Learner-Centered Teaching in Physics and Astronomy

Edward Prather

University of Arizona

Center for Astronomy Education (CAE)

http://astronomy101.jpl.nasa.gov

Thanks and Support

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- NSF CCLI Phase III Grant
  "Collaboration of Astronomy Teaching Scholars (CATS)"
- JPL's NASA Exoplanet Exploration Public Engagement Program
- Sloan Digital Sky Survey (SDSS) EPO & Zooniverse
- AUI NRAO
- NSF PAARE - CAMPARE

NSF: Collaboration of Astronomy Teaching Scholars (CATS)

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- Jessica Kapp, Univ. of Arizona
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- Michelle Krok, Univ of Alaska
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- Chris Lintott, Univ. of Oxford
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- Benjamin Mendelsohn, West Valley College
- Ed Montiel, Univ. of Arizona
- Peter Newbury, Univ. of British Columbia
- Lee Powell, Texas Lutheran Univ.
- Matthew Price, Ithaca College
- Jordan Raddick, Johns Hopkins Univ.
- Travis Rector, Univ. of Alaska
- Paul Robinson, Westchester CC
- Wayne Schlingman, Univ. of Arizona
- Hannah Sugarman, Univ. of Arizona
- Colin Wallace, UC Boulder
- James Wysong Jr., Hillsborough CC
- Todd Young, Wayne St. College

CATS Collaboration of Astronomy Teaching Scholars

An NSF Funded Center for Astronomy Education (CAE) Program

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

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stephen brookfield skillful teacher

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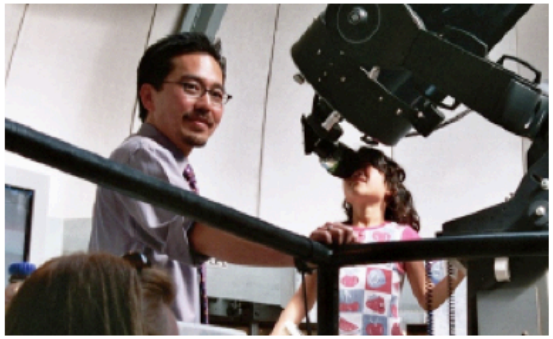
Moderation Continues to Grow by Leaps & Bounds

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 AstroIrner@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 AstroIrner@CAE for a number of years. Moving ... More >>



Teaching Excellence Workshops >>

Collaboration of Astronomy Teaching Scholars >>

AstroIrmer@CAE >>

Who Teaches Astro 101? >>

» 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

astro101: Workshops

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

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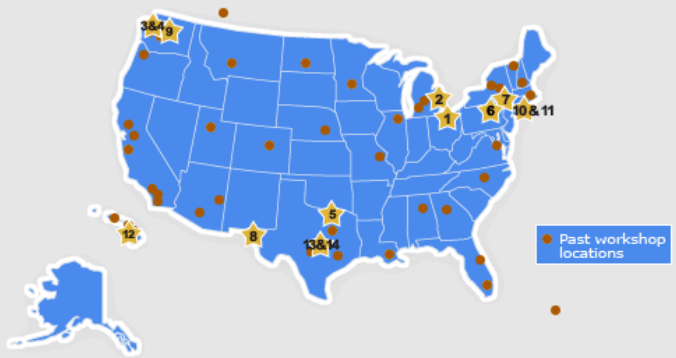
Home > Workshops

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
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   September 18-19, 2010
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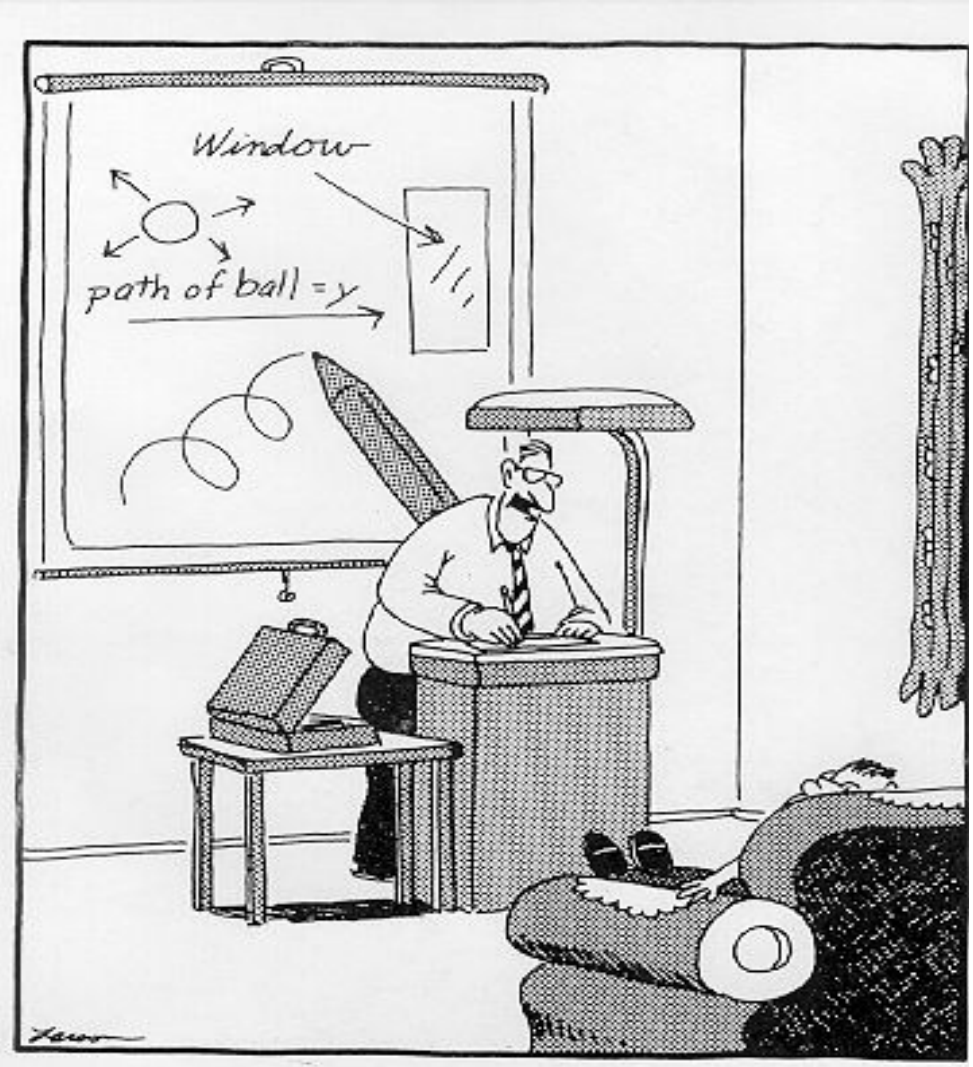
    May 21 & 22, 2011
11. Boston, MA
    Tier II,CATS,Special Topics
    May 22, 2011
12. Hilo, HI

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

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

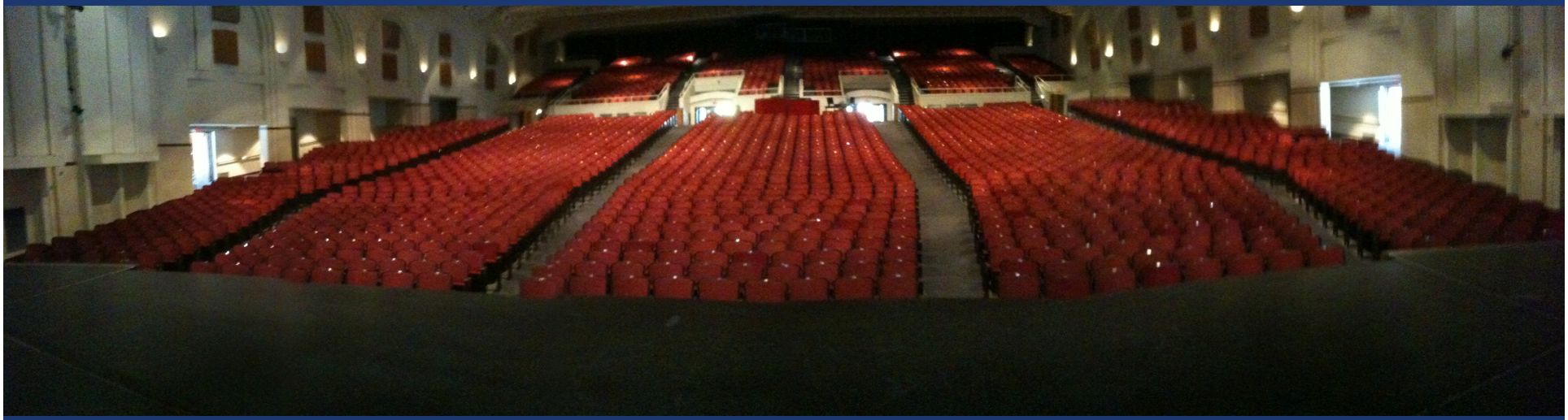
- Audience participation is strongly encouraged!!!!!!



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"

Interactive Lecturing: Non-Stop Metacognition, Discourse and Feedback/Assessment



Center for Astronomy Education

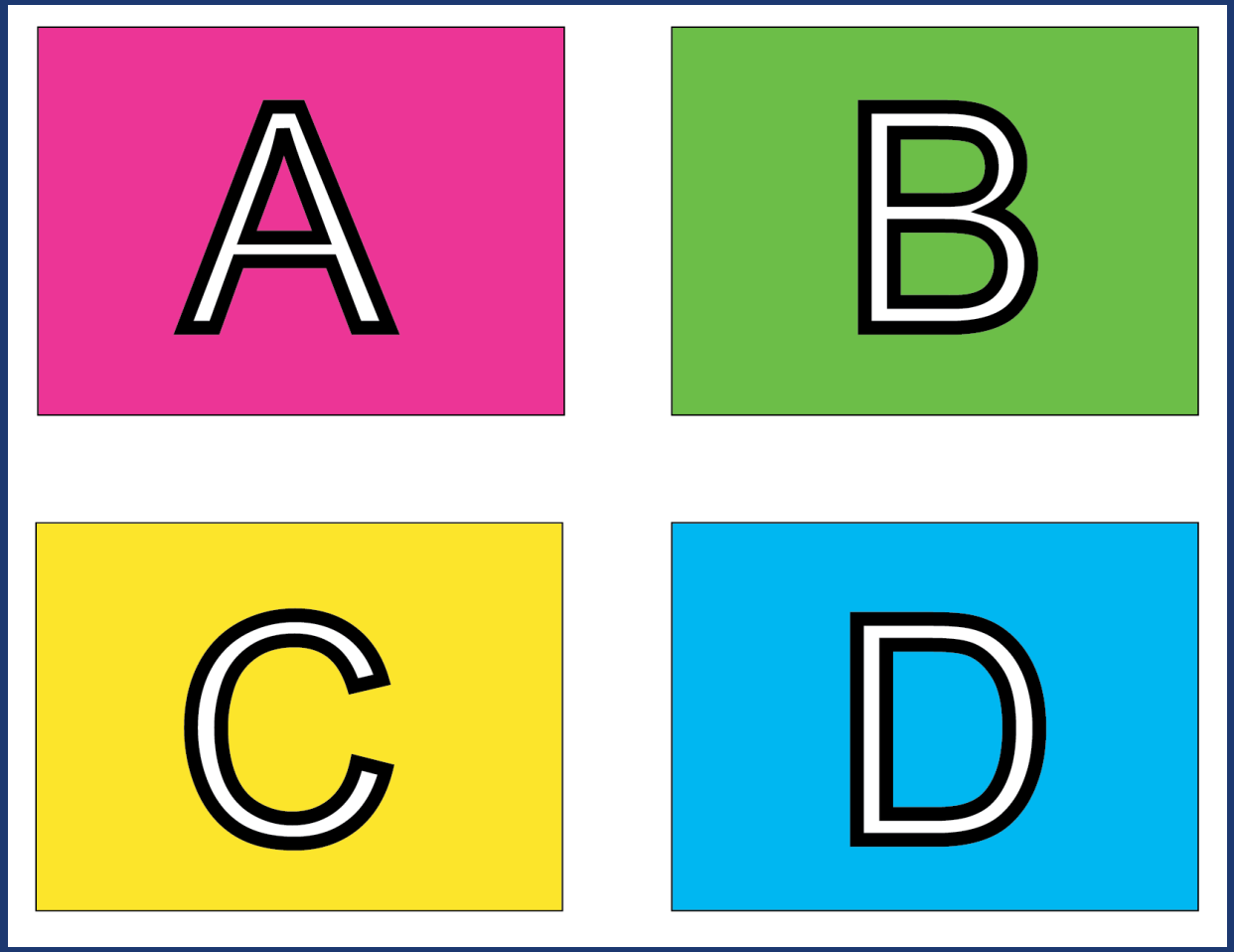
» *Dedicated to the professional development of introductory astronomy instructors*

Techniques for all size classes

Techniques for all size classes

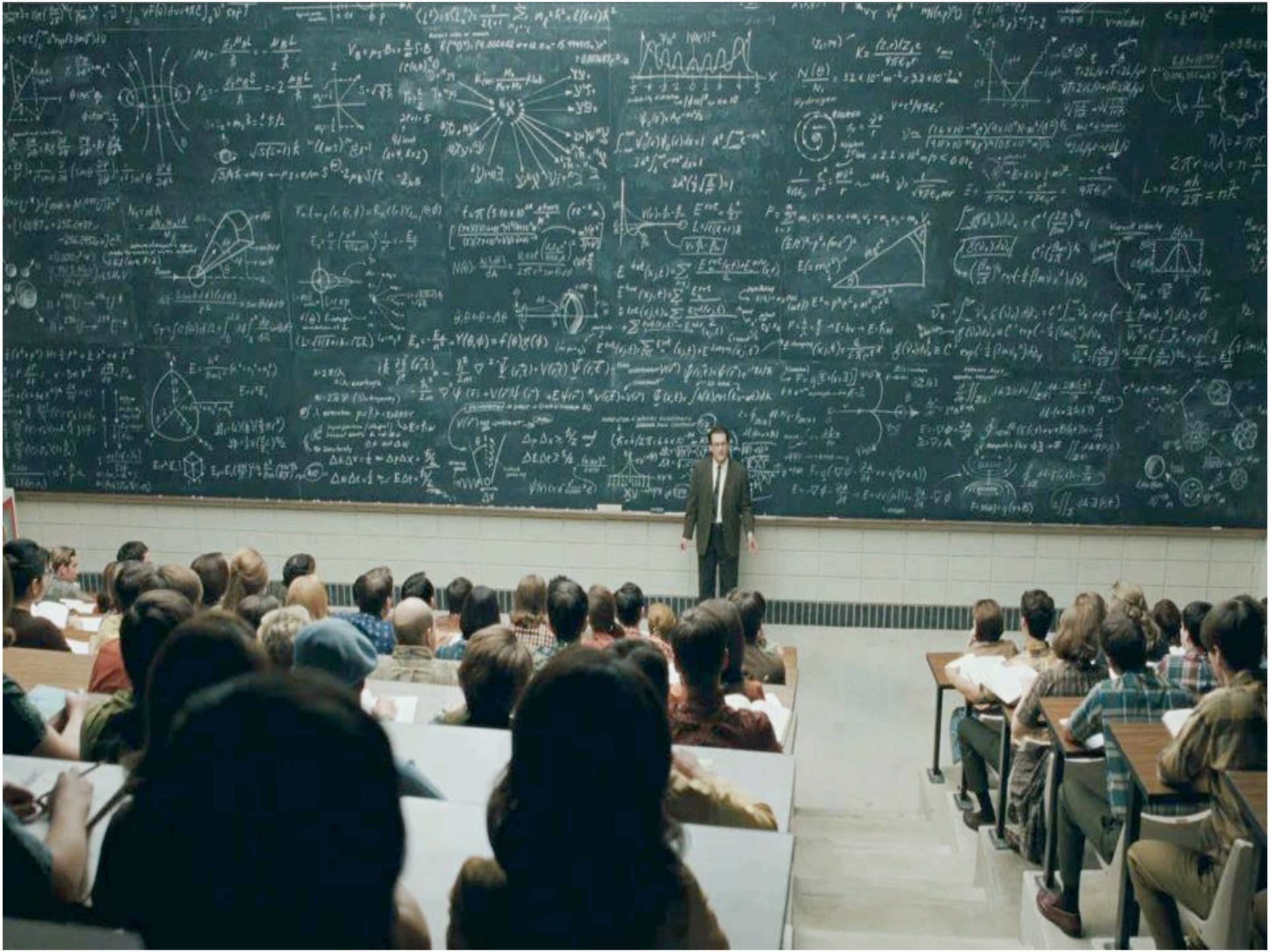
Peer Teaching Assistance – Ambassadors of science in my class and in our society.

