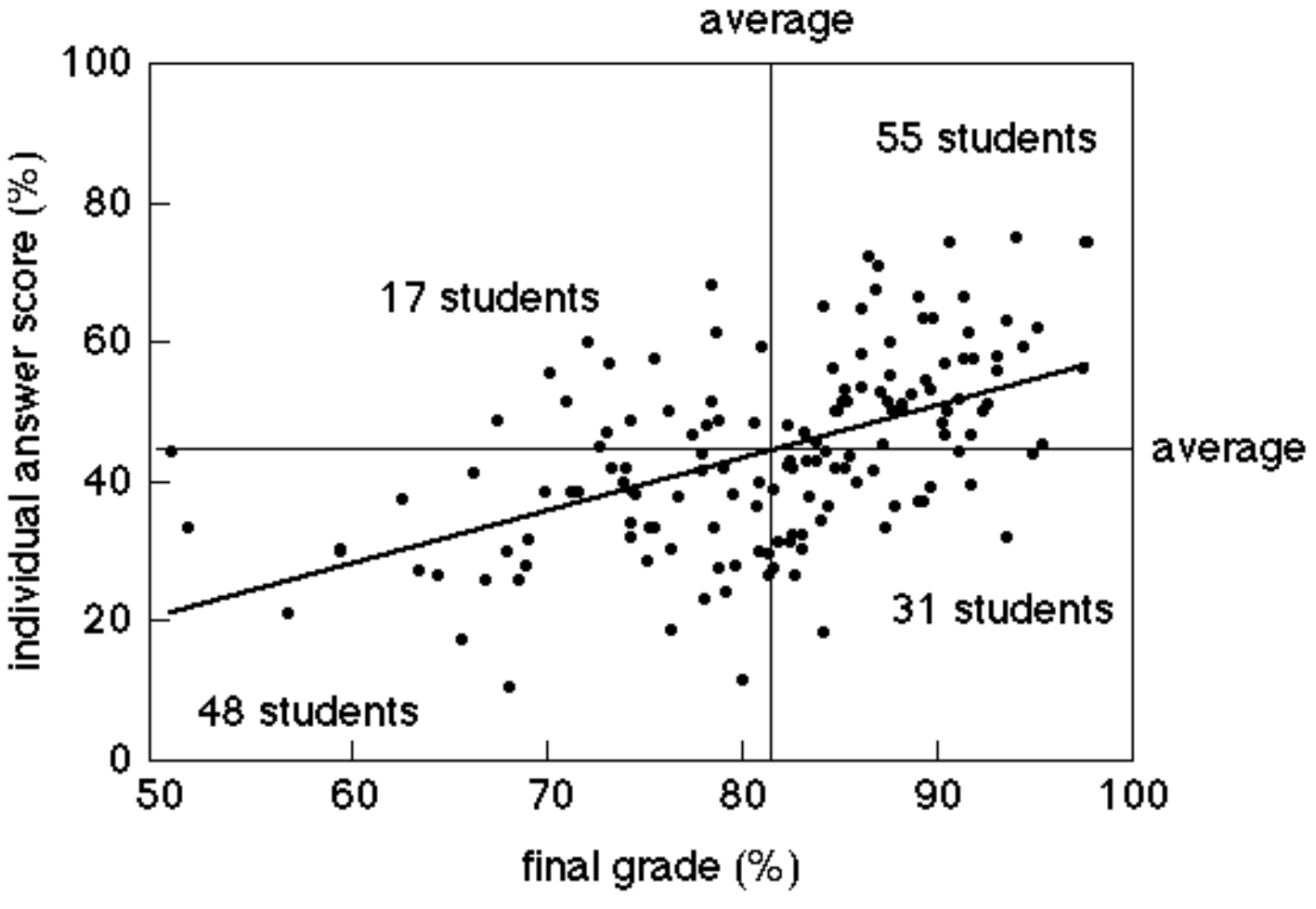

ESSENTIAL ELEMENTS

❶ Reading (before class)

❷ Participation (during class)

❸ Problem-solving (after class)

❹ Appropriate testing/assessment

READING

Incentive: Web-based assignment due night before class

- two free-response questions on content
- "What did you find difficult or confusing about the reading?"

