Decoding the Literature

Scholarship of Teaching & Learning Network (SoTL)

Presented by:

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Decoding the Literature

Interactive vs. Traditional methods of lecturing

May 2, 2022   12PM-130PM

Online seminar & discussion

Who am I?

Current role: Academic Developer, Scholarship of Teaching & Learning

Learning & Teaching Team – Institute for Academic Development

- BSc and MSc in Geology from Carleton University and University of British Columbia (Canada)
- PhD in Geoscience Education from University of Canterbury (NZ)
- Research interests:
  - authentic and situated learning (sociology),
  - inclusive pedagogies,
  - volcanology and natural hazards education,
  - academic development,
  - philosophy of higher education and its future

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What does Scholarship of Teaching & Learning mean to you?

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Decoding the Literature series

Why? Extensive history and catalogue of education literature; can be jargon rich.

How does it work? Reading & discussion series. Read the article; I will summarise and we will discuss together

Question for you all:

What types of literature would you like to hear about in future sessions? What topics? Think about it, let me know.

Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses

Richard R. Hake[a)]
Department of Physics, Indiana University, Bloomington, Indiana 47405

(Received 6 May 1996; accepted 4 May 1997)

A survey of pre/post-test data using the Halloun–Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory is reported for 62 introductory physics courses enrolling a total number of students $N=6542$. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a
conceptual understanding is tak
ratio of the actual average gai
$-\%\langle pre\rangle$). Fourteen ''traditi

How did you go reading this article?

interactive-engagement (IE) methods achieved an average gain $\langle g\rangle_{T\text{-ave}}=0.23\pm0.04$ (std dev). In sharp contrast, 48 courses ($N=4458$) which made substantial use of IE methods achieved an average gain $\langle g\rangle_{IE\text{-ave}}=0.48\pm0.14$ (std dev), almost two standard deviations of $\langle g\rangle_{IE\text{-ave}}$ above that of the traditional courses. Results for 30 ($N=3259$) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes–Wells imply that IE strategies enhance problem-solving ability. The conceptual and problem-solving test results strongly suggest that the classroom use of IE methods can increase mechanics-course effectiveness well beyond that obtained in traditional practice.

Full citation: Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American journal of Physics*, *66*(1), 64-74.

Introduction & context

First year physics teaching; Mid-1990s; USA

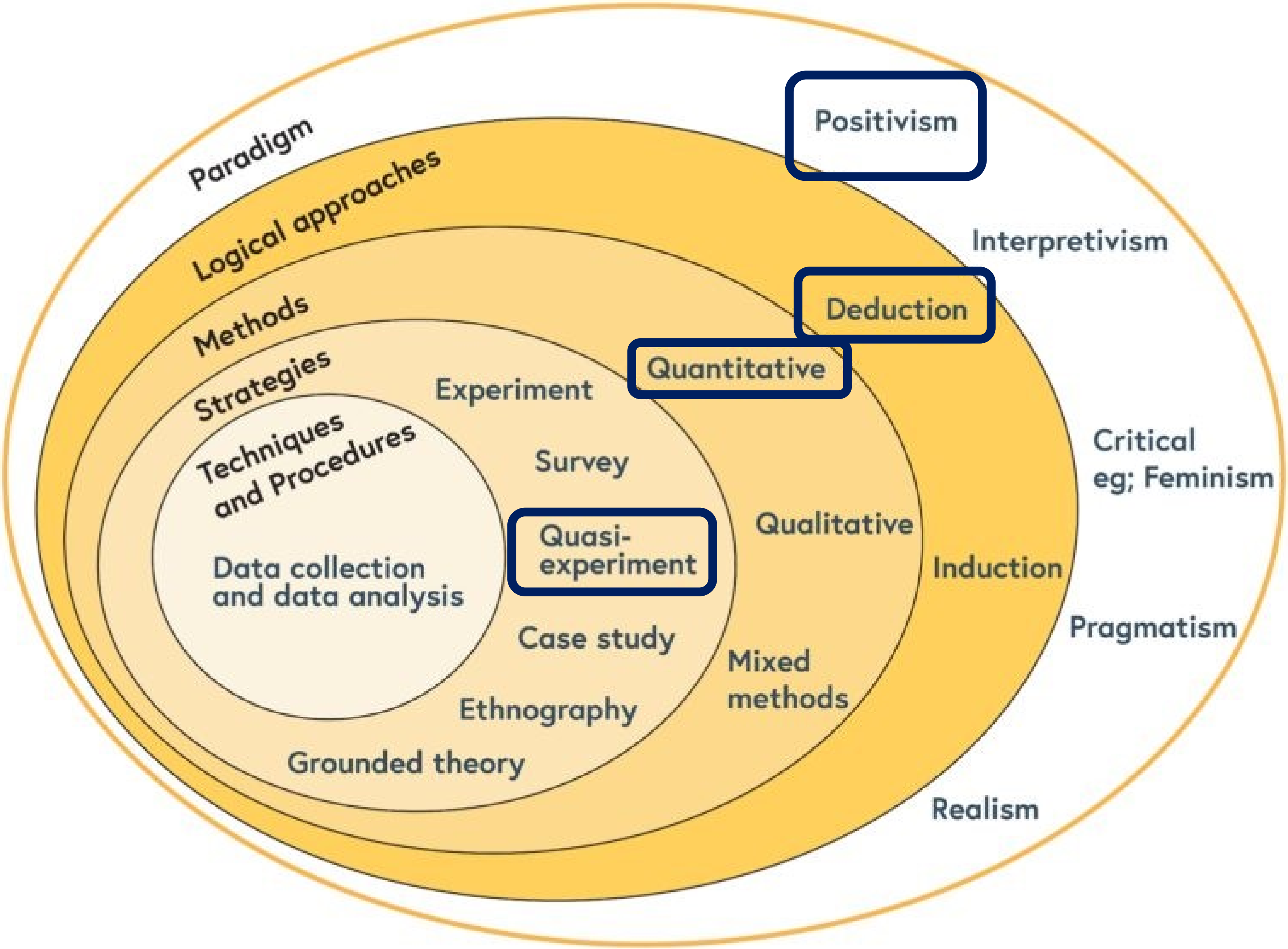
The problem: Despite so-called improvements, many academics used ‘stand-and-deliver’ passive approaches in physics teaching. But, Hake proposes that “passive-student introductory physics courses, even those delivered by talented and popular instructors, imparted little conceptual understanding {i.e., learning} of Newtonian physics.” (pg. 64)

→ Examine ‘learning gains’ with validated concept inventories

Research question:

Can the classroom use of **interactive engagement** method increase the effectives of introductory mechanics courses, well beyond that attained by traditional methods?

