# Learner Centered Teaching in Physics and Astronomy


## Dr. Edward Prather

University of Arizona

*Center for Astronomy Education (CAE)*

http://astronomy101.jpl.nasa.gov




# Collaboration of Astronomy Teaching Scholars (CATS)

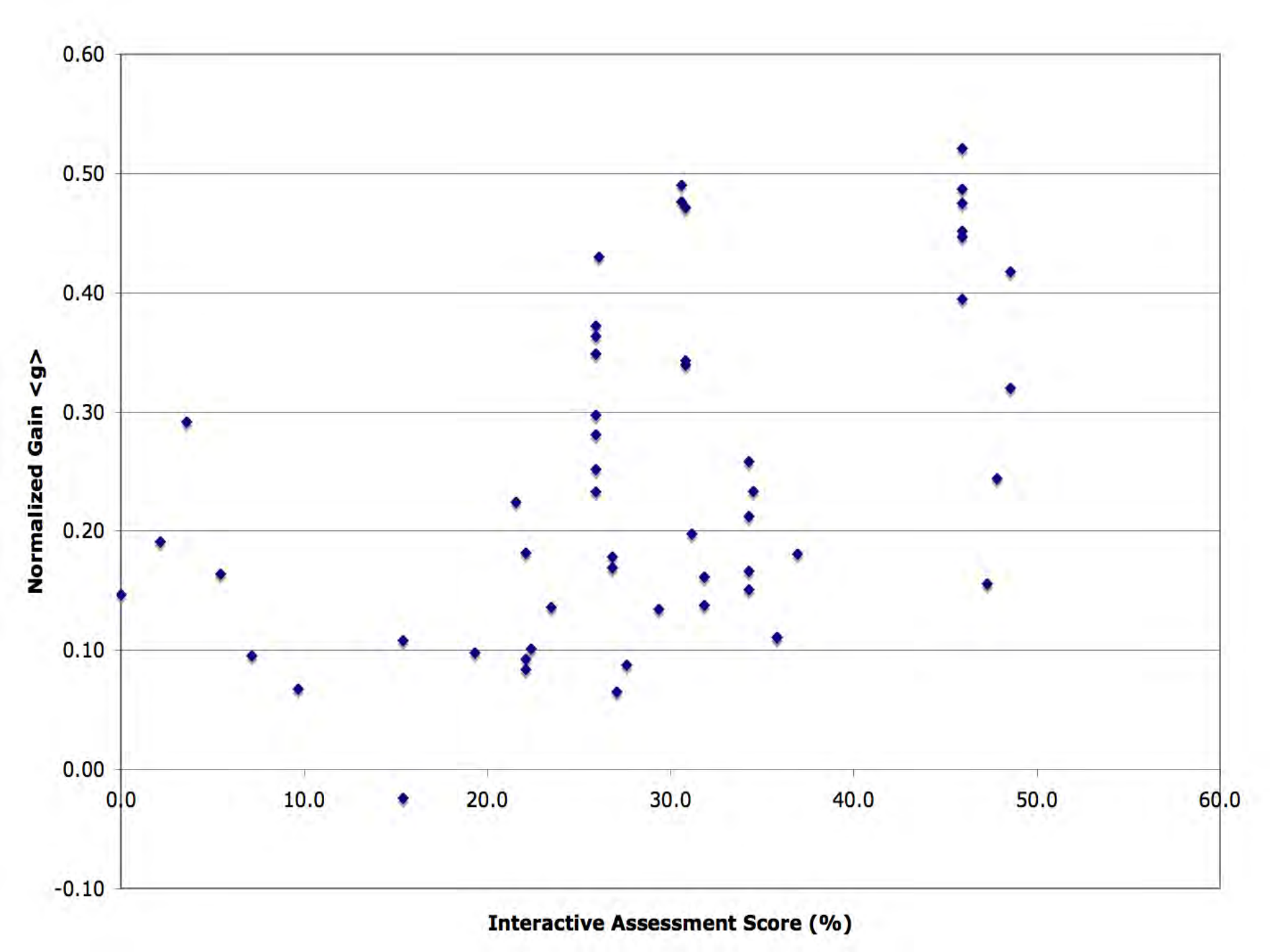
- Leilani Arthurs, UNL
- Duncan Brown, Syracuse Univ.
- Sanlyn Buxner, Univ. of Arizona
- David Consiglio, Bryn Mawr College
- Tim Chambers, U Michigan
- Steve Desch, Guilford Tech. CC
- Doug Duncan, CU Boulder
- Jeffrey Eckenrode, Pacific Science CTR
- Tom English, Guilford Tech. CC
- John Feldmeier, Youngstown State Univ.
- Amy Forestell, SUNY New Paltz
- Rica French, MiraCosta College
- Adrienne Gauthier, Dartmouth
- Pamela Gay, SIU-Edwardsville
- Dennis Hands, High Point Univ.
- Kevin Hardegree-Ullman, University of Toledo
- Melissa Hayes-Gehrke, Univ. of Maryland
- Seth Horstein, CU Boulder
- David Hudgins, Rockhurst Univ.
- Chris Impey, Univ. of Arizona
- Julia Kamenetzky, Univ of Arizona
- Jessica Kapp, Univ. of Arizona
- John Keller, Cal Poly SLO
- Julia Kregenow, Penn State
- Michelle Wooten, Univ of Alabama
- Kevin Lee, UNL & NSF
- Patrick Len, Cuesta College
- Chris Lintott, Univ. of Oxford
- Michael LoPresto, Henry Ford CC
- Daniel Loranz, Truckee Meadows CC
- Julie Lutz, Univ. of Washington
- Danny Martino, Santiago Canyon College
- Benjamin Mendelsohn, West Valley College
- Ed Montiel, Louisiana State University
- Peter Newbury, Univ. of British Columbia
- Lee Powell, UN Kearney
- Matthew Price, Ithaca College
- Jordan Raddick, Johns Hopkins Univ.
- Alex Rudolph, Cal Poly - Pomona
- Travis Rector, Univ. of Alaska
- Paul Robinson, Westchester CC
- Wayne Schlingman, Ohio State
- Sébastien Cormier, San Diego College
- Colin Wallace, UNC
- Kathryn Williamson, NRAO
- James Wysong Jr., Hillsborough CC
- Todd Young, Wayne St. College

# Take Home Messages

- Research-validated interactive learning strategies can benefit ALL students in ALL classroom environment - BUT
- The quality of our implementation is likely the most deterministic factor toward student achievement

# CAE National Study

- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180 (now with sections >750!)