Instructor benefit:

- learns what students find difficult
- turn student difficulties into ConcepTests

☞ *Just-in-time teaching* (Evelyn Patterson, USAFA)

READING

Quality of reading and assignment matters!

Class	FCI pre	reading	assignment	correct
11a (F96)	0.68	standard	summaries	83%
11a (F97)	0.68			
1a (F98)	0.49			

READING

Quality of reading and assignment matters!

Class	FCI pre	reading	assignment	correct
11a (F96)	0.68	standard	summaries	83%
11a (F97)	0.68	new	summaries	89%
1a (F98)	0.49	new	responses	82%

READING

Reading:

- is a valuable skill
- provides multiple exposure
- is self-paced

Textbooks can be edited (but lectures can't)

PROMOTING PARTICIPATION

- Motivate students
- Choose appropriate questions
- Poll students for answers
- Reward participation

CHOOSING GOOD QUESTIONS

- Focus on a key concept

- Engage student interest

  demonstrations

  real-life situations

  magic/intrigue

- Identify student difficulties (research)

  use optimum (35–65%) range

  use typical student responses

RESOURCES

Peer Instruction: A User's Manual
Eric Mazur (Prentice Hall, 1997)

http://galileo.harvard.edu

POLLING METHODS

Methods:

- show of hands
- flashcards
- classroom network

Trade-offs:

- anonymity
- cost
- complexity and reliability

REWARDING STUDENTS

- Reward participation

  credit for reading contingent on participation

  conceptual and quantititave questions on exams

- Don't penalize collaboration

  noncompetitive grading

  promote group work on homework

PROBLEM SOLVING

- Home work

  mostly quantitative problems

  20% of final grade

- Workshops (discussion sections)

  tutorial worksheets

  instructor demonstrates one problem

  group work on difficult homework problems

THE PROBLEM WITH PROBLEMS

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. You circle around, but there are no empty spots. You decide to wait at one end of the lot, where you can see (and command) about 20 spaces.

THE PROBLEM WITH PROBLEMS

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area. You circle around, but there are no empty spots. You decide to wait at one end of the lot, where you can see (and command) about 20 spaces. On average people shop for about 2 hours.

THE PROBLEM WITH PROBLEMS

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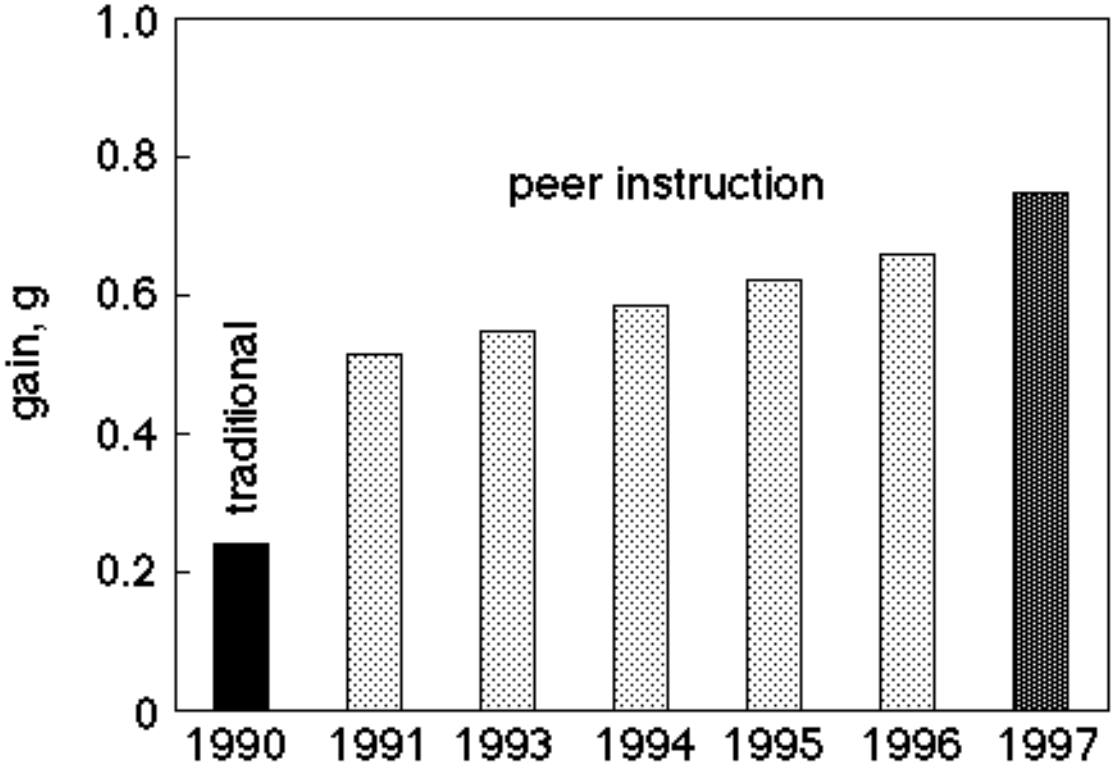
THE PROBLEM WITH PROBLEMS