Class Response System—Medium Tech



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.

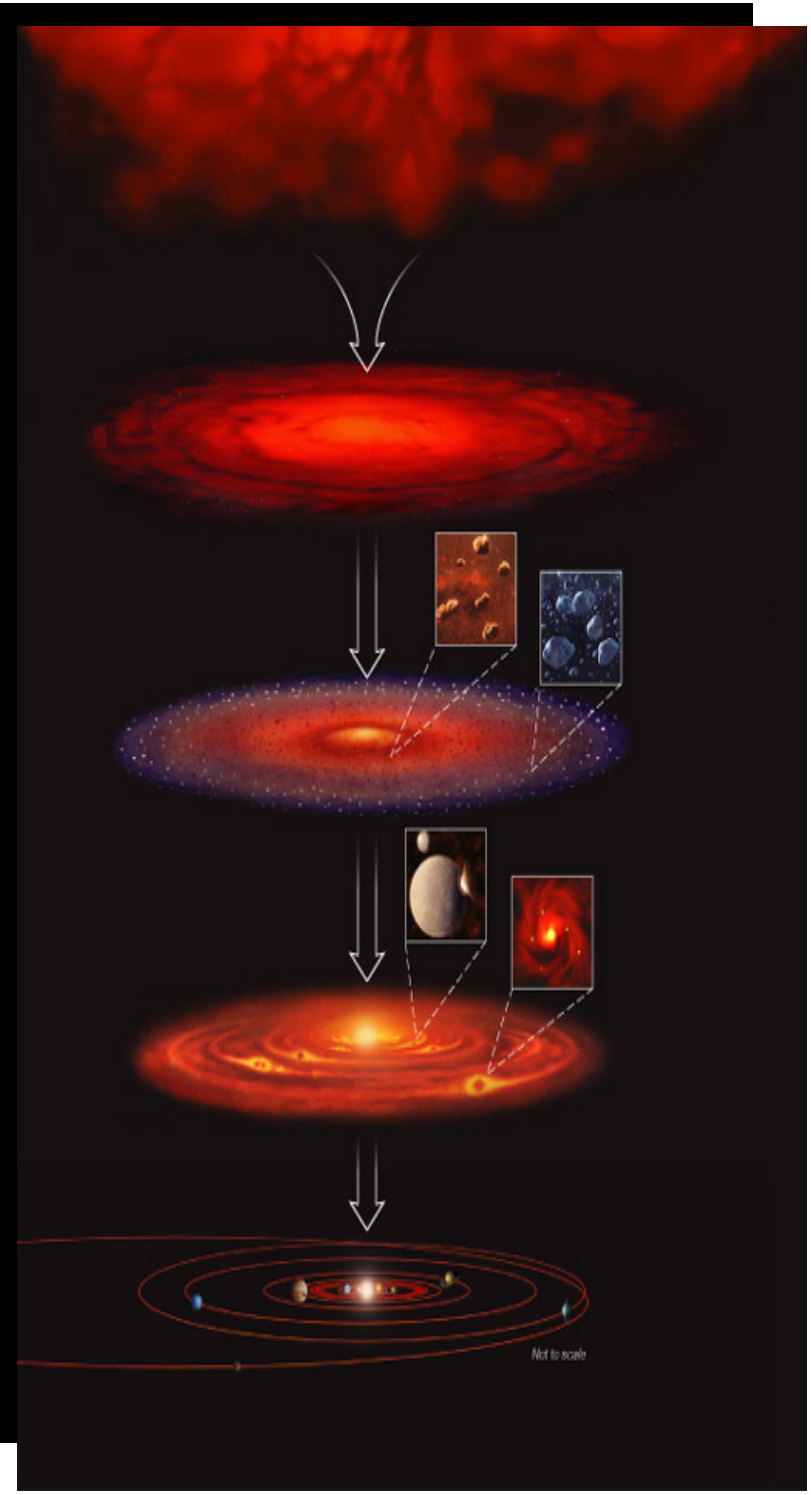
Stephen Brookfield (2006), *The Skillful Teacher*, Jossey-Bass Publishers



Are you really teaching if no one is learning?

And How would you know anyway?

What are each of these?



Which of these is an image of our Milky Way Galaxy

Image 1.

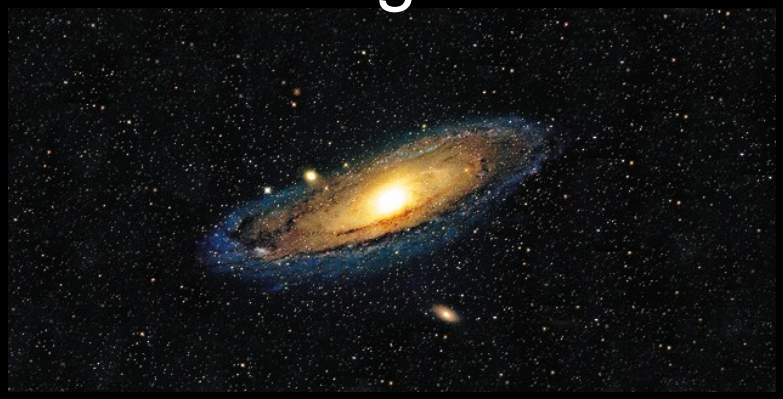
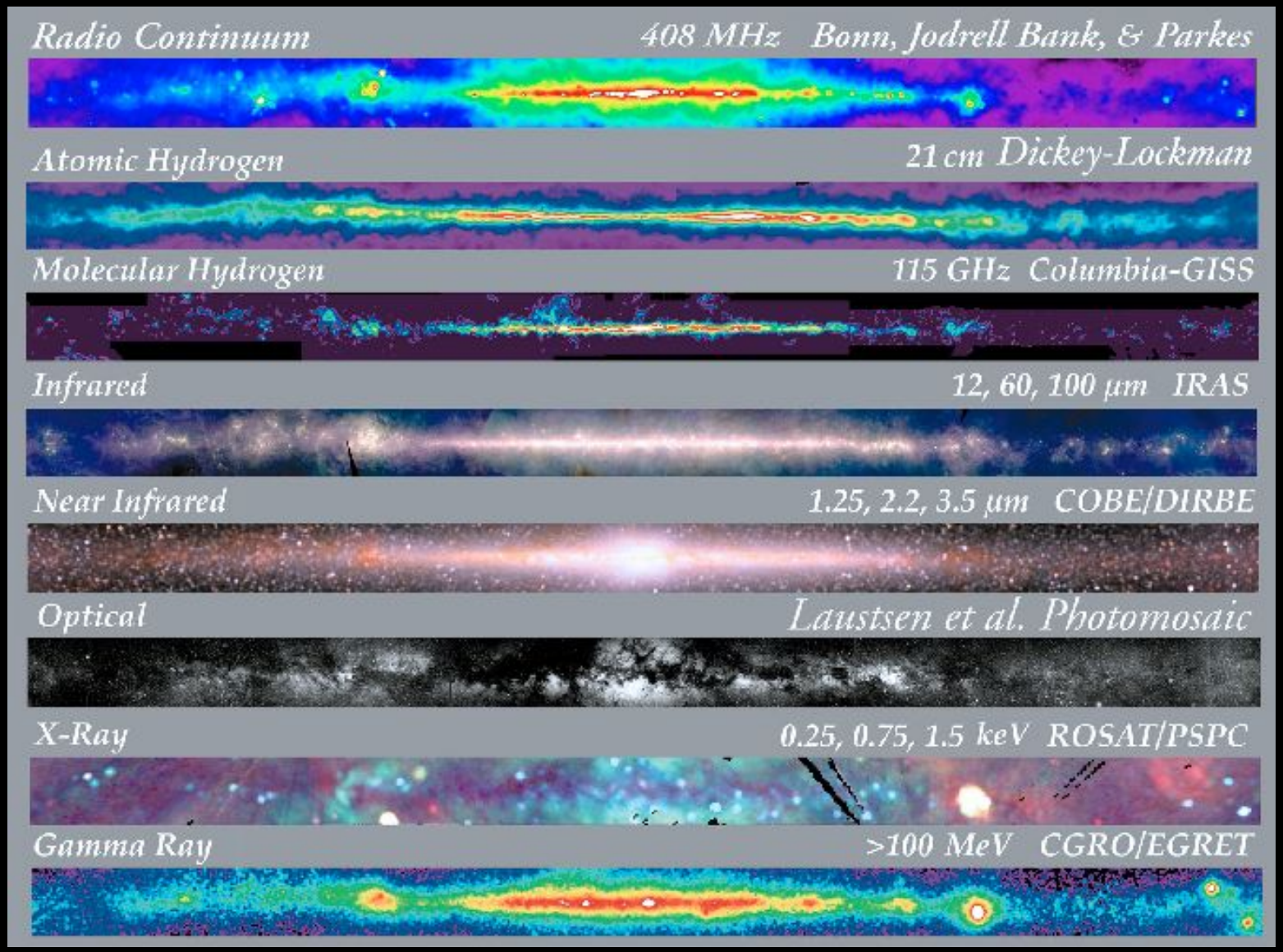


Image 2.

A. Only Image 1.
B. Only Image 2.
C. Both could be
D. Neither could be

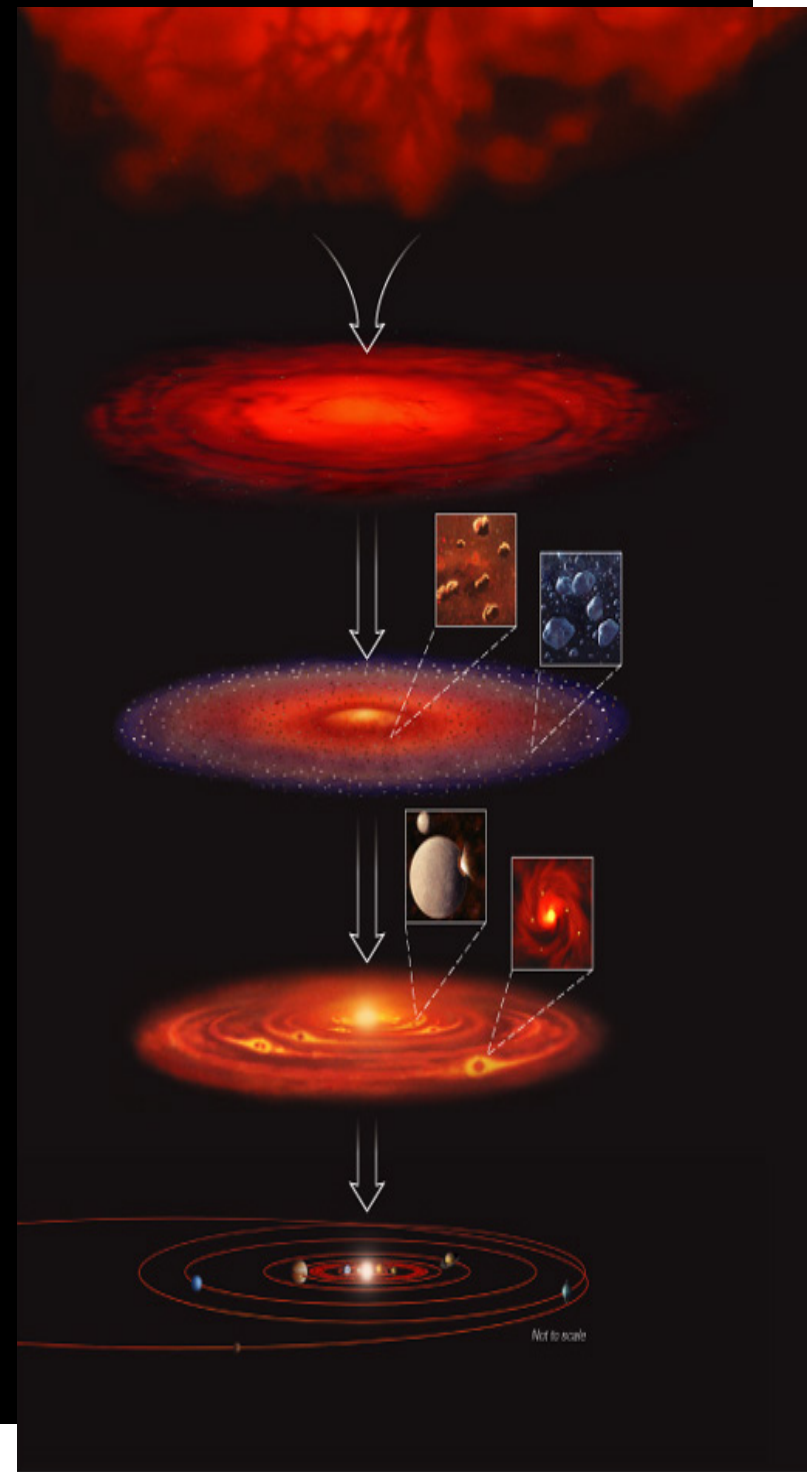
Our view of the Milky Way Galaxy

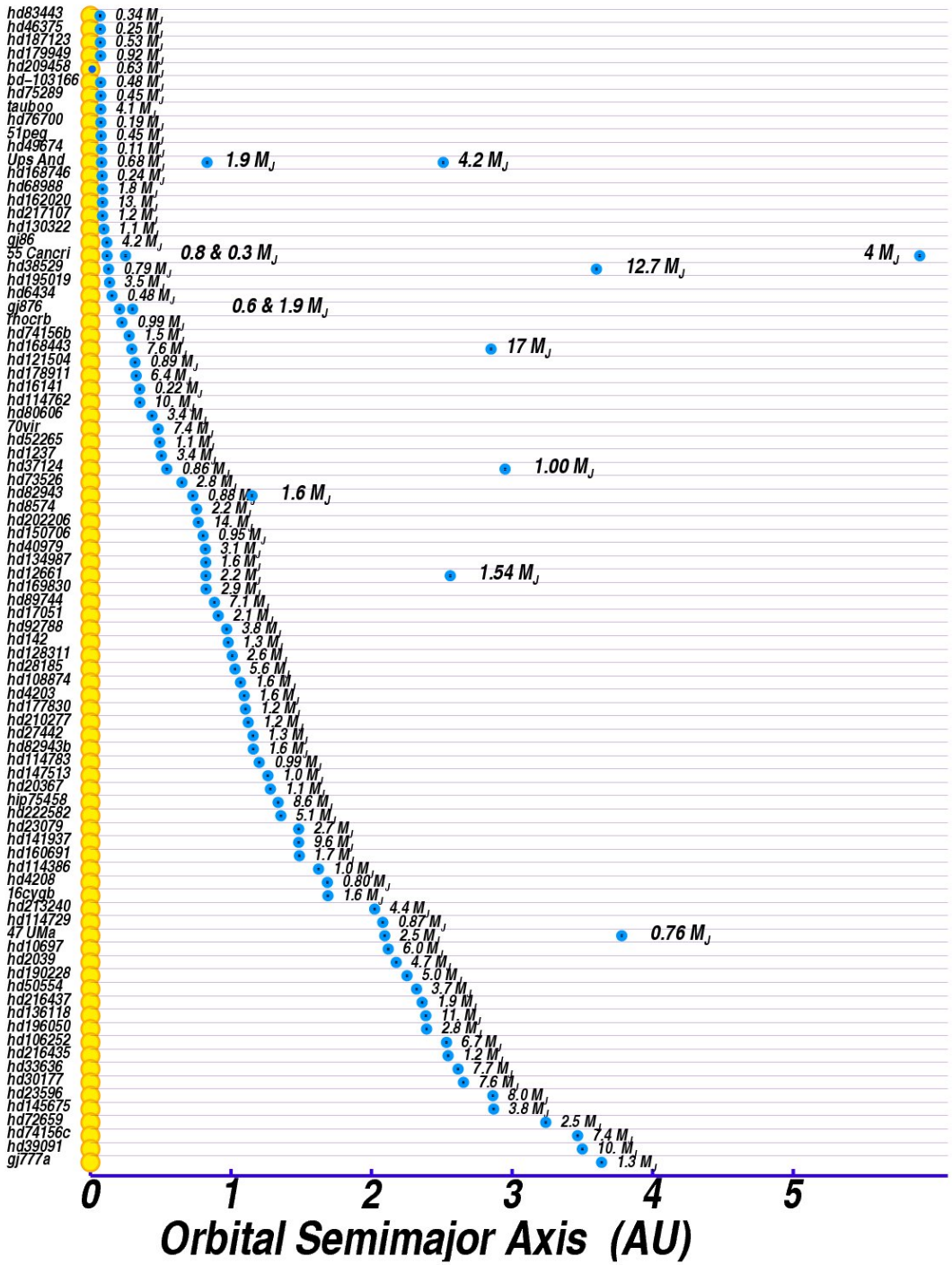
Our Multi-Wavelength View of the MWG



In these?

