When Students Are Not Learning, Are You Really Teaching?

Dr. Edward Prather

The University of Arizona,
Department of Astronomy
and Steward Observatory

CATS Collaboration of Astronomy Teaching Scholars
An NSF Funded Center for Astronomy Education (CAE) Program

Center for Astronomy Education
» Dedicated to the professional development of introductory astronomy instructors

How Proper Implementation of Interactive Learning Strategies can Elevate Student Learning and Provide Feedback on Their Success

Edward E. Prather

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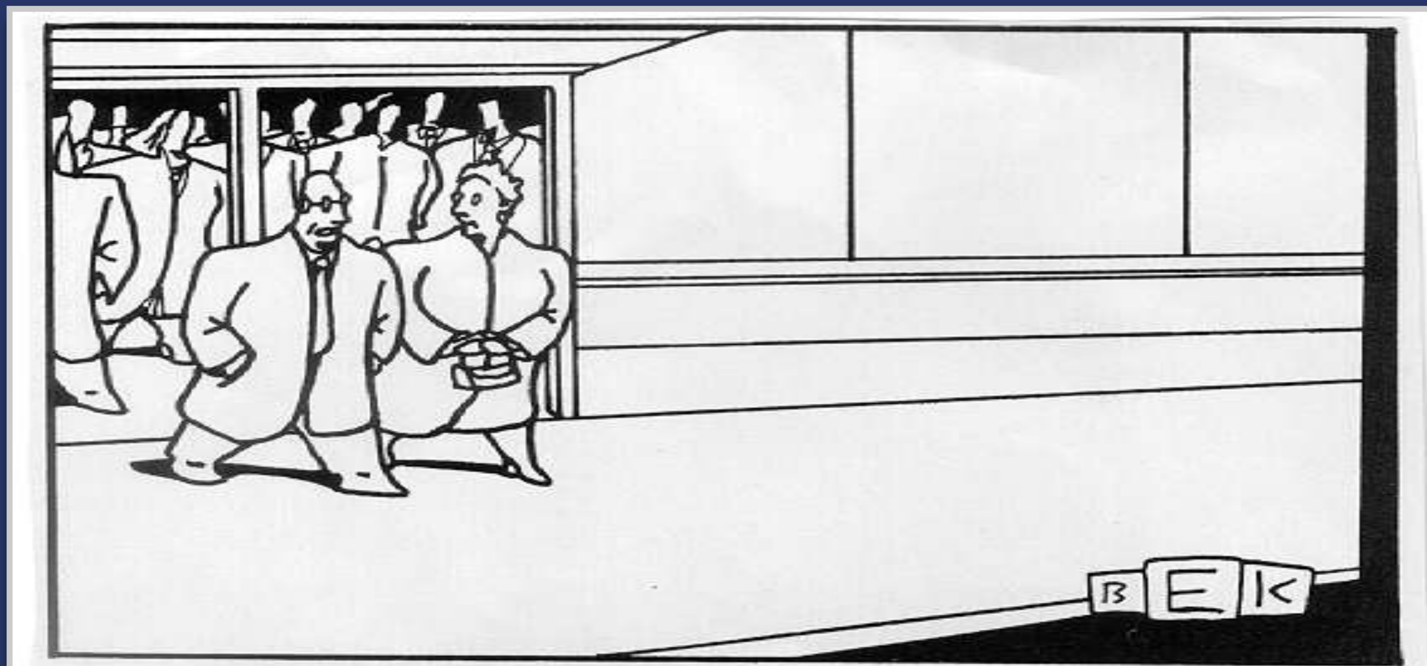
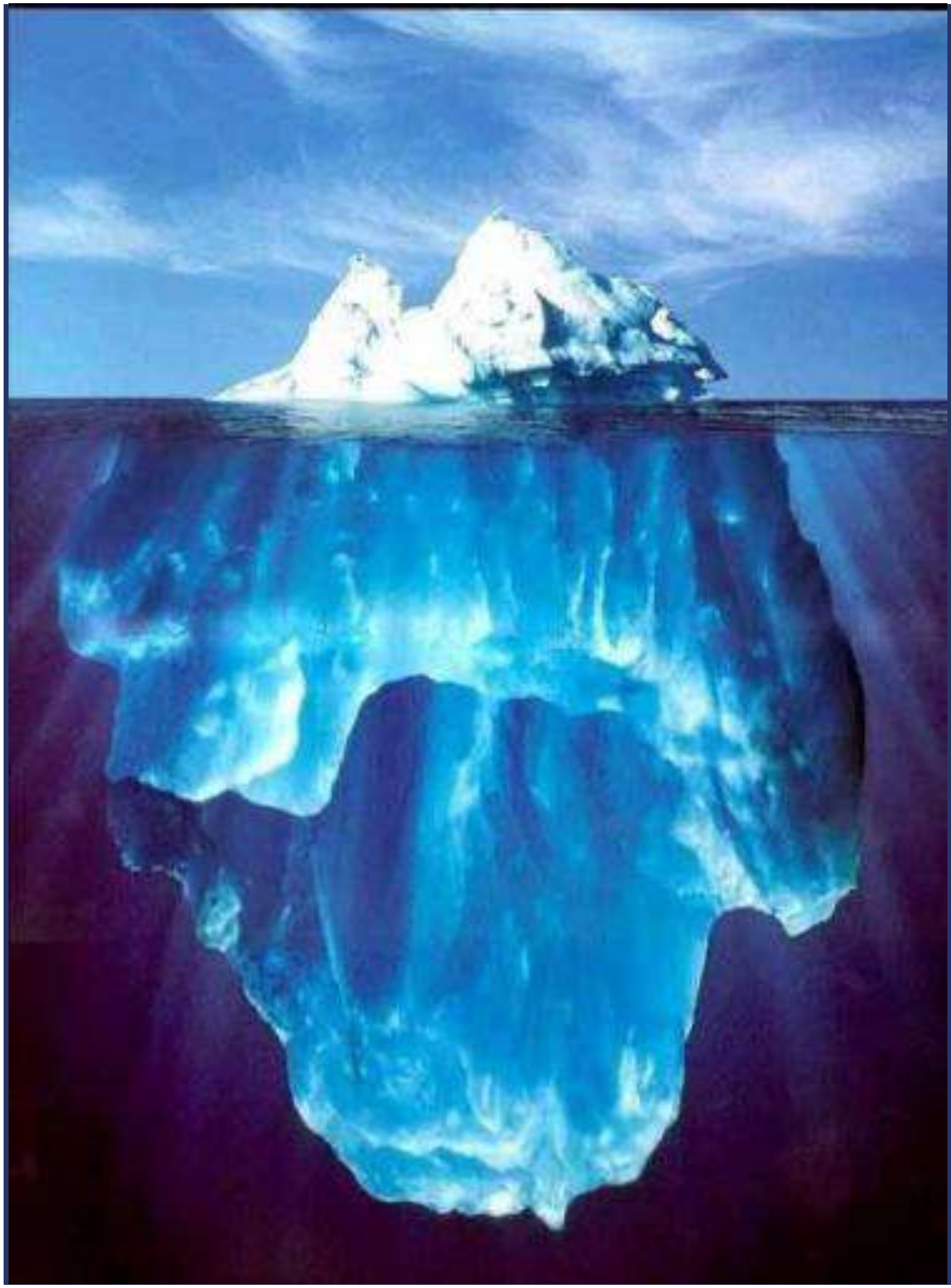
Another talk about teaching and learning…..