0.60
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Normalized Gain <g>
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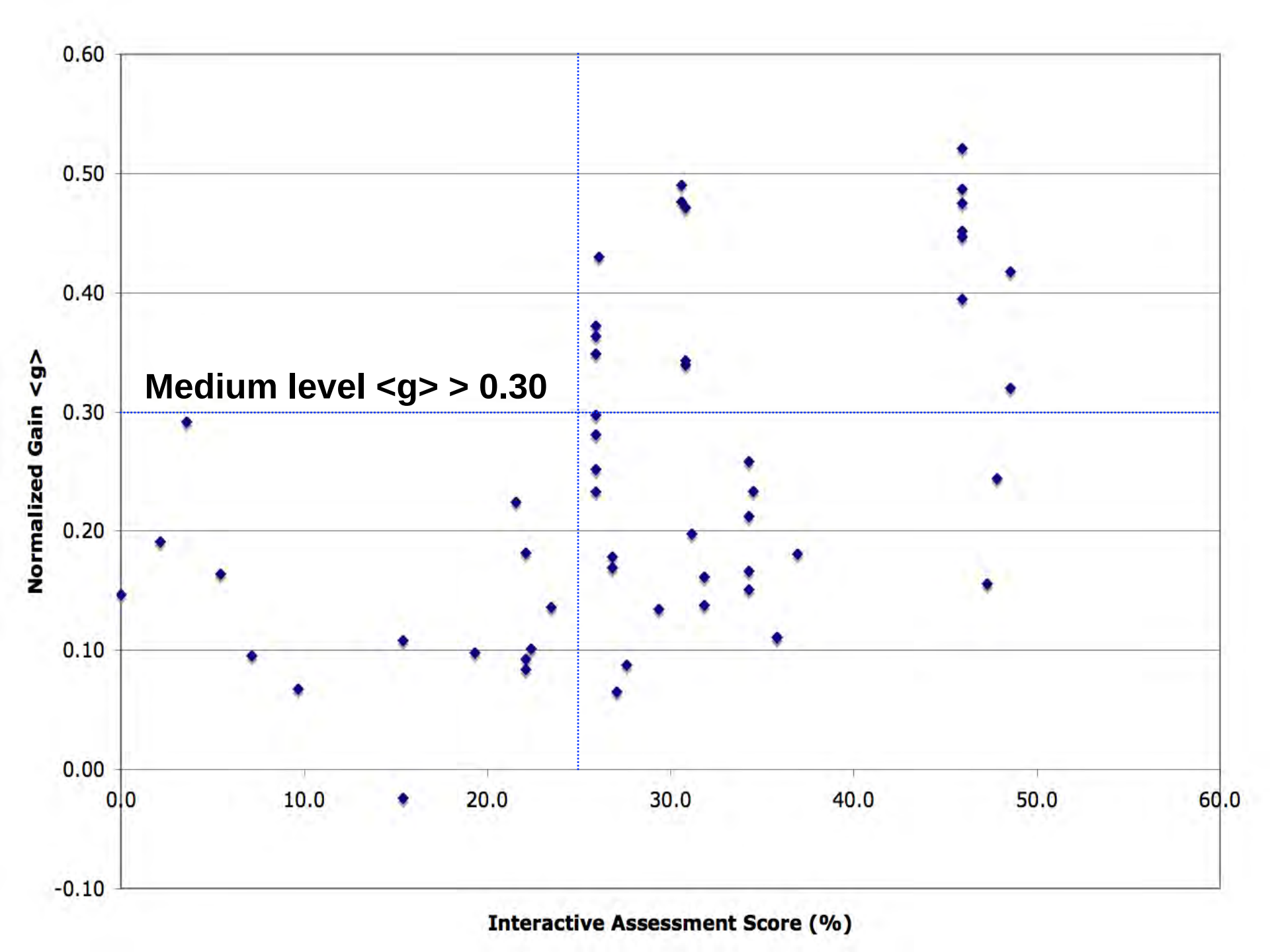
10.0
20.0
30.0
40.0
50.0
60.0
Interactive Assessment Score (%)


Medium level <g> > 0.30
Normalized Gain <g>
Interactive Assessment Score (%)
0.60
0.50
0.40
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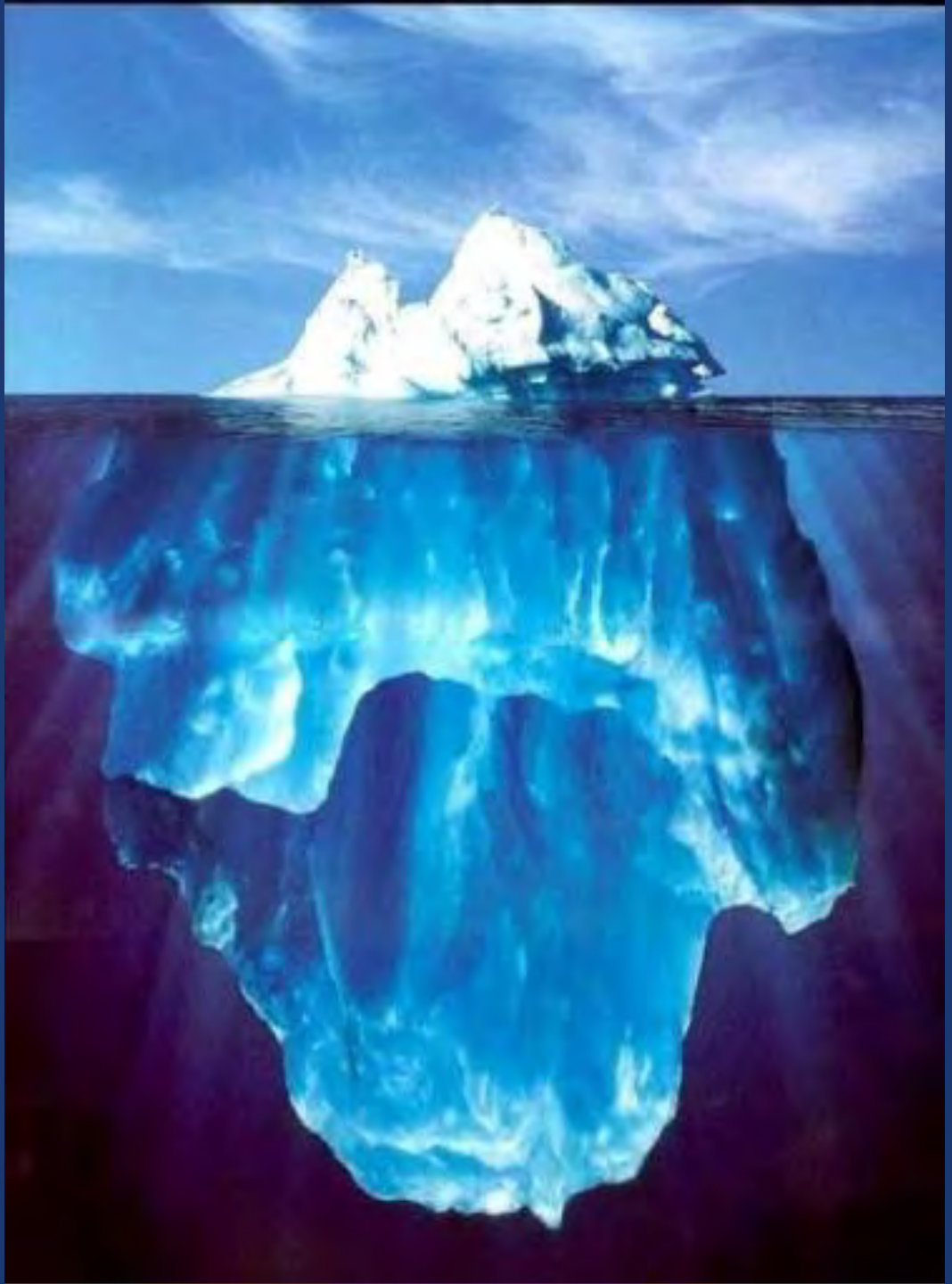

Just the tip of the iceberg of what it takes to create a highly functioning interactive engagement classroom

# CAE
## Center for Astronomy Education

» *Dedicated to the professional development of introductory astronomy instructors*

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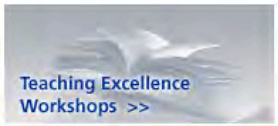
## Moderation Continues to Grow by Leaps & Bounds

### Tips from Our New Guest Moderator on Moderation

Hello, fellow astronomy educators! I'm Patrick M. Len ("P-dog" to my students), and I am your new Guest Moderator for AstroImer@CAE. I currently teach physics and astronomy at Cuesta College, a small community college in San Luis Obispo, CA, and have taught physics and astronomy at Cosumnes River College (Sacramento, CA), Sonoma State University (Rohnert Park, CA), and University of California (Davis, CA).

I have been closely following AstroImer@CAE for a number of years. Moving ... More >>







## » More Teaching Strategies

**CAE Methods & Materials:**
**A "Newbie" Instructor's Perspective**
This Month's Teaching Strategy comes to us from Joe Kabbes (Harper Community College). We met Joe at our CAE Teaching Excellence Workshop in St. Louis last summer.... More >>


**Revisiting Think-Pair-Share:**
**An Expanded "How-To" Guide**
After attending the Austin CAE Teaching Excellence Workshop in January, Amy Forestell, UT Austin graduate student, decided to take a look at the Think-Pair-Share... More >>


**Classroom Assessment Techniques:**
**A Brief Overview**
In our CAE Teaching Excellence Workshops, we discuss quite a few *classroom assessment techniques* that could be used to improve learning in an introductory... More >>

Additional Teaching Strategies >>

## » Seeing the Universe through NASA's Eyes

**NASA's Image of the Day Gallery**

Astronomy101.jpl.nasa.gov/workshops

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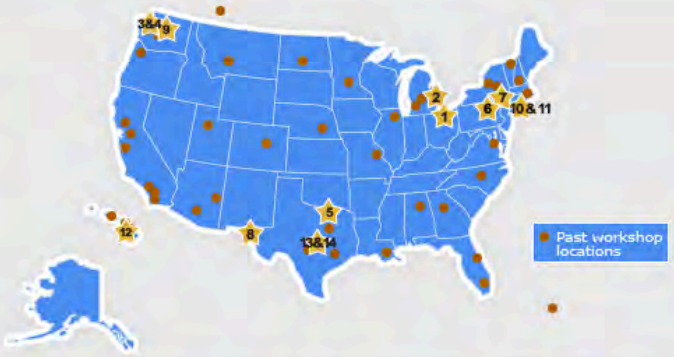
# Workshops