Research paradigm:
all valid and useful



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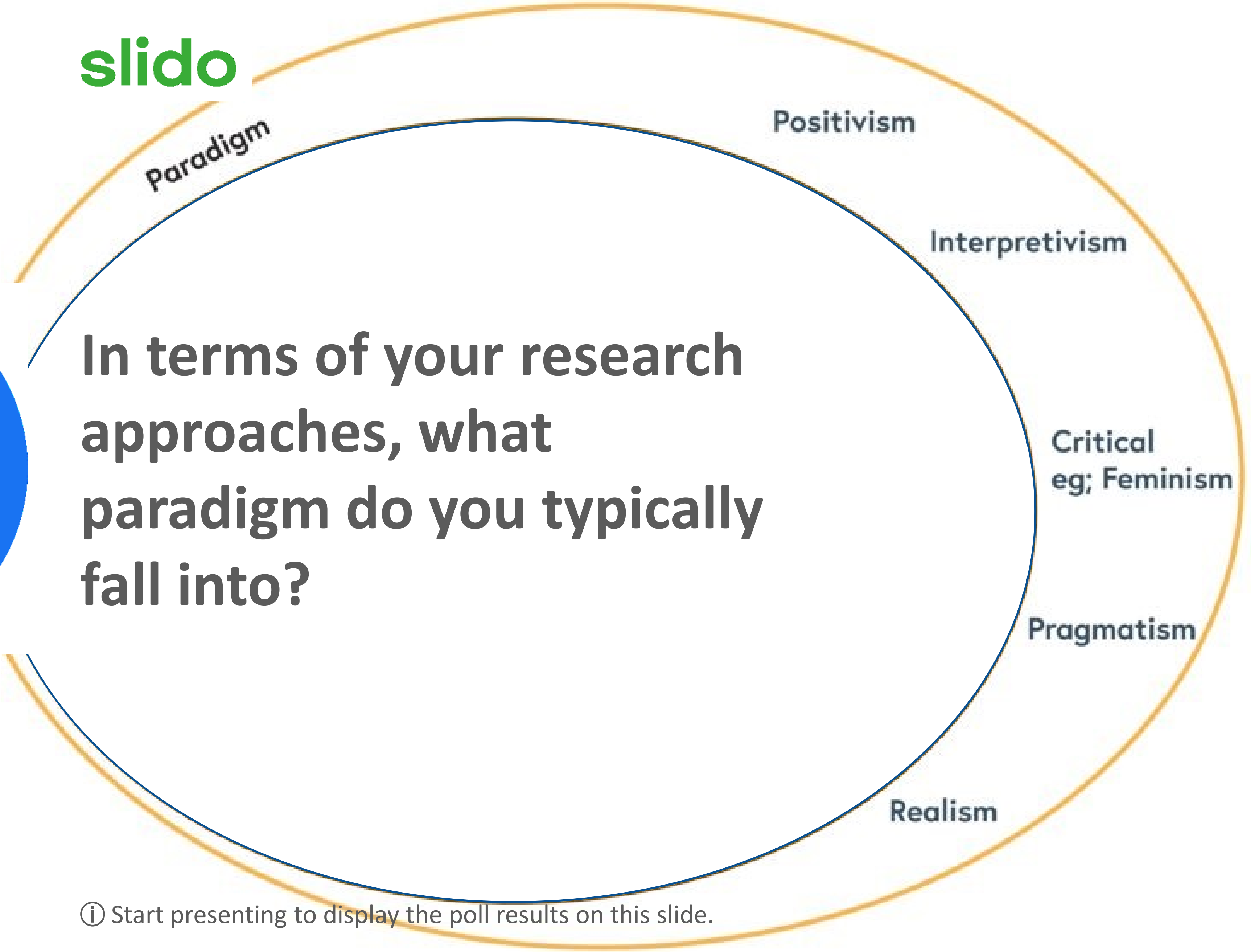

In terms of your research approaches, what paradigm do you typically fall into?

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Methodology

Pre-post testing using **validated** concept inventories (i.e., tests)

- Halloun-Hestenes Mechanics Diagnostic test; Force Concept Inventory; Mechanics Baseline test
- 62 introductory courses – 14 traditional (T), and 48 interactive (IE)
- 6542 individual students (paired tests)

Actively requested data from physics community with sampling bias (negative results would likely not send data).

Author did not collect the majority of data themselves

Defining ‘interactive’ and ‘traditional’

Pg. 65

For survey classification and analysis purposes I define:

(a) ‘‘Interactive Engagement’’ (IE) methods as those *designed at least in part to promote conceptual understanding through interactive engagement of students in heads-on (always) and hands-on (usually) activities which yield immediate feedback through discussion with peers and/or instructors*, all as judged by their literature descriptions;

(b) ‘‘Traditional’’ (T) courses as those reported by instructors to *make little or no use of IE methods, relying primarily on passive-student lectures, recipe labs, and algorithmic-problem exams*;

(c) Interactive Engagement (IE) courses as those reported by instructors to *make substantial use of IE methods*;

Interactive engagement

- Collaborative peer instruction
- Microcomputer-based labs
- Concept tests
- Modeling
- Active learning problem sets
- Overview case studies
- PER (physics education research) texts
- Socratic Dialogue Inducing labs, etc.

