Interactive Questioning and Learning

Alexander L. Rudolph

Department of Physics, California State Polytechnic University

(Cal Poly Pomona)

Mira Costa College
Regional Teaching Exchange
May 8, 2010

Please take a clicker!

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

Thanks and Support

Hosts

- Rica French
- Mira Costa College

Collaborators

- Ed Prather
- Gina Brissenden
- Wayne Schlingmann

} University of Arizona, Department of Astronomy and the Center for Astronomy Education (CAE)

- David Consiglio, Bryn Mawr College
- Vicente Gonzaga, Cal Poly Pomona undergraduate

Grants and other financial support

- NSF Grant No. DUE-0715517, a CCLI Phase III Grant "Collaboration of Astronomy Teaching Scholars (CATS)"
- NSF Grant No. AST-0847170, "The California-Arizona Minority Partnership for Astronomy Research and Education (CAMPARE)"
- Michael Greene, Exoplanet Exploration Public Engagement Program (NASA JPL)
- Michelle Thaller, Spitzer Education and Public Outreach Program (CalTech)

Some Quotes to Frame Our Discussion

The best learners…often make the worst teachers. They are, in a very real sense, perceptually challenged. They cannot imagine what it must be like to struggle to learn something that comes so naturally to them.

Stephen Brookfield

Lecture has often been described as the process of taking the information contained in the teachers notes and transferring them into the students notes without the information passing through the brains of either

A mind is a fire to be kindled,
not a vessel to be filled

Plutarch

It's not what the teacher does that matters; rather, it is what the students do

The fatal pedagogical error is to give answers to students who do not yet have questions

What are clickers?

Clickers are:

- A useful tool for engaging students in the classroom
- An increasingly simple technology to use
- Fun for both students and instructors

Clickers are *not*:

- The only way to engage students in interactive learning

Let’s try out clickers

Which of the following best describes your academic training?

A) STEM Discipline
B) Social Sciences
C) Humanities
D) Library Sciences
E) Other

Let’s try out clickers

Which statement best reflects your familiarity with Classroom Response Systems (“clickers”)?

A) Classroom response what?
B) Heard of them.
C) Done some research into systems.
D) Have experience using systems in class.
E) I could be giving this talk.

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

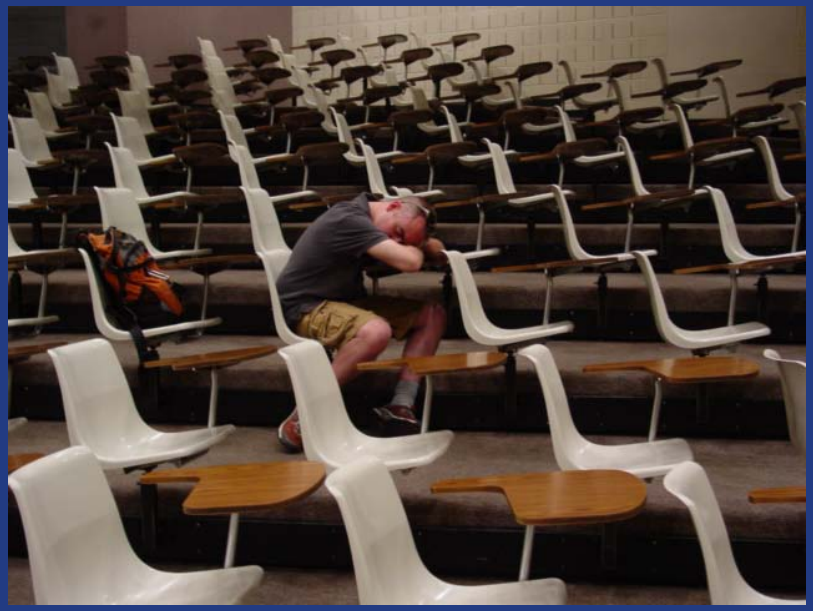
Why should you want to use Interactive Learning strategies?

And what are they anyhow?

Interactive Learning is a tool that can change the way students learn!

We've been teaching the same way for a long time…

2000 years ago



Today

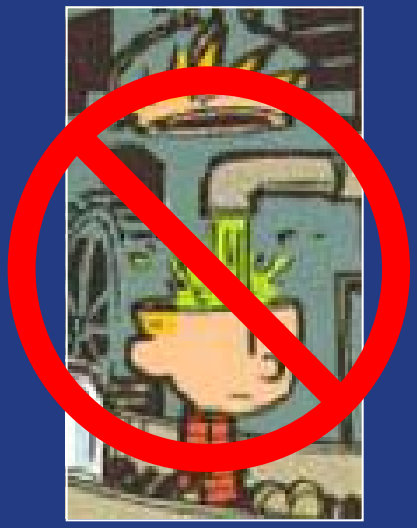
How effective are we?

A Commonly Held Inaccurate Model of Teaching and Learning

from ***How People Learn***

"Students enter your lecture hall with *preconceptions* about how the world works.

If their initial understanding is not engaged, they may fail to grasp the new concepts and information that are taught, or they may learn them for the purposes of a test but revert to their preconceptions outside the classroom"



HOW PEOPLE LEARN, National Research Council
National Academy Press, 2000.

A cautionary tale…

…about a violin

From Carl Weiman's*
"Physics of Everyday Life" class, Univ. of Colo.

*Nobel prize winner AND good teacher

Teaching is not telling… Learning is not listening

- Weiman reports the following example of trying to teach how a violin works—that the body of a violin is essential for amplifying the sound of the strings
- Most students have the preconception that the strings make all the sound
- Explaining about sound and how a violin works, he shows the class a violin and tells them that the strings cannot move enough air to produce much sound, so actually the sound comes from the wood in the back
- 15 minutes later in the lecture he asked students a question—the sound they hear from a violin is produced

  a. mostly by the strings, b. mostly by the wood in the violin back, c. both equally, d. none of the above

What fraction of the students got the right answer?

A) 0%
B) 10%
C) 30%
D) 70%
E) 90%

B) Only 10% of students gave the correct answer.

Fifteen minutes later in the same lecture!

Teaching by telling is surprisingly ineffective…

…if you want student to master concepts.

Minds must be *active* to learn

Clickers and "peer discussion" of conceptual questions forces students to talk and reason during class. Like this…

What is Interactive Learning?

- Interactive Learning is a set of strategies to get students *actively involved* in their learning
  - Think-Pair-Share Questions
  - Lecture Tutorials and Ranking Tasks
  - Interactive Demonstrations
- Interactive Learning uses a combination of lecture, real-time assessment, and peer interaction and instruction
- Research has shown that Interactive Learning strategies lead to significant improvement in conceptual understanding by students compared with lecture alone

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

Think-Pair-Share (TPS) Questions

- Short (10-20 minute) lecture on topic
- "Think-Pair-Share" Question posed
- Students given time to think
- Students record individual answers
- Students discuss with their neighbors
- Students record revised answers
- Instructor leads class discussion

Adapted from Eric Mazur, "Peer Instruction: A user's manual"

Know fear…have twins

Your sister-in-law calls to say she is having fraternal (non-identical) twins. Which of the following is most likely?

A. Twin boys

B. One boy and one girl

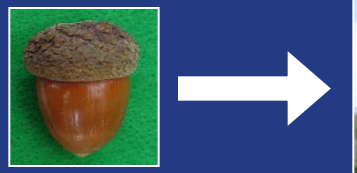
C. Twin girls

D. They are all equally likely

“I think that I shall never see…”

Considering that a tiny acorn can grow into a mighty oak tree, which of the following contribute the majority of the mass of the tree?

A. soil
B. air
C. water
D. sunlight
E. minerals in the soil



Were you paying attention during ER?

If you breathe in O_2 and out CO_2, why does mouth-to-mouth CPR work?