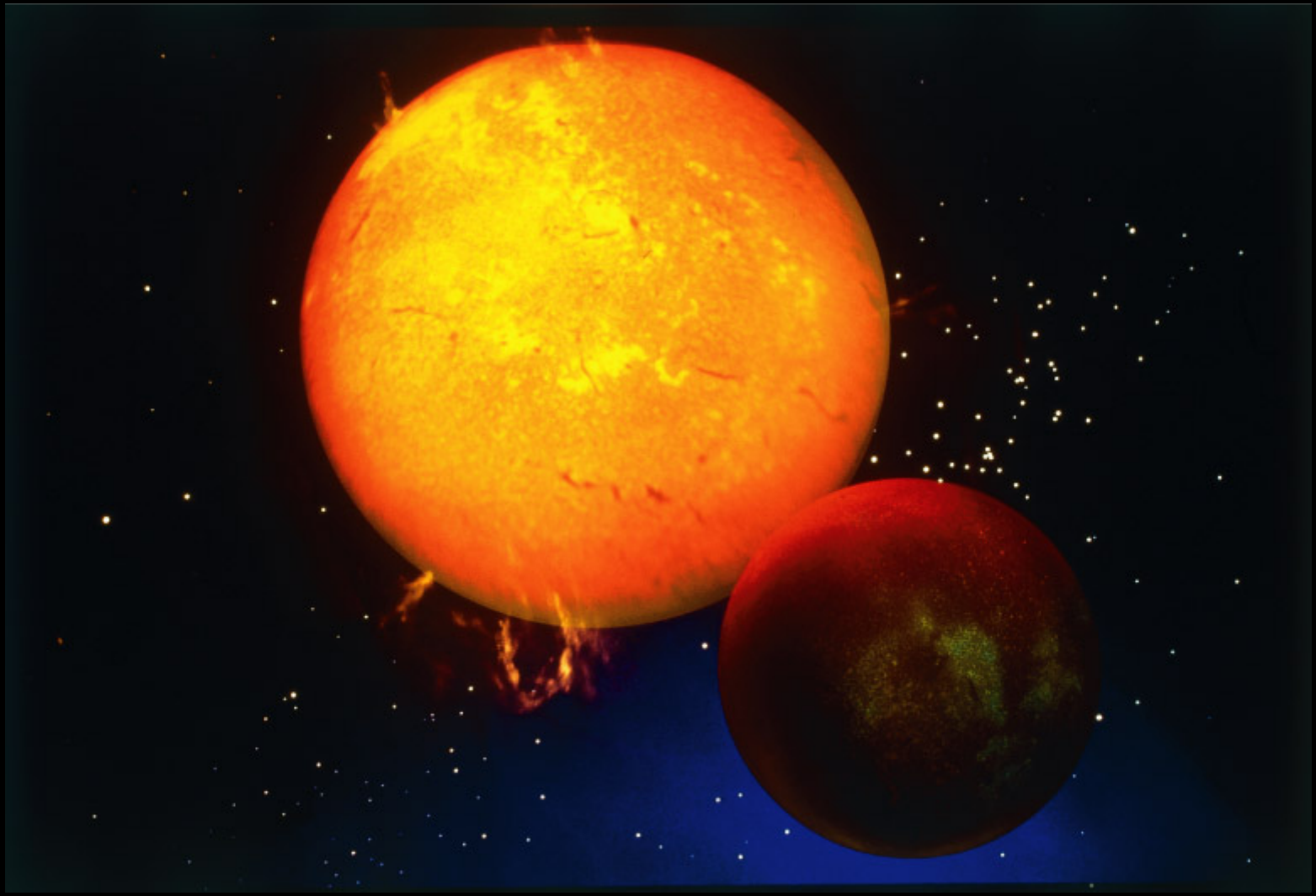
Are there a lot of these….. ?

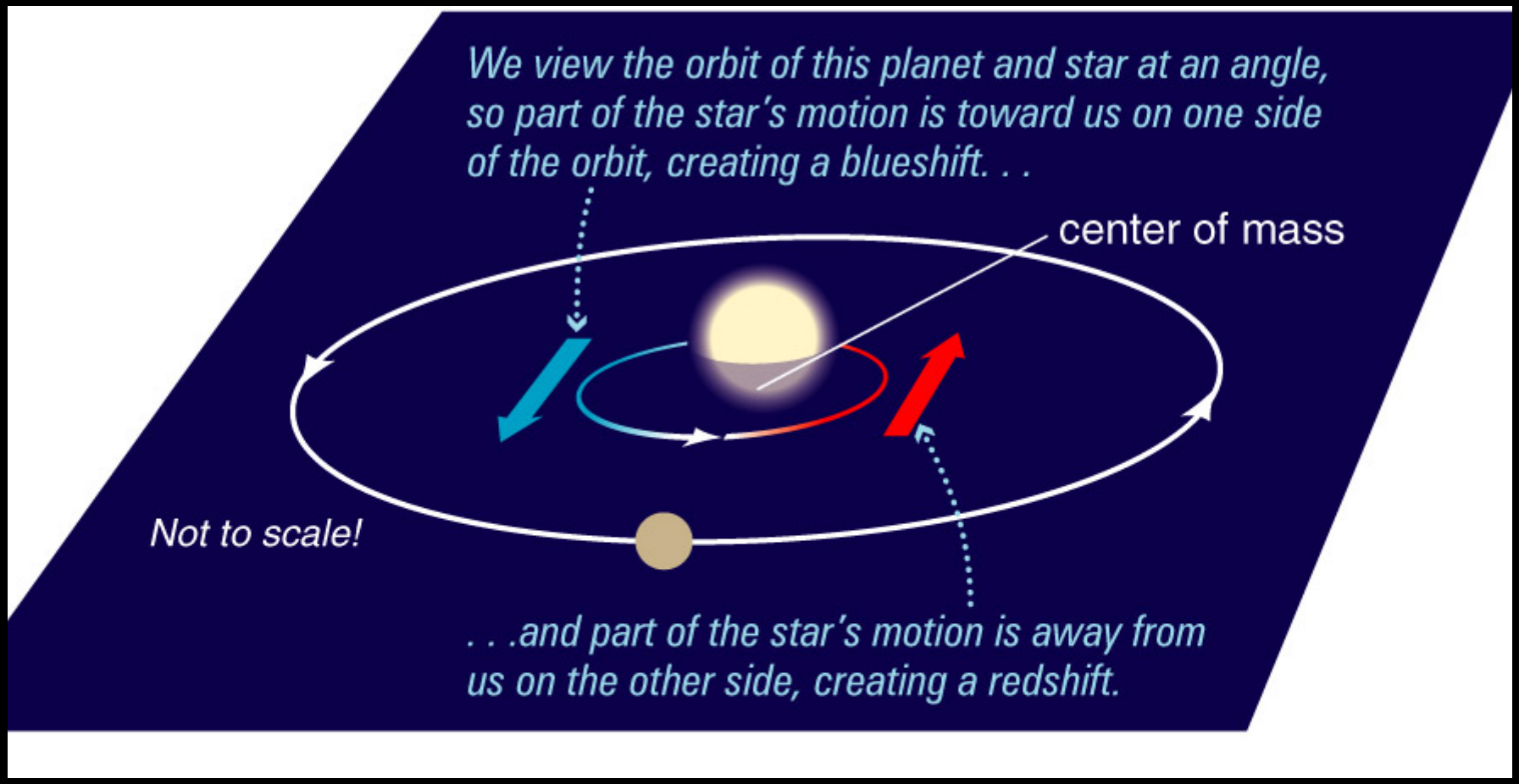


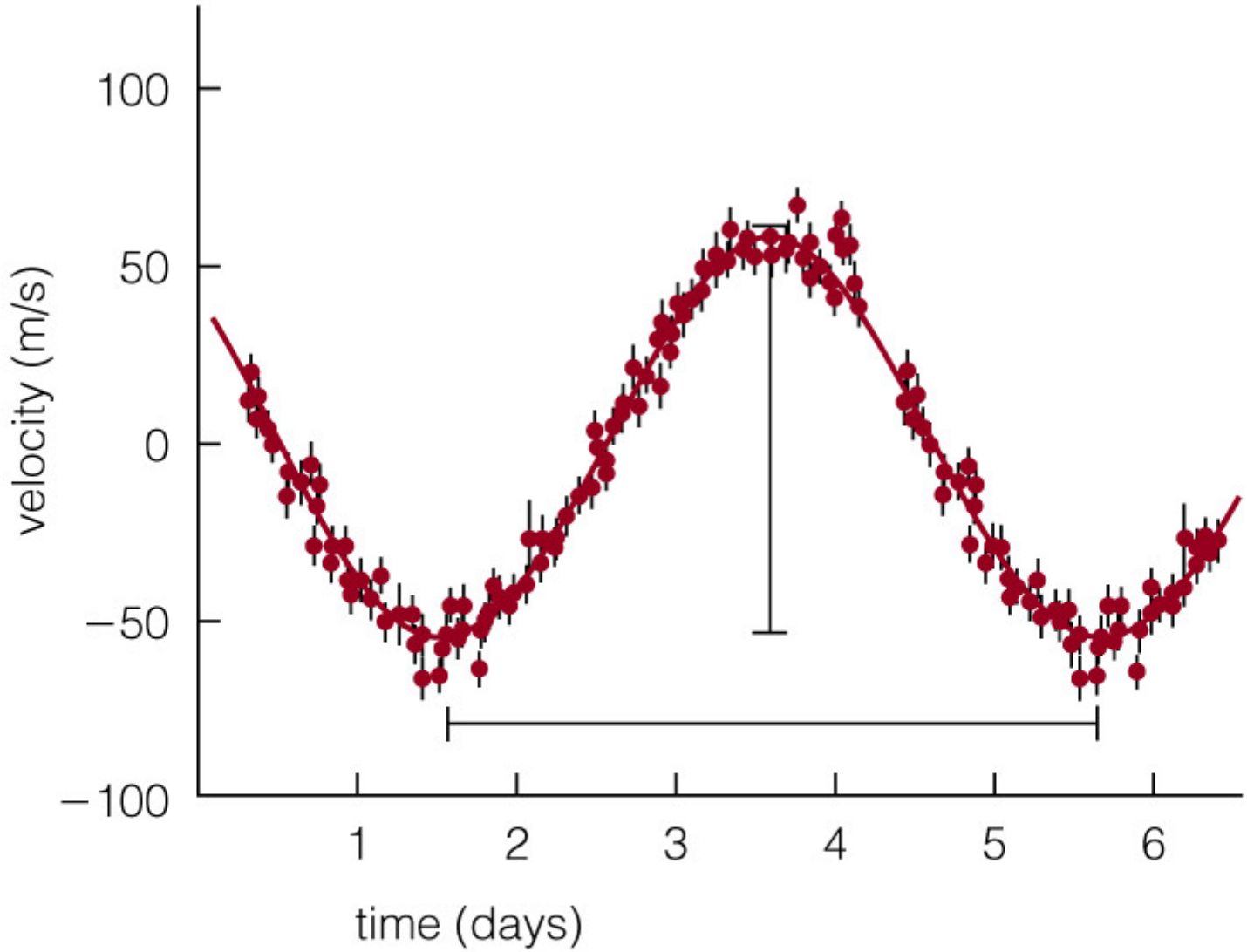


G. Marcy and P. Butler

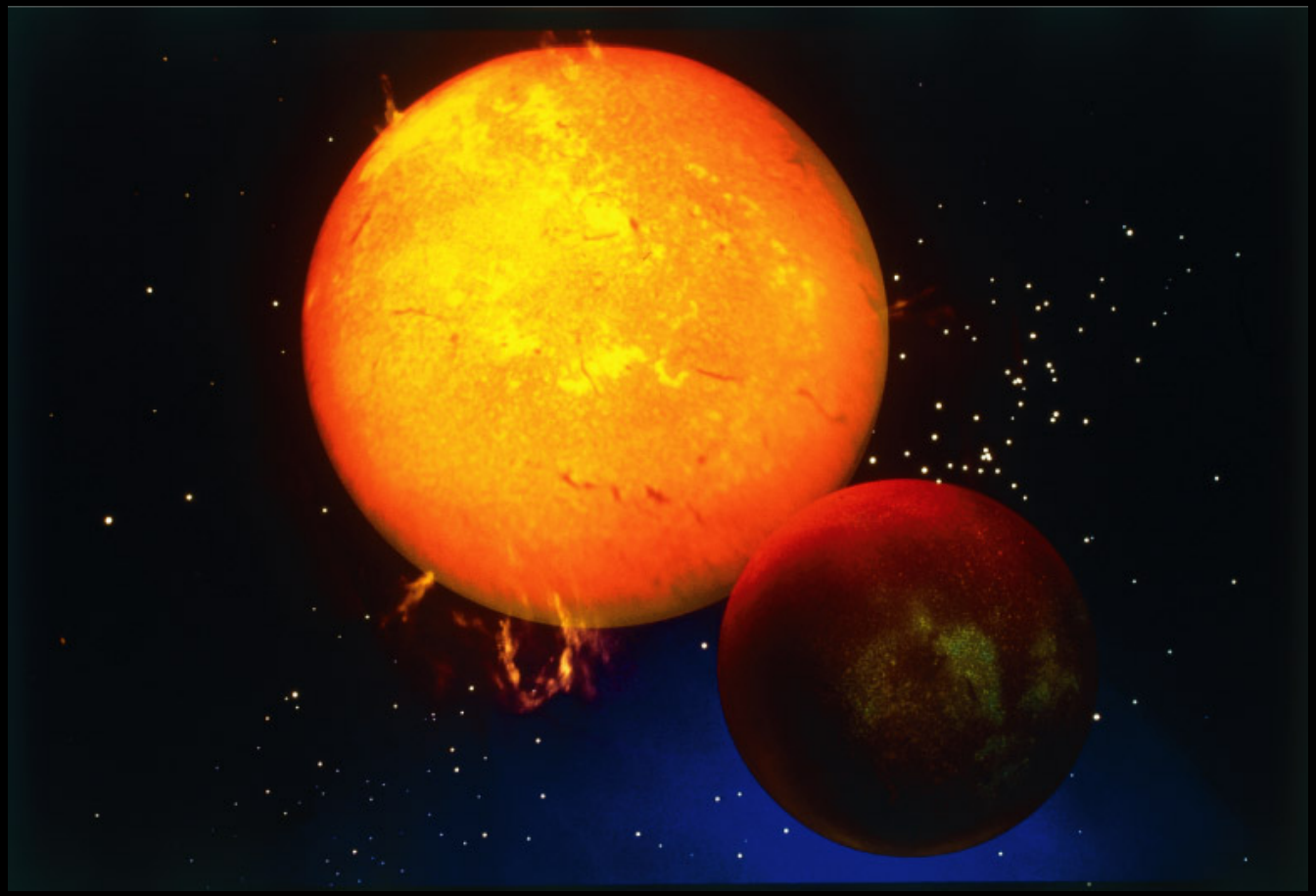
These Extrasolar Planets were all found by analyzing the Doppler shift in the stars light.