On a Saturday afternoon, you pull into a parking lot with unmetered spaces near a shopping area where people are known to shop, on average, for two hours. You circle around, but there are no empty spots. You decide to wait at one end of the lot, where you can see (and command) about 20 spaces.

How long do you have to wait before someone frees up a space?

TRADITIONAL VS. PEER INSTRUCTION



COVERAGE

Traditional lecture:

- "covers" a lot
- students retain little

Peer Instruction:

- less material treated in class
  (reading & lecture *can* still cover the same)
- students learn more

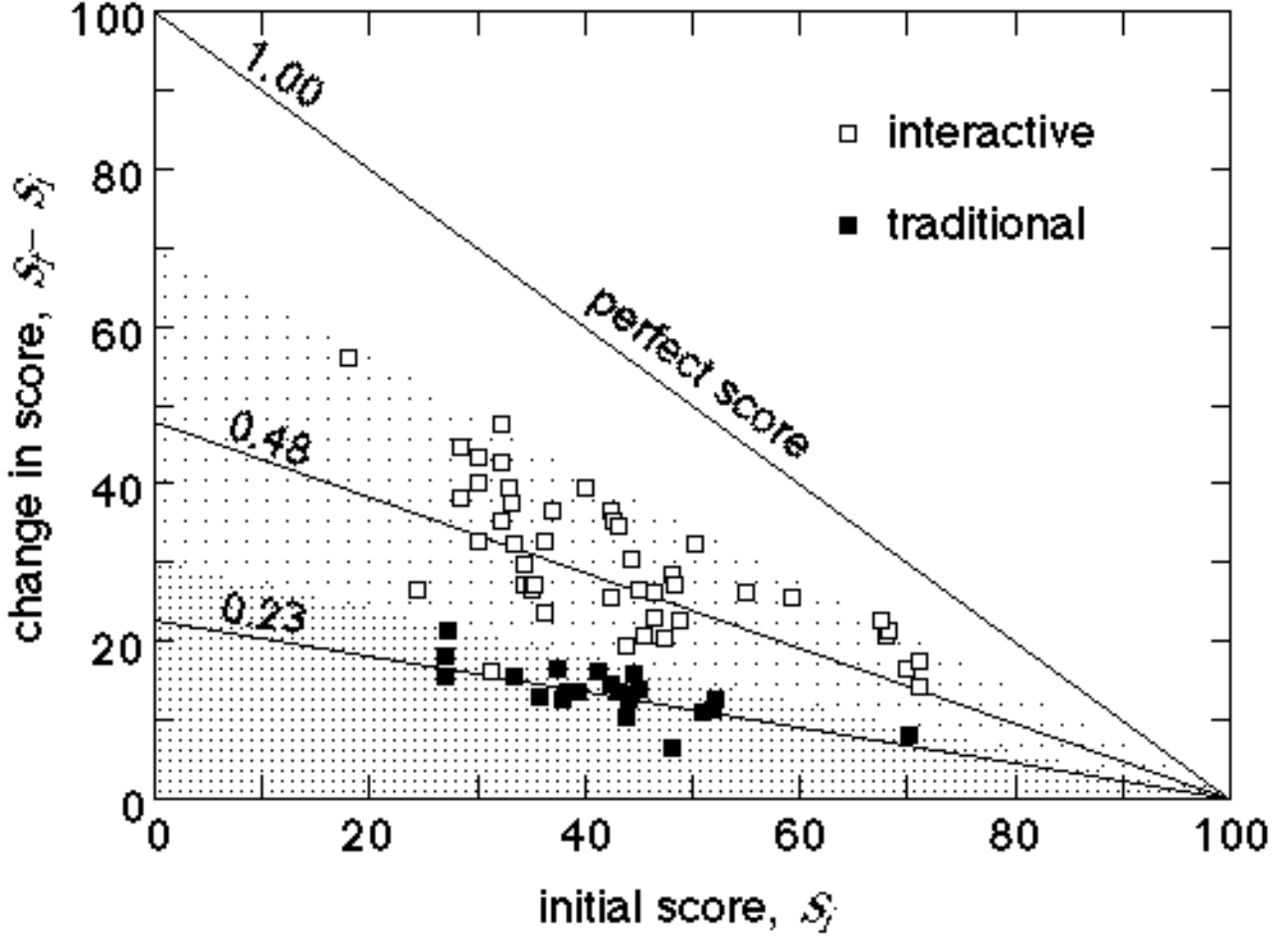
EFFECTIVE TIME MANAGEMENT

Time allotment:

• "lecturing"	1/3 – 1/2
• ConcepTests (incl. explanations)	1/2 – 2/3

ConcepTest: 10–15 minutes

• Read question	1 minute
• Individual thinking	1 minute
• Discussion (listen, don't talk!)	2–3 minutes
• Explanation	as necessary


100
80
60
40
20
0
0
20
40
60
80
100
change in score, $S_f - S_i$
initial score, S_i
1.00
0.48
0.23