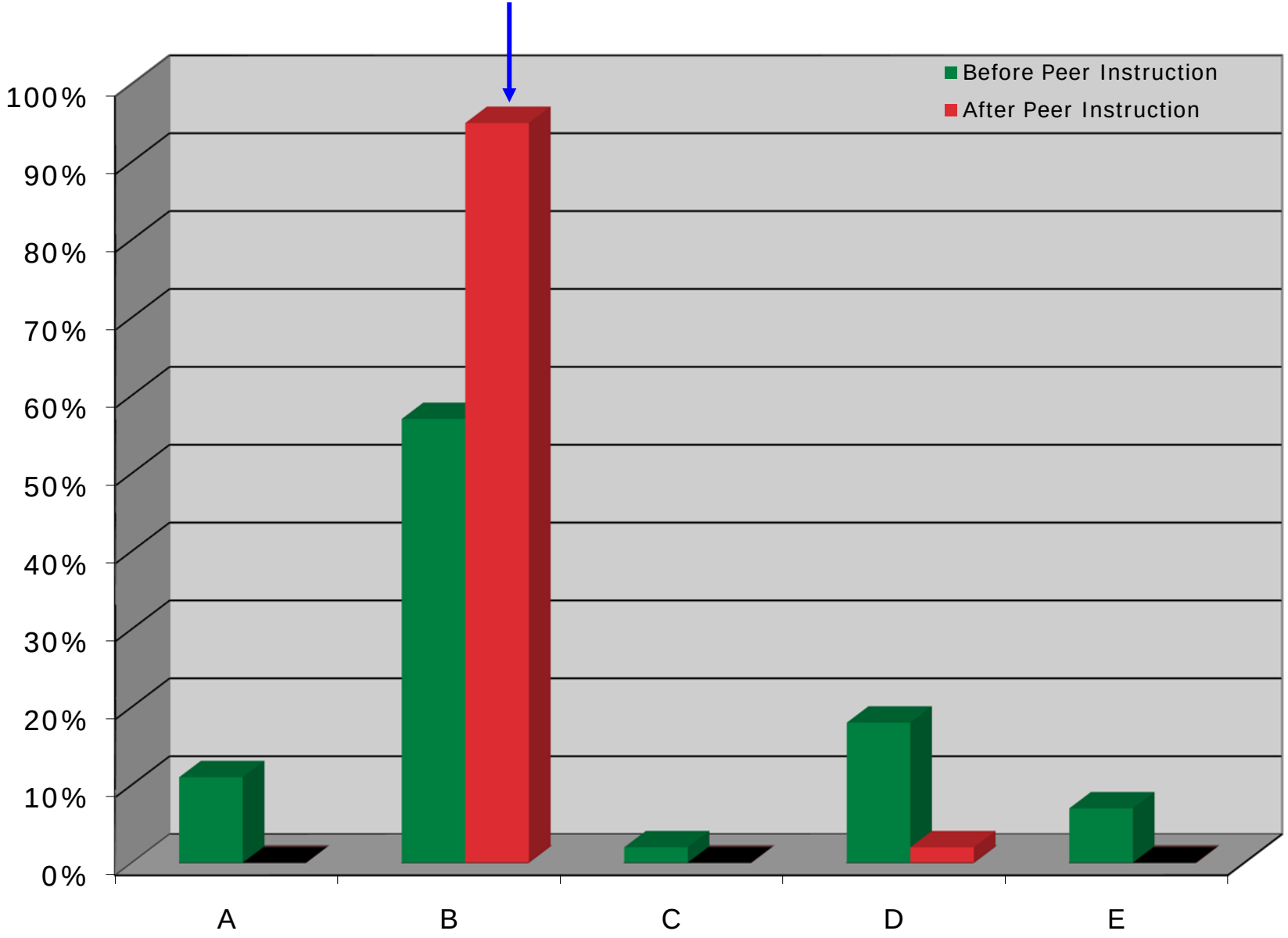
A. Humans can convert CO_2 to needed O_2

B. It's the physical breathing action, not the O_2 that mouth-to-mouth actually provides

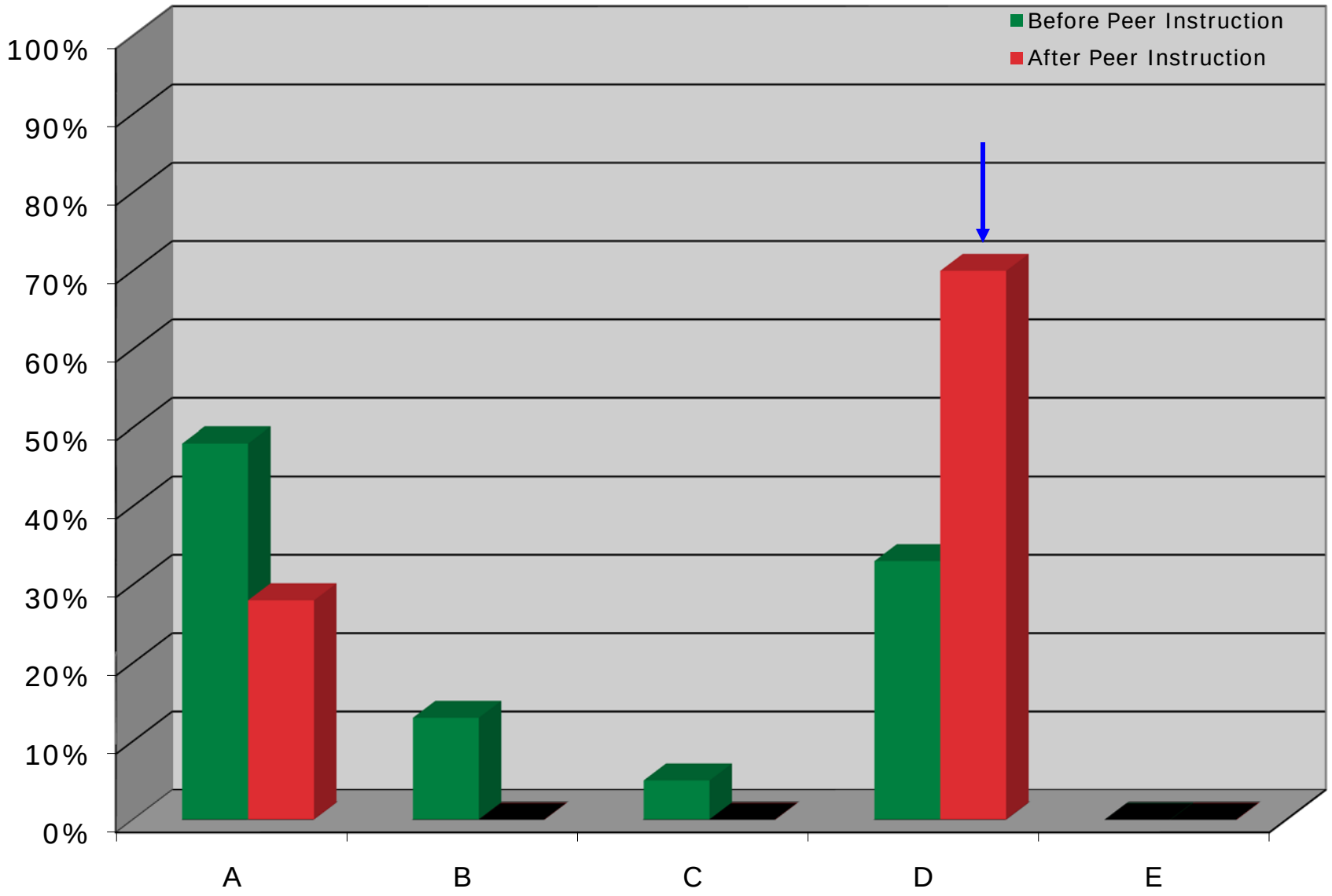
C. You exhale CO_2 *and* O_2

D. Mouth-to-mouth doesn't actually work except on TV

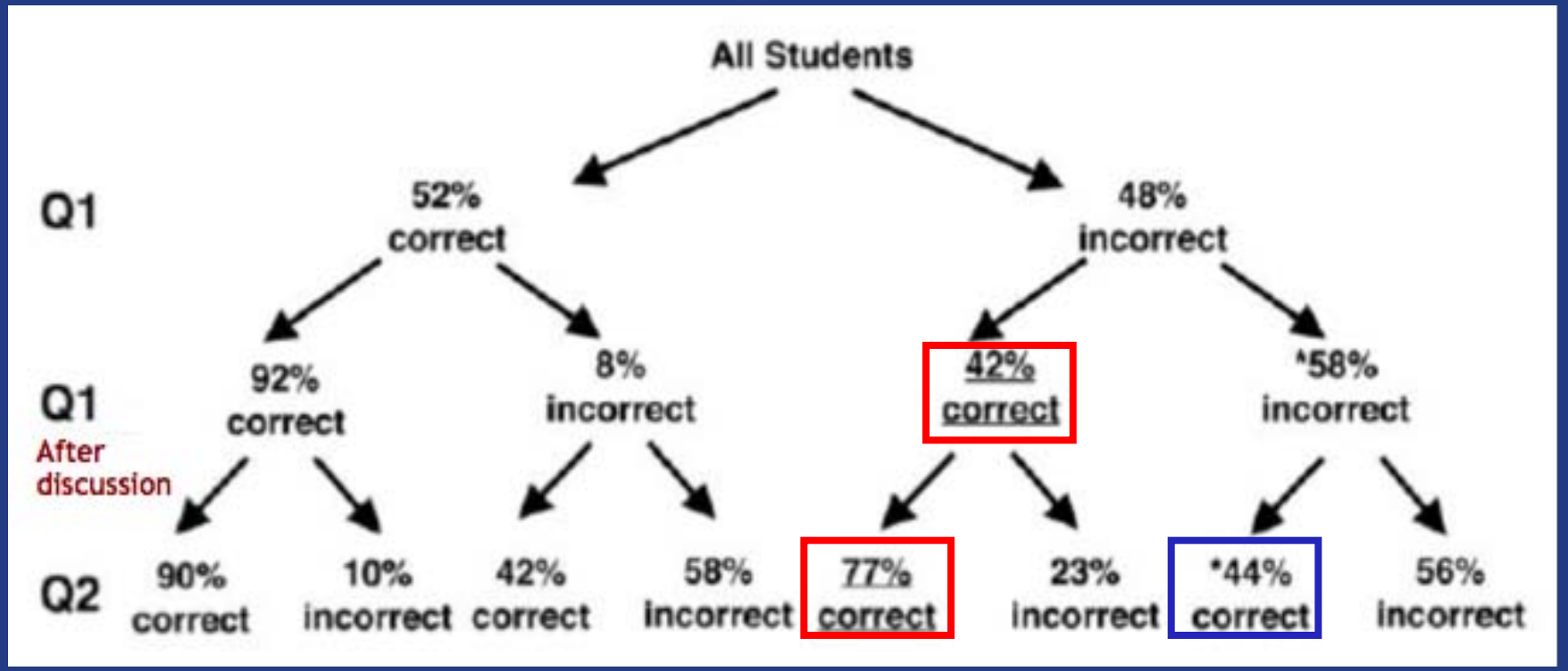
Peer Instruction Can Be Very Powerful



Sometimes Further Teaching is Needed



How do we know that peer instruction produces genuine learning, not just "copycat" behavior?