## Teaching Excellence Workshops

**Workshops Locations**
*Click a location to register for a specific workshop*




### Fall/Winter 2010/11

0. Boulder, CO
Cosmos in the Classroom
July 31 - August 4, 2010
1. Oberlin, OH
Tier I
September 18-19, 2010
2. Dearborn, MI
Regional Teaching Exchange
October 01 - 02, 2010
3. Seattle, WA
Tier I,CATS
January 8-9, 2011
4. Seattle, WA
Tier II,CATS,Special Topics
January 9, 2011
5. Plano, TX
Regional Teaching Exchange
February 12, 2011

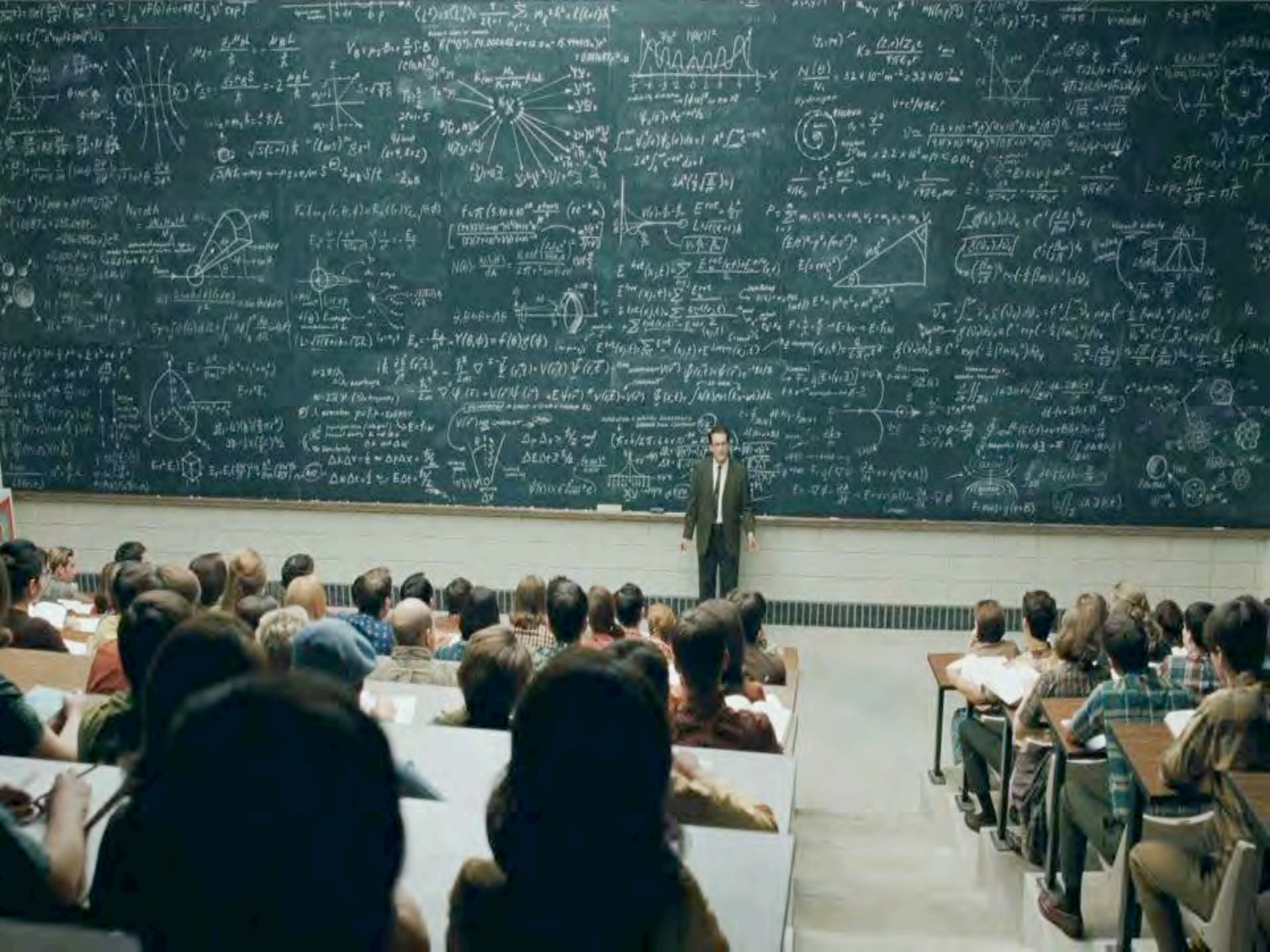
### Spring/Summer 2011

7. New Paltz, NY
CATS,Regional Teaching Exchange
March 26, 2011
8. El Paso, Texas
Tier I
April 15 - 16, 2011
9. Seattle, WA
CATS,Regional Teaching Exchange
April 16, 2011
10. Boston, MA
Tier I,CATS
May 21 & 22, 2011
11. Boston, MA
Tier II,CATS,Special Topics
May 22, 2011
12. Hilo, HI

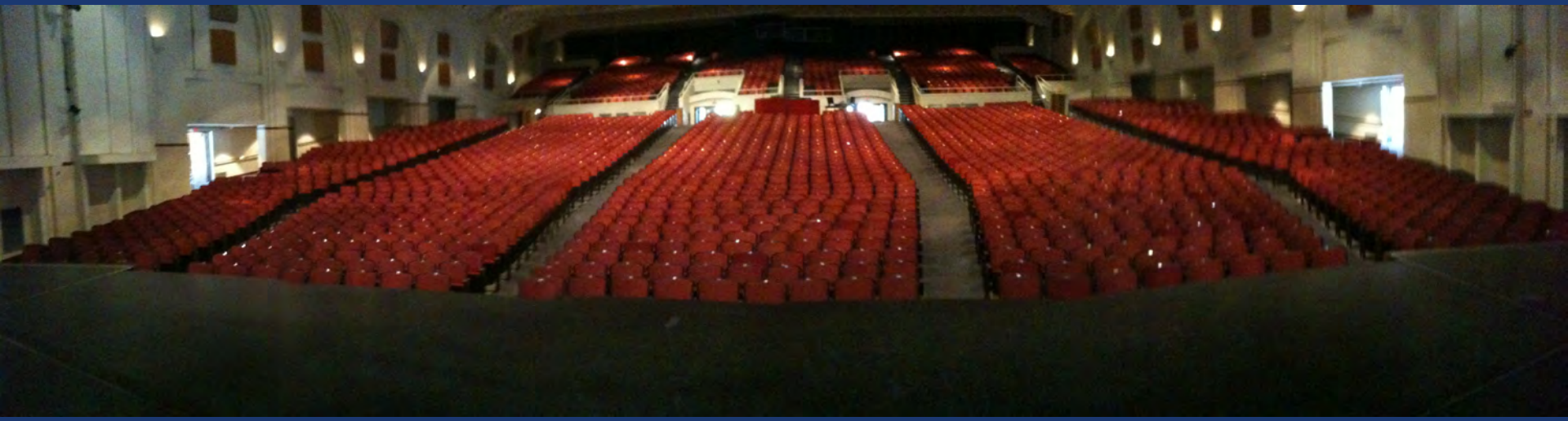
### Fall/Winter 2011/12

13. Austin, TX
Tier I,CATS
January 7-8, 2012
14. Austin, TX
Tier II,CATS,Special Topics
January 8, 2012

"Most ideas about teaching are not new, but not everyone knows the old ideas." Euclid (300 B.C.)



# Centennial Hall Performing Arts Theater at University of Arizona



# Perspectives on Teaching in the Active Learning Environment

"I'm comfortable engaging with my students."

"I know how to get my students to intellectually engage in critical reasoning and problem solving."

"I know how to create highly interactive learning environments that get all my students collaborating."

"I know what to do when my students get stuck."

"I know how to handle a group that is asking for answers."

"I know how to handle a group that is not collaborating."