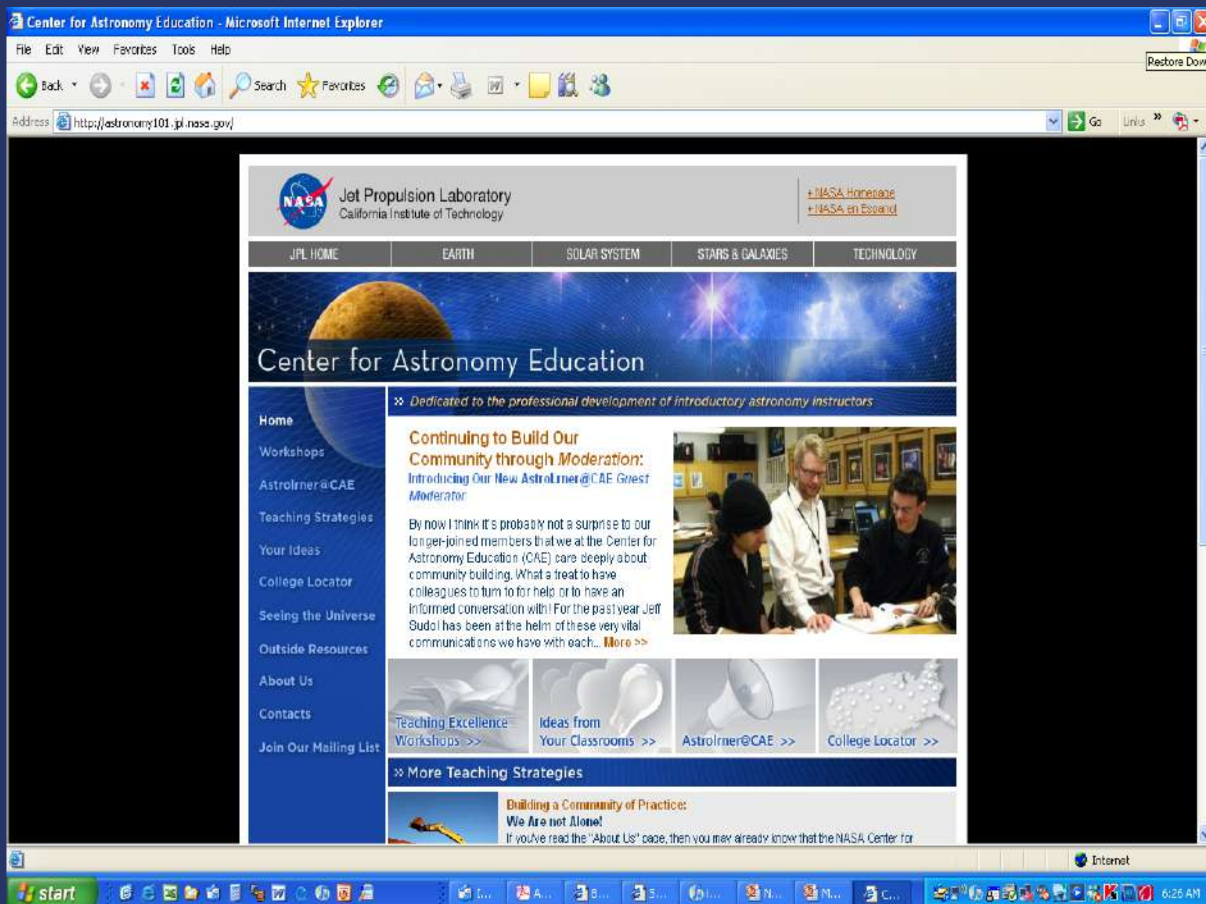


"I've seen it performed many times, but I can't remember ever sleeping through it so peacefully."



Just the tip of the iceberg

http://astronomy101.jpl.nasa.gov/



Class Response System – Medium Tech

A	B
C	D

From *How People Learn*

"Humans are viewed as goal-directed agents who actively seek information. They come to formal education with a range of prior knowledge, skills, beliefs, and concepts that significantly influence what they notice about the environment and how they organize and interpret it. This, in turn, affects their abilities to remember, reason, solve problems, and acquire new knowledge. … If students' initial ideas and beliefs are ignored, the understandings that they develop can be very different from what the teacher intends."

How People Learn: Brain, Mind, Experience, and School (Expanded Edition),
National Research Council, National Academy Press, 2000.

How People Learn

- Students enter the classroom with preconceptions about how the world works. *If their initial understanding is not fully engaged, they may fail to grasp new concepts in meaningful ways that last beyond the purposes of an exam.*

- To fully develop competence, students must:
  (1) have a deep foundation of factual knowledge, (2) understand interrelationships among facts and concepts and (3) organize knowledge in ways that facilitate retrieval and application

- A "metacognitive" approach to instruction can help students learn to take control of their own learning and monitor progress.

How People Learn: Brain, Mind, Experience, and School (Expanded Edition),
National Research Council, National Academy Press, 2000.

Key results from research into cognition and instruction

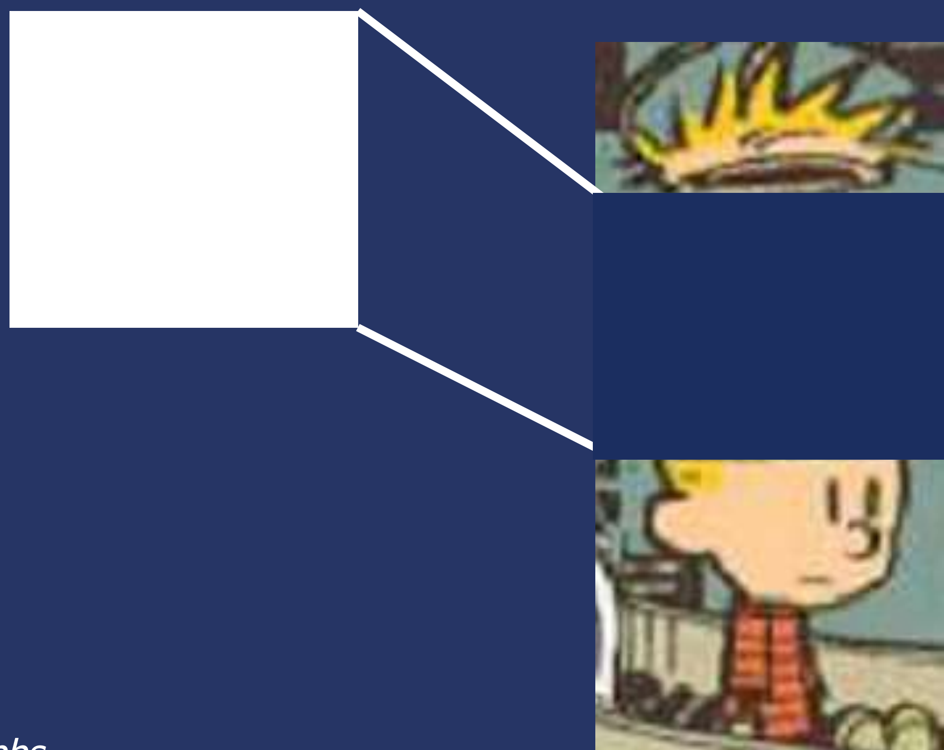
- Learning is productive / constructive - learning requires mental effort.
- Knowledge is associative / linked to prior mental models and cognitive structures.
- The cognitive response is context dependent – what and how you learn depends on the educational setting.
- Most people require some social interactions in order to learn deeply and effectively.

Joe Reddish, 2001. AAPT, San Diego

Active Learning:

when students take active responsibility for participating in and monitoring of their own learning by engaging in critical reasoning about the ideas presented in the class.

A Commonly Held Inaccurate Model of a Student's Conceptual Framework



Bill Watterson,
Calvin and Hobbs

A Commonly Held Inaccurate Model of Teaching and Learning

Bill Watterson,
Calvin and Hobbs

"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"

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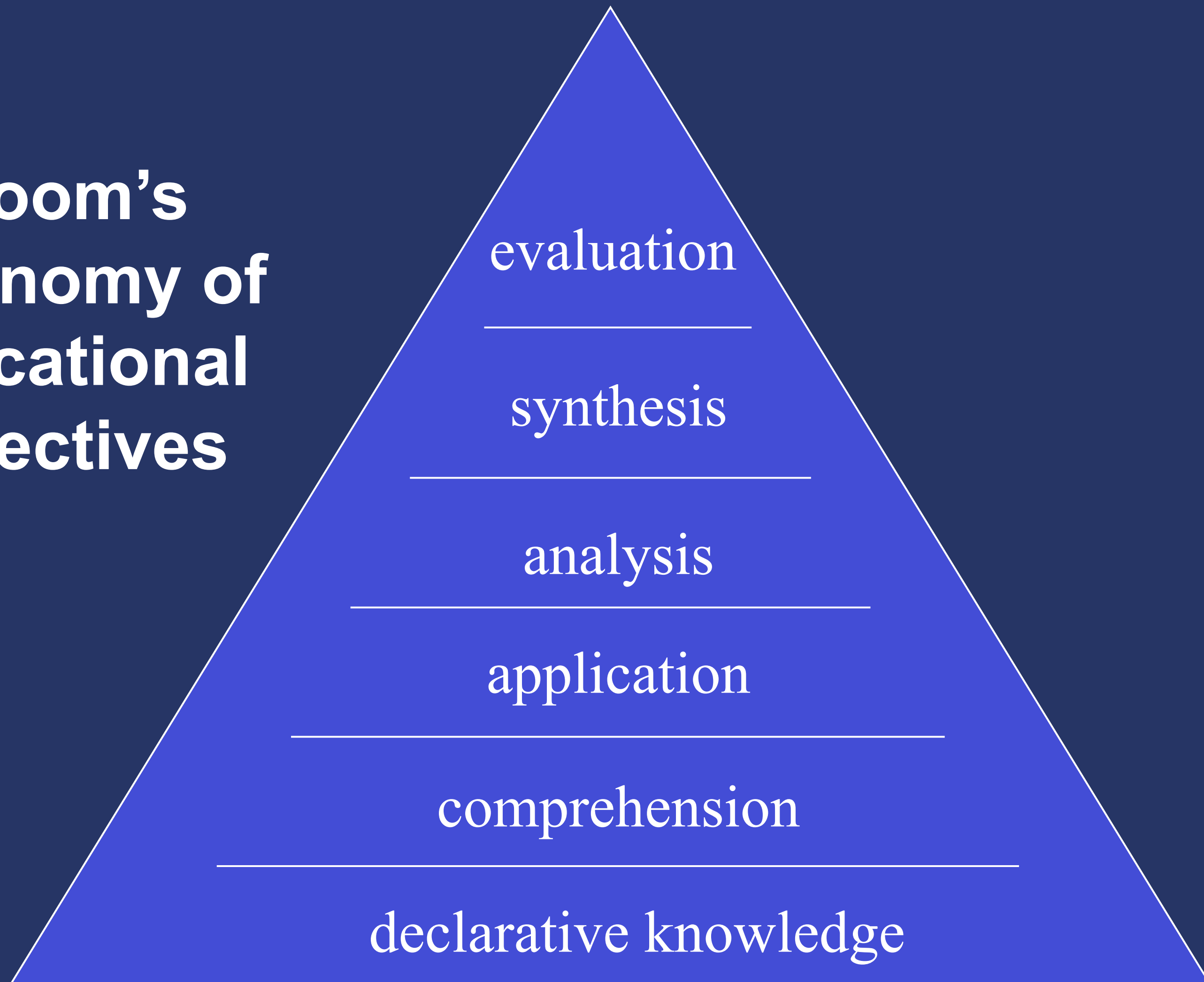
Does your class intellectually challenge students or re-enforce the memorization of facts and declarative knowledge?