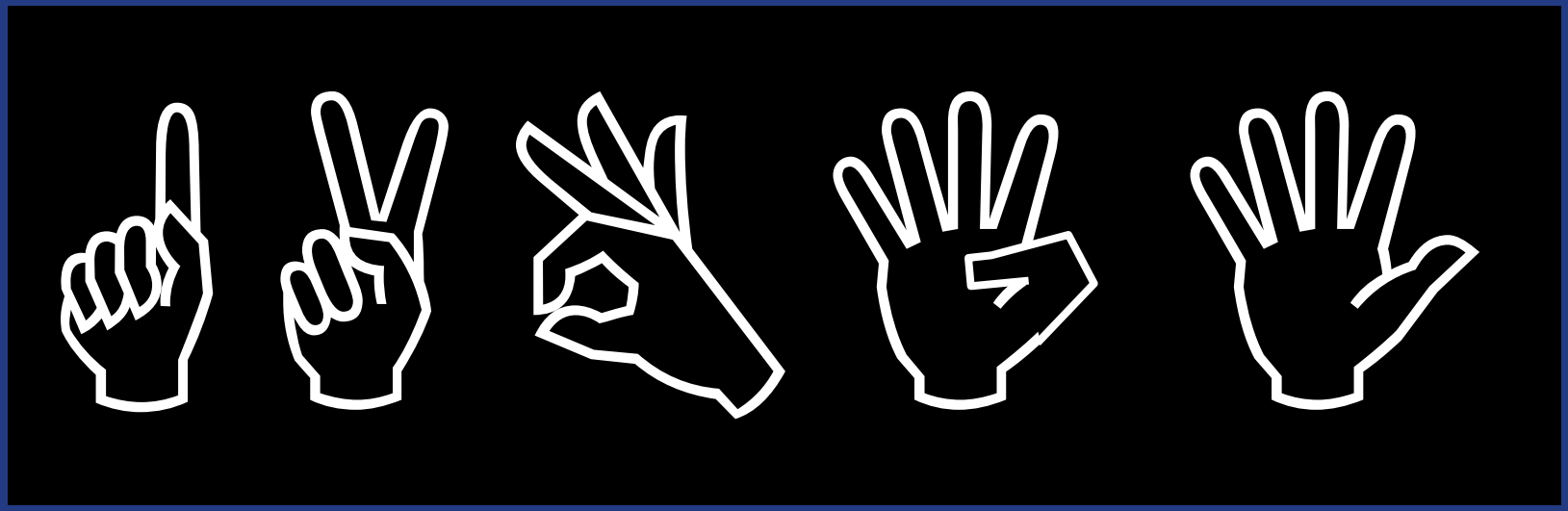
M. K. Smith et al. (U of Colorado, Science, Jan 2009)

Goals for the Workshop

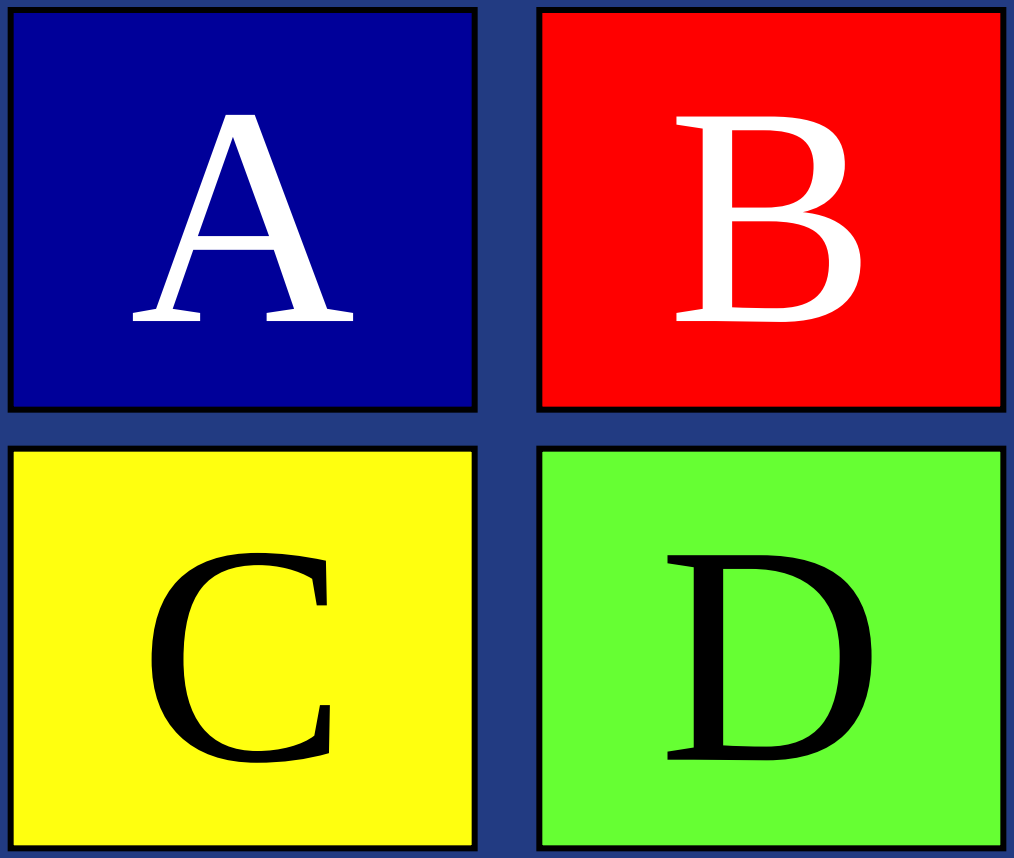
- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

Classroom Response System – "High" Tech

Classroom Response System – Low Tech



Classroom Response System – Medium Tech



Clickers v. Flashcards

	Clickers	Flashcards
Participation	+	+
Interactive Questioning	+	+
Feedback (to inst.)	+	+
Feedback (to stud.)	+	–
Feedback Saved	+	–
Credit	+	–
Cost	–	+
Answer tied to student	–	+
Class Time	+/–	+/–

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

Question

So, what's the big deal with clickers and flashcards?

Why not just use a show of hands?

Some Answers

1) Herd instinct
2) Shy students don't participate
3) Anonymity is desirable (surveys)
4) Sensitive topics (e.g., "Human Sexuality" class)

Implementation is key!!!!

Rule #1: simultaneous

Rule #2: anonymous

Rule #3: resist broadcasting/giving answers too early (or maybe at all!)

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

How could we do research on the effectiveness of our instruction?

- Which instructional methods, strategies, activities and interventions work best in the classroom?
- Do they work in all classrooms at all types of institutions, or only ones with certain characteristics?
- Do they work for all students equally well, or do some students benefit more (or less) from particular strategies?
- How can we easily evaluate the success of our instruction and measure how much our students learn as a result of my instruction?

The Concept Inventory

Research-based, multiple-choice assessment instrument, which is used to provide insight into both student comprehension of fundamental concepts and the effectiveness of instructional strategies by probing students' understanding of key scientific concepts before and after formal instruction.