Learning Gains

MEASURE OF LEARNING GAINED FROM A SPECIFIC ACTIVITY OR COLLECTION OF ACTIVITIES.

PROVIDE TEST BEFORE ACTIVITY (PRE-TEST) AND THEN AFTER ACTIVITY (POST-TEST)

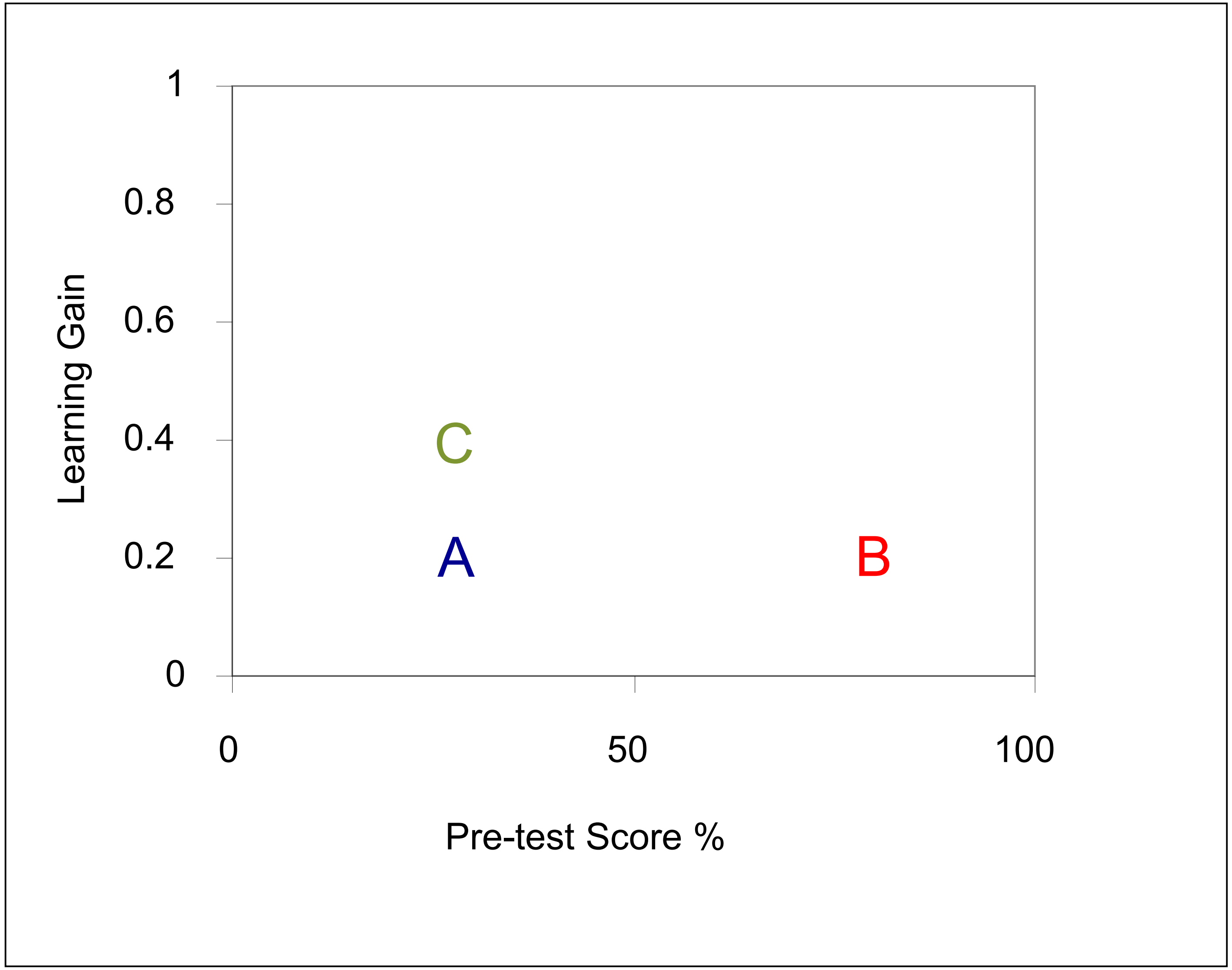
CAN HAVE GAINED OR LOST KNOWLEDGE. NOT MEASURING RETENTION

$$\text{Learning gain} = \frac{(\text{Post test \%} - \text{Pre-test \%})}{(100\ \% - \text{Pre-test \%})}$$

how much students learned expressed as a fraction of what they could have learned

$$\text{Learning gain} = \frac{(\text{Post test \%} - \text{Pre-test \%})}{(100\% - \text{Pre-test\%})}$$

Regardless of where students 'start' we can see their gains in knowledge
Test results are normalised