Bloom's Taxonomy of Educational Objectives



The Role of Assessment in the Development of the College Introductory Astronomy Course A "How-to" Guide for Instructors. Astronomy Education Review, 1(1), 1-24, 2002. G. Brissenden, T.F. Slater, and R. Matheiu.

Most ideas about teaching are not new, but not everyone knows the old ideas.

Euclid (300 B.C.)

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

2000 years ago

Today

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

2000 years ago

Today

Techniques for all size classes

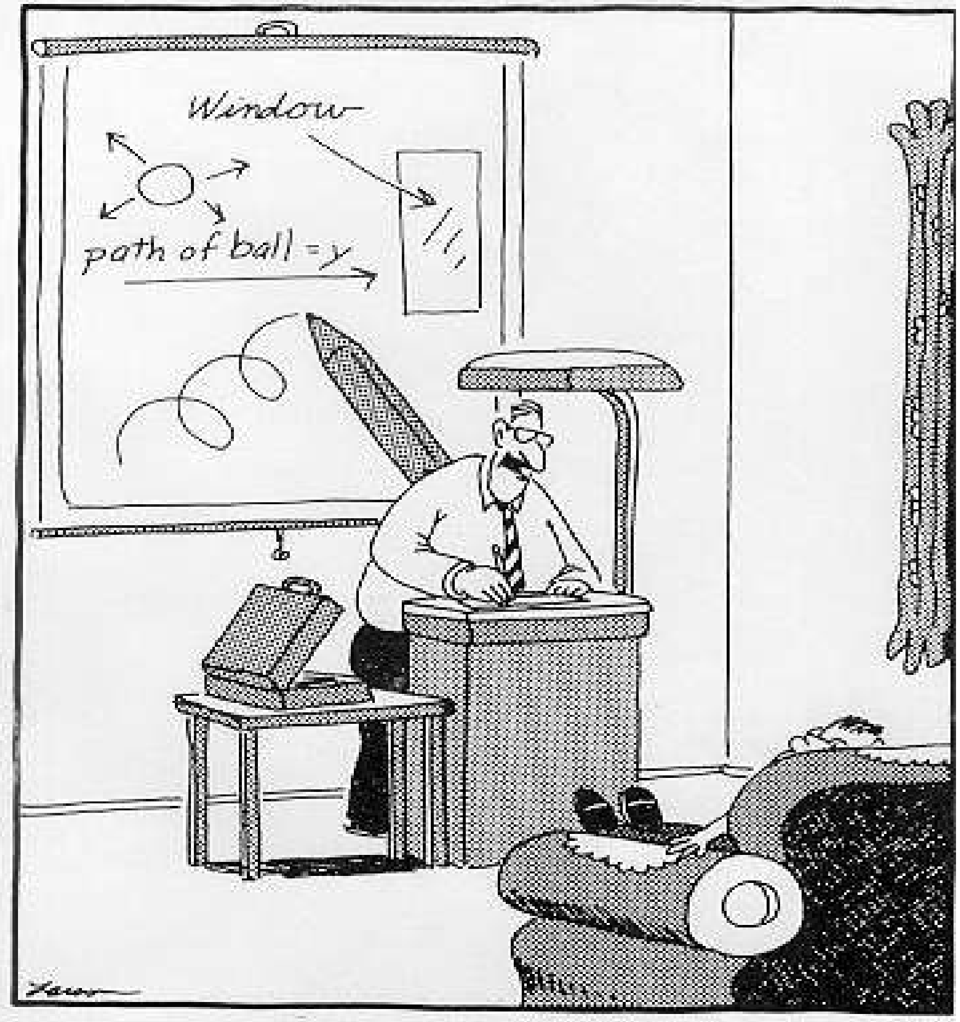
Techniques for all size classes

Techniques for all size classes


Where do we live?
On a planet
On a star
On a cloud
On a moon
On a galaxy

If a Picture is worth a thousand words, then what is a real-world, first-hand, experience worth?

- Audience participation is strongly encouraged
- Demos are sometimes life-threatening



Eventually, Billy came to dread his father's lectures over all other forms of punishment.

"Eventually, Billy came to dread his father's lectures over all other forms of punishment"

The Montillation of Traxoline

It is very important that you learn about traxoline. Traxoline is a new form of zionter. It is montilled in Ceristanna. The Ceristannians gristerlate large amounts of fevon and then brachter it to quasel traxoline. Traxoline may well be one of our most lukized snezlaus in the future because of our zionter lescelidge.

(attributed to the insight of Judy Lanier)

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<u>Directions</u>: Answer the following questions in complete sentences. Be sure to use your best handwriting.

1. What is traxoline?
2. Where is traxoline montilled?
3. How is traxoline quaselled?
4. Why is it important to know about traxoline?

What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal). Use demonstrations (interactive lecture demos)
- Just In Time Teaching
- In-class quizzes (graded/ungraded)
- In-class writing (with/without discussion)
  - muddiest point
  - summary of today's main points
  - 5-minute free writing
- Think-Pair-Share (Peer Instruction-*ConcepTests*)
- Small Group Interactions (closed/open; in/out of class)
- Student Debates (individual/group)
- Whole Class Discussions
- Jigsawing

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Issues with Questioning in the Classroom

1. Insufficient "Wait-Time"
2. The Rapid-Reward
3. The Programmed Answer
4. Fixation at a Low-Level of Questioning
5. Non-Specific Feedback Questions
6. Teacher's Ego-Stroking & Classroom Climate

Promoting a higher level of engagement and feedback when doing demos and using media in the classroom

The teachable moment is extended when students thinking is made explicit and held accountable BEFORE an outcome is provided. This is your chance to make connections and build a desire for the answers your classroom activity will display.

Tobias, S. *Revitalizing Undergraduate Science-Why Some Things Work and Most Don't,* Research Corporation, 1992.

Sokoloff, David and Ronald Thornton," Using Interactive Lecture Demonstrations to Create an Active Learning Environment," *The Physics Teacher* 35, 340-347 (1997).

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Some Examples of Writing Prompts

- Illustrate the meaning of "standard candle" using one example taken from everyday life and one example from astronomy.
- What about the enterprise of science makes it different than business?
- If we establish communication with an intelligent, extraterrestrial civilization, who should speak for Earth and what should he/she/they say?
- What were the most important ideas we learned about today?
- What do you need to do to get high grades in this course and what will you do differently before the next exam?

What Can I do Besides Lecture to Engage Students in their Learning?

- Ask students questions (not all questions are equal). Use demonstrations (interactive lecture demos)
- Surprise quizzes (graded/ungraded)
- In-class writing (with/without discussion)
  - muddiest point
  - summary of today's main points
  - 5-minute free writing
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Learner-centered teaching and learning strategies:

designed to intellectually and actively engage students in their learning, e.g.,

- Interactive Lectures, Demonstrations, and Simulations
- Think-Pair-Share or PeerInstruction and ClassAction
- Lecture -Tutorials and Ranking -Tasks

Teaching and Learning Astronomy in the 21st Century, Prather, E.E., Rudolph, A.L., & Brissenden, G. Physics Today, Oct 2009

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Think-Pair-Share or Peer Instruction

How using a combination of conceptually challenging questions, classroom feedback and student-to-student discussions can increase understanding and provide data on students' learning for you and them.

Crouch, C. H. & Mazur, E. 2001, "Peer Instruction: Ten Years of Experience and Results," *American Journal of Physics*, 69(9), 970, 2001

Development and Application of a Situated Apprenticeship Approach to Professional Development of Astronomy Instructors, Prather, E. E., and Brissenden, G. The Astronomy Education Review, 7(2), 2008

Clickers as Data Gathering Tools and Students' Attitudes, Motivations, and Beliefs on Their Use in this Application, Prather, E. E., Brissenden, G., The Astronomy Education Review, 8 (1), 2009 .

Effective Multiple Choice Questions

Consider your answer to these questions about writing multiple-choice questions.

In a multiple-choice question, when is the longest answer the correct answer?

A. Rarely

B. Sometimes

C. It's common for it to be the correct answer, and it's often stuffed with new information that should have gone in the main part of the course but we forgot so now we're putting it in the quiz because we can't possibly leave out the tiniest detail

D. Occasionally

Adapted from: http://blog.cathy-moore.com/2007/08/can-you-answer-these-6-questions-about-multiple-choice-questions/

Consider your answer to these questions about writing multiple-choice questions.

When is it NOT a good idea to avoid negative questions?

A. Never
B. Sometimes
C. Always
D. What?

Adapted from: http://blog.cathy-moore.com/2007/08/can-you-answer-these-6-questions-about-multiple-choice-questions/

Consider your answer to these questions about writing multiple-choice questions.

How often is the correct choice “A”?

A. Usually

B. Frequently

C. Often

D. Almost never, because if “A” is the right answer, then the learner doesn’t have to read all the other options we spent so much time writing and revising, and where’s the return on investment in that?