Development of the FCI

- Years of Physics Education Research has shown that lecture alone is not sufficient to maximize students conceptual understanding in introductory Physics classes*
- This was given a great push forward by the development of the Force Concept Inventory**, a 30-question multiple-choice survey on the basic concepts of Newton's Laws
- The FCI is now widely used as the standard measure of students' learning in introductory Physics classes

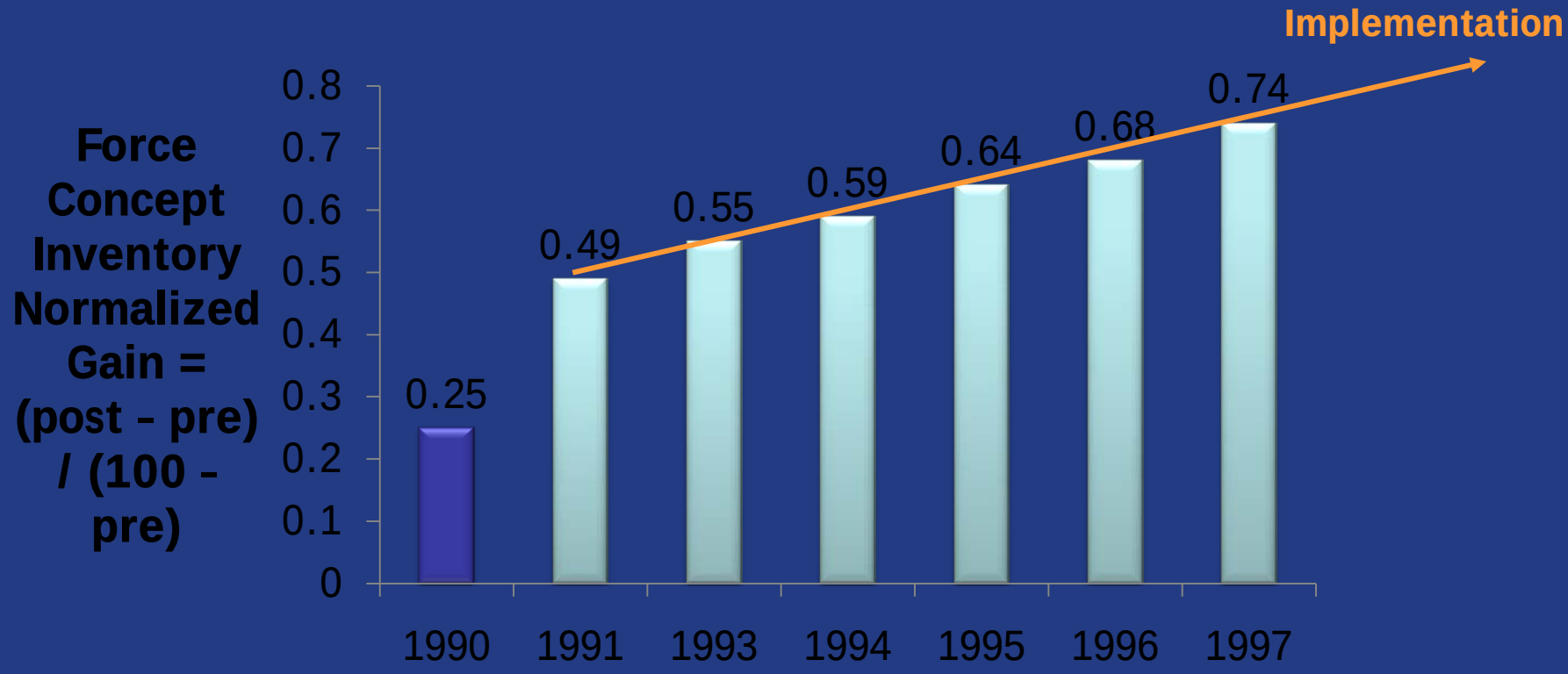
*See McDermott and Redish, "Resource Letter: PER-1: Physics Education Research," Am. J. Phys. **67** (9), 755-767 (1999)

Hestenes, Wells, & Swackhamer, "Force Concept Inventory," Phys. Teach. **30, 141-158 (1992)

Halloun, Hake, Mosca, & Hestenes, Force Concept Inventory (Revised, 1995) in Eric Mazur, *Peer Instruction: A User's Manual* (Prentice Hall, 1997)

Measuring the Effects in a Classroom

- Crouch & Mazur (2001) – Harvard Univ., calculus-based physics courses, started using peer instruction in 1991