Student A

30% pre-test

44% post-test = LG of 0.2

Student B

80% pre-test

84% post-test = LG of 0.2

Student C

30% pre-test

58% post-test = LG of 0.4

The data

High gains: 0.7 and above
Med gains: 0.3-0.7
Low gains: below 0.3

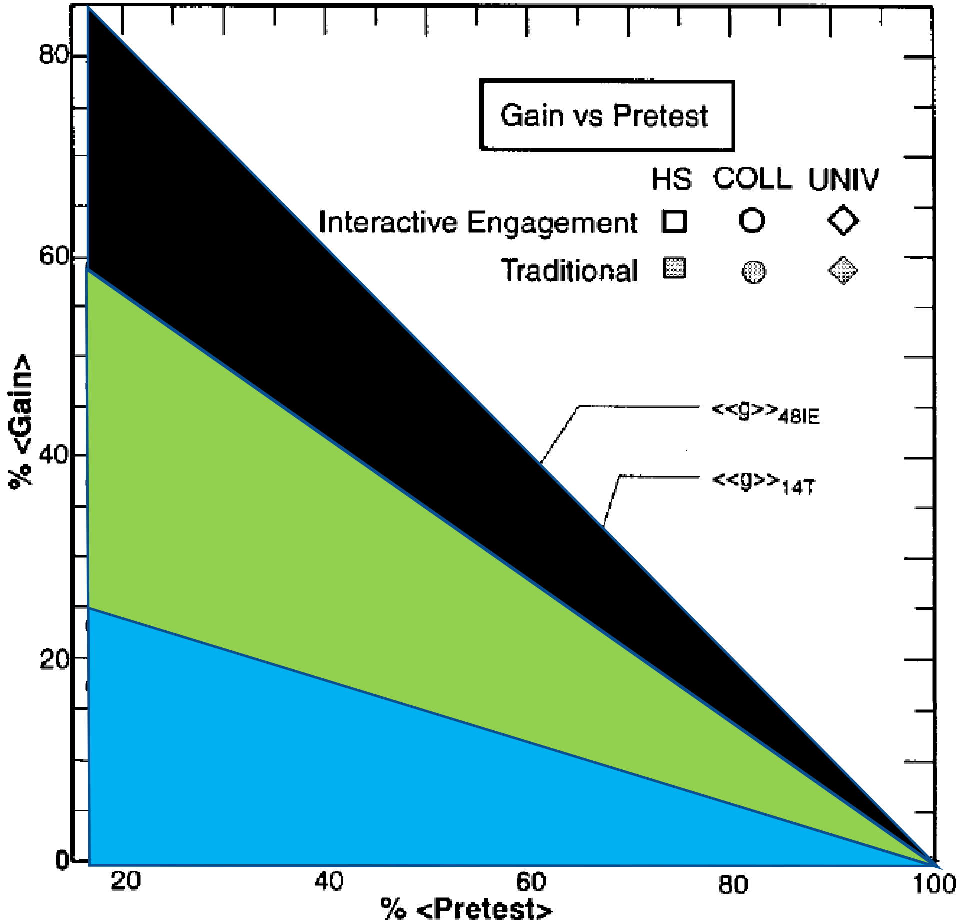


Fig. 1. %⟨Gain⟩ vs %⟨Pre-test⟩ score on the conceptual Mechanics Diagnostic (MD) or Force Concept Inventory (FCI) tests for 62 courses enrolling a total $N=6542$ students: 14 traditional (T) courses ($N=2084$) which made little or no use of interactive engagement (IE) methods, and 48 IE courses ($N=4458$) which made considerable use of IE methods. Slope lines for the average of the 14T courses $\langle\langle g\rangle\rangle_{14T}$ and 48 IE courses $\langle\langle g\rangle\rangle_{48\mathrm{IE}}$ are shown, as explained in the text.

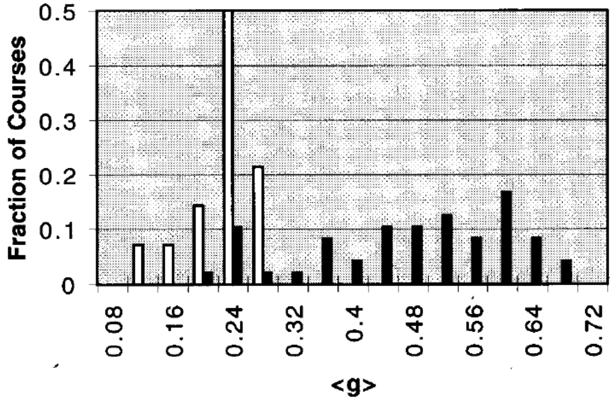


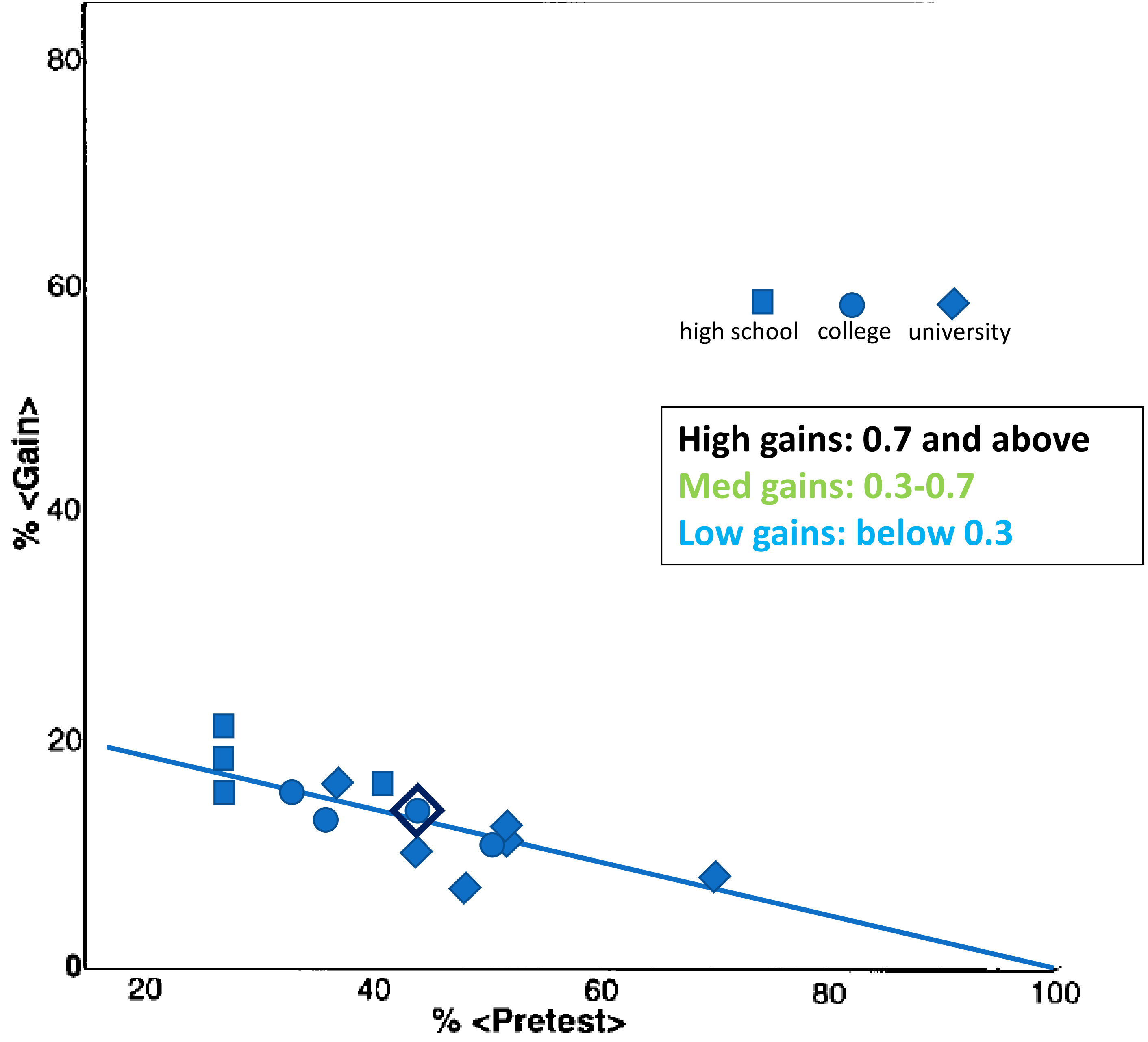
Fig. 2. Histogram of the average normalized gain $\langle g\rangle$: white bars show the *fraction* of 14 traditional courses ($N=2084$), and black bars show the *fraction* of 48 interactive engagement courses ($N=4458$), both within bins of width $\delta\langle g\rangle=0.04$ centered on the $\langle g\rangle$ values shown.