Adapted from: http://blog.cathy-moore.com/2007/08/can-you-answer-these-6-questions-about-multiple-choice-questions/

Consider your answer to these questions about writing multiple-choice questions.

When is “All of the above” the correct answer?

A. With alarming regularity
B. When we try to cover too much in one question
C. When we use a question to teach instead of assess
D. All of the above

Adapted from: http://blog.cathy-moore.com/2007/08/can-you-answer-these-6-questions-about-multiple-choice-questions/

Consider your answer to these questions about writing multiple-choice questions.

We can confuse learners when we:

A. fail to actually complete the sentence we started in the question.

A. inconsistent grammar in the options.

B. sometimes we veer off into another idea entirely.

C. wombats.

Adapted from: http://blog.cathy-moore.com/2007/08/can-you-answer-these-6-questions-about-multiple-choice-questions/

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Class Response System – Medium Tech

A

B

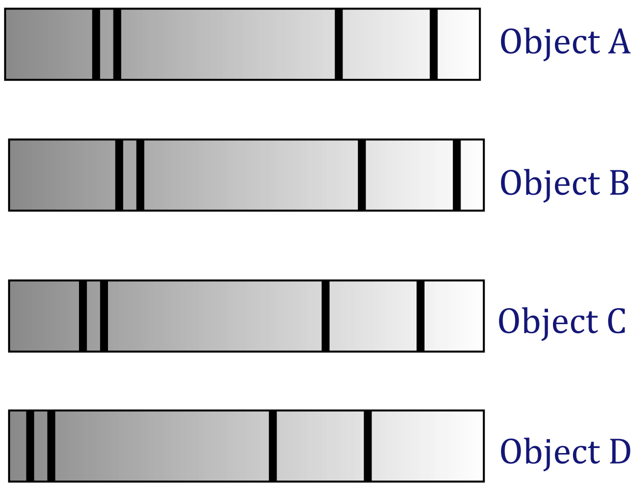
C

D

Use the four spectra for objects A-D, shown below, to answer the next question. Note that one of the spectra is from an object at rest (not moving relative to Earth) and the remaining spectra come from objects that are all moving away from the observer. [*Assume that the left end of the spectrum corresponds with short wavelengths and the right end corresponds with long wavelengths*.]

Of the objects that are moving, which is moving with the fastest speed?

A. Object A
B. Object B
C. Object C
D. Object D
E. They are moving the same speed, the speed of light.



An important line in the spectrum of a typical cloud of hydrogen gas occurs at 486 nm for a cloud that is not moving relative to an observer. Imagine that you observe four different clouds of gas (A-D) from Earth and discover that this line is at the wavelength shown in the table below for each of the four clouds.

STAR	Wavelength of Absorption line
A	449 nm
B	460 nm
C	458 nm
D	447 nm

Based on the information in the table above, which of the following is the most accurate ranking of the distance to the clouds (A-E), from closest to farthest from Earth.

A. B, C, A, D

B. D, A, C, B

C. A=B=C=D

D. Cannot be determined from the information provided.

Given that a seed grows into a massive tree, where does most of the mass of the tree come from?

A. From water

B. 2. From dirt and soil

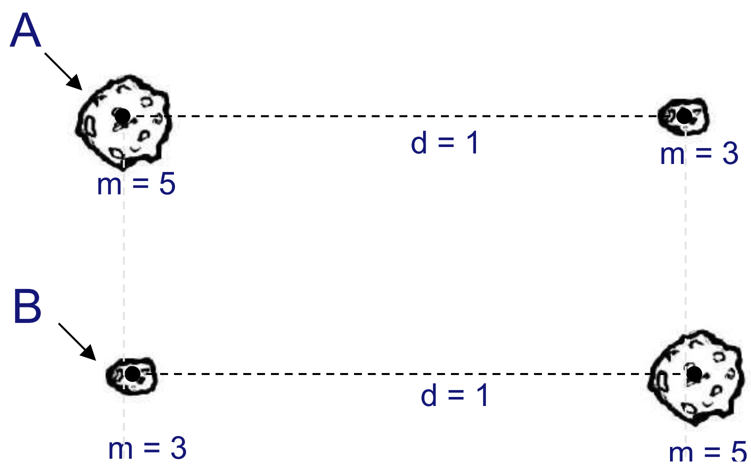
C. 3. From the air

D. 4. Its already in the seed.

Which of the descriptions given below best describes the sign a person will have if born on that day?

A. Taurus is high in the southern sky at sunset.
B. Aquarius is on the eastern horizon at sunrise.
C. Scorpius is on the western horizon at noon.
D. Leo is high in the southern sky at midnight.

Which is greater, the gravitational force exerted by asteroid "A" on its "partner" asteroid or the gravitational force exerted by asteroid "B" on its "partner" asteroid.

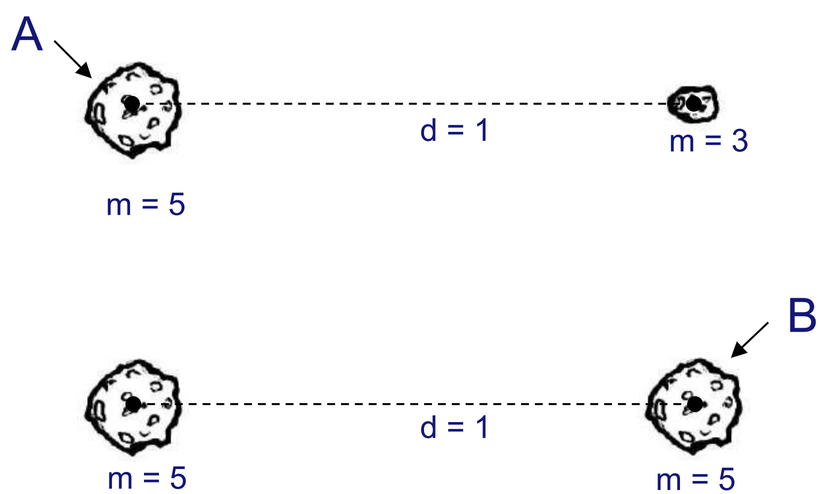


A. The force exerted by A on its partner asteroid is greater.

B. The force exerted by B on its partner asteroid is greater.

C. The same force is exerted by asteroid "A" and asteroid "B".

Which would experience a greater acceleration, as a result of the gravitational force exerted on it, asteroid “A” or asteroid “B”?



A. Asteroid A would experience the greater acceleration.

B. Asteroid B would experience the greater acceleration.

C. The asteroids will experience the same acceleration.

Create a suitable questions to use for think-pair-share?

- Work with a small group
- Make sure your question is multiple choice
- Coordinate how your group will model “think – pair – share” using your question

On the topic of:

Research on the effectiveness of instruction

- Which instructional methods, strategies, activities and interventions work best in the classroom (in our case the Astro 101 classroom)?
- Do they work in all classrooms at all types of institutions, or only ones with certain characteristics?
- How can we easily evaluate the success of our instruction and measure how much our students learn as a result?

The Bottom Line

Question: can interactive learning strategies have a positive impact on students' conceptual learning of key ideas in Astro 101?

Answer: Yes! But…

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Our Recent National Study

When: Fall 2006 to Fall 2007

What: A national study of learning in Astro 101 classrooms

Why: To determine how instructional contexts affects student learning

How: The “Light and Spectroscopy Concept Inventory” (LSCI) was administered pre- and post-instruction

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.

The Instrument: the LSCI

- The Light and Spectroscopy Concept Inventory
  - 26 multiple-choice questions designed to test students' conceptual understanding of these topics in the context of astronomy
- The topics of light and spectroscopy were chosen because they are common to all Astro 101 courses, regardless of their astronomy content