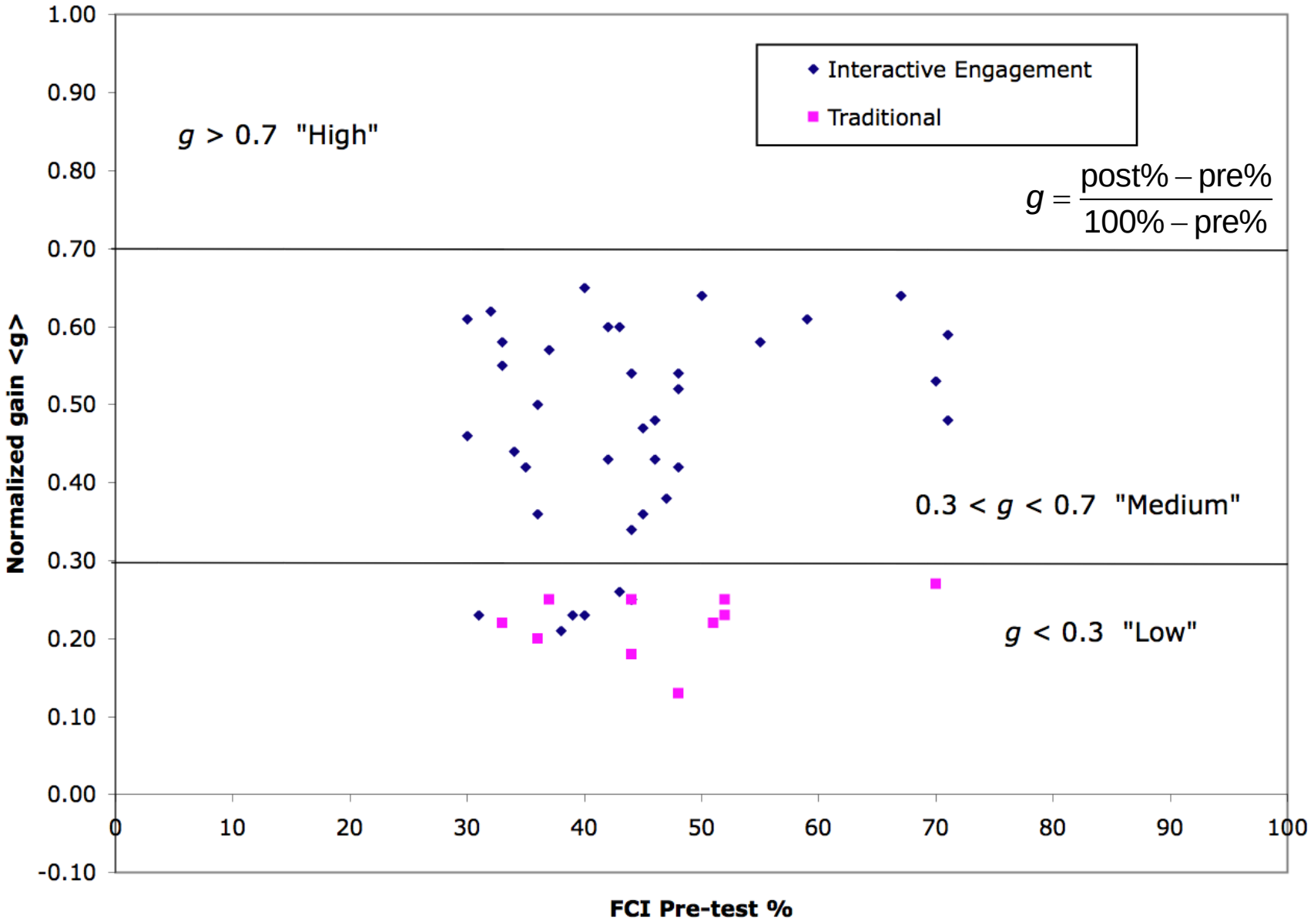


C. Crouch & E. Mazur, "Peer Instruction: Ten years of experience and results," Am. J. Phys. **69(9)**, 970-977 (2001).

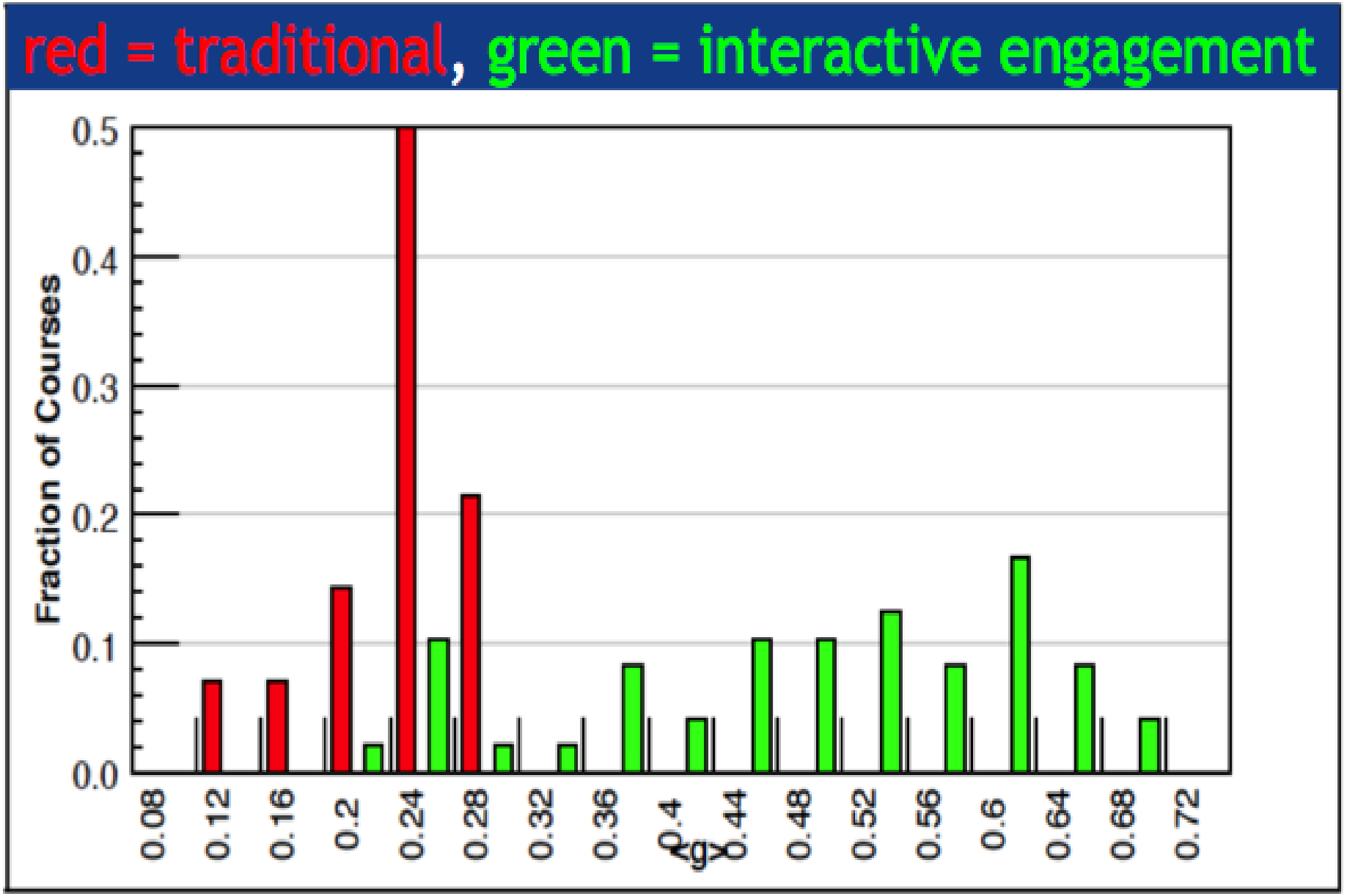
A National Study by Hake

- The biggest boost to the idea that interactive learning strategies stimulated measurable gains in students' conceptual understanding came from the meta-study of Hake
- Hake's study:
  - Focused on introductory Physics classes (primarily college level)
  - Included over 6000 students
  - Was national in scope
  - Used the FCI pre- and post-instruction to gauge the level of student learning
  - Compared traditional lecture-based courses to those incorporating interactive learning strategies (self-reported)

*R. Hake, "Interactive-engagement vs traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses," Am. J. Phys. **66**, 64-74 (1998).



R. Hake, "…A six-thousand-student survey…" AJP 66, 64-74 (1998).



R. Hake, "…A six-thousand-student survey…" AJP 66, 64-74 (1998).

A National Study in Astronomy

A National Study Assessing the Teaching and Learning of Introductory Astronomy, Part I: The Effect of Interactive Instruction, Prather, E. E., Rudolph, A.L., Brissenden, G., & Schlingman, W.M., American Journal of Physics, 77(4), April 2009.