We view the orbit of this planet and star at an angle, so part of the star's motion is toward us on one side of the orbit, creating a blueshift. . .
center of mass
Not to scale!
. . .and part of the star's motion is away from us on the other side, creating a redshift.


100
50
0
−50
−100
velocity (m/s)
1
2
3
4
5
6
time (days)

Amount of Doppler shift in Star's light $\approx \dfrac{M_p}{\sqrt{(M_s \times d)}}$



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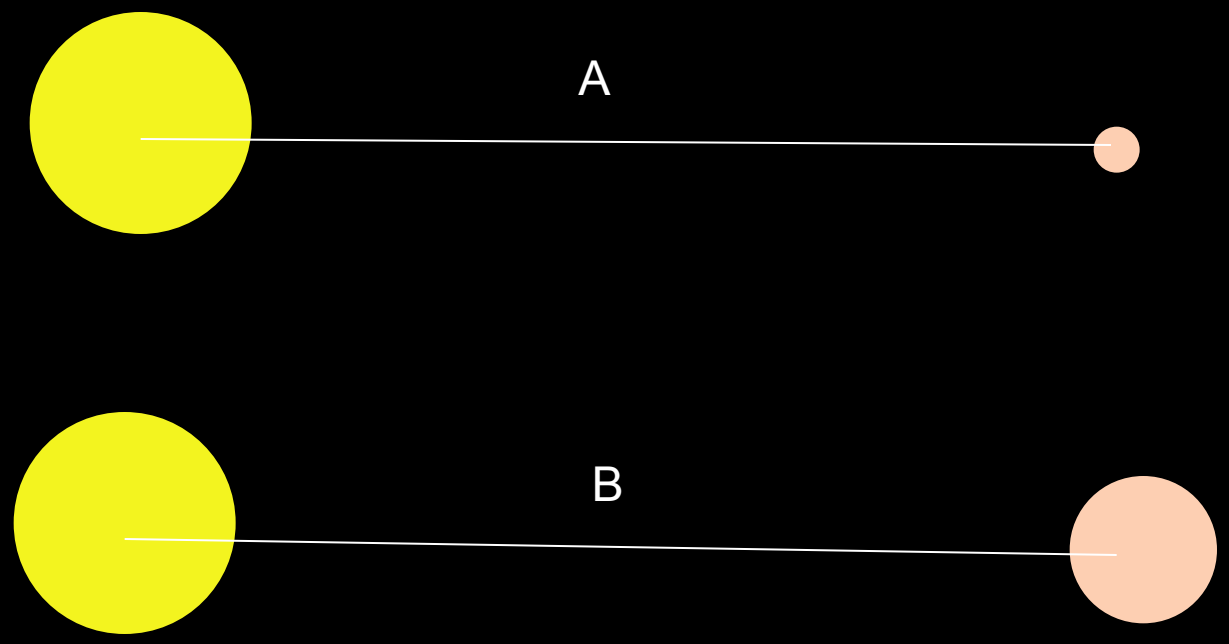
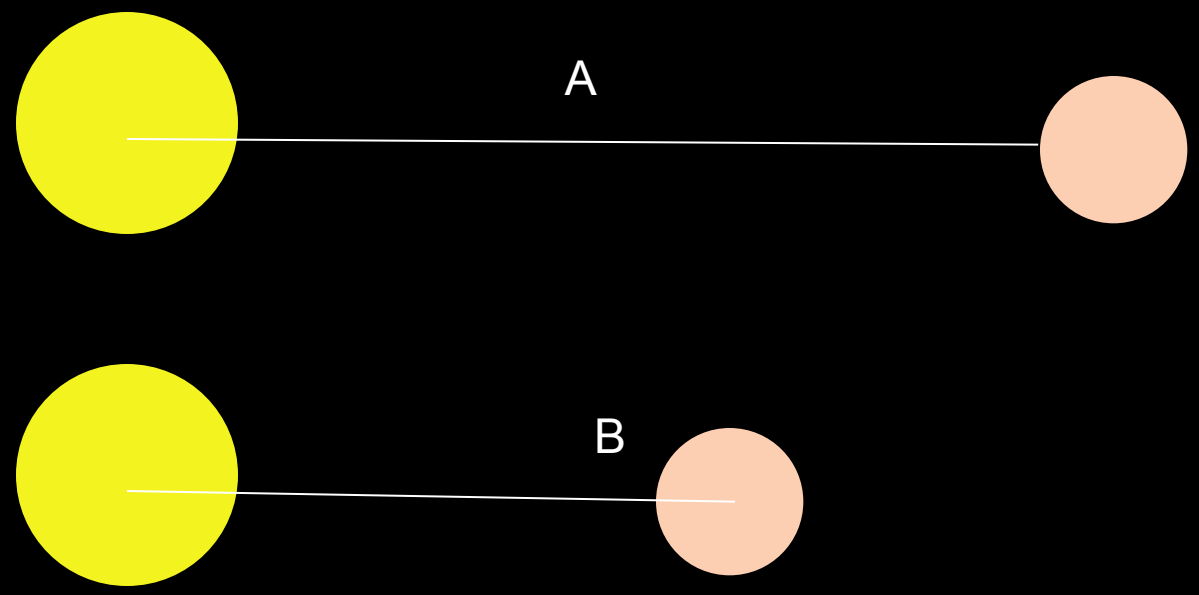
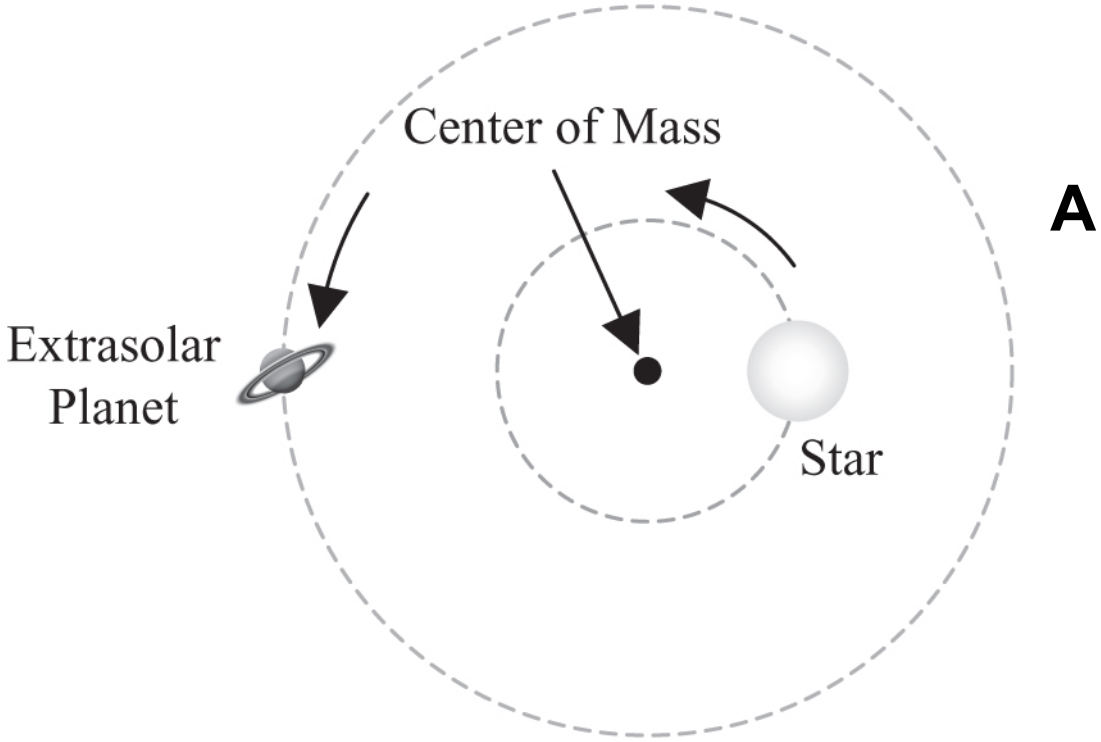


Amount of Doppler shift in Star's light

$$\approx \frac{M_p}{\sqrt{(M_s \times d)}}$$





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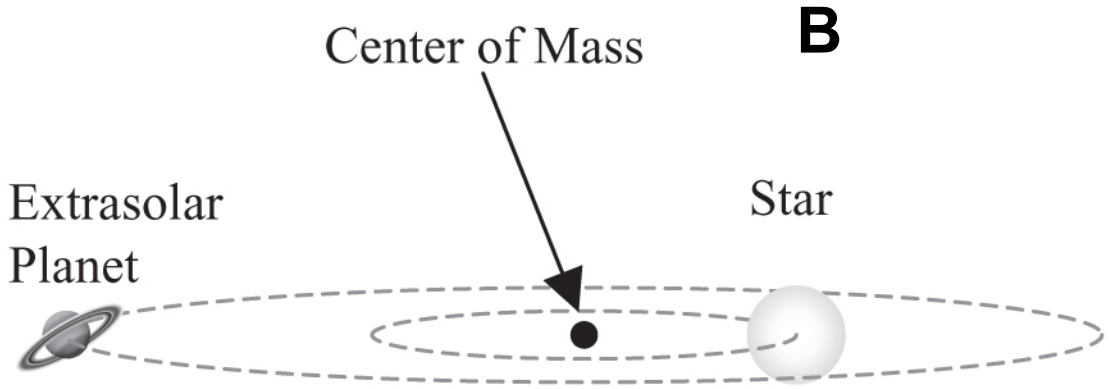

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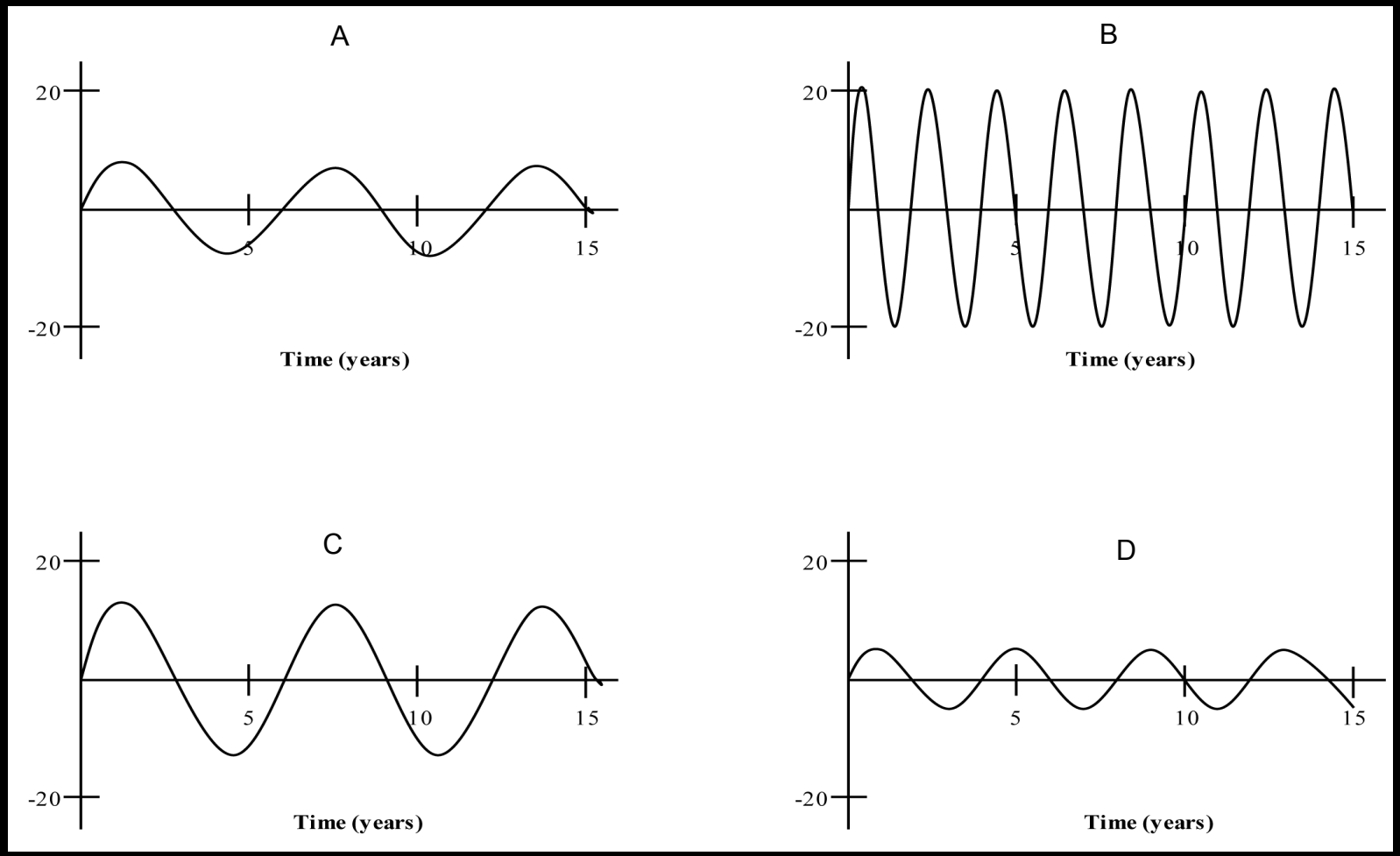
In general, how does the direction the extrasolar planet is moving compare with the direction the star is moving?

A. Same Direction
B. Opposite Direction
C. Cannot be determined

Which object takes a greater amount of time to complete one orbit?

A. the extrasolar planet
B. the star
C. they both take the same amount of time
D. can’t be determine

Shown below are the radial velocity vs time graphs for four stars in different extrasolar planet systems (A-D).
In which system would we detect the greatest amount of Doppler Shift in the Star's light?



It is hardest to detect a planet in an extrasolar planet system when

A. a low mass planet is far from a low mass star.
B. a high mass planet is close to a high mass star.
C. a low mass planet is far from a high mass star.
D. a high mass planet is far from a low mass star.
E. a low mass planet is close to a high mass star.

In which of the extrasolar planet systems (A-D) below would it be <u>easiest</u> to detect the planet?