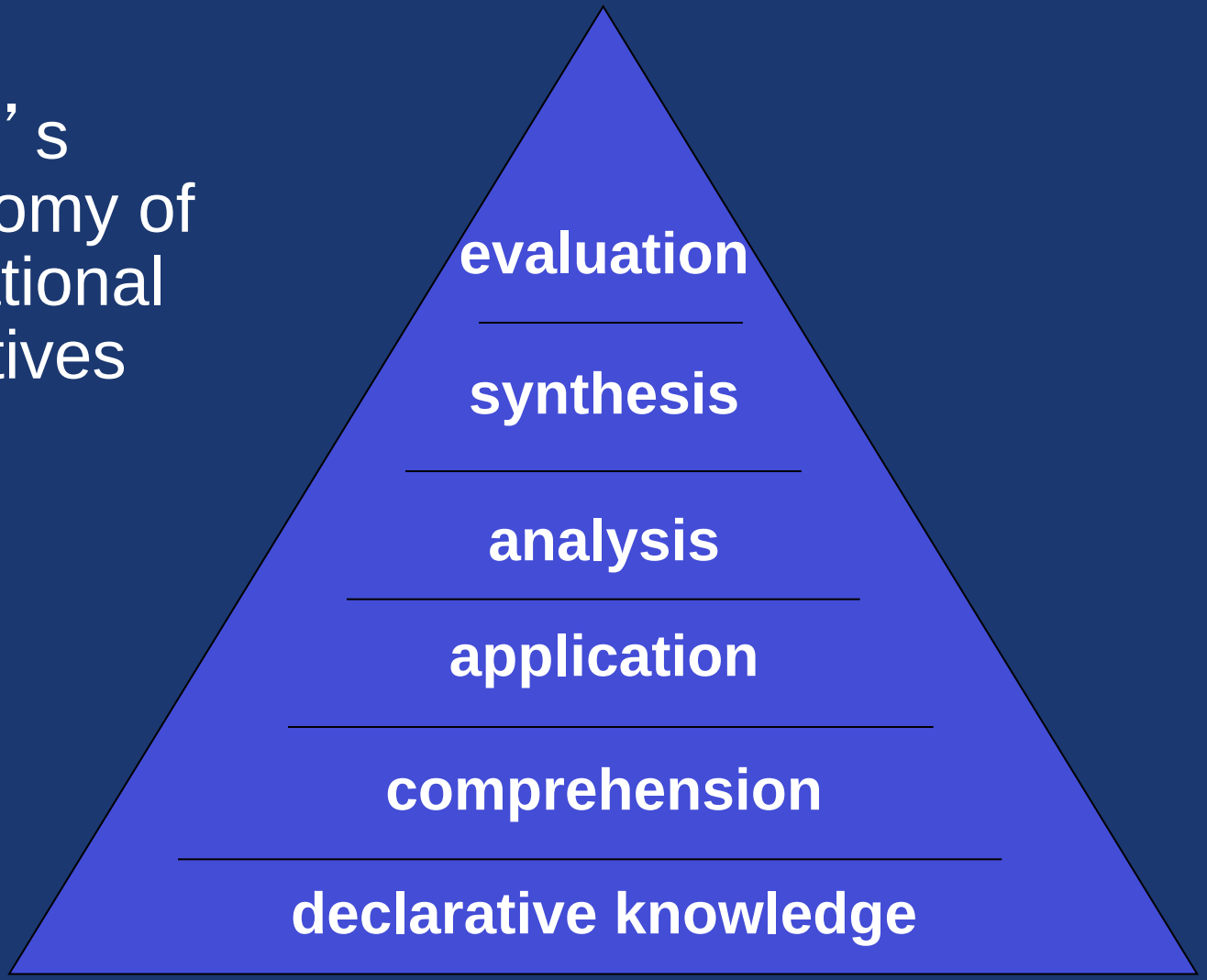
etc., etc., etc…

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

- Ask students questions (not all questions are equal)
- Use interactive videos, demonstrations, animations, and simulations
- In-class writing (with or without discussion)
  - Muddiest Point
  - Summary of Today's Main Points
  - Writing Reflections
- Think-Pair-Share or Peer Instruction
- Small Group Interactions
  - Concept Maps
  - Case Studies
  - Sorting Tasks
  - Ranking Tasks
  - Lecture-Tutorials
- Student Debates (individual/group)
- Whole Class Discussions

Does your class intellectually engage your students and deepen their conceptual understanding and critical thinking ability or does it reinforce the memorization of facts and declarative knowledge?

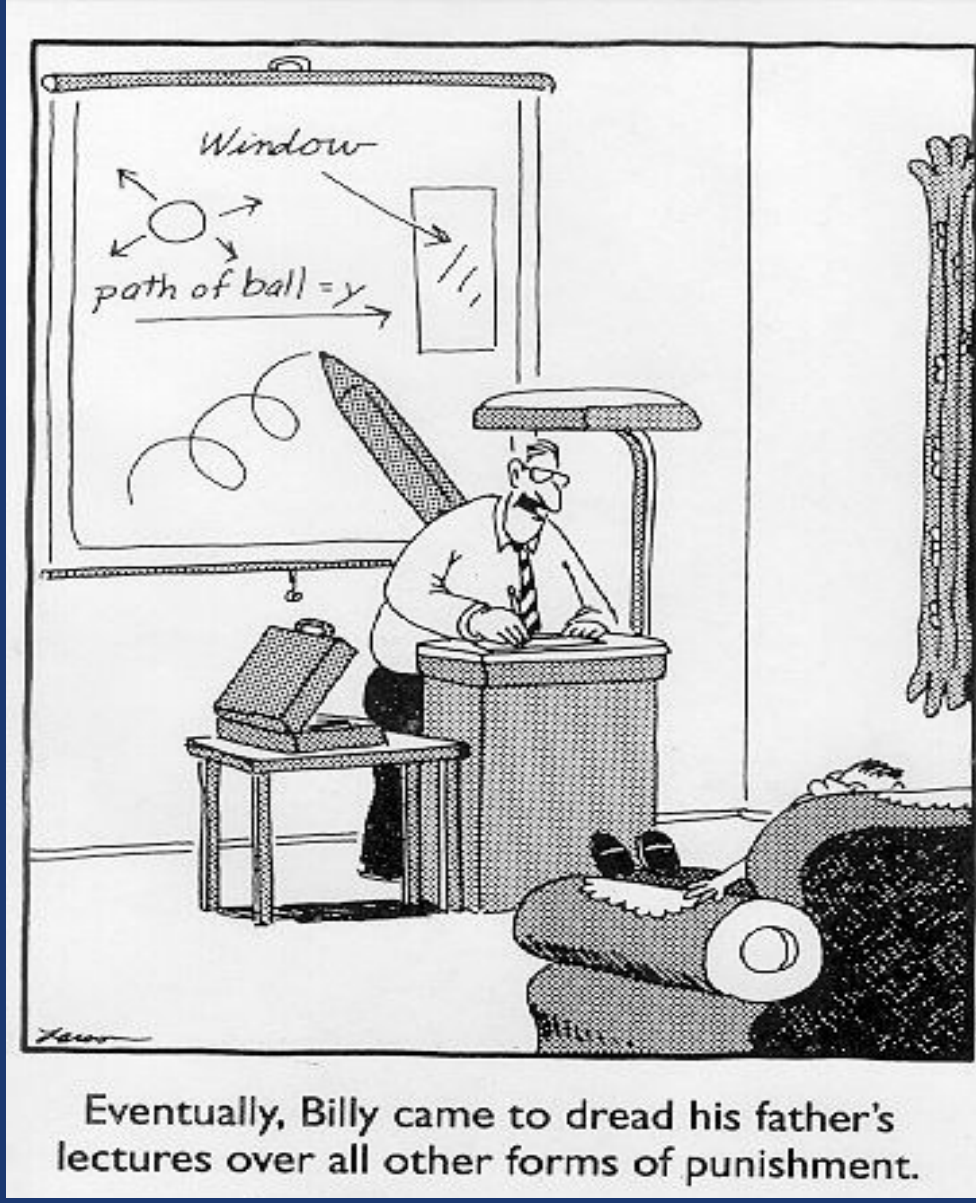
Bloom's Taxonomy of Educational Objectives



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

Please participate in the role of a good student!

Don’t get stuck or caught up in thinking like a PHD Physicist or Astronomer!!!!!




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”**

# Todays Topic:
# *"Motion of Extrasolar Planets"*

*Please pay attention to:*

The sequencing of different instructional strategies
The different implementation methods used
How feedback was incorporated
How collaboration was encouraged and motivated

# Tutorial:
# Motion of Extrasolar Planets

- **Work with a partner!**
- **Read the instructions and questions carefully.**
- **Discuss the concepts and your answers with one another. Take time to understand it now!!!!**
- **Come to a consensus answer you both agree on.**
- **If you get stuck or are not sure of your answer, ask another group.**

# CAE National Study

- Almost 4000 students
- 31 institutions
- 36 instructors
- 69 different sections
  - Section sizes vary from <10 to 180 (now with sections >750!)