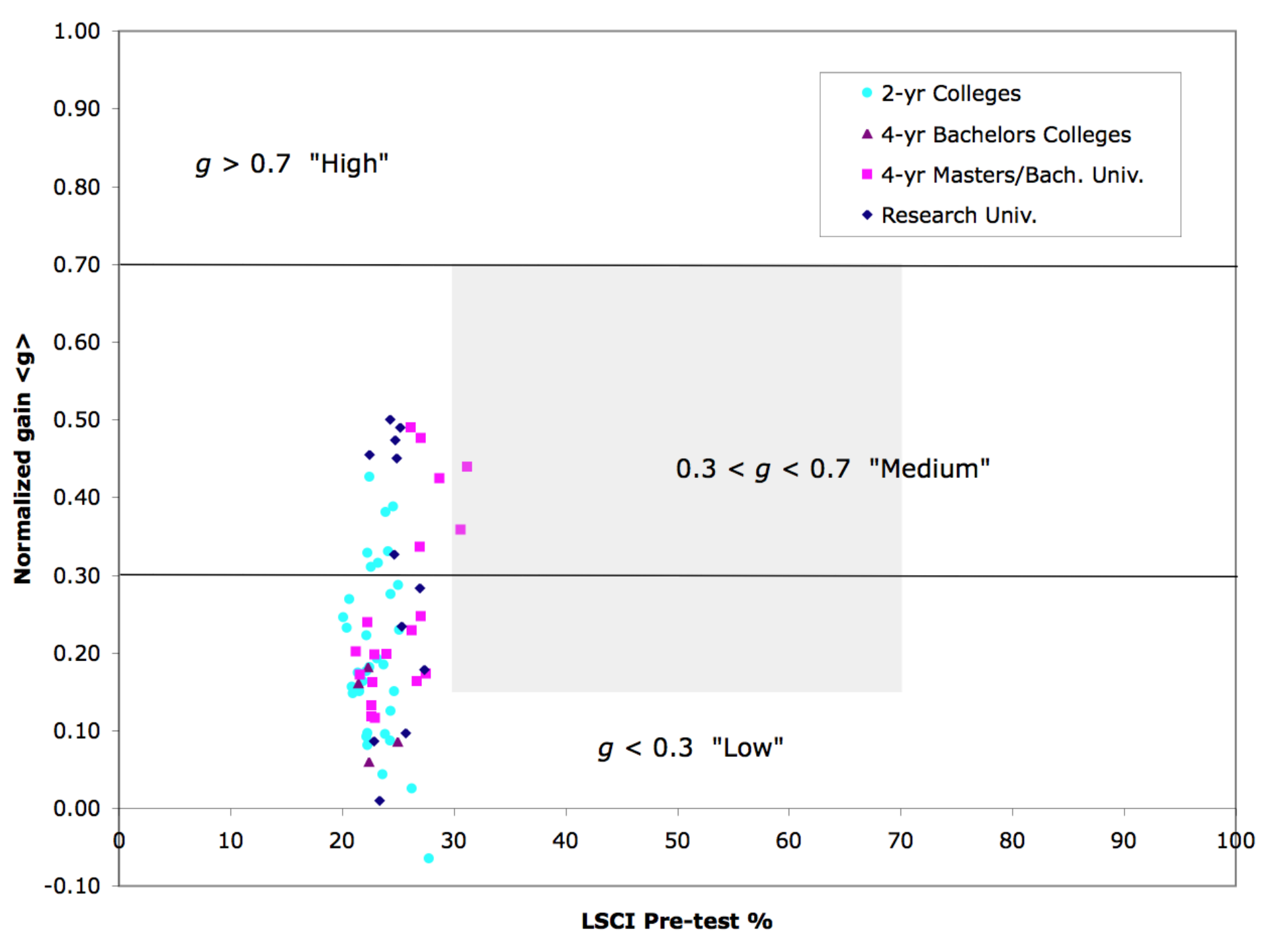
Participants

- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180

Demographic Survey

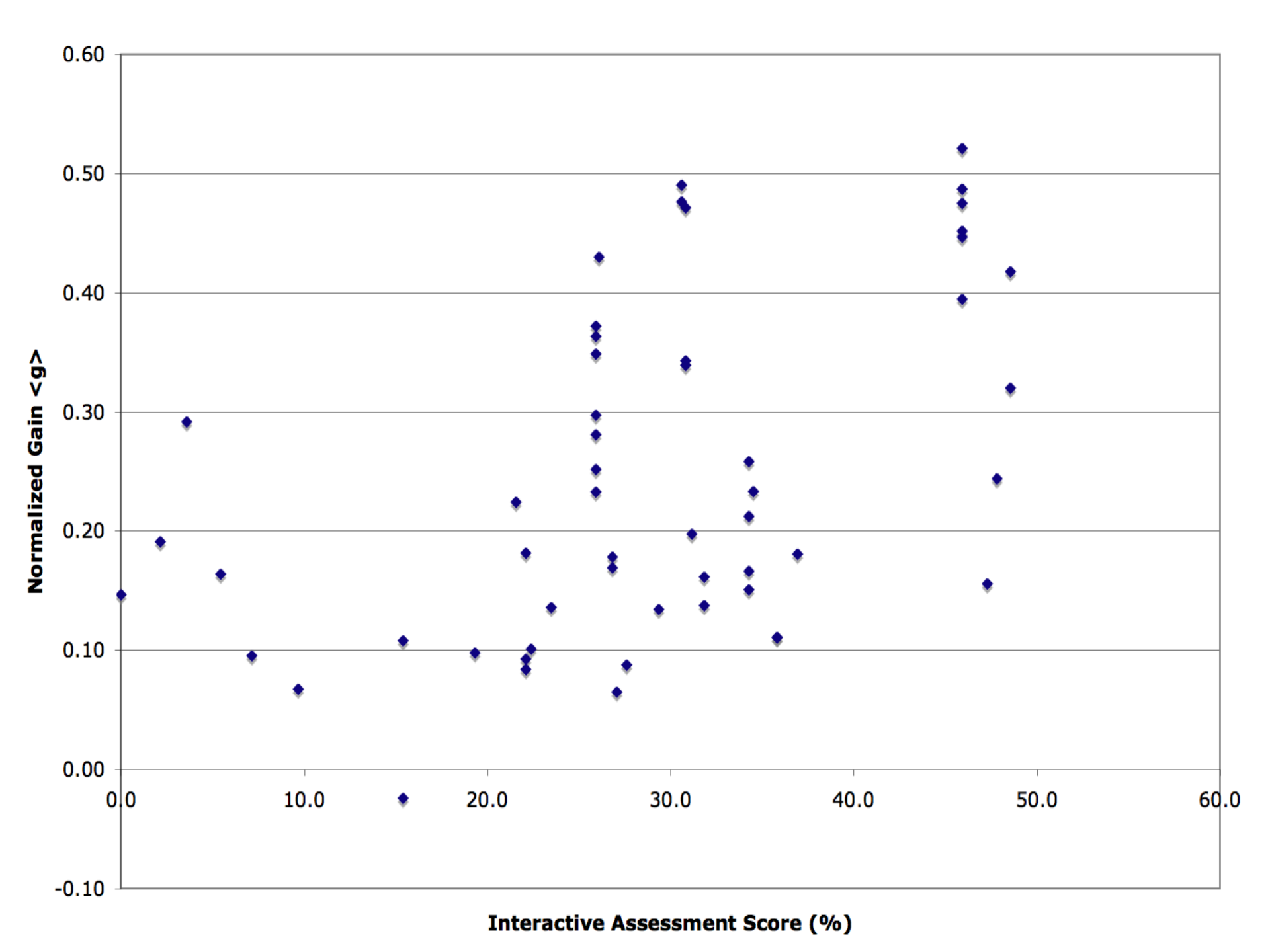
- The Light and Spectroscopy Concept Inventory was accompanied by an additional 15 demographic questions to allow us to determine how such factors as
  - Gender
  - English as a native language
  - Socioeconomic background (parental income, education, etc.)
  - Overall GPA
  - Major
  - Number of prior science or astronomy courses
  - Level of mathematical preparation

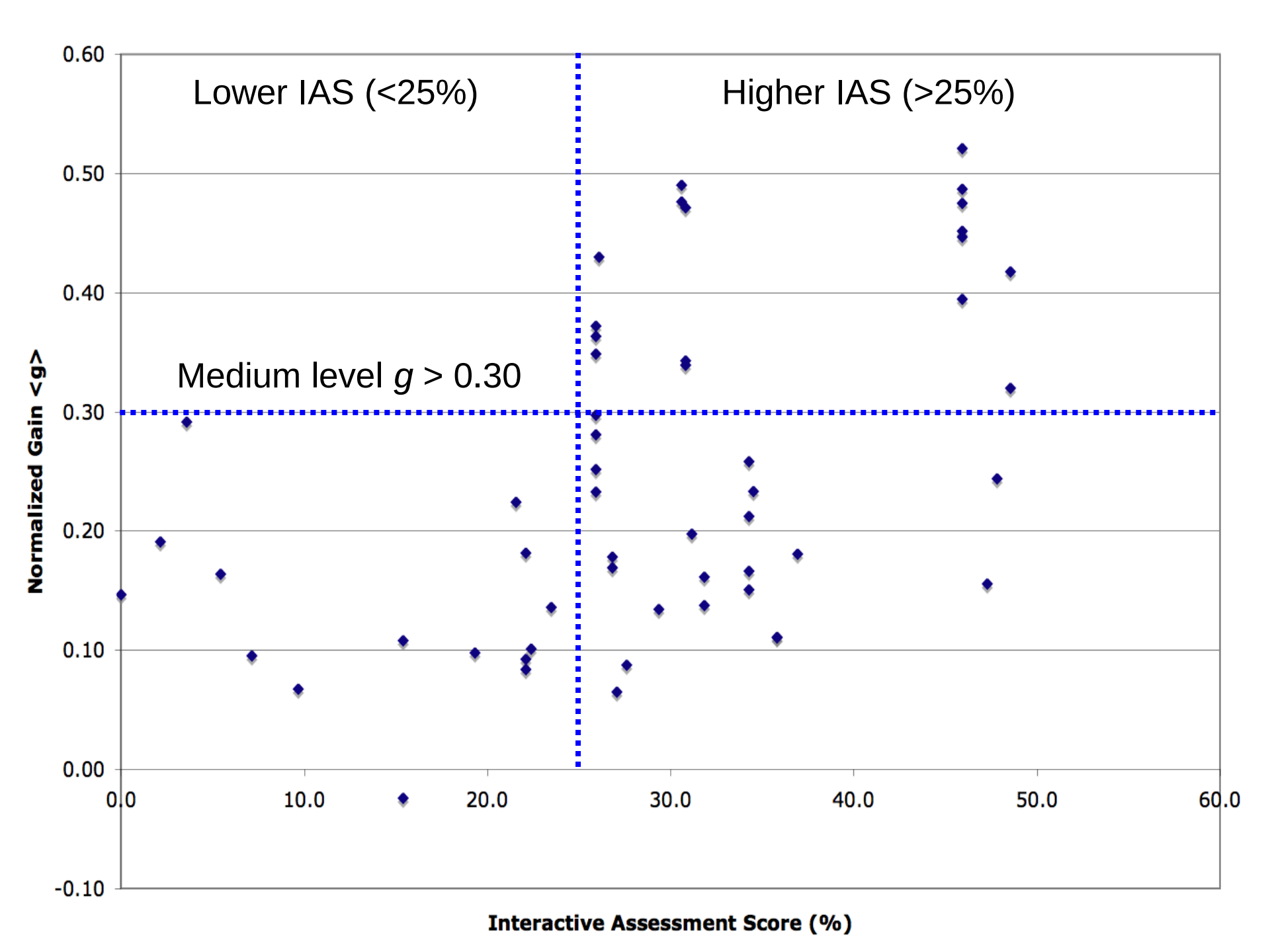
  interact with instructional style to influence student conceptual learning
- This survey also gave us a snapshot of who is taking Astro 101 courses in the US