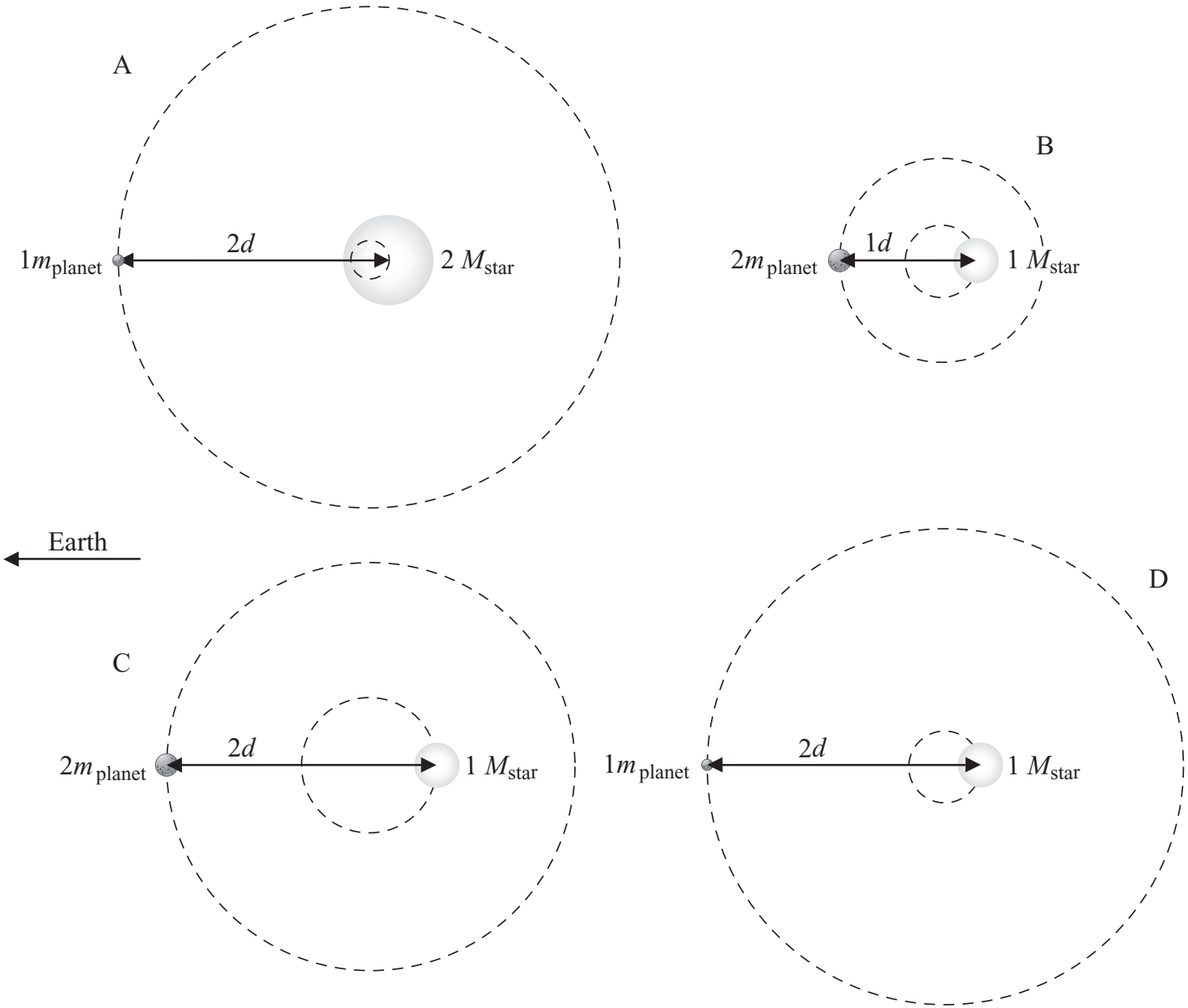


Figure 3

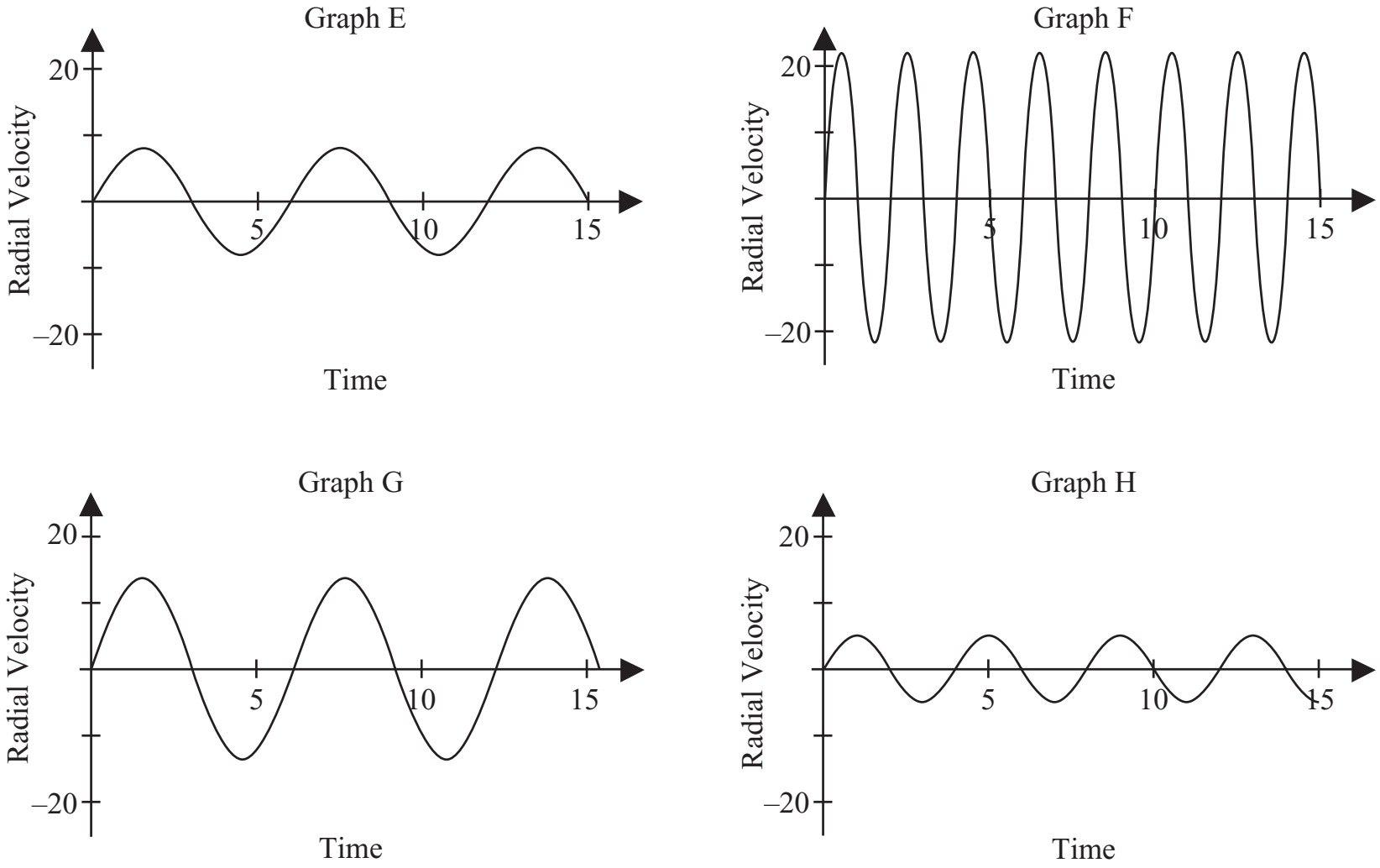
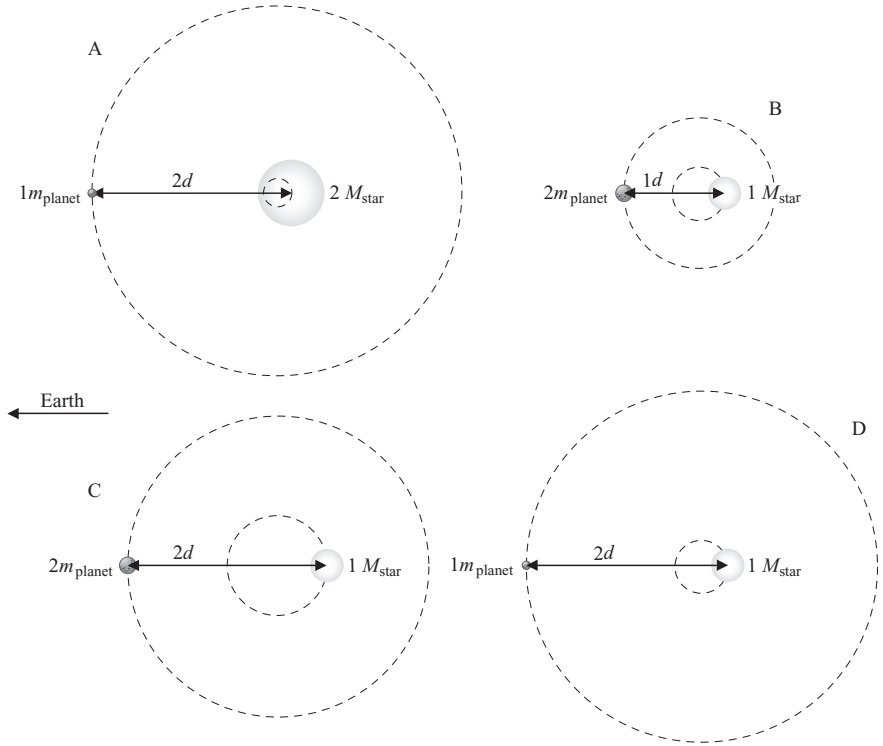

Graph E
20
–20
Radial Velocity
5
10
15
Time
Graph F
20
–20
Radial Velocity
5
10
15
Time
Graph G
20
–20
Radial Velocity
5
10
15
Time
Graph H
20
–20
Radial Velocity
5
10
15
Time

Figure 4



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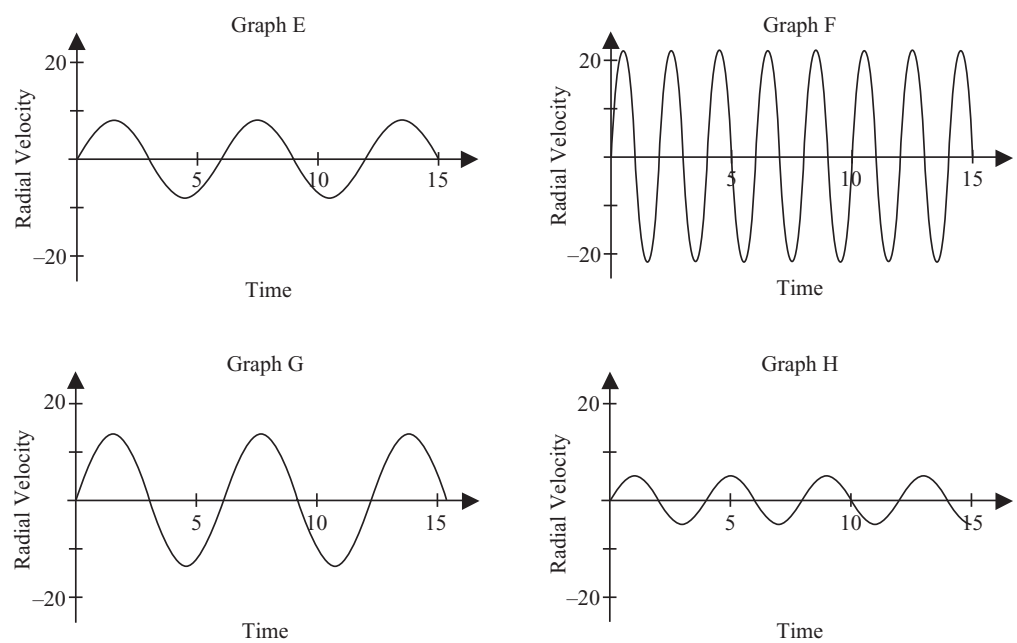
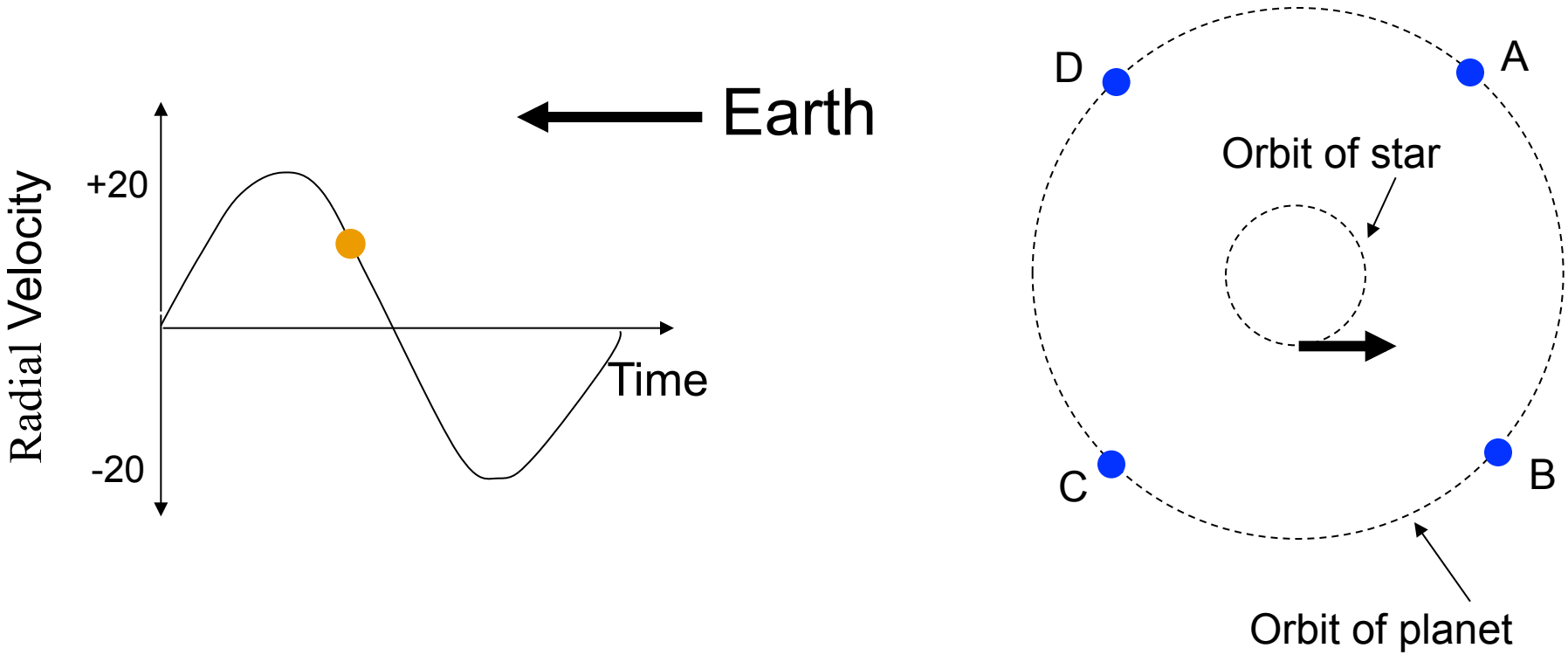
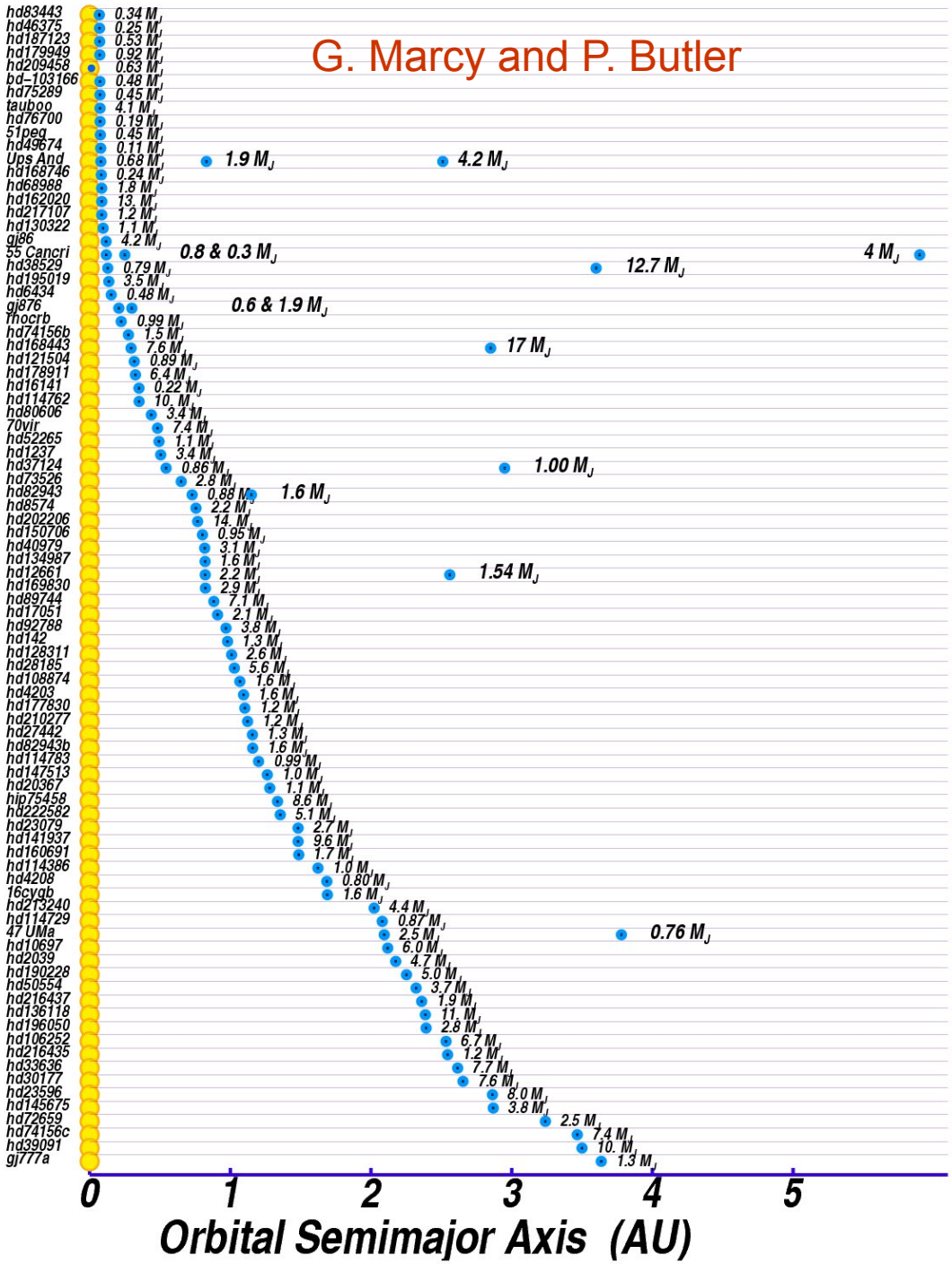