Assuming that an average normalised gain is a measure of effectiveness of a course

Result 1. All traditional courses resulted in low learning gains

$g_{14T} = 0.23 \pm 0.04$ sd

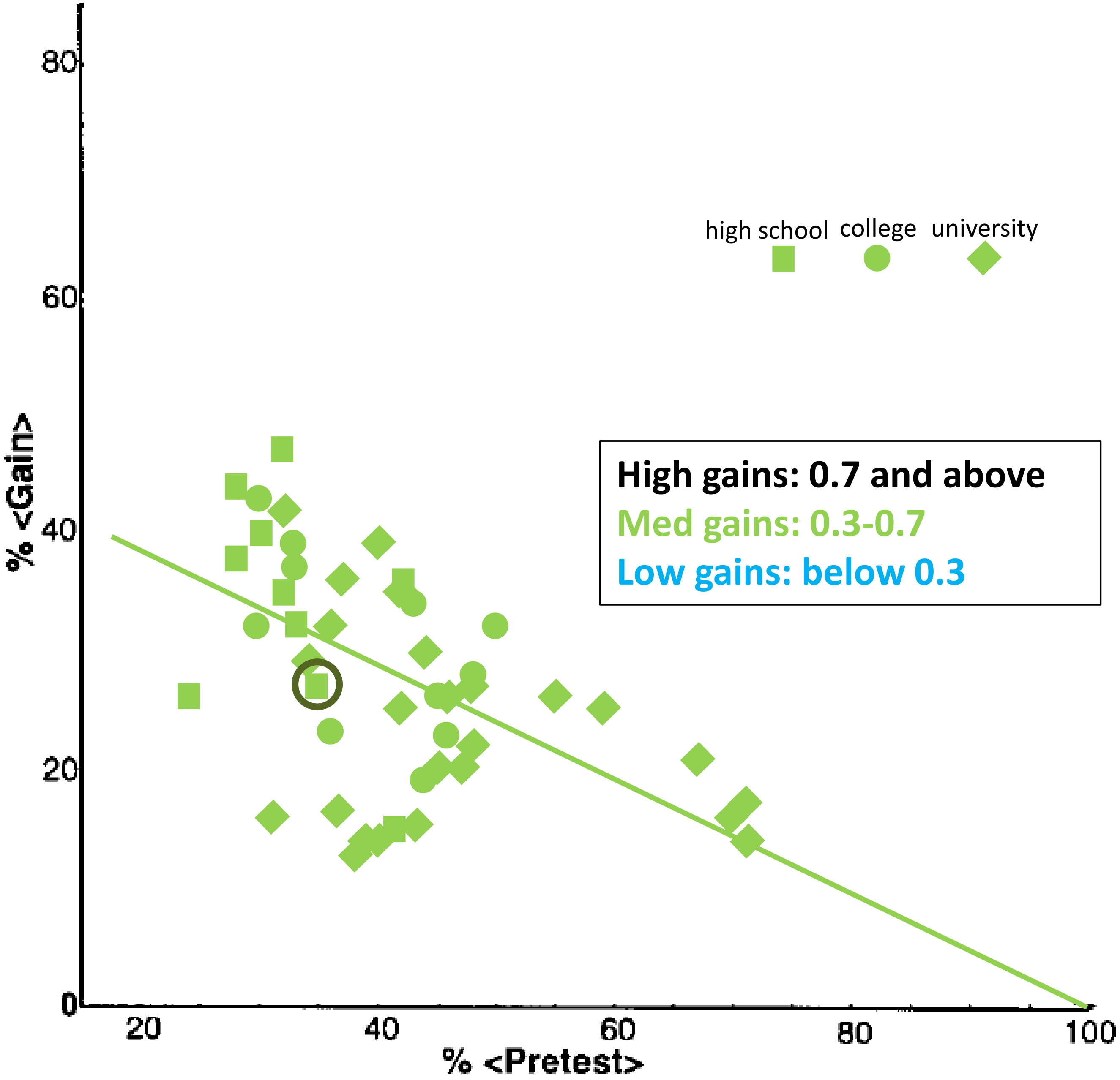
- lt blue – individual course (average of all students in course)
- dk blue – average of course averages