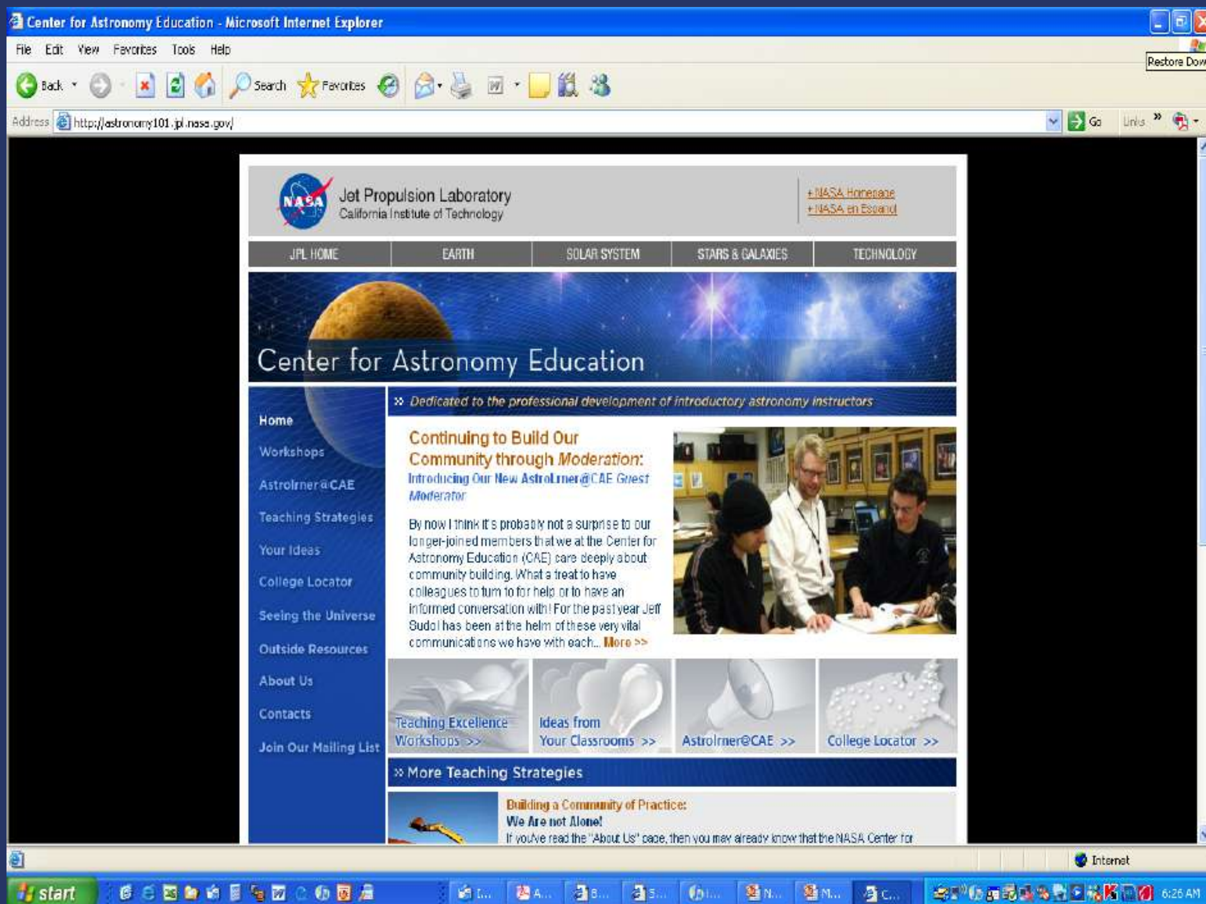
Development of the Light and Spectra Concept Inventory, Bardar, Erin M. (Weeks), Prather, E. E., Bresher, Kenneth and Slater, T. F. Astronomy Education Review, 5(2), 2007.

Participants

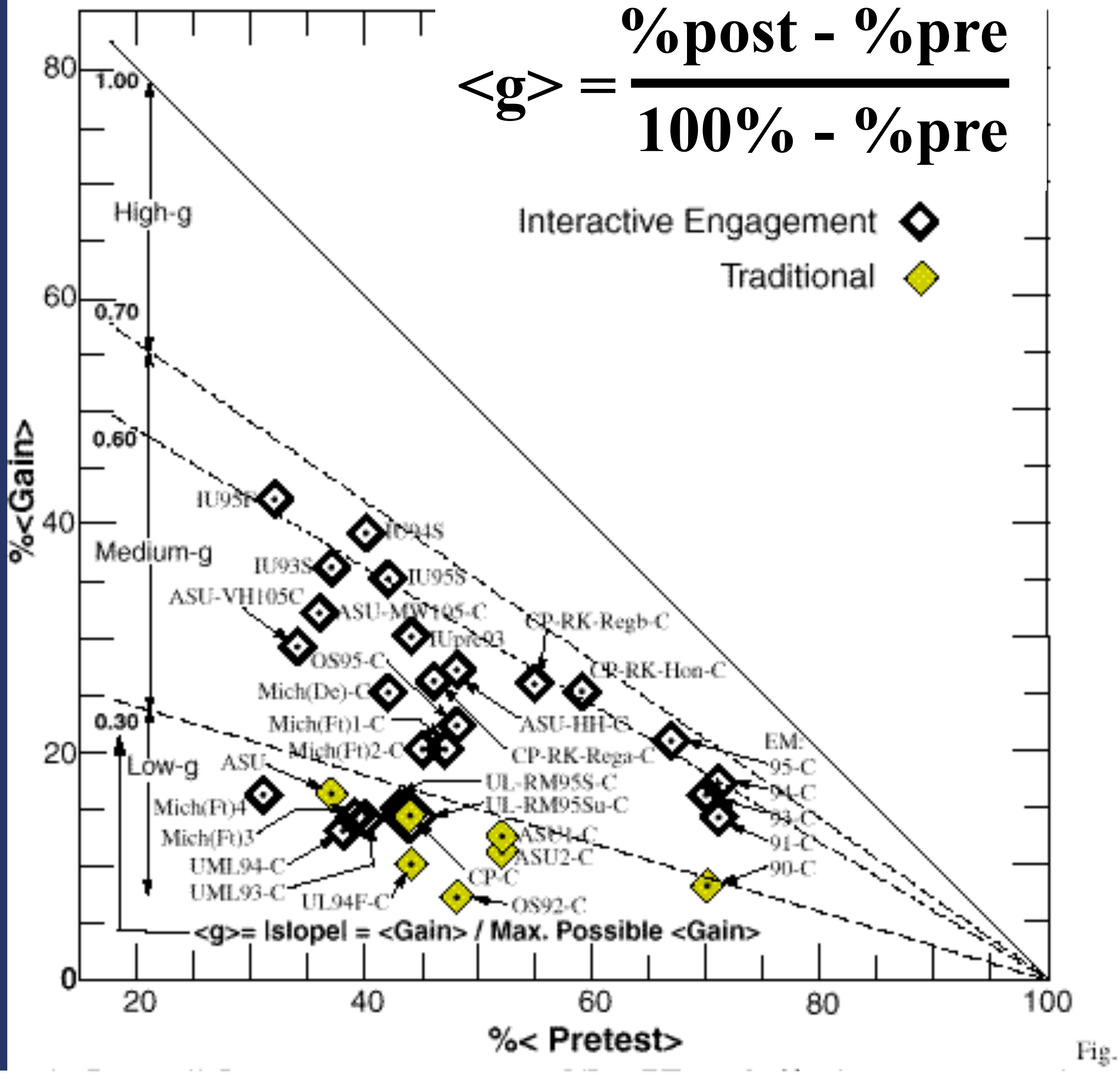
- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180