Figure 4



Given the location marked on the star's radial velocity curve, at which location in the planet's orbit would you expect the planet to be?



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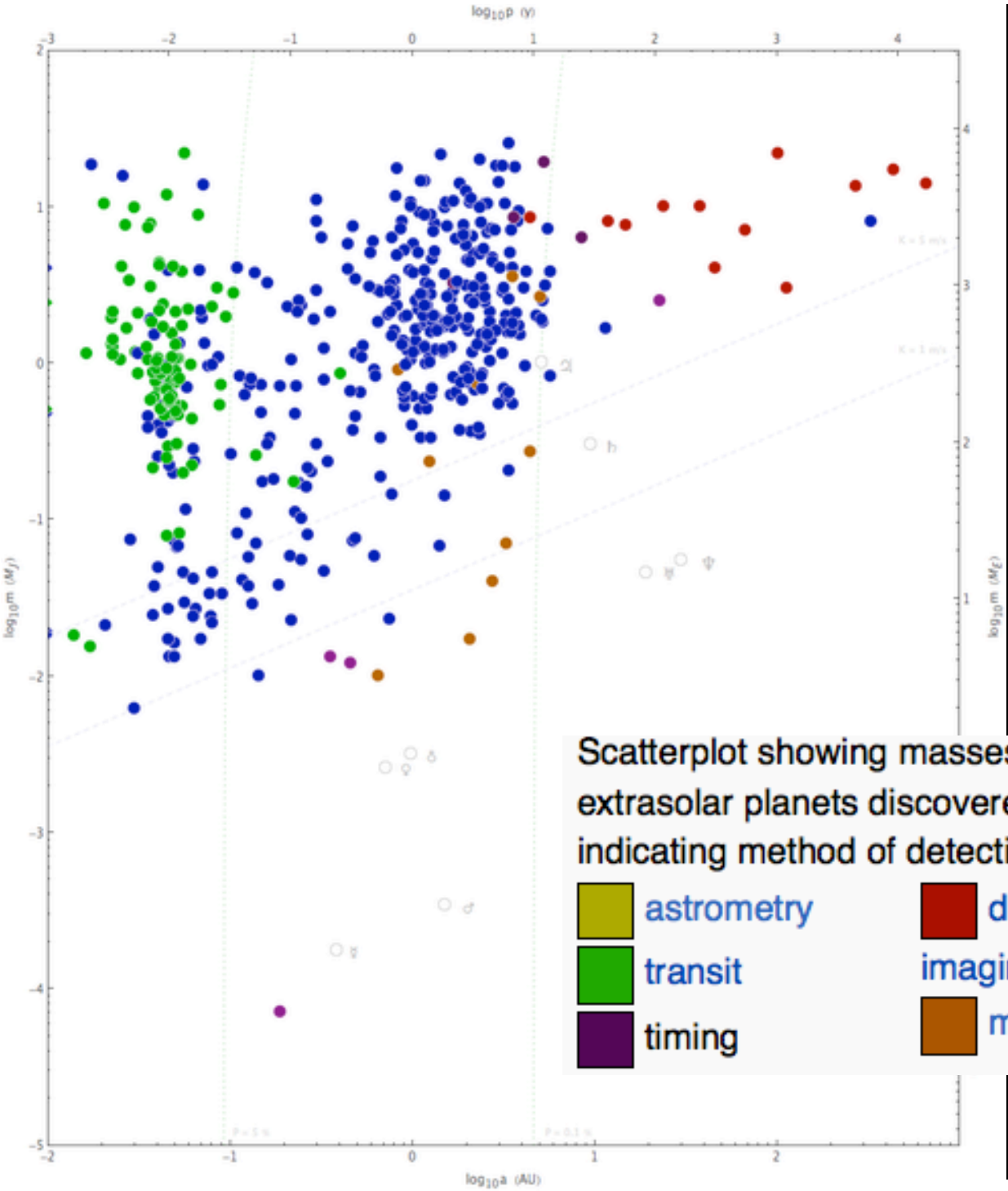


Rank the different methods for finding extrasolar planets from most successful to least.

Scatterplot showing masses and orbital periods of all extrasolar planets discovered through 2010-10-03, with colors indicating method of detection:

- astrometry
- direct imaging
- radial velocity
- transit
- microlensing
- pulsar timing
- timing

The Kepler Mission

http://en.wikipedia.org/wiki/Kepler_Mission

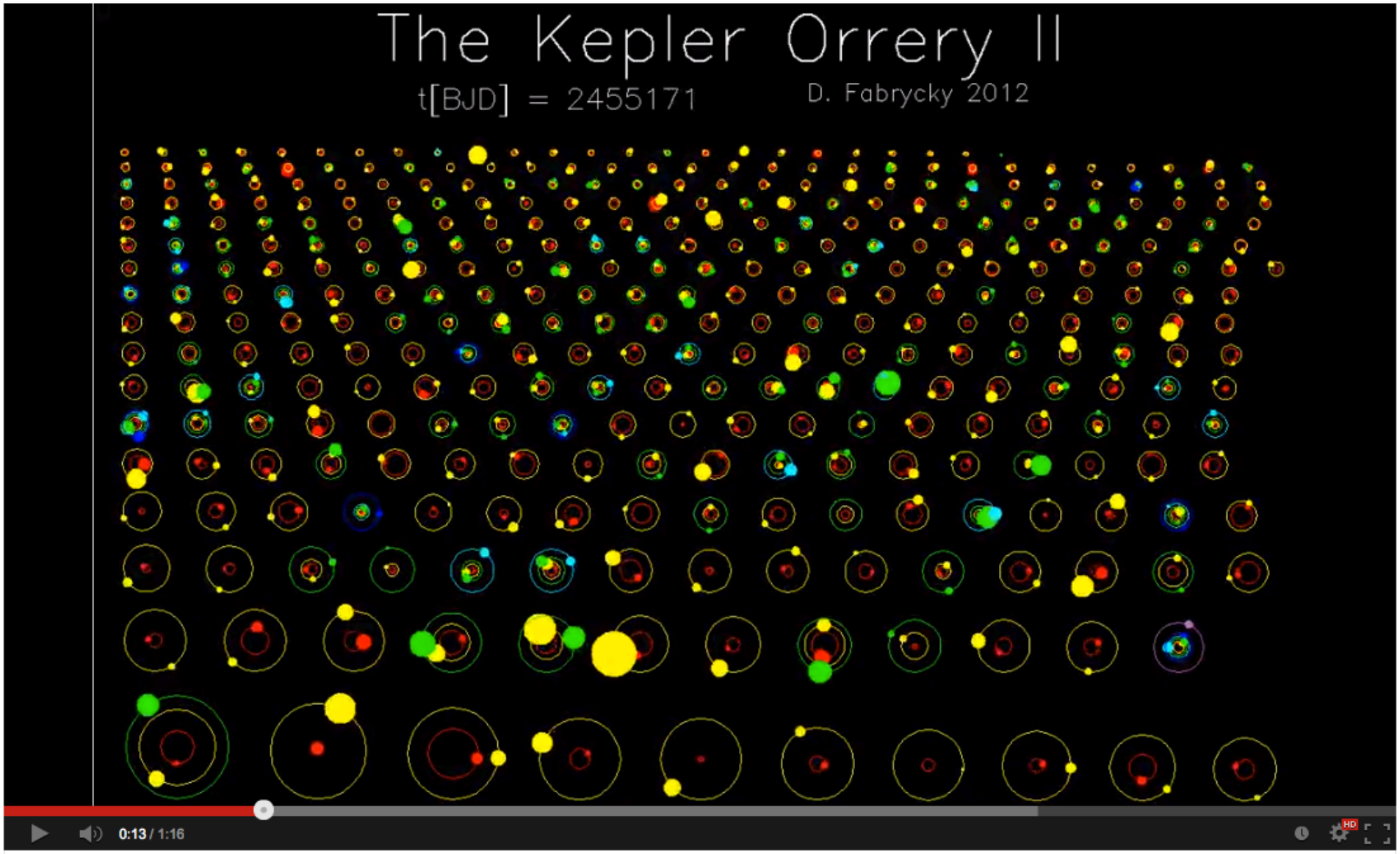
The Kepler Mission uses a telescope in space, which detects extrasolar planets by measuring the slight decrease in the brightness of a star caused when the extrasolar planet passes in from of the star. This is commonly referred to as the "Transit Method"

On December 20, 2011, the *Kepler* team announced the discovery of the first Earth-size exoplanets, Kepler-20e and Kepler-20f, orbiting a Sun-like star, Kepler-20.

The Kepler Mission

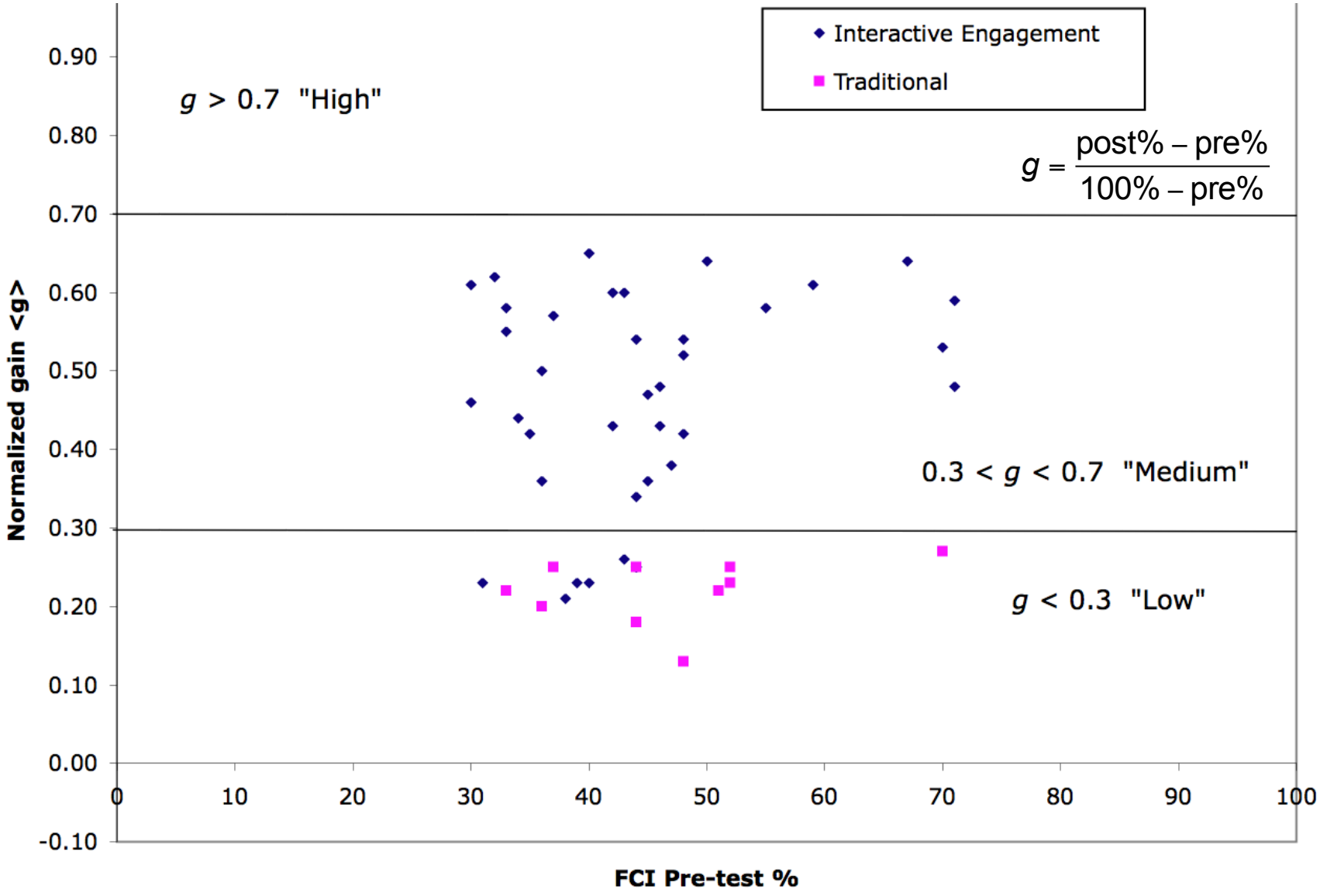
http://en.wikipedia.org/wiki/Kepler_Mission

As of July 2013, *Kepler* had found 134 confirmed exoplanets in 76 stellar systems, along with a further 3,277 unconfirmed planet candidates. In November 2013, astronomers reported, based on *Kepler* space mission data, that there could be as many as 40 billion Earth-sized planets orbiting in the habitable zones of sun-like stars and red dwarf stars within the Milky Way Galaxy….