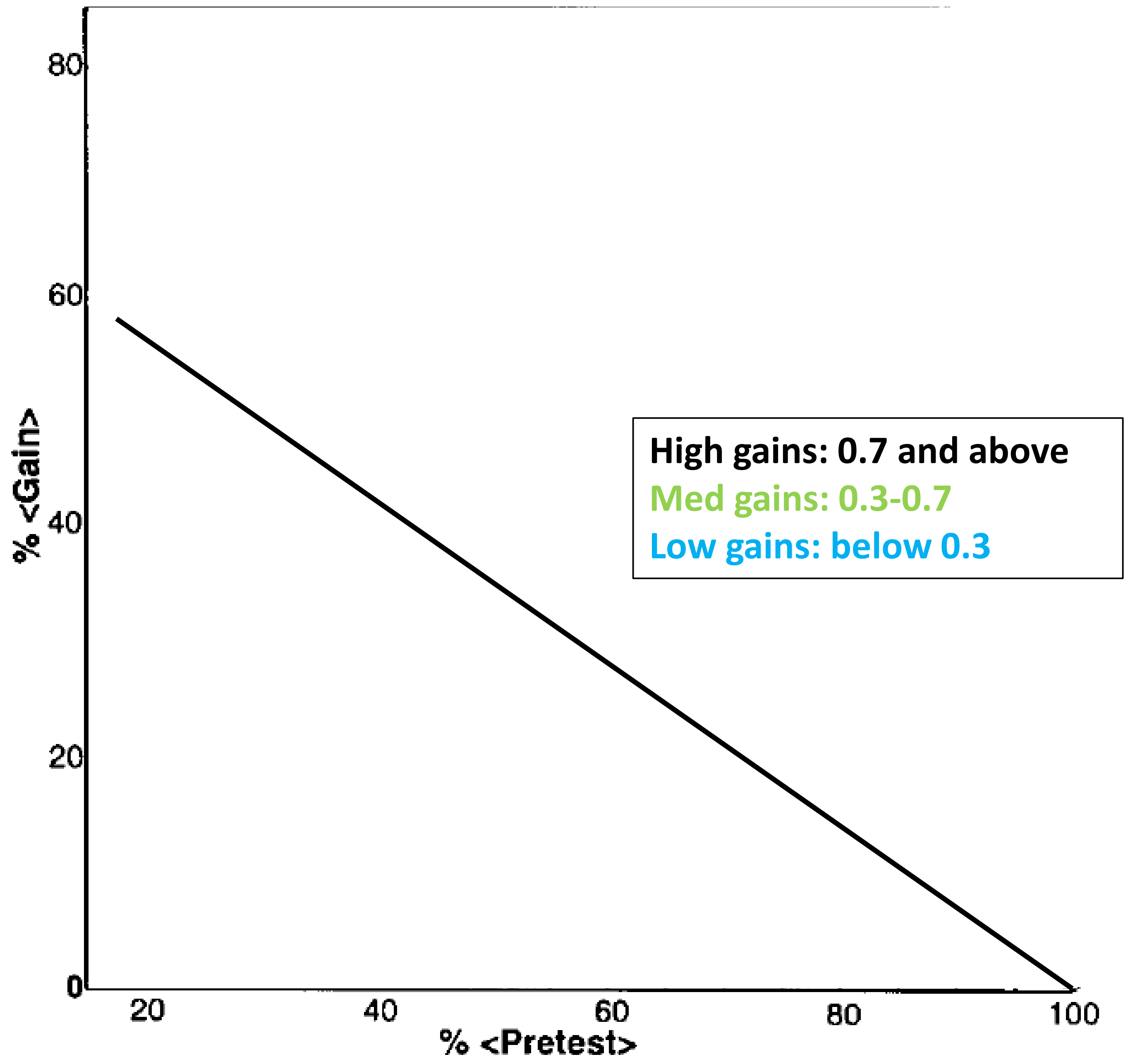
Result 2. 85% of interactive engagement courses resulted in med gains & 15% in low gains

g_{41IE} = 0.48 ± 0.14 sd

- lt green – individual course (average of all students in course)
- dk green – average of course averages