This was a truly national study

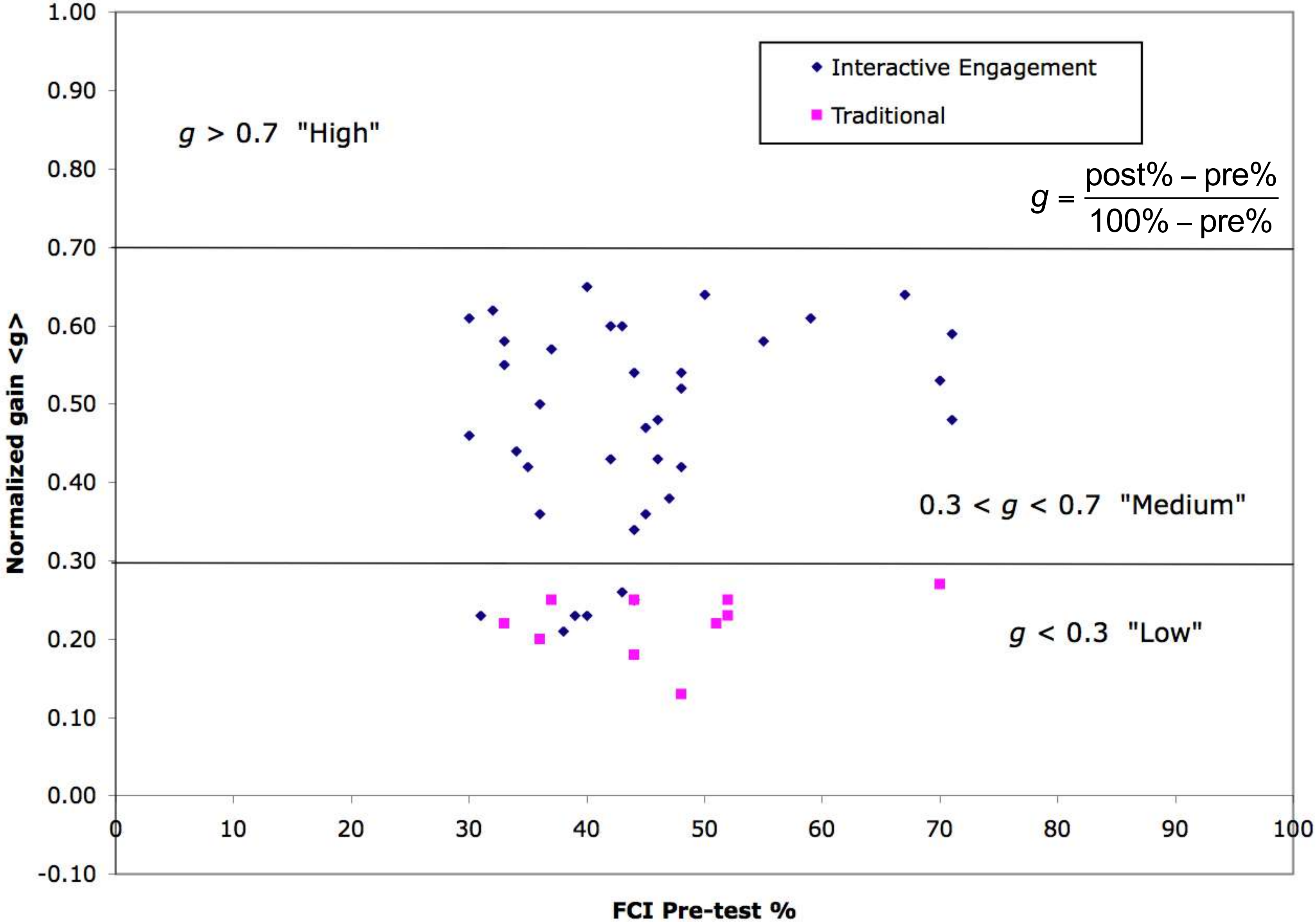
http://astronomy101.jpl.nasa.gov/

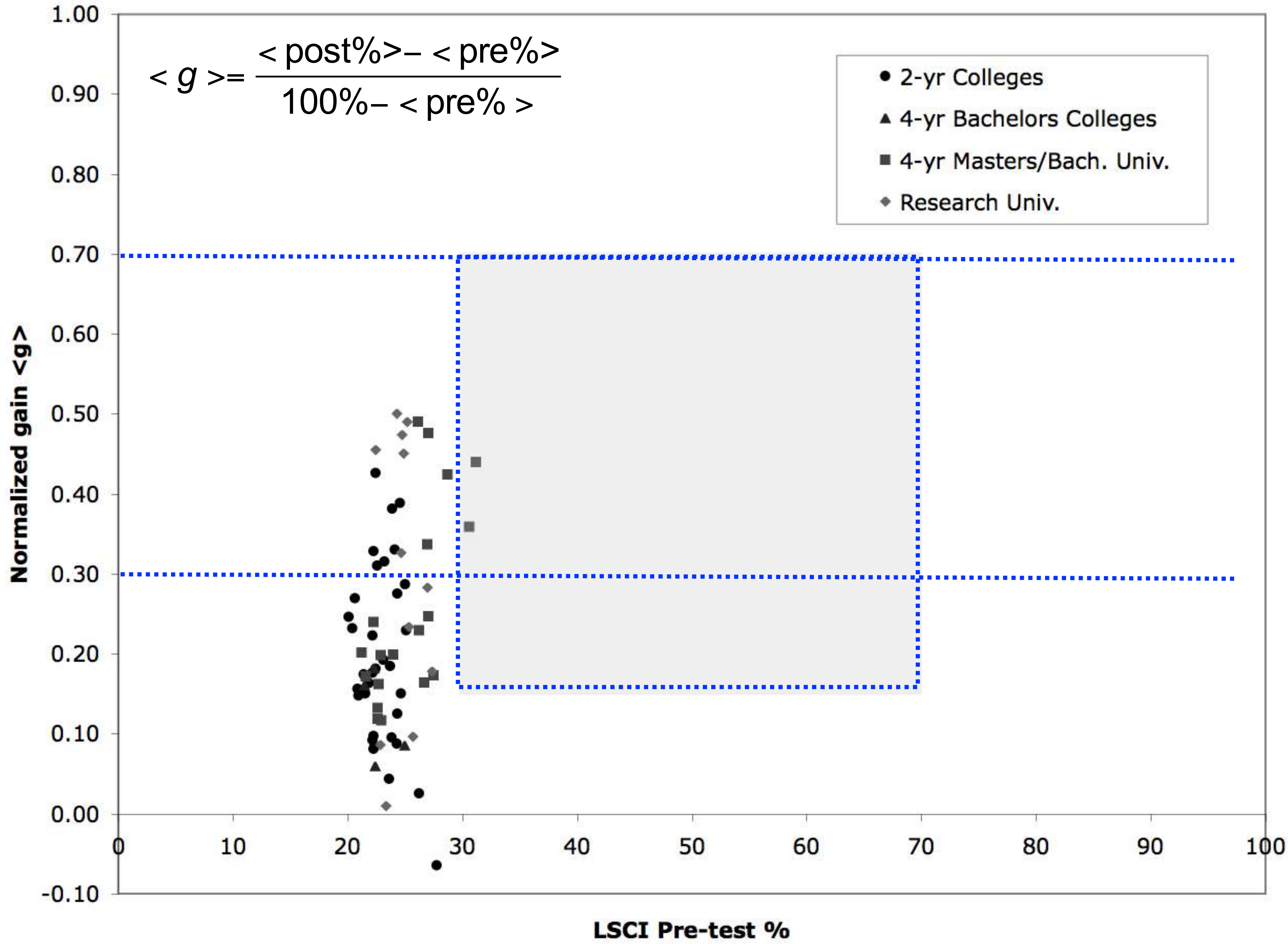


$$\langle g \rangle = \frac{\%post - \%pre}{100\% - \%pre}$$

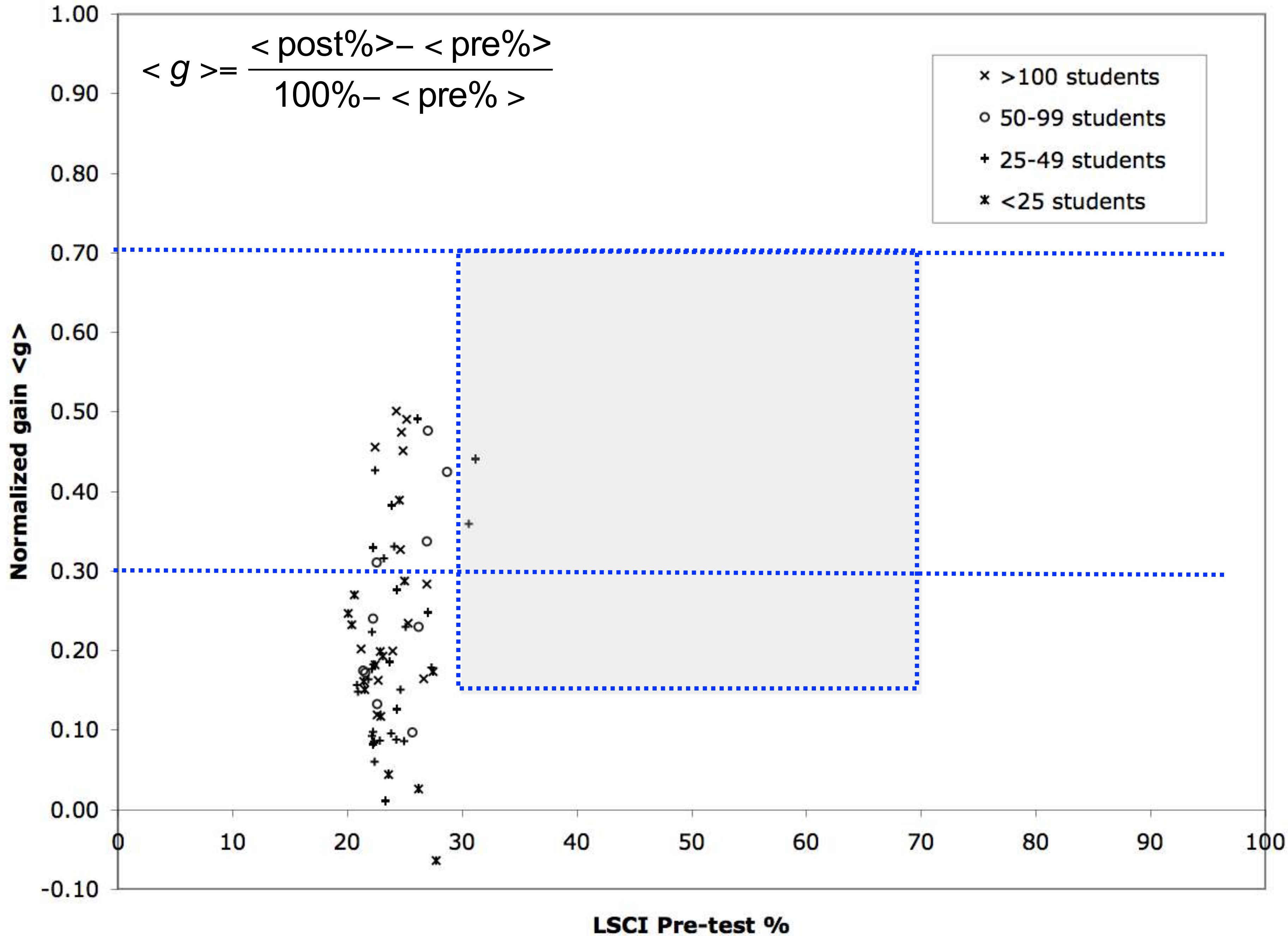


Results from a 6000 student study of Physics Students – *Hake AJP 1998*





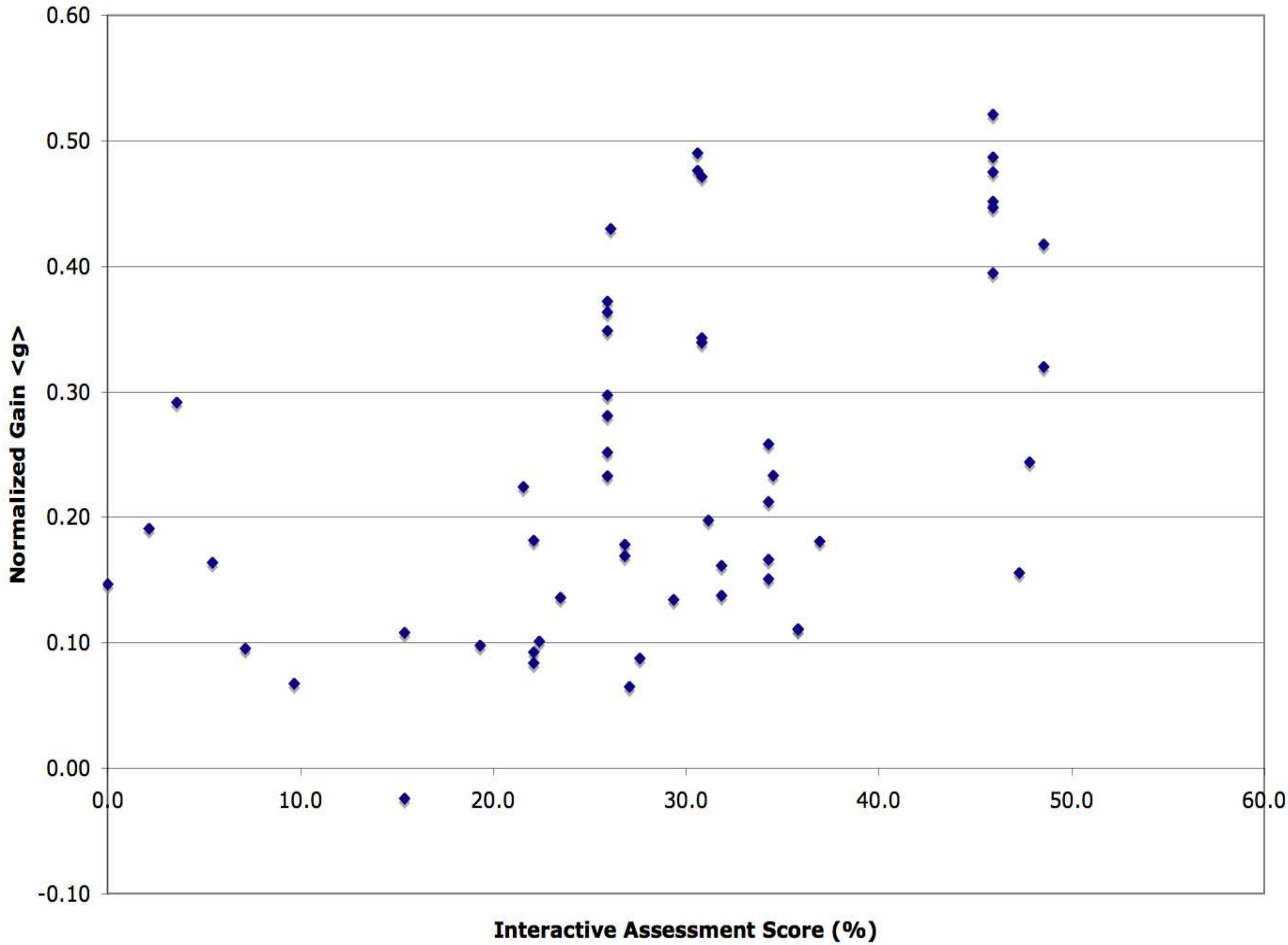
$$\langle g \rangle = \frac{\langle post\% \rangle - \langle pre\% \rangle}{100\% - \langle pre\% \rangle}$$
2-yr Colleges
4-yr Bachelors Colleges
4-yr Masters/Bach. Univ.
Research Univ.
Normalized gain <g>
LSCI Pre-test %
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
10
20
30
40
50
60
70
80
90
100