http://www.youtube.com/watch?v=wj2vv6nVlM0

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



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

Our Recent 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

Our Premise: Implementation is the critical variable

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Workshops

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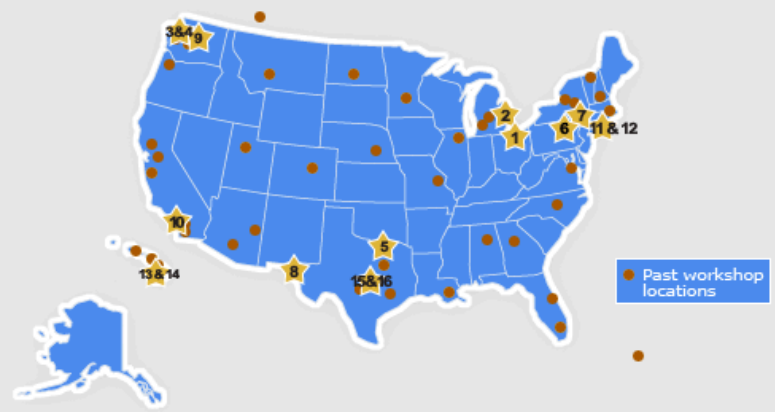

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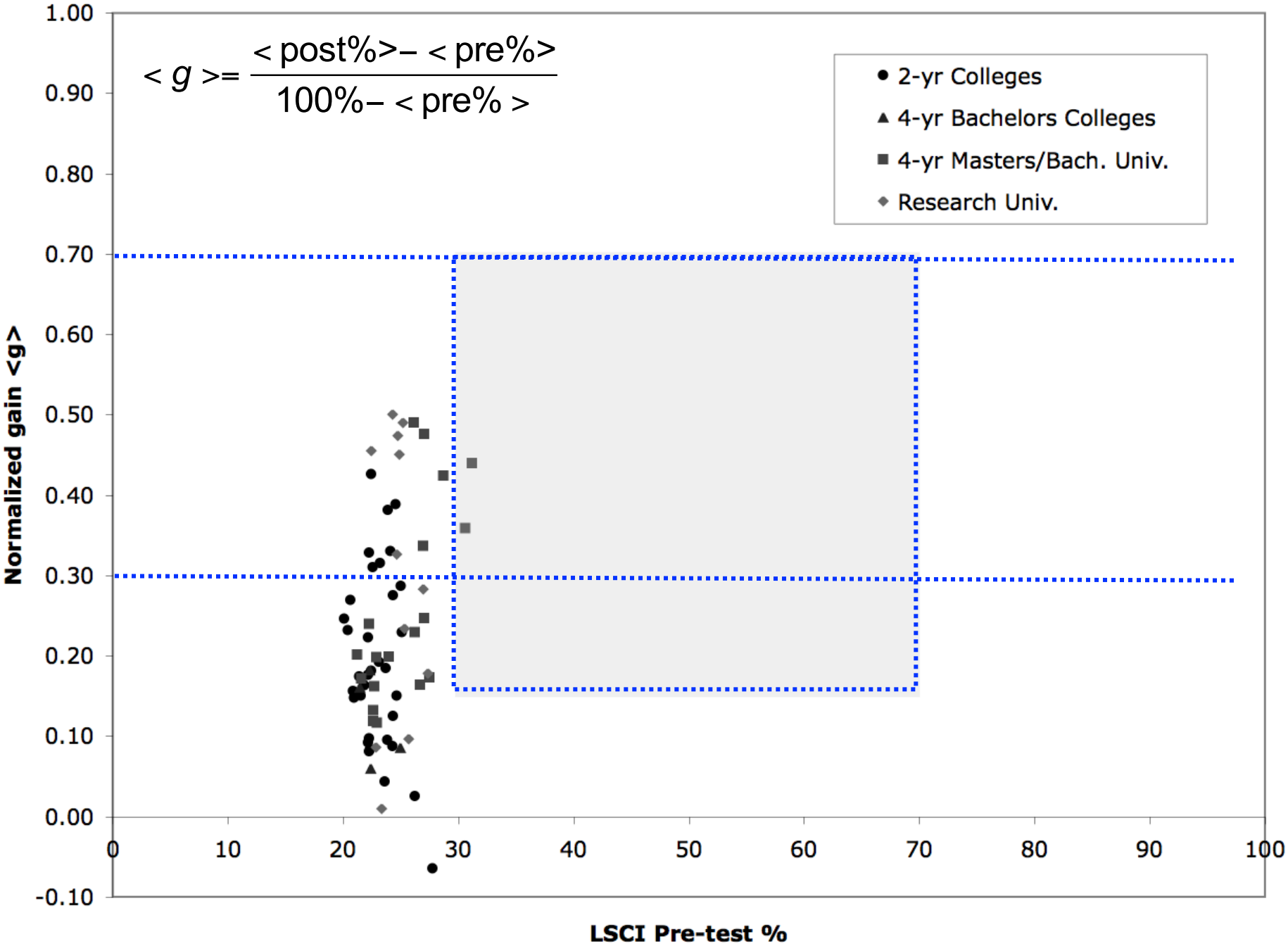
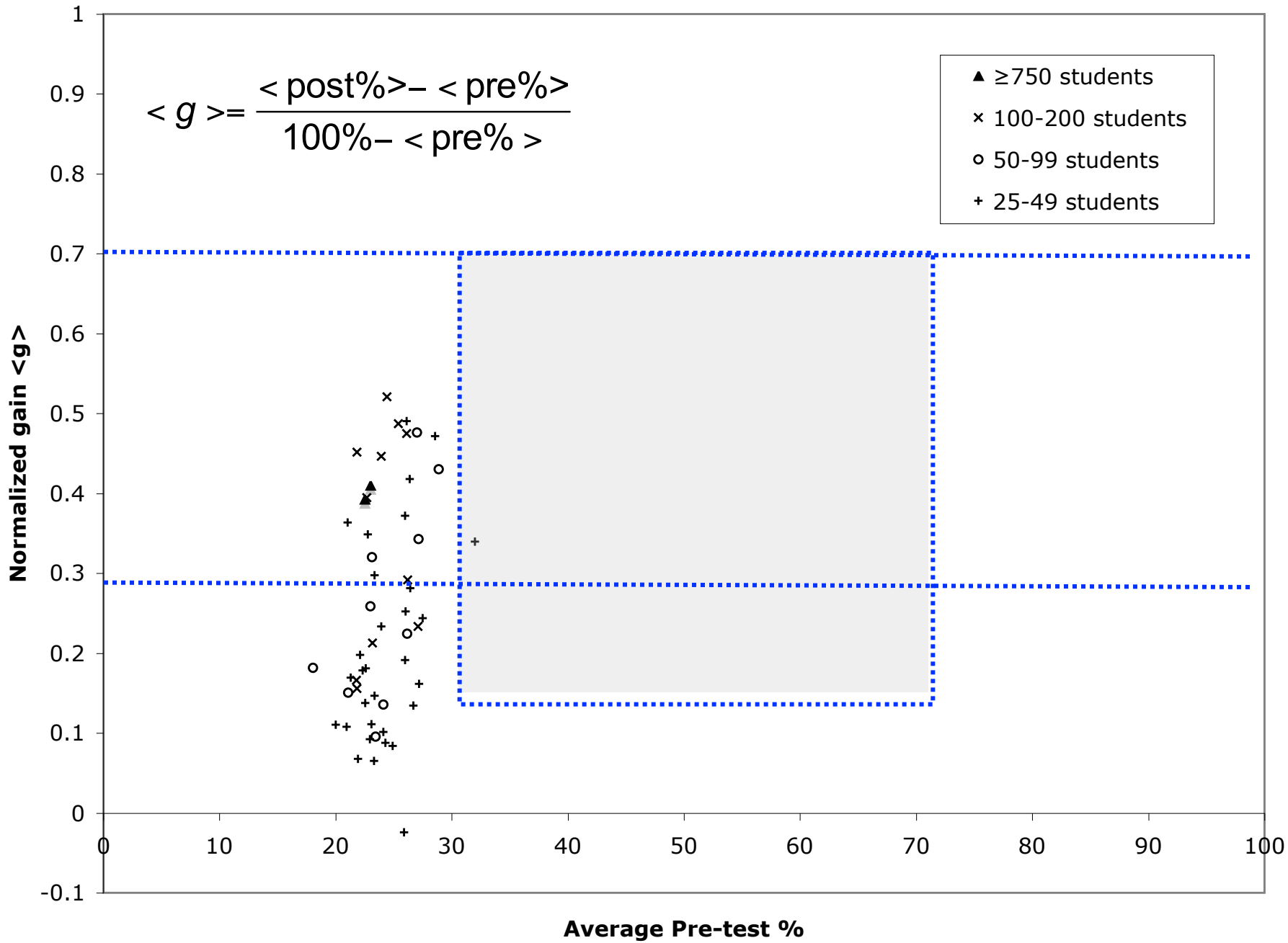


A National Study Assessing the Teaching and Learning of Introductory Astronomy Part I: The Effect of Interactive Instruction, **Prather, E. E., Rudolph, A., Brissenden, G and Schlingman, W., American Journal of Physics, 77(4), 2009.**



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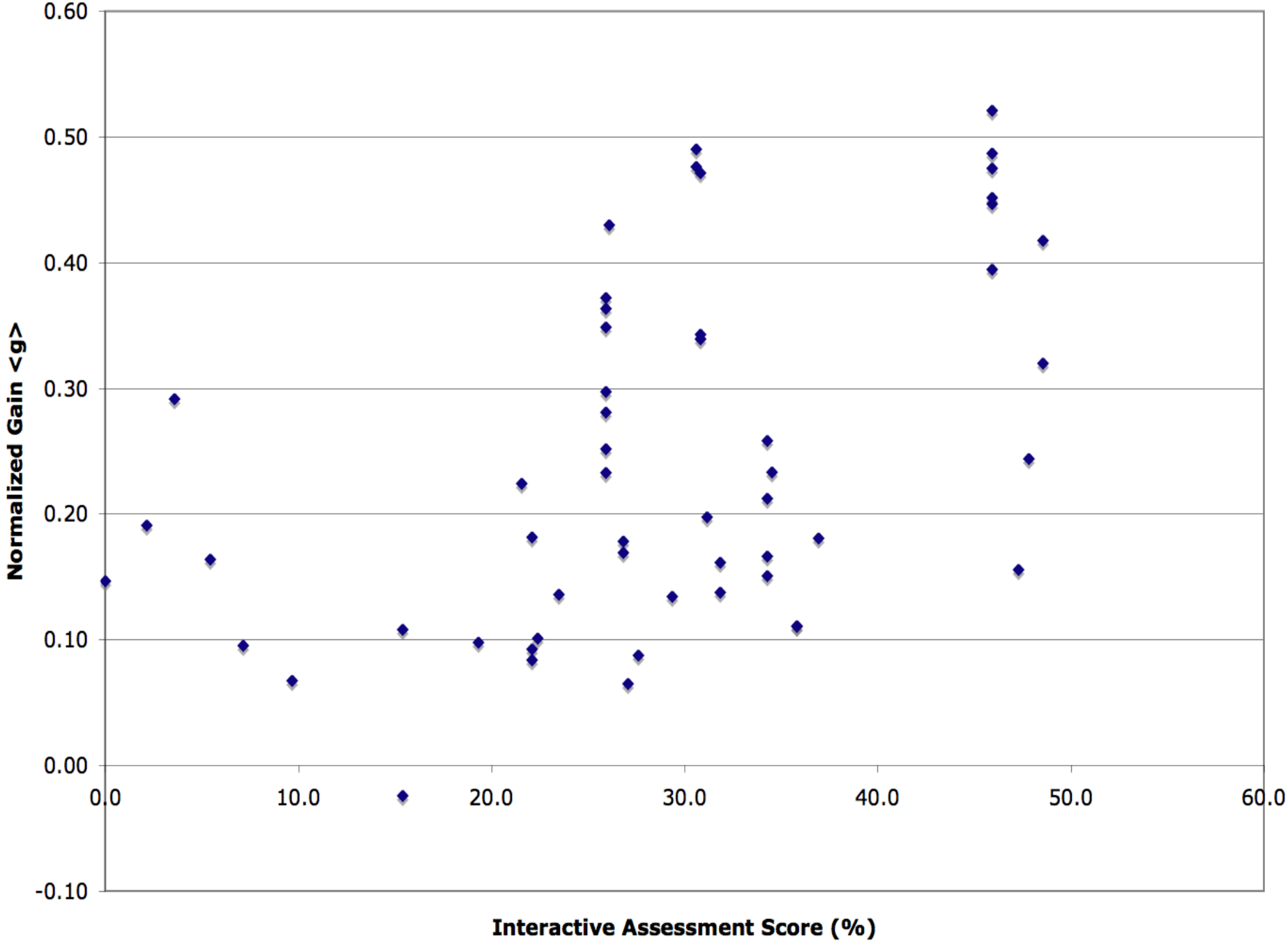
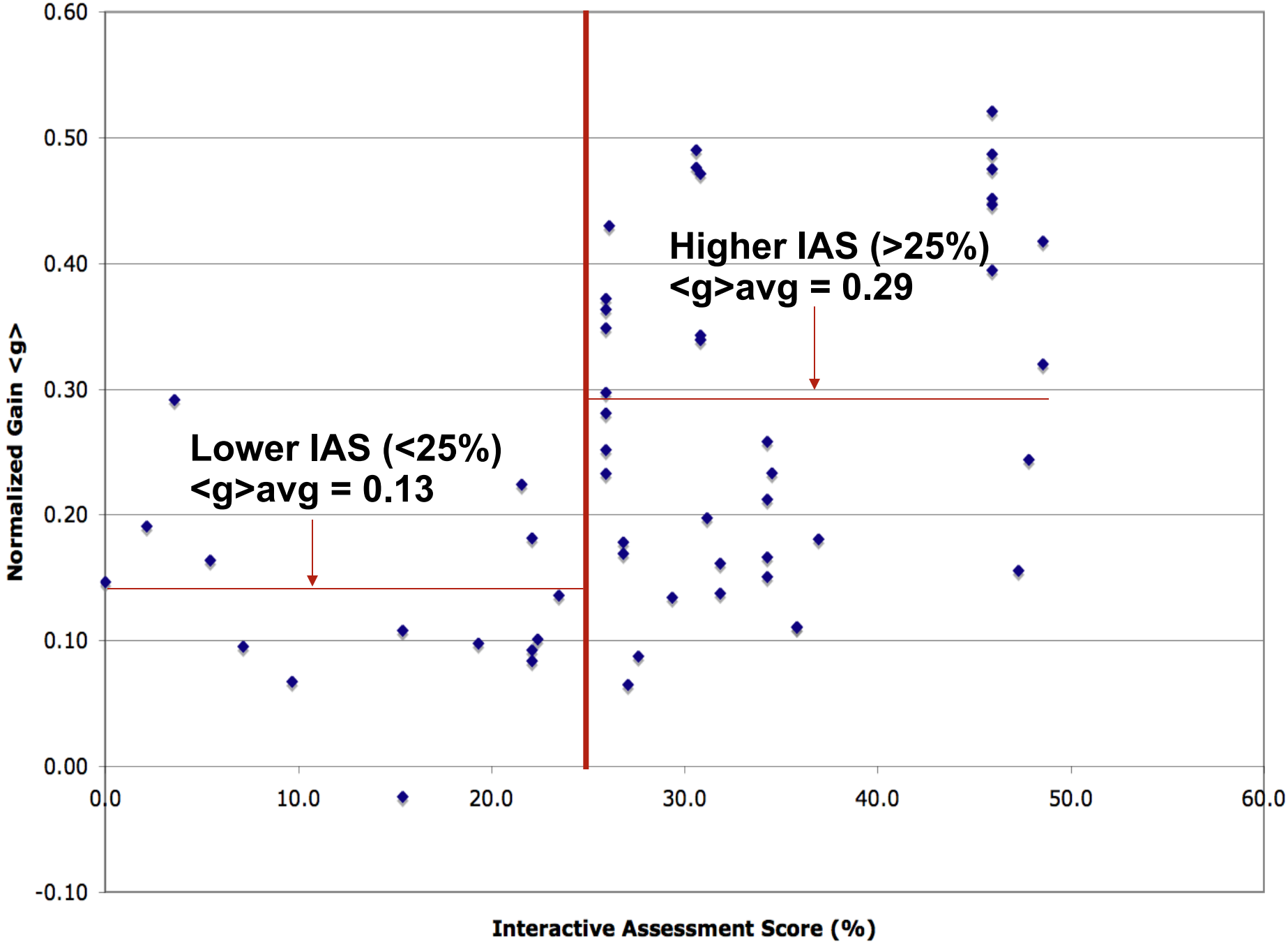
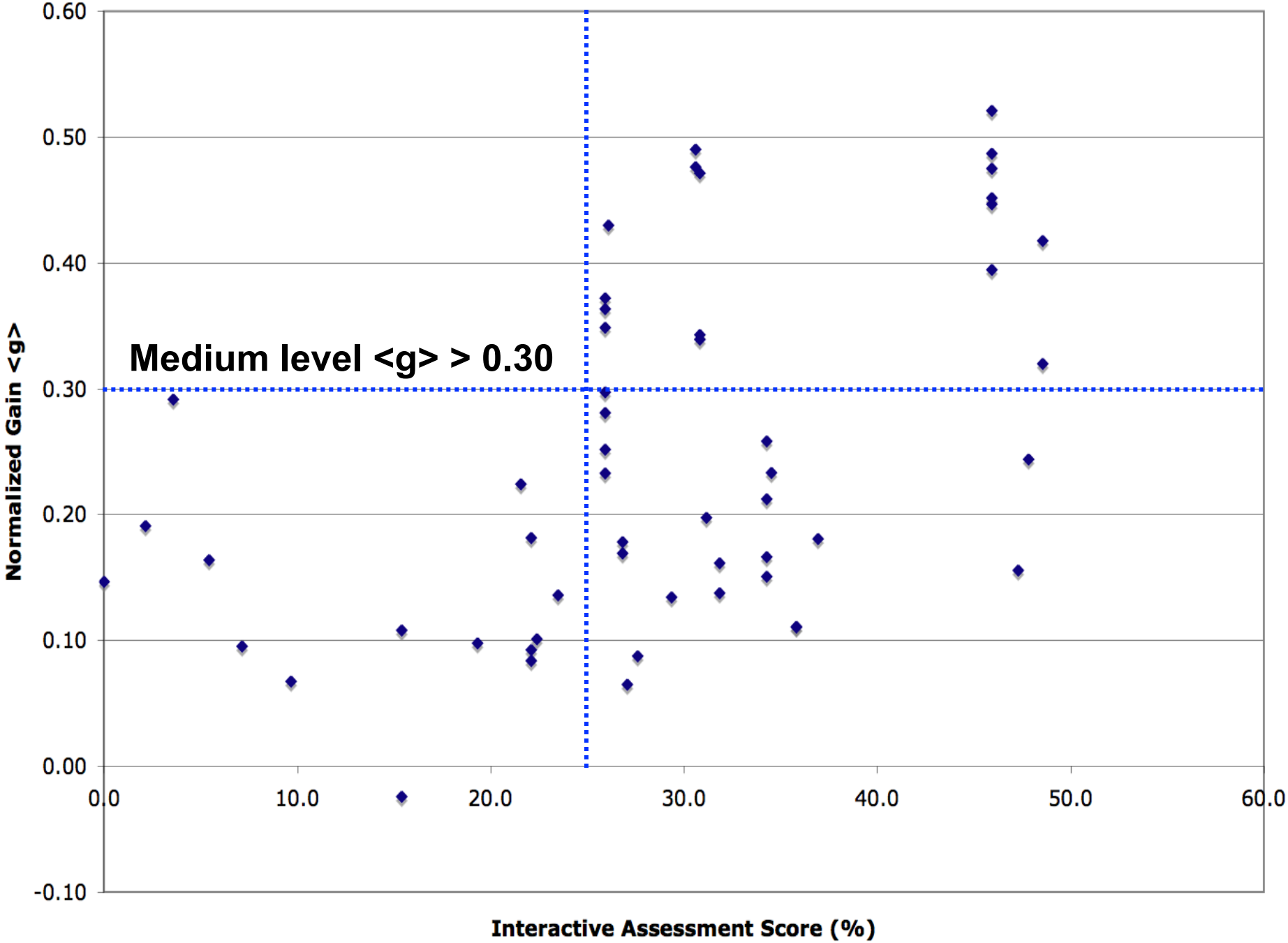
Instructor Surveys