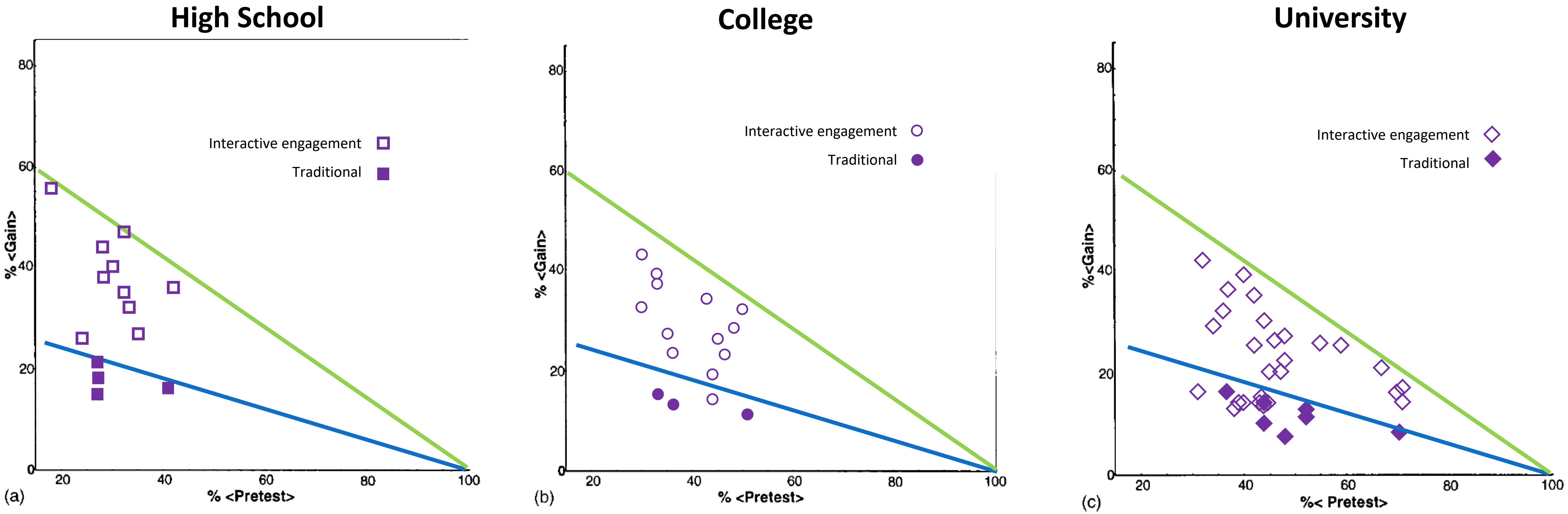


Result 3. 0% of courses resulted in high gains



High gains: 0.7 and above
Med gains: 0.3-0.7
Low gains: below 0.3

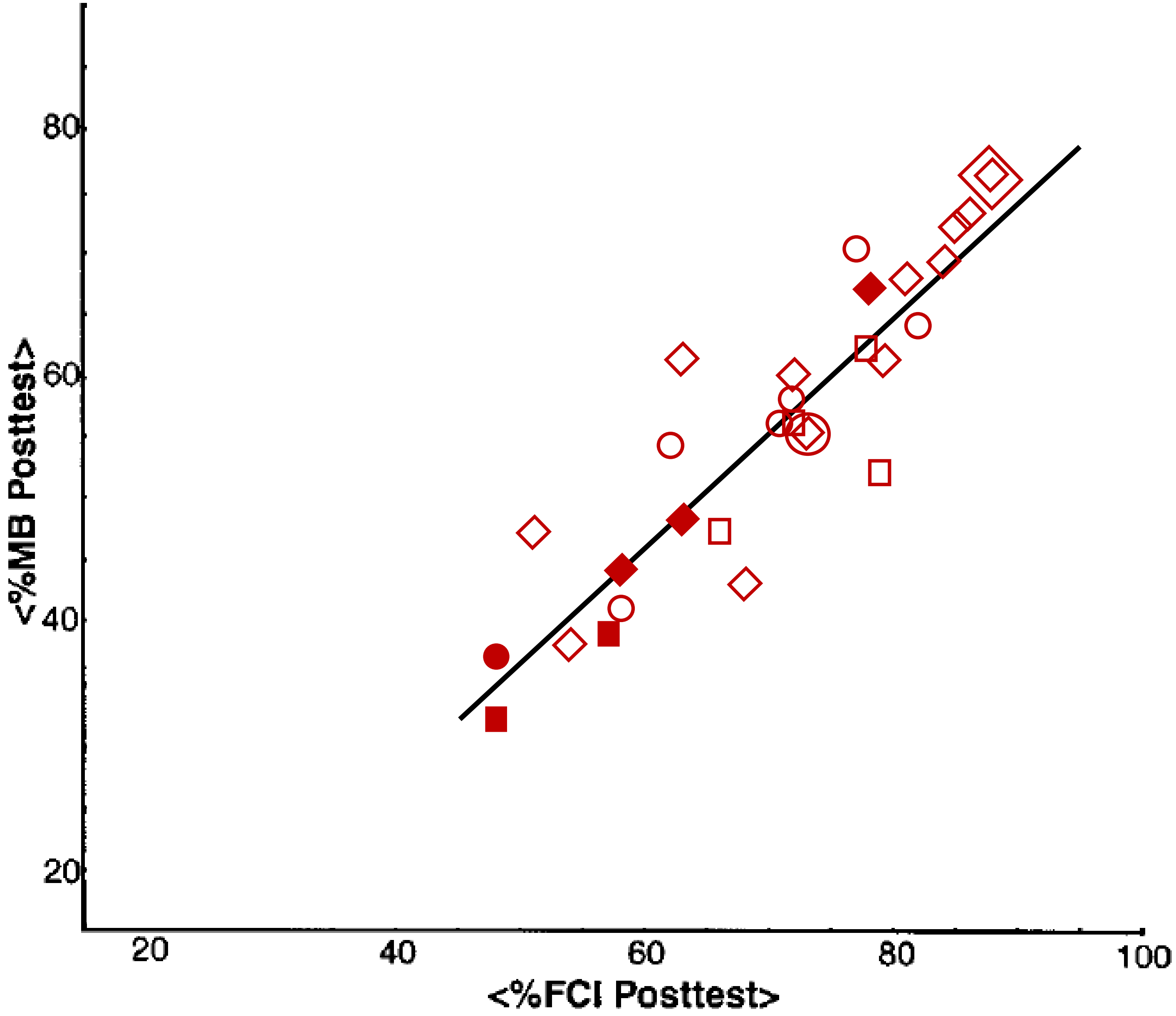
Result 4. Interactive methods had higher gains, no matter the educational context



r=+0.91

Result 5. IE = both higher FCI and Mechanics Baseline post-test results

open symbols = IE



Potential sources of error

Content validity (confusing questions & wording) – *slightly revised version of test shows no impact to average gains*

False positives (right answers for wrong reasons) – *instructors self-reported 'rare'*

Teaching to the test – *instructors self-reported 'No'*

Test-question leakage – *one instance; data removed from study*

Lower/higher proportion of mechanics content within semester – *doesn't appear to influence average gains*

Giving grades for completing the pre-/post-test – *no influence*

Hawthorne effect – *some new IE courses likely influenced by this effect; minimal influence*

Data summary

Interactive engagement (IE) courses had higher gains than those with traditional lecturing (roughly by a factor of 2; above 2 standard deviations)

Some IE courses still obtain low gains; due in part to "**implementation problems**" amongst other potential failures

Interactive methods were more effective **across educational levels** (h.s., college, uni)

IE may **increase problem solving ability** (MB post-test results)

Most sources of error were deemed uninfluential

→ "The difference in testing primarily reflects variation in the effectiveness of the pedagogy and implementation of the {interactive engagement} pedagogy" pg. 70

My critique of the research

Sampling and data retrieval ethics and biases – Are the data points used in this research representative of the physics teaching done at the time?