perfect score
interactive
traditional

INDEX

Unlock index

STATISTICS

Print Stats

Save Stats

Clear Stats

• 193 rd AAS Meeting (1/7/99)

START AT 11:57:34 AM – Title page (0:00:00)
0:00:00 – index (0:00:04)
0:00:05 – CT Movie (0:00:04)
0:00:10 – IS IT ANY GOOD? (0:00:14)
0:00:25 – Student Reactions (0:00:04)
0:00:29 – WHY DOES IT WORK? (0:00:01)
0:00:30 – index (0:00:06)
0:00:37 – CT Movie (0:00:00)
0:00:38 – index (0:00:02)
0:00:40 – ConcepTest (0:00:02)
0:00:42 – CT Movie (0:00:28)
0:01:11 – IS IT ANY GOOD? (0:00:07)
0:01:18 – Student Reactions (0:00:01)
0:01:19 – index
START AT 12:35:08 PM – Title page

• 193 rd AAS Meeting (1/7/99)

START AT 12:42:36 PM – Title page (0:00:06)
0:00:06 – Statistics (0:00:02)
0:00:09 – index
START AT 12:42:44 PM – Title page
START AT 12:44:25 PM – Title page (0:08:38)
0:06:56 – OUTLINE (0:01:53)
0:08:50 – PROBLEM (0:01:58)
0:10:48 – Pepsi commercial (0:01:53)
0:12:41 – Gibberish (0:02:45)
0:15:27 – Trent Lott (0:03:20)
0:18:47 – Waste of time (0:00:10)