# This was a truly national study

# CAE National Professional Development Program

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## Workshops

### Teaching Excellence Workshops

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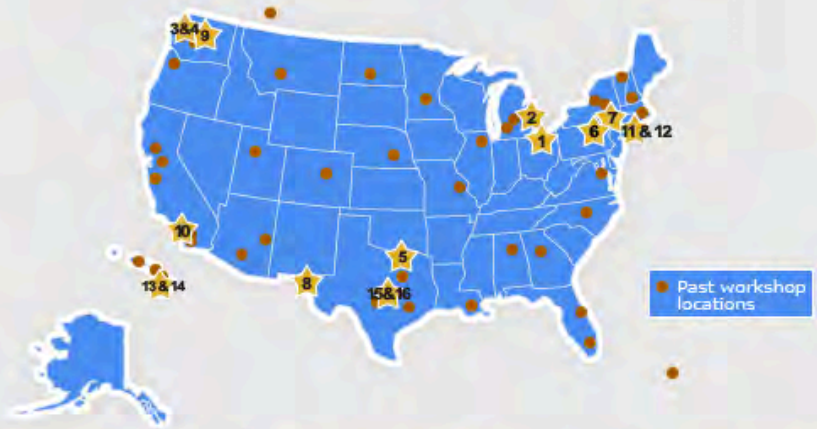


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   February 12, 2011