Instrument validity – How robust and valid were the concept inventories as measures of physics learning? Better tests?

Our results are always only as good as the measures we employ.

Student population – Who were the students in the experiment?

More statistical tests - (e.g., Effect sizes) could have been run to compare differences between groups

Replicability - If you repeated this experiment in other contexts, would you get the same results? More replication is needed

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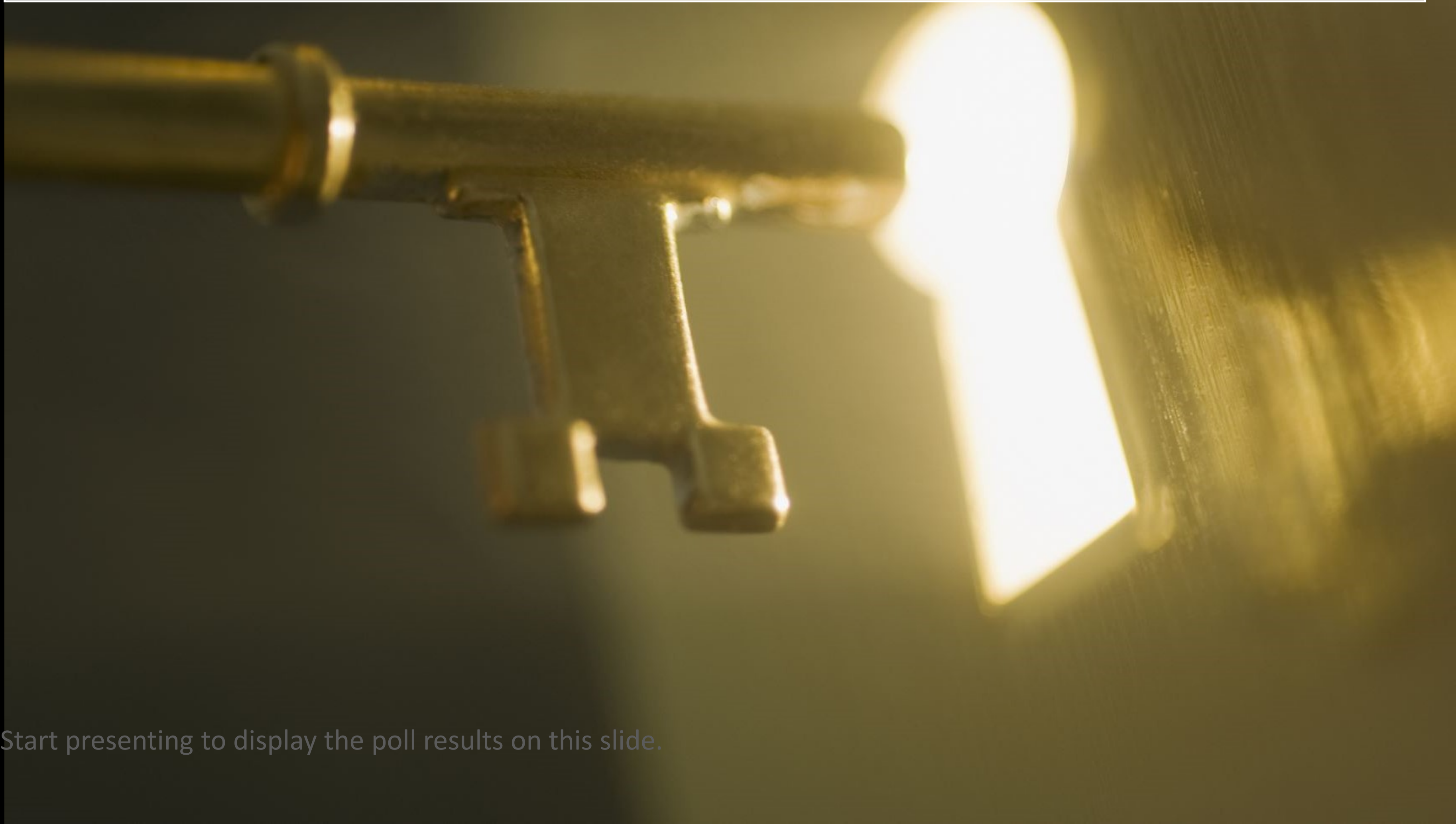
What are the key takeaways for you?



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Interactive engagement should be explored by physics educators; **implementation** of specific techniques refined and integrated

Resourcing to support curriculum transformation from stand-and-deliver to interactive engagement (engagement isn't free/cheap)

Training to support staff to take-up interactive engagement techniques

Advocated for **{physics} education research**

Selected implications (from the authors)

Why does this paper still have value in 2022?

- One of the original pieces to ‘prove’ the **effectiveness** of active learning techniques, over passive techniques
- Popularised pre-post testing & **learning gains as a method** (vs. exam scores; vs. self-reports)
- Encouraged researchers and practitioners to **observe** and reflect on when they are asking students to be interactive (rather than passive)
- **Connected** physicists, education researchers, cognitive scientists and instructors to try and work together to improve outcomes

Research that has built upon Hake’s work

In geosciences, Elkins & Elkins (2007) showed that field-based learning results in higher LG than lecture-based learning

In engineering, Yadav et al (2001) found that Problem-based learning produced higher LG than traditional lectures

Concept inventories are built for many disciplines, and allow us to compare instruction techniques across contexts and cultures

Want to do your own Hake-style investigation?

What do you need?

Step 1. Concept inventory

What's next?

Thanks!

Events: Sign up for future events. Go to MyEd Events, search SoTL

- Next upcoming event: Reading & Writing about Teaching (May 10)
- Next Decoding event: Debunking learning styles (June 27)

Want to talk about your own SoTL work? Get in touch – email me (j.dohaney@ed.ac.uk)

SoTL Network Survey:
https://edinburgh.onlinesurveys.ac.uk/sotl-network-welcome-survey