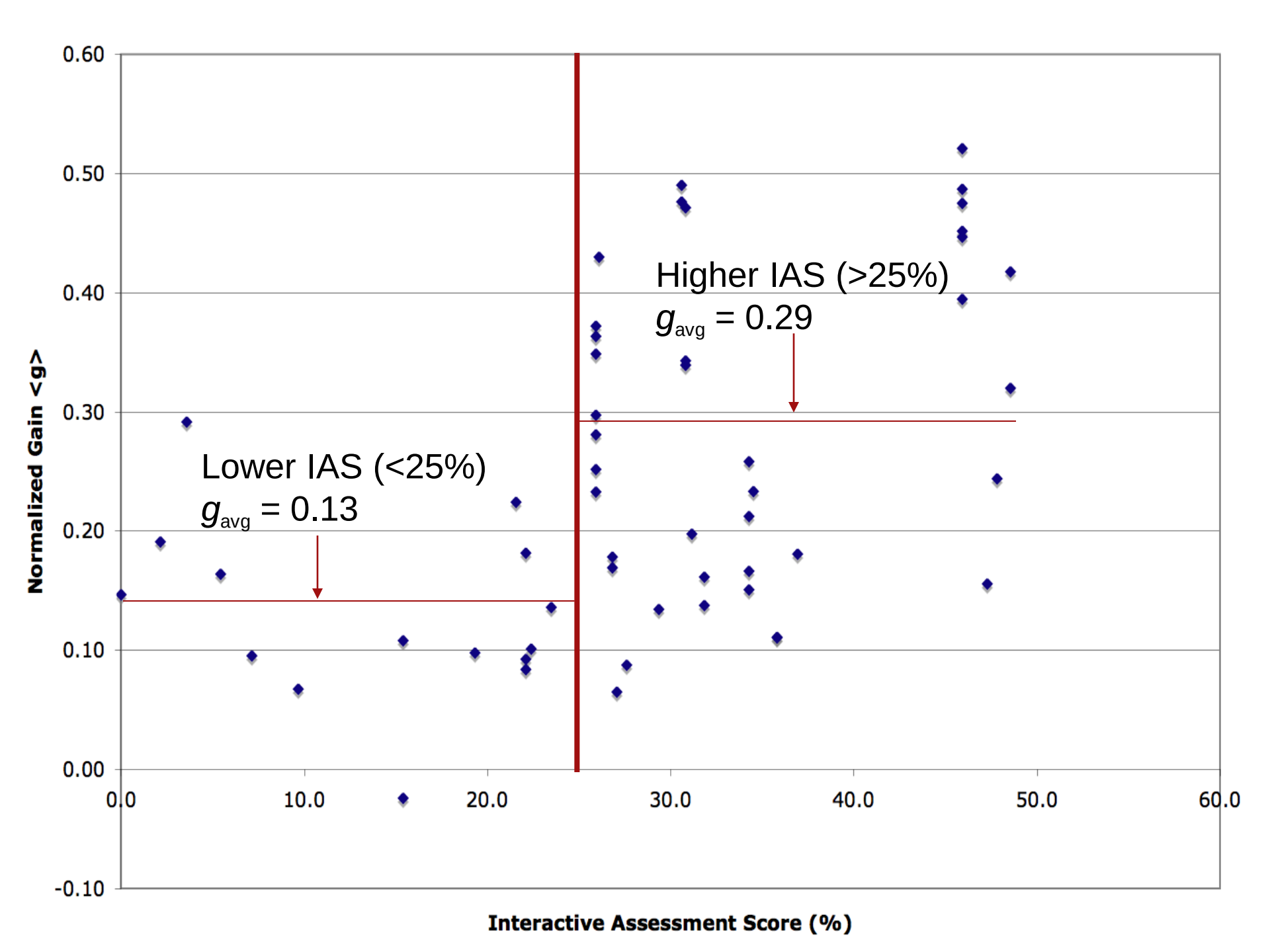

1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Normalized gain <g>
0
10
20
30
40
50
60
70
80
90
100
LSCI Pre-test %
g > 0.7 "High"
0.3 < g < 0.7 "Medium"
g < 0.3 "Low"
2-yr Colleges
4-yr Bachelors Colleges
4-yr Masters/Bach. Univ.
Research Univ.

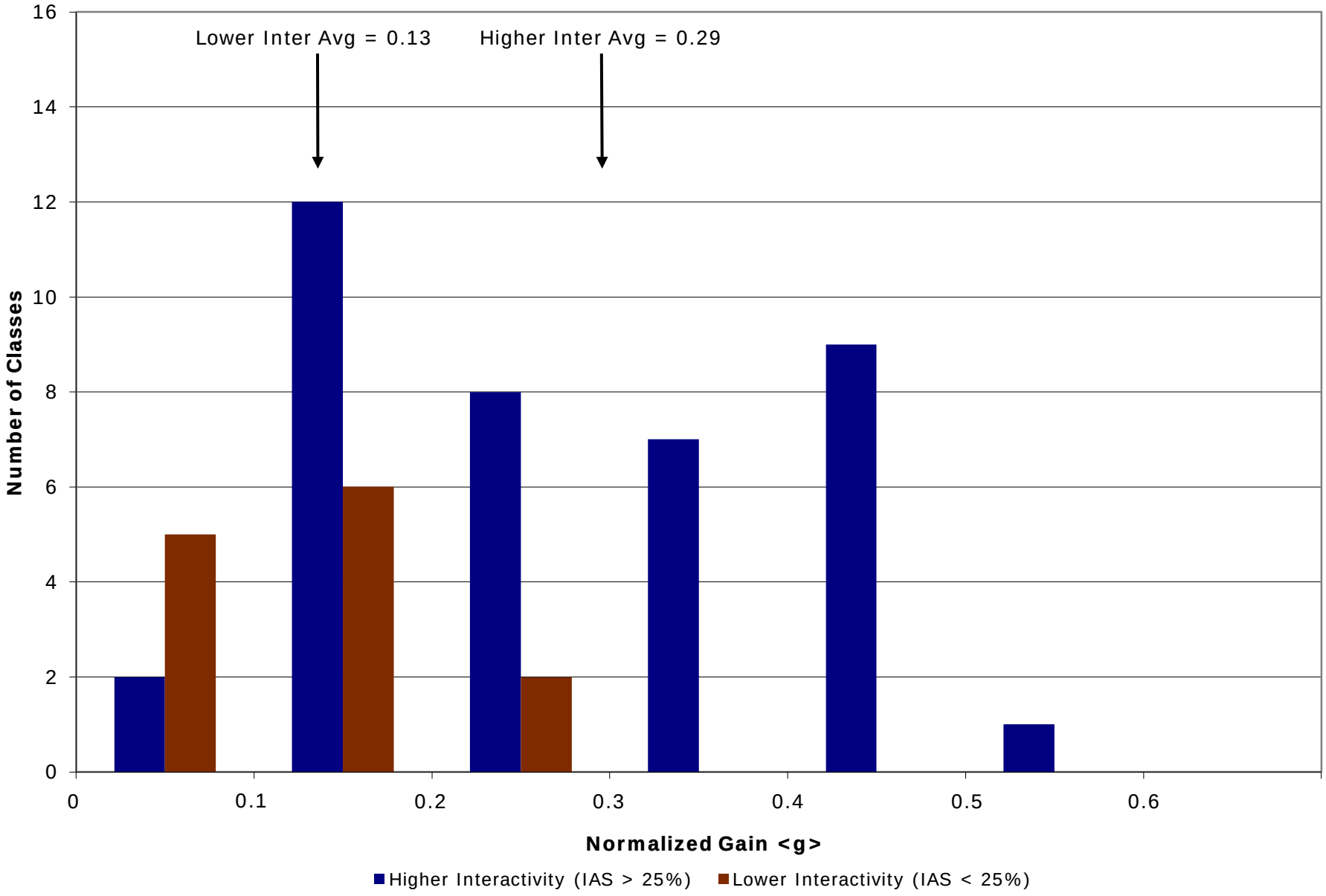
Instructor Surveys

- To assess the level of interactivity in each classroom, we asked each instructor to fill out a questionnaire, the "Interactivity Assessment Instrument" (IAI) detailing how they spend their class time
- This survey was used to construct an "Interactivity Assessment Score" (IAS) based on what percentage of total class time is used for interactive activities such as:
  - Peer instruction activities such as Think-Pair-Share (TPS) questions
  - Collaborative learning activities such as Lecture Tutorials or Ranking Tasks
  - Predictive activities such as interactive demonstrations


0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Normalized Gain <g>
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)


Lower IAS (<25%)
Higher IAS (>25%)
Medium level g > 0.30
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Normalized Gain <g>
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)