6. State College, PA
   Tier I

**Spring/Summer 2011**

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   April 16, 2011
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    May 7, 2011
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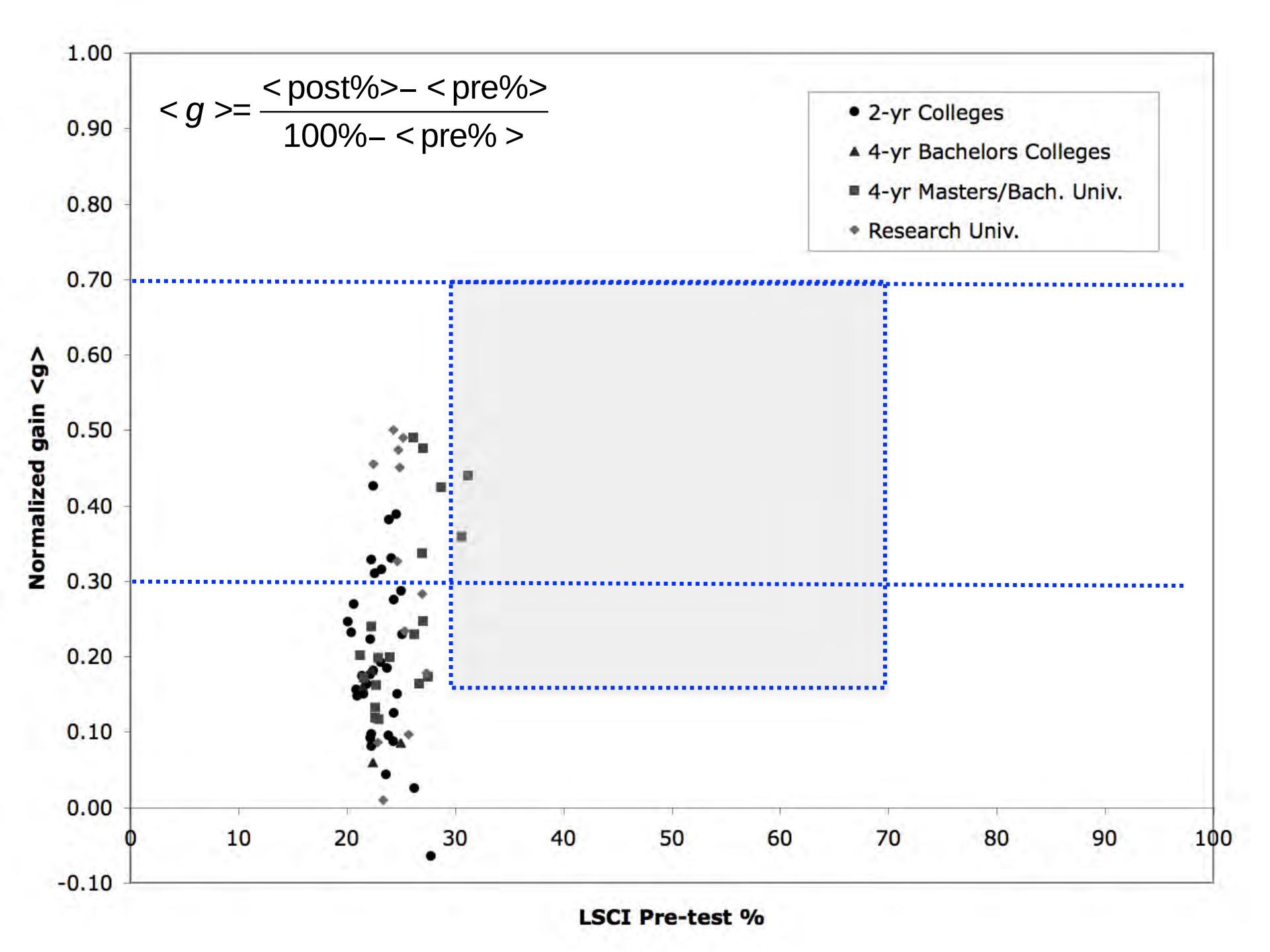
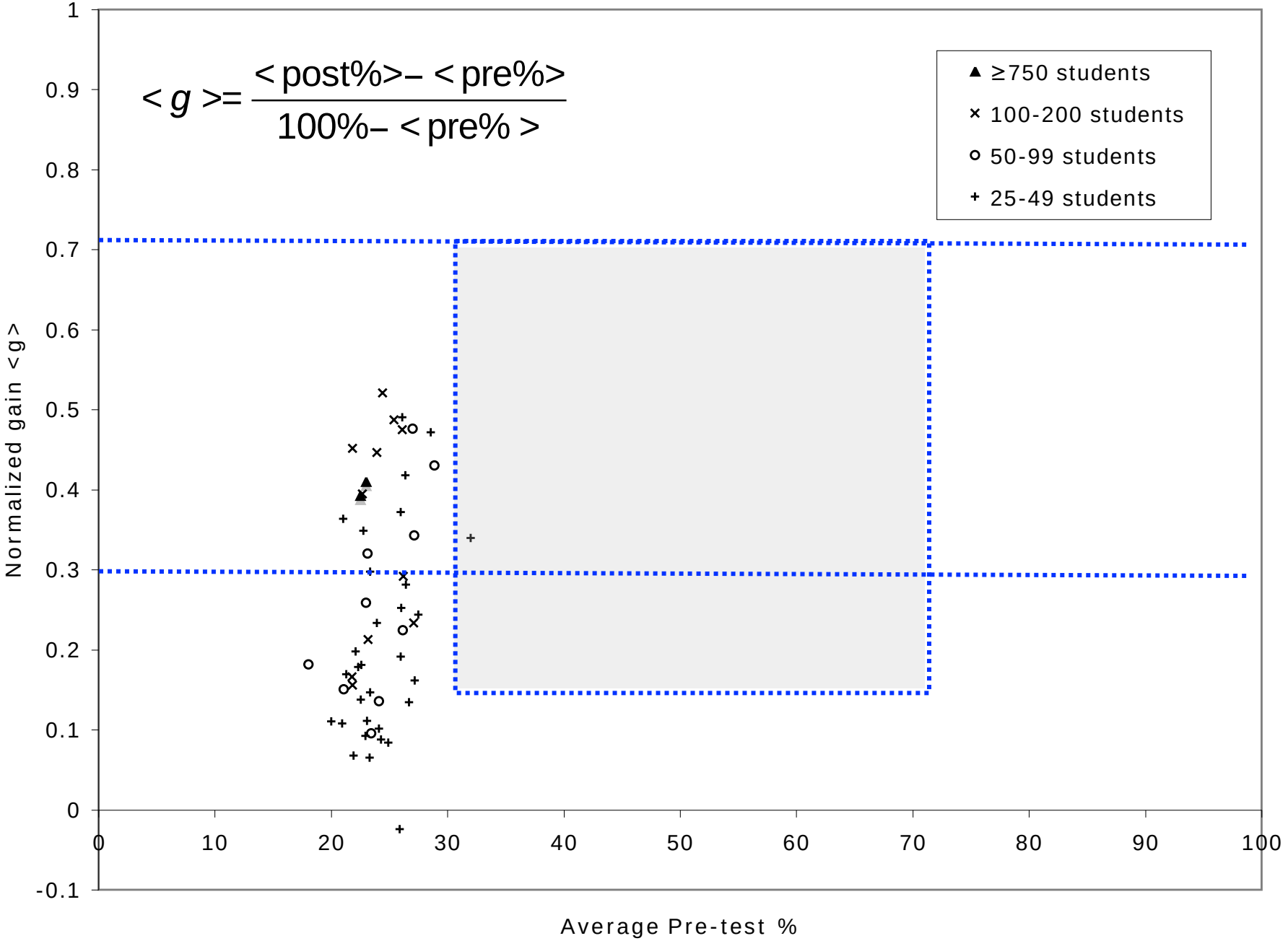
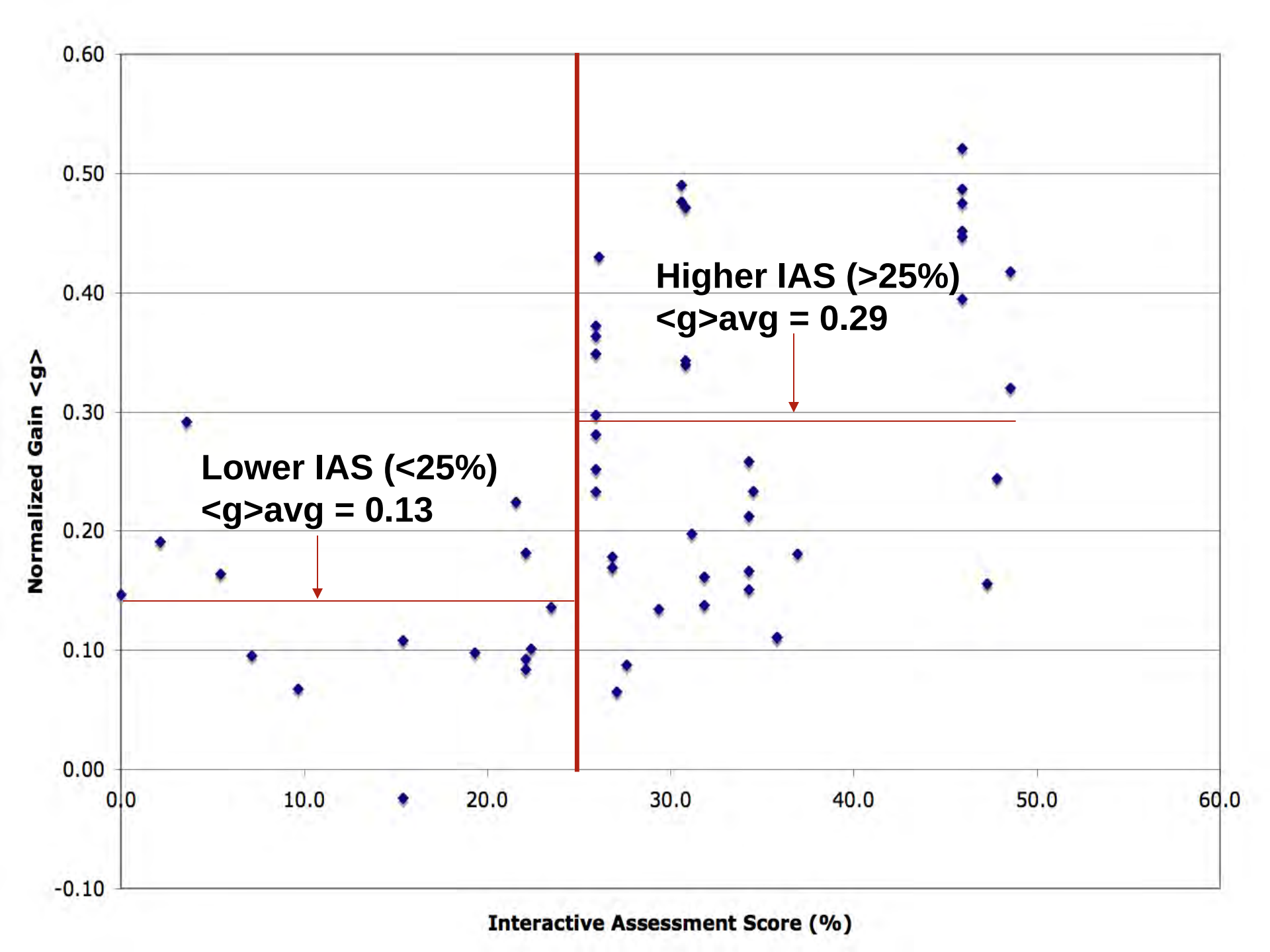