$$\langle g \rangle = \frac{\langle post\% \rangle - \langle pre\% \rangle}{100\% - \langle pre\% \rangle}$$
>100 students
50-99 students
25-49 students
<25 students
Normalized gain <g>
LSCI Pre-test %
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
10
20
30
40
50
60
70
80
90
100

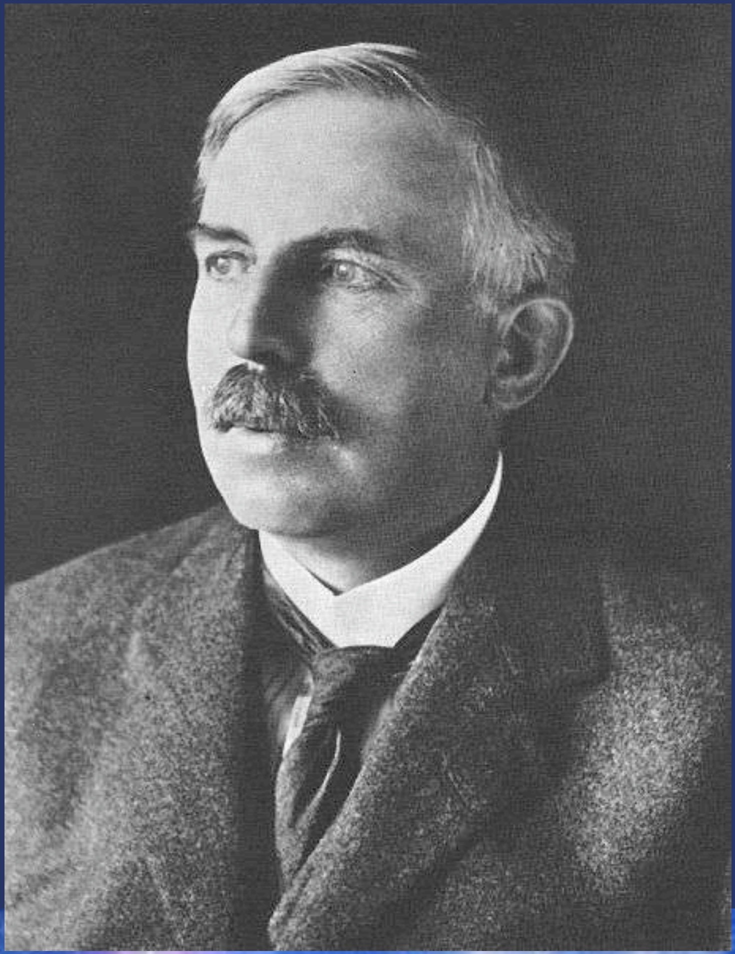
Instructor Surveys

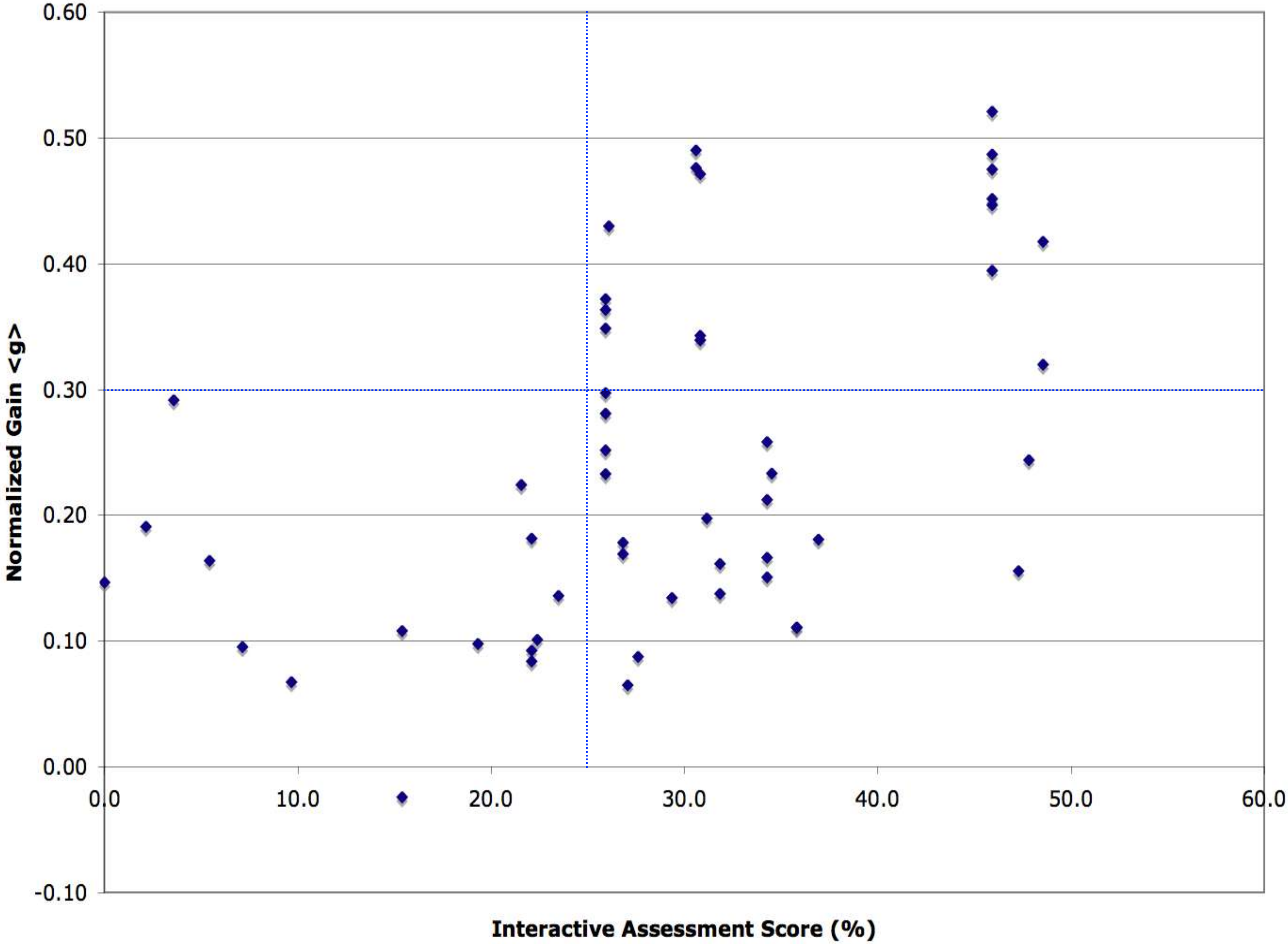
- To assess the level of interactivity in each classroom, we asked each instructor to fill out a survey detailing how they spent their class time
- This survey was used to construct an "Interactivity Assessment Score" (IAS) based on what percentage of total class time is used for interactive activities