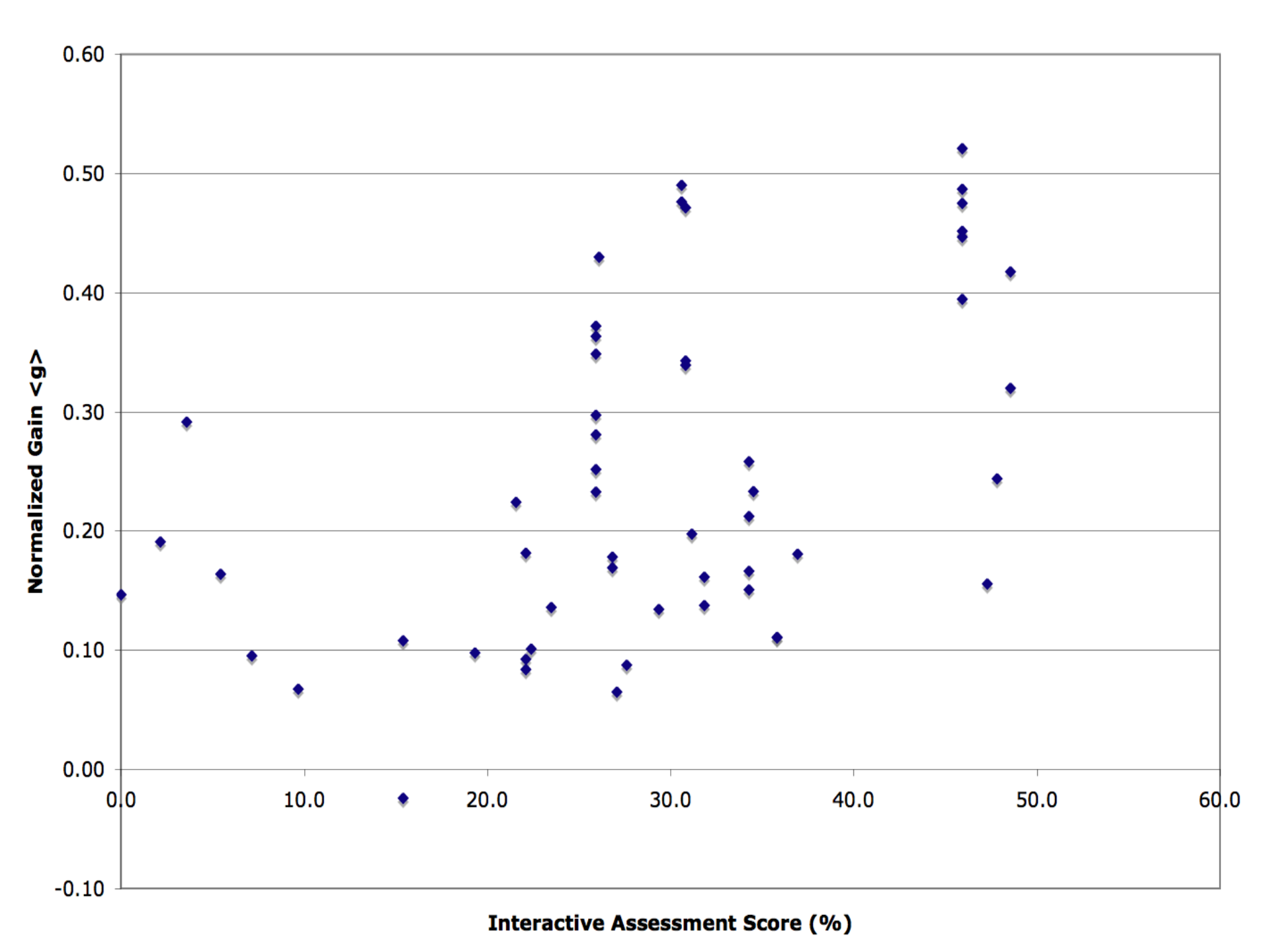

0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Normalized Gain <g>
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)
Higher IAS (>25%)
g_{avg} = 0.29
Lower IAS (<25%)
g_{avg} = 0.13


Lower Inter Avg = 0.13
Higher Inter Avg = 0.29
Number of Classes
16
14
12
10
8
6
4
2
0
0
0.1
0.2
0.3
0.4
0.5
0.6
Normalized Gain <g>
Higher Interactivity (IAS > 25%)
Lower Interactivity (IAS < 25%)

Multivariate modeling

- We conducted a full multivariate model of our data, with 13 independent variables (12 demographic variables and interactivity) to explain one dependent variable, *learning gain*

A National Study Assessing the Teaching and Learning of Introductory Astronomy, Part II: The Connection between Student Demographics and Learning, Rudolph, A. L., Prather, E. E., Brissenden, G., Consiglio, D., & Gonzaga, V. submitted to Astr. Ed. Review


0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
Normalized Gain <g>
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)

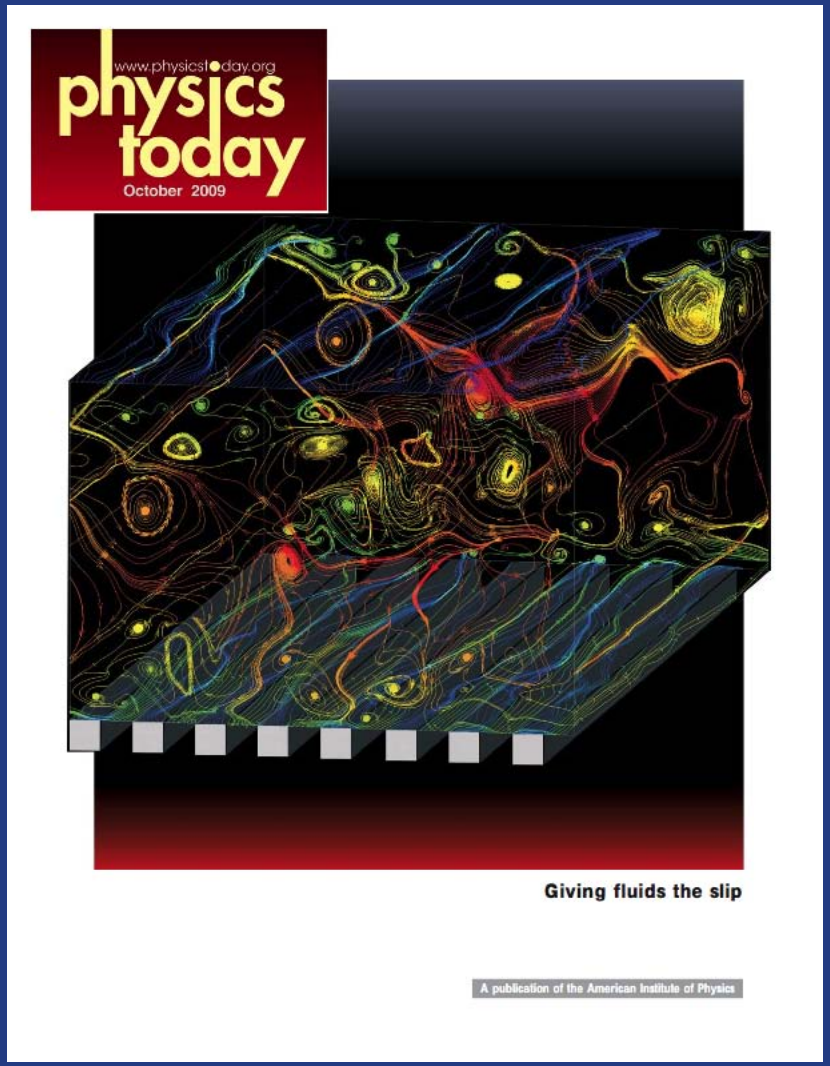
Multivariate modeling

- We conducted a full multivariate model of our data, with 13 independent variables (12 demographic variables and interactivity) to explain one dependent variable, *learning gain*
- We found that, not surprisingly, a number of student characteristics (more years in college, more math and science background) led to higher gains
- However, none of the ascribed characteristics, other than gender, had any affect on gain (men did slightly better than women, on average)

- Most importantly, we confirm that level of interactivity is the *single most important variable* in explaining the variation in gain, even after controlling for all other variables
- In addition, testing for correlations between interactivity and student characteristics showed that interactive learning strategies *equally benefit men and women, students of all ethnicities, native and non-native English speakers, as well as students of all academic ability, mathematical preparation and previous physical science coursework*

A National Study Assessing the Teaching and Learning of Introductory Astronomy, Part II: The Connection between Student Demographics and Learning, Rudolph, A. L., Prather, E. E., Brissenden, G., Consiglio, D., & Gonzaga, V., Astronomy Education Review, 9, 010107 (2010)

To learn more see the October 2009 issue of *Physics Today*



Teaching and learning astronomy in the 21st century, Prather, E. E., Rudolph, A.L., & Brissenden, G., *Physics Today*, 62(10), 41-47

Goals for the Workshop

- Why Interactive Learning? What is it?
- Demonstrate Interactive Questioning
  - Think-Pair-Share Questions
- Clickers v. Flashcards
- Best pedagogical practices
- But does it work?
- Potential pitfalls
- Answer your questions

Class time management

- Using clickers or flashcards *does* take class time
- However, once you learn to manage the process, it can be reasonably efficient
- The first time you use clickers or flashcards, explain the procedure
- Know that you (and your students) will get better with practice

Interactive Learning Techniques Contradict Student Expectations

- **Students in large lecture classes have certain expectations**
  - If you want to interact, sit in front
  - If you want to interact a lot, sit in front and raise your hand
  - If you want to be anonymous, work on homework, read the paper, or sleep…sit in back
- **Interactive Learning strategies contradict these expectations**

Explaining What You are Doing is Critical

- **To help reshape students expectations, you need to explain what you are doing and why**
  - Active Learning lasts longer then passive listening
  - They remember answers better than if you just tell them the answers
  - They will remember even better if they have discussed the questions with each other before answering
  - You will give some (or all of the) credit for participation so they need not obsess about their clicker grade (if you use clickers)
  - TPS questions allow you to find out if they understand without them having to raise their hands
  - Research shows that students in classes using these techniques do better on exams
  - Many students find using clickers and flashcards fun!

Explaining What You are Doing is Critical

- In fact, what you will be doing is changing their expectations about what it means to learn!
- Many students think learning is coming to class, listening to a lecture, then regurgitating that material on a test
- What Interactive Learning strategies do is promote the idea that students learn by grappling actively with the material
- If you don't provide answers to the questions you pose, you further reinforce the idea that *they* are responsible for their own learning

Explaining What You are Doing is Critical

- **This is more work for students than just taking notes**

  It means they have to talk to the person next to them…
  …who they may think is an idiot.

  Without explanation why they must explain and debate with others, students may protest.

  Real student quote: "I expected you to teach me, I didn't expect to have to *learn!*"

- **You must explain why you are using Interactive Learning strategies, or students will not be happy!**

Credit

There are multiple approaches to giving credit

- Some instructors give credit for right answers to motivate students to try to figure out the answers
- There is some research that shows that group dynamics work better if there is credit given for participation only
- I personally give credit for participation alone
- Most clicker software allows enough flexibility to make your own choice

Questions?