$< g >= \frac{< post\% > - < pre\% >}{100\% - < pre\% >}$
2-yr Colleges
4-yr Bachelors Colleges
4-yr Masters/Bach. Univ.
Research Univ.
Normalized gain <g>
LSCI Pre-test %
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
10
20
30
40
50
60
70
80
90
100


$< g >= \frac{< post\% > - < pre\% >}{100\% - < pre\% >}$
≥750 students
100-200 students
50-99 students
25-49 students
Normalized gain <g>
Average Pre-test %
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
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


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

# 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 the level of interactivity is the *single most important variable* in explaining the variation in gain, even after controlling for all other variables

| | Normalized Gain | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | | 2 | | 3 | | 4 | |
| | Coefficients | Standardized Coefficients | Coefficients | Standardized Coefficients | Coefficients | Standardized Coefficients | Coefficients | Standardized Coefficients |
| Independent Variable | (standard error) | | (standard error) | | (standard error) | | (standard error) | |
| 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.

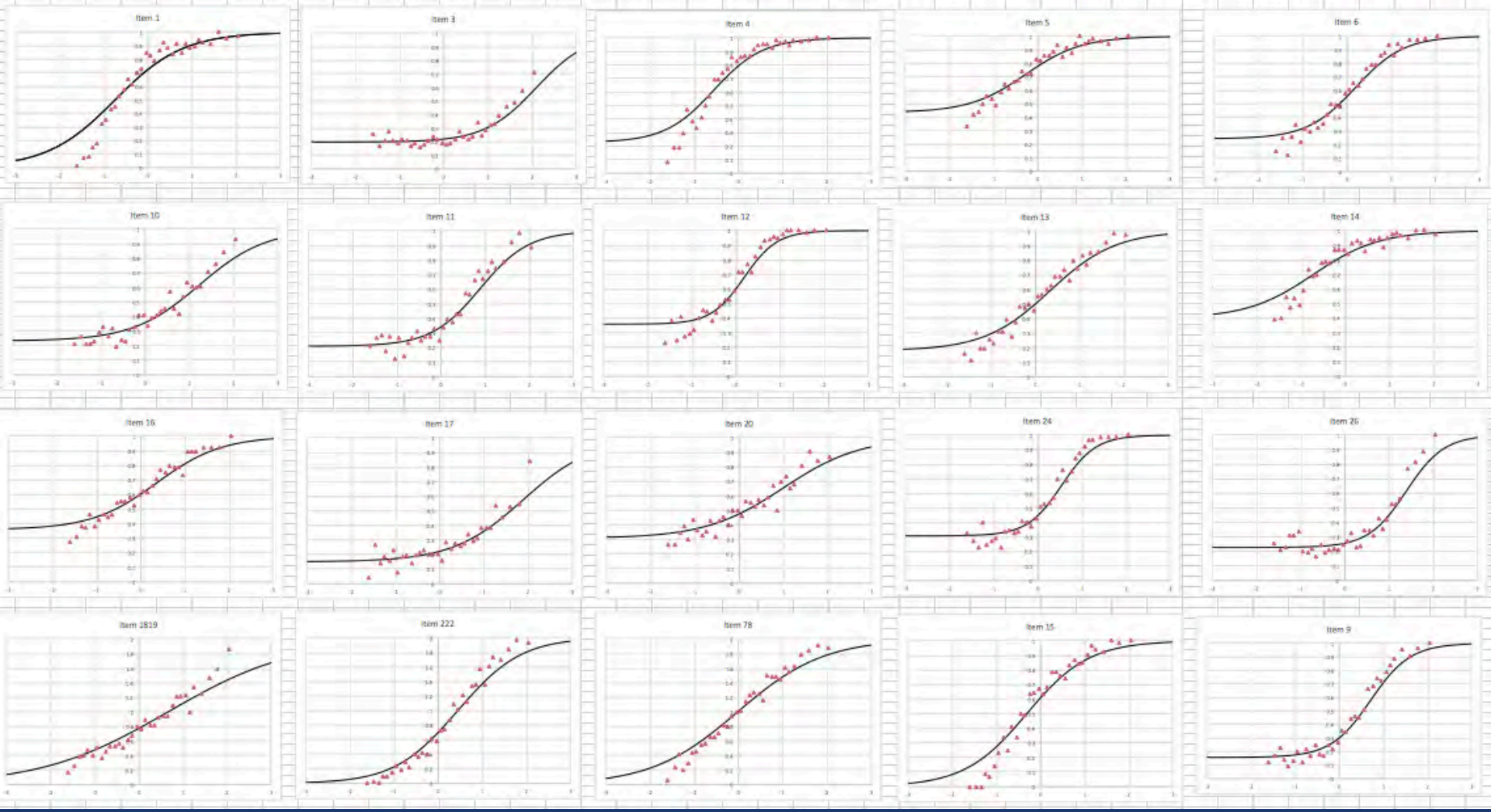
# The take home message Part II

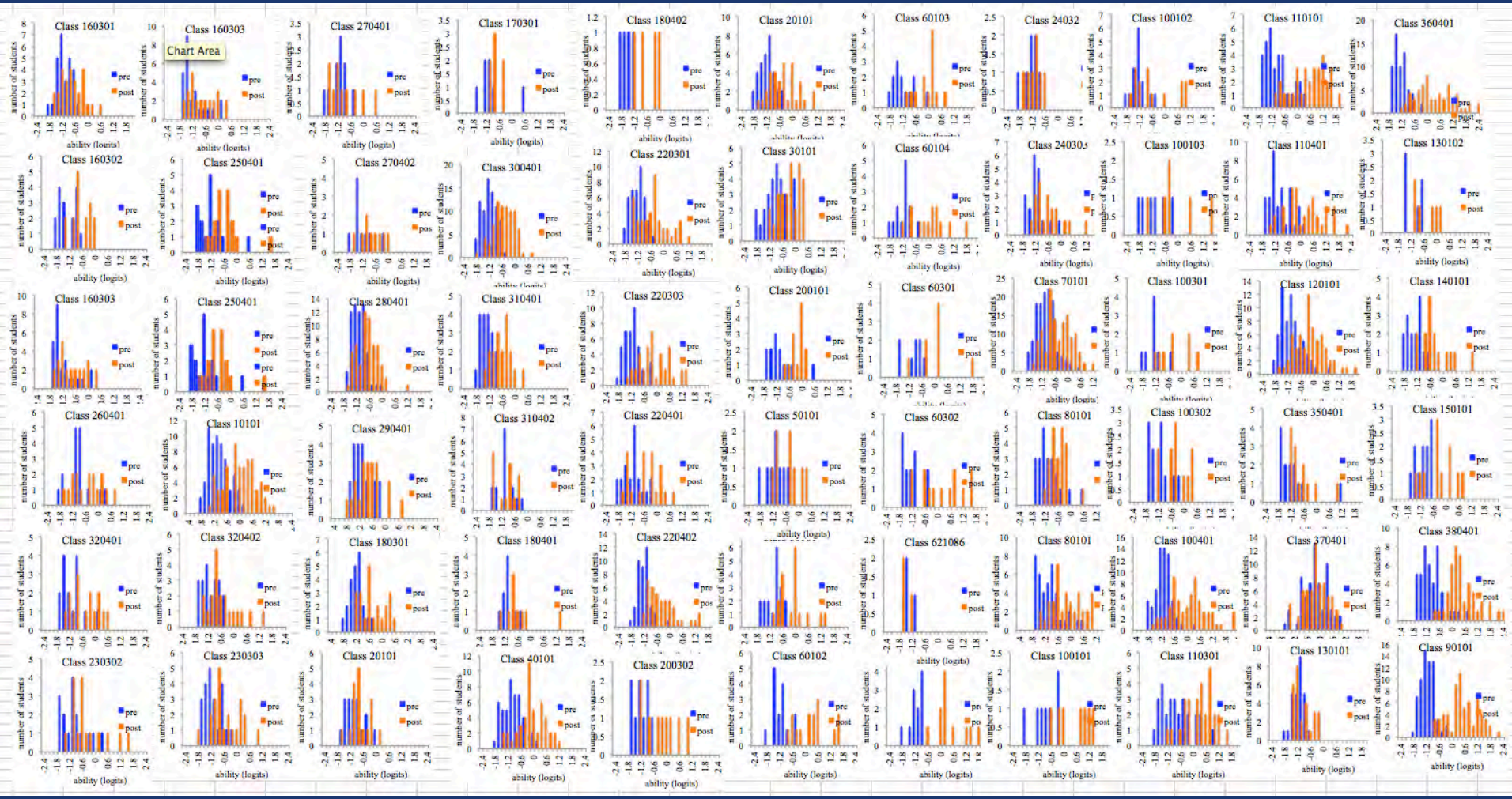
Implementation is the most important factor to success in student learning.

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

# Item Response Theory (IRT)

$$P(X_{pi}=1|\theta_p, b_i)=\frac{\exp[\theta_p - b_i]}{1+\exp[\theta_p - b_i]}$$






# Center for Astronomy Education

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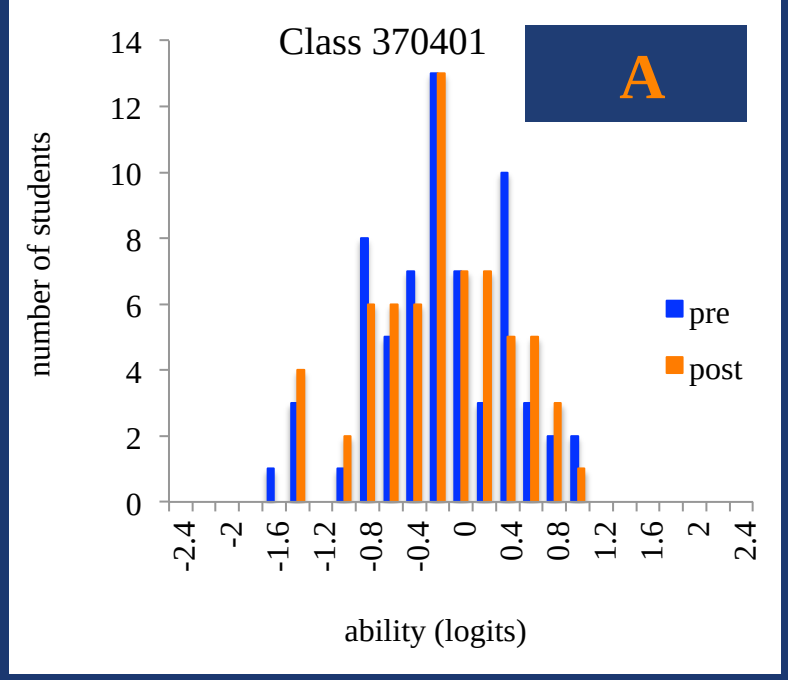
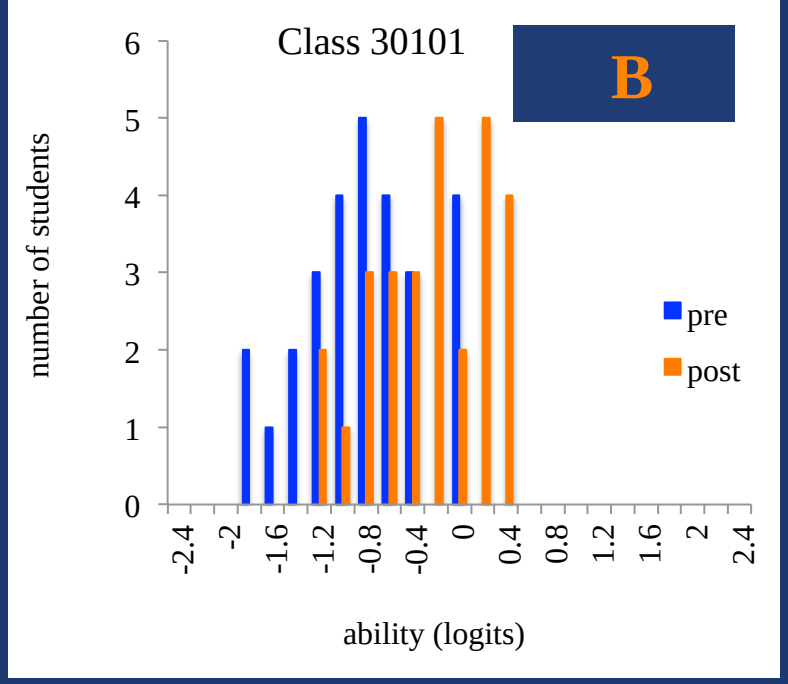