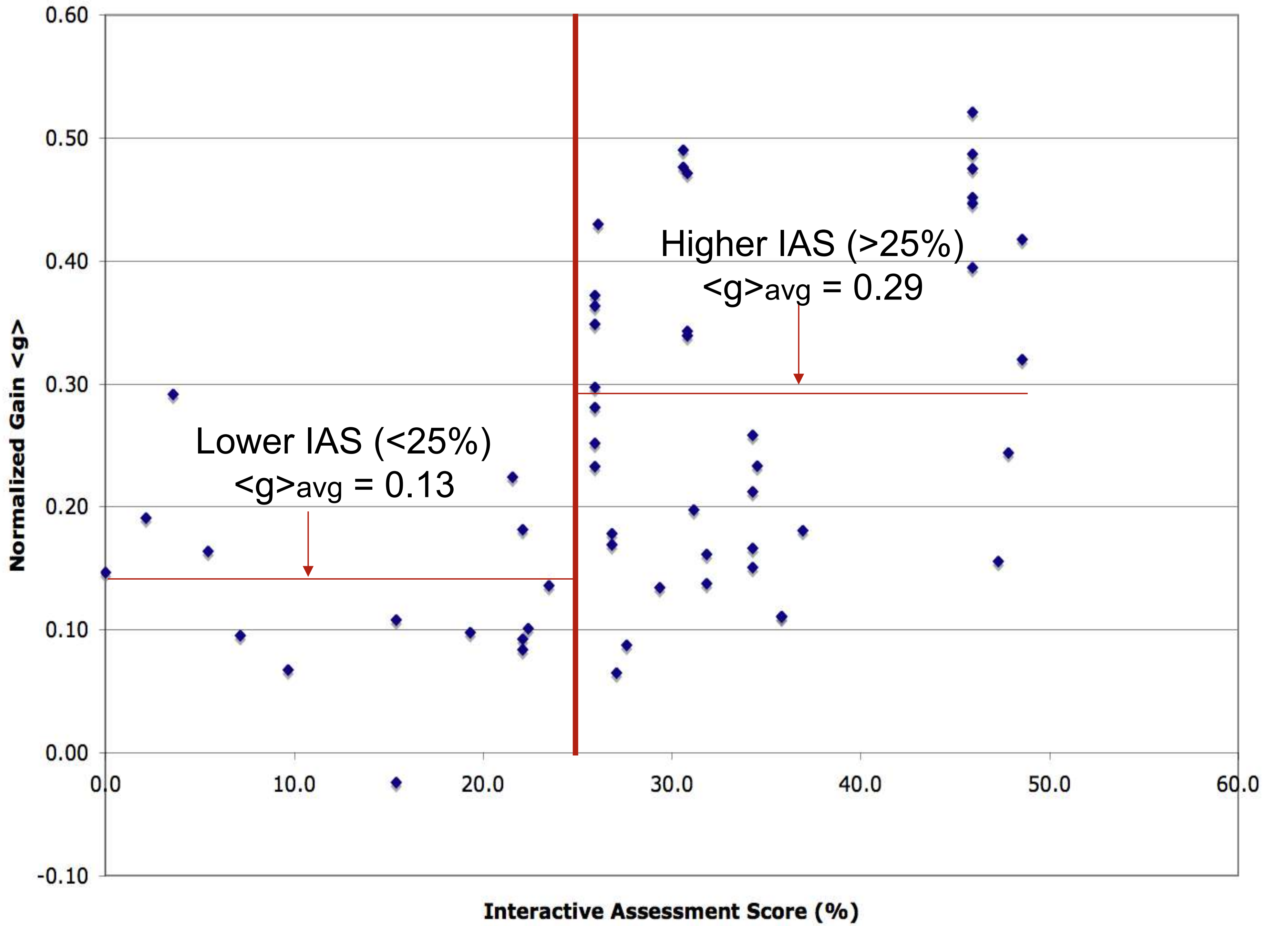

Normalized Gain <g>
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0.0
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)

Rutherford's attitudes are common among Physicists

- All science is either physics or stamp collecting
- The only possible conclusion that social sciences can draw is some do, some don't
- If your result needs a statistician then you should design a better experiment




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

Demographic Survey

- We also asked 15 demographic questions to allow us to determine how such factors as
  - Gender
  - Ethnicity
  - English as a native language
  - Parental education
  - Overall GPA
  - Major
  - Number of prior science courses
  - Level of mathematical preparation

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

- We conducted a full multivariate modeling analysis of our data
- 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

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Independent Variable	Normalized Gain 1 Coefficients (standard error)	 1 Standardized Coefficients	 2 Coefficients (standard error)	 2 Standardized Coefficients	 3 Coefficients (standard error)	 3 Standardized Coefficients	 4 Coefficients (standard error)	 4 Standardized Coefficients
Constant	-0.070		-0.235**		-0.266*		-0.208**	
	(0.059)		(0.060)		(0.120)		(0.061)	
Male	0.093**	0.183**	0.087**	0.170**	0.085*	0.167*	0.087**	0.171**
	(0.016)		(0.015)		(0.038)		(0.015)	
White	0.019	0.032	0.012	0.020	0.033	0.055	0.013	0.021
	(0.020)		(0.020)		(0.055)		(0.019)	
Native English speaker	0.019	0.022	0.013	0.015	-0.049	-0.057	0.011	0.013
	(0.029)		(0.028)		(0.080)		(0.028)	
Father with Bachelor's degree or higher	0.008	0.015	0.004	0.008	0.004	0.008	0.005	0.009
	(0.016)		(0.016)		(0.016)		(0.016)	
Natural log of Family Income	0.002	0.008	0.002	0.008	0.002	0.006	0.003	0.008
	(0.010)		(0.009)		(0.009)		(0.009)	
Class year	0.018*	0.071*	0.024**	0.092**	0.024**	0.093**	0.024**	0.093**
	(0.008)		(0.008)		(0.008)		(0.008)	
College GPA	0.036**	0.106**	0.037**	0.109**	0.067**	0.197**	0.036**	0.106**
	(0.010)		(0.010)		(0.026)		(0.010)	
Arts, Humanities, or Social Science major	0.101**	0.176**	0.104**	0.181**	0.010	0.018	0.023	0.040
	(0.018)		(0.017)		(0.042)		(0.041)	
Last math class taken	0.031**	0.214**	0.034**	0.230**	0.040**	0.274**	0.034**	0.229**
	(0.005)		(0.005)		-0.011		(0.005)	
Number of previous physical science course	0.024**	0.120**	0.024**	0.120**	0.021	0.105	0.023**	0.119**
	(0.006)		(0.006)		(0.015)		(0.006)	
Previous Astrophysics course	-0.029	-0.039	-0.028	-0.039	-0.031	-0.042	-0.030	-0.041
	(0.022)		(0.022)		(0.022)		(0.022)	
Pretest Percent Correct	-0.005**	-0.224**	-0.005**	-0.213**	-0.005**	-0.213**	-0.005**	-0.212**
	(0.001)		(0.001)		(0.001)		(0.001)	
Interactivity Score			0.0051**	0.258**	0.0062	0.314	0.0043**	0.217**
			(0.0006)		(0.0037)		(0.0007)	
Cross term: Interactivity score X Arts, Humanities, Soc Sci Major					0.0032*	0.183*	0.0027*	0.158*
					(0.0013)		(0.0013)	
Cross term: Interactivity score X Male					0.0001	0.004		
					(0.0012)			
Cross term: Interactivity score X White					-0.0006	-0.044		
					(0.0018)			
Cross term: Interactivity score X Native English speaker					0.0022	0.129		
					(0.0027)			
Cross term: Interactivity score X College GPA					-0.0010	-0.182		
					(0.0008)			
Cross term: Interactivity score X Last math class taken					-0.0002	-0.057		
					(0.0004)			
Cross term: Interactivity score X Number of previous physical science courses					0.0001	0.016		
					(0.0005)			
F Value	*18.2***		*24.3***		*16.2***		*23.0***	
N	*910*		*910*		*910*		*910*	
Adjusted R-Square	*0.185*		*0.250*		*0.250*		*0.253*	

***p < .05**
****p < .01**

The take home message Part I

The results of our investigation reveal that the positive effects of interactive learning strategies apply equally to men and women, across ethnicities, for students with all levels of prior mathematical preparation and physical science course experience, independent of GPA, and regardless of primary language. These results powerfully illustrate that all categories of students can benefit from the effective implementation of interactive learning strategies.

The take home message Part II

Implementation is the most important factor to success in student learning.

More work on professional development of faculty is needed if we are to side wide spread adoption and proper implementation of research-validated instructional strategies.

Help People.

If you can't help them,
at least try not to hurt them.

The Dalai Lama

When Students Are Not Learning, Are You Really Teaching?

Dr. Edward Prather

The University of Arizona.
Department of Astronomy and Steward Observatory

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