Class 370401
A
number of students
ability (logits)
pre
post
0
2
4
6
8
10
12
14
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4


Class 30101
B
number of students
ability (logits)
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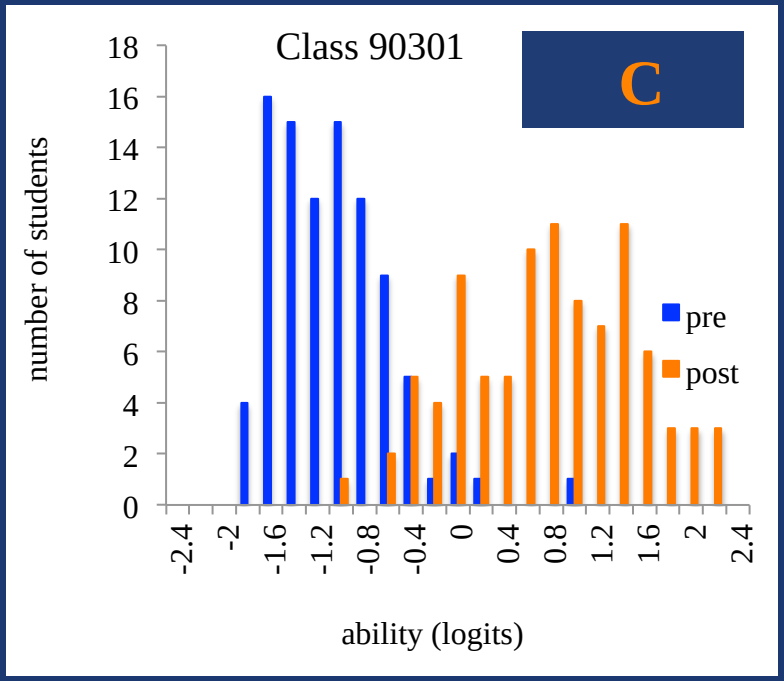
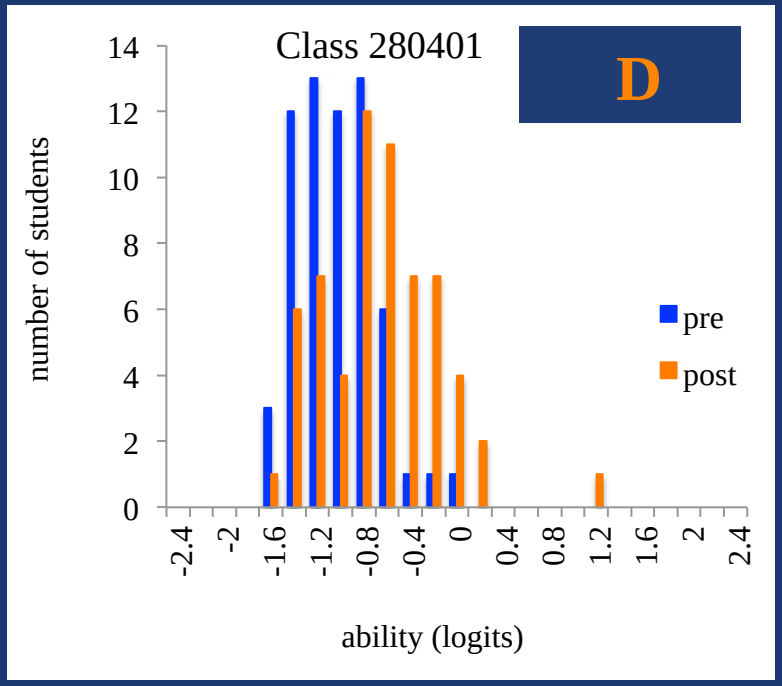
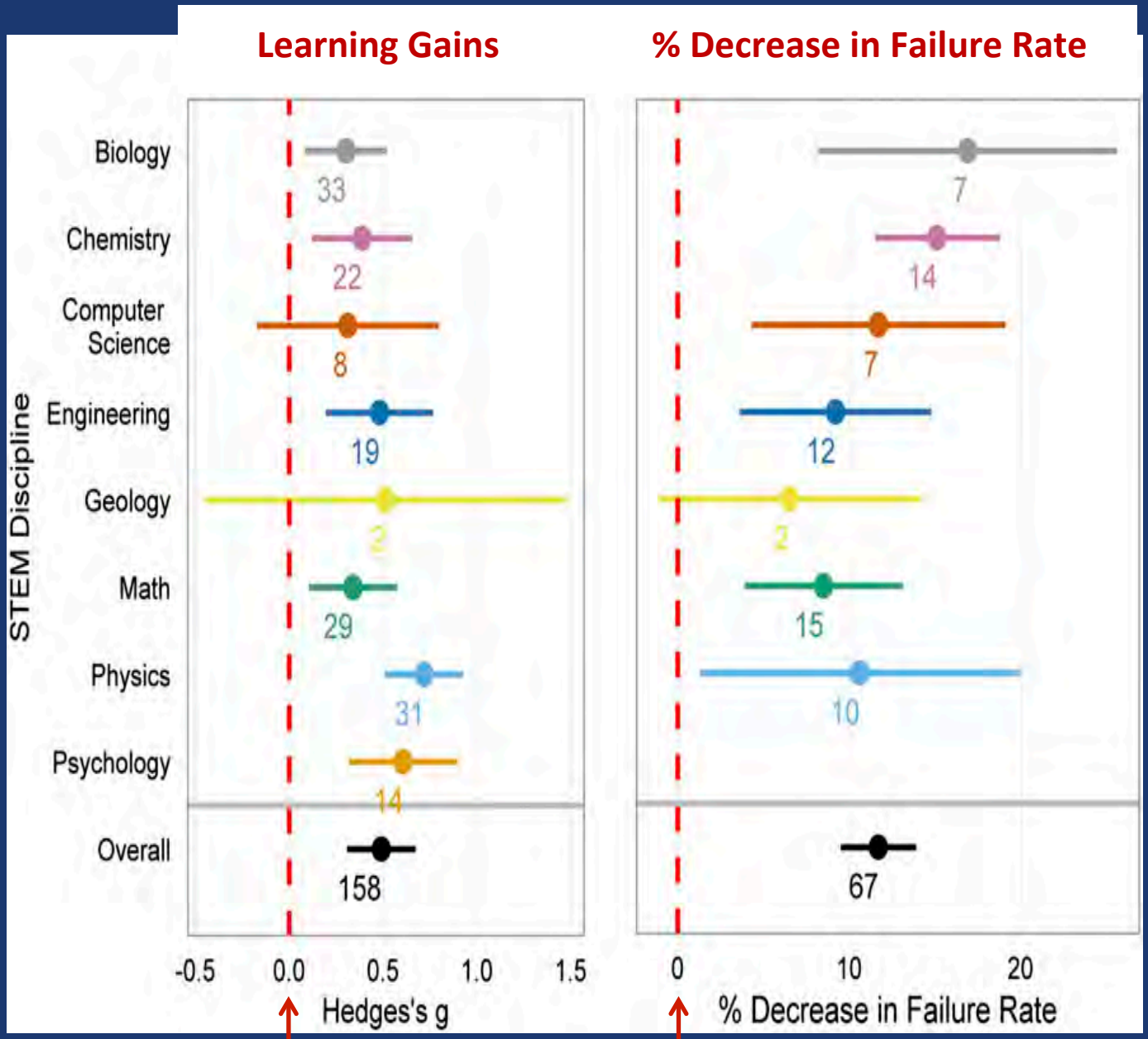
5
6
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4


Class 90301
C
number of students
ability (logits)
pre
post
0
2
4
6
8
10
12
14
16
18
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4


Class 280401
D
number of students
ability (logits)
pre
post
0
2
4
6
8
10
12
14
-2.4
-2
-1.6
-1.2
-0.8
-0.4
0
0.4
0.8
1.2
1.6
2
2.4




Numbers indicate # of studies reviewed

traditional lecture class - mean scores

Freeman S et al. PNAS 2014;111:8410-8415