- 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
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


Medium level <g> > 0.30
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

	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

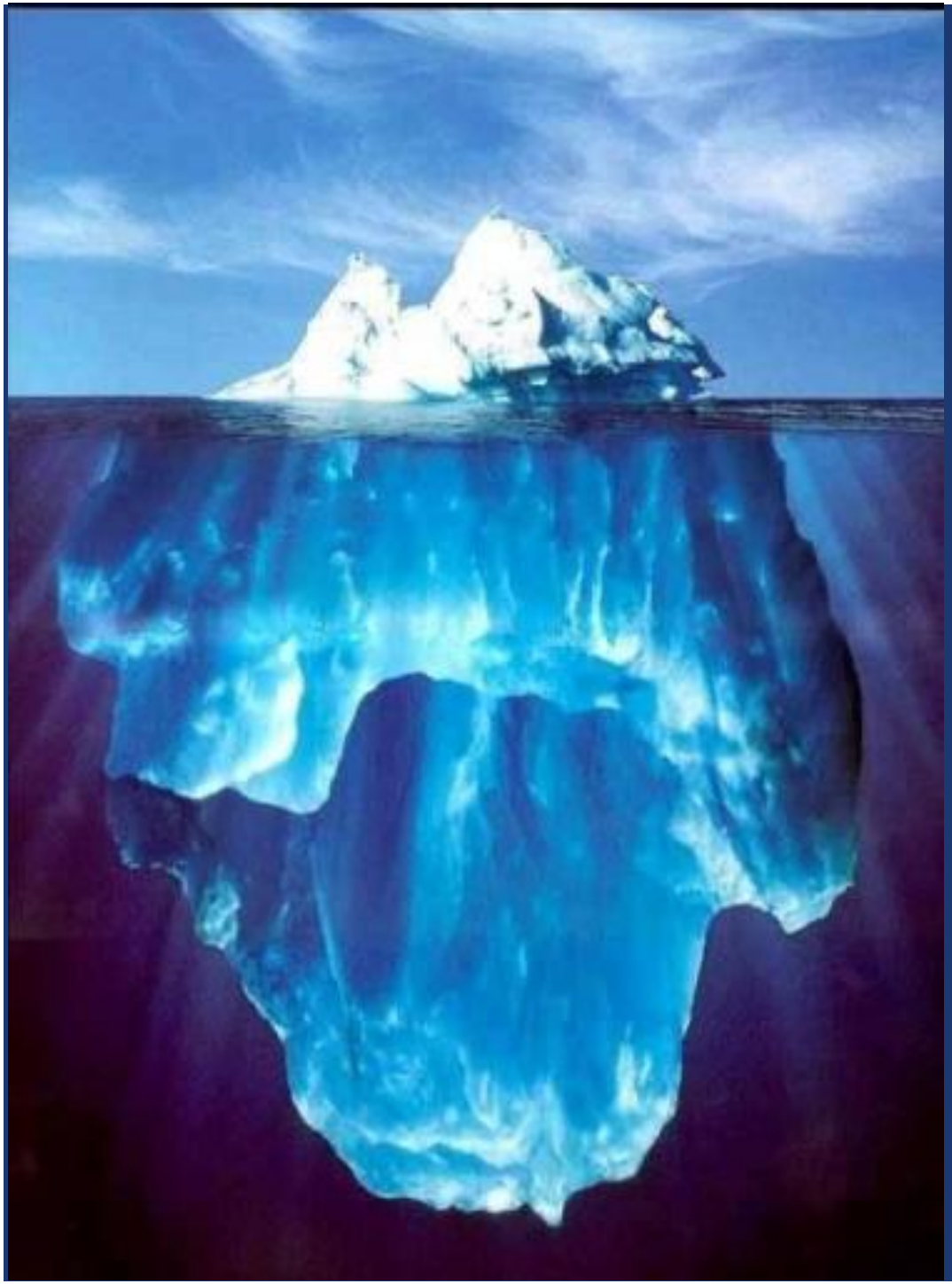
Implementation is the most important factor to success in student learning.

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

Getting Our “challenges” on the Table

- Time, time, time!
- Department support…..
- *Teaching resources …..*
- *Reward structures … etc……*

The REAL challenge is ADAPTION and IMPLEMENTATION!!!!



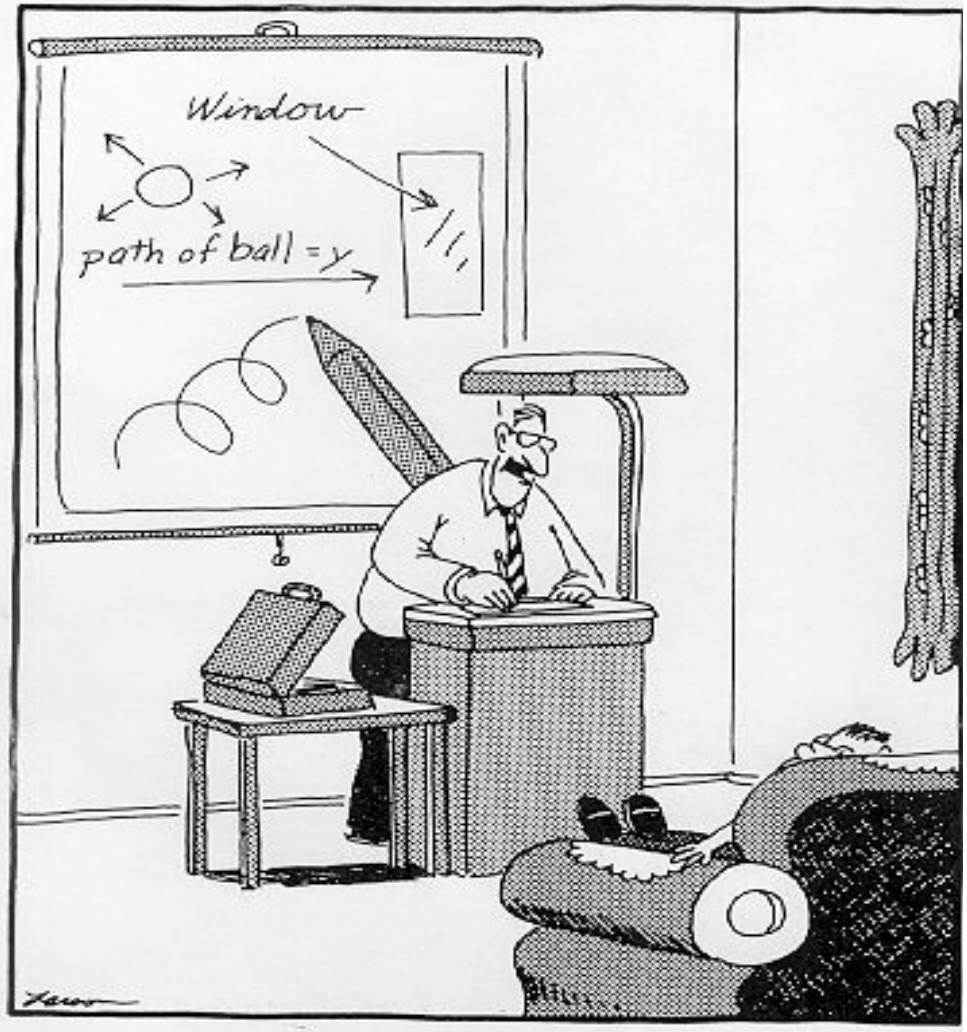
Just the tip of the iceberg of what it takes to create a highly functioning interactive engagement classroom

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

Euclid (300 B.C.)

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

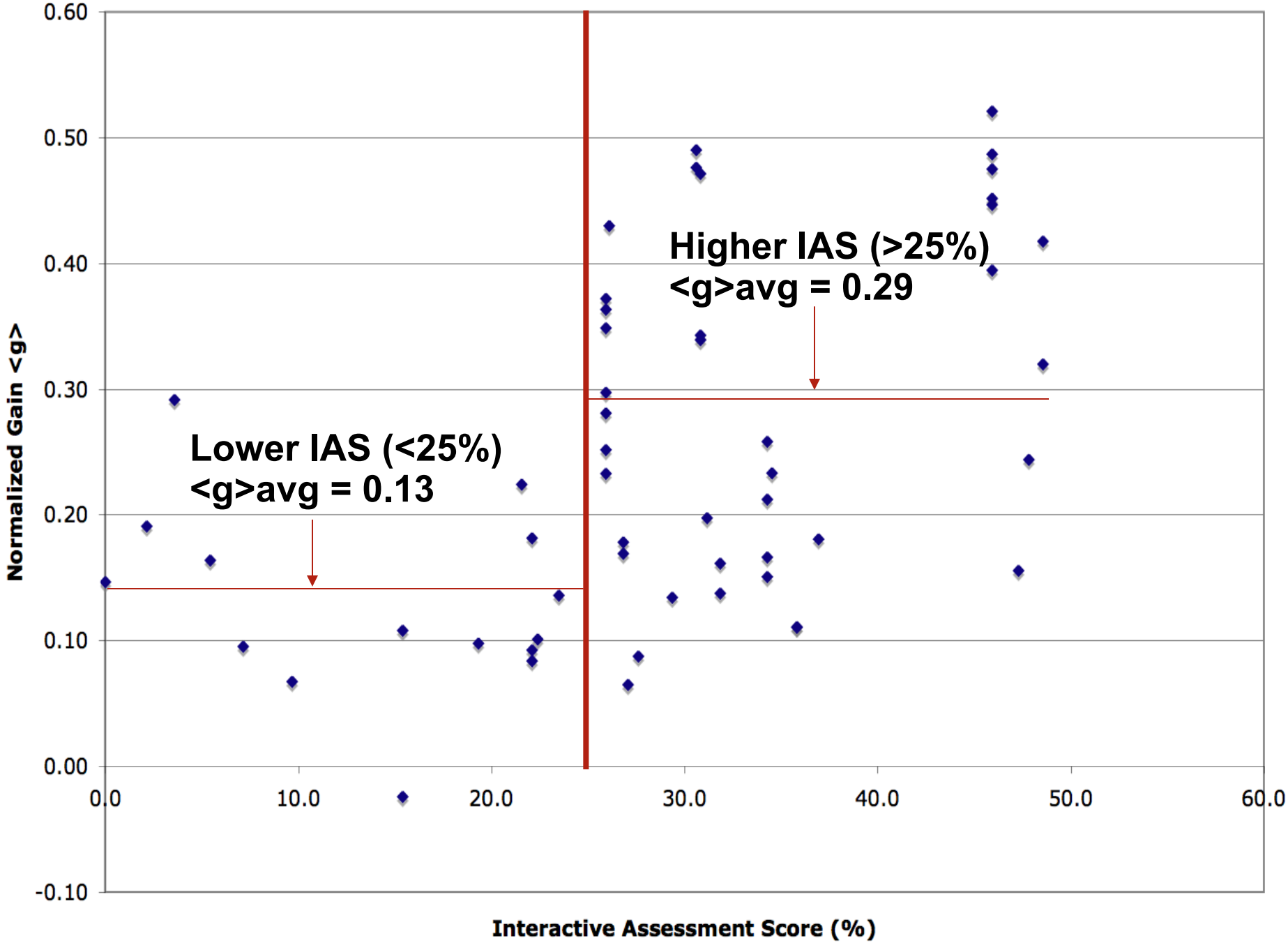


Eventually, Billy came to dread his father's lectures over all other forms of punishment.

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

What Can I do Besides Lecture to Deeply and Intellectually 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 PeerInstruction
- Small Group Interactions
  - Concept Maps
  - Case Studies
  - Sorting Tasks
  - Ranking Tasks
  - Lecture-Tutorials
- Student Debates (individual/group)
- Whole Class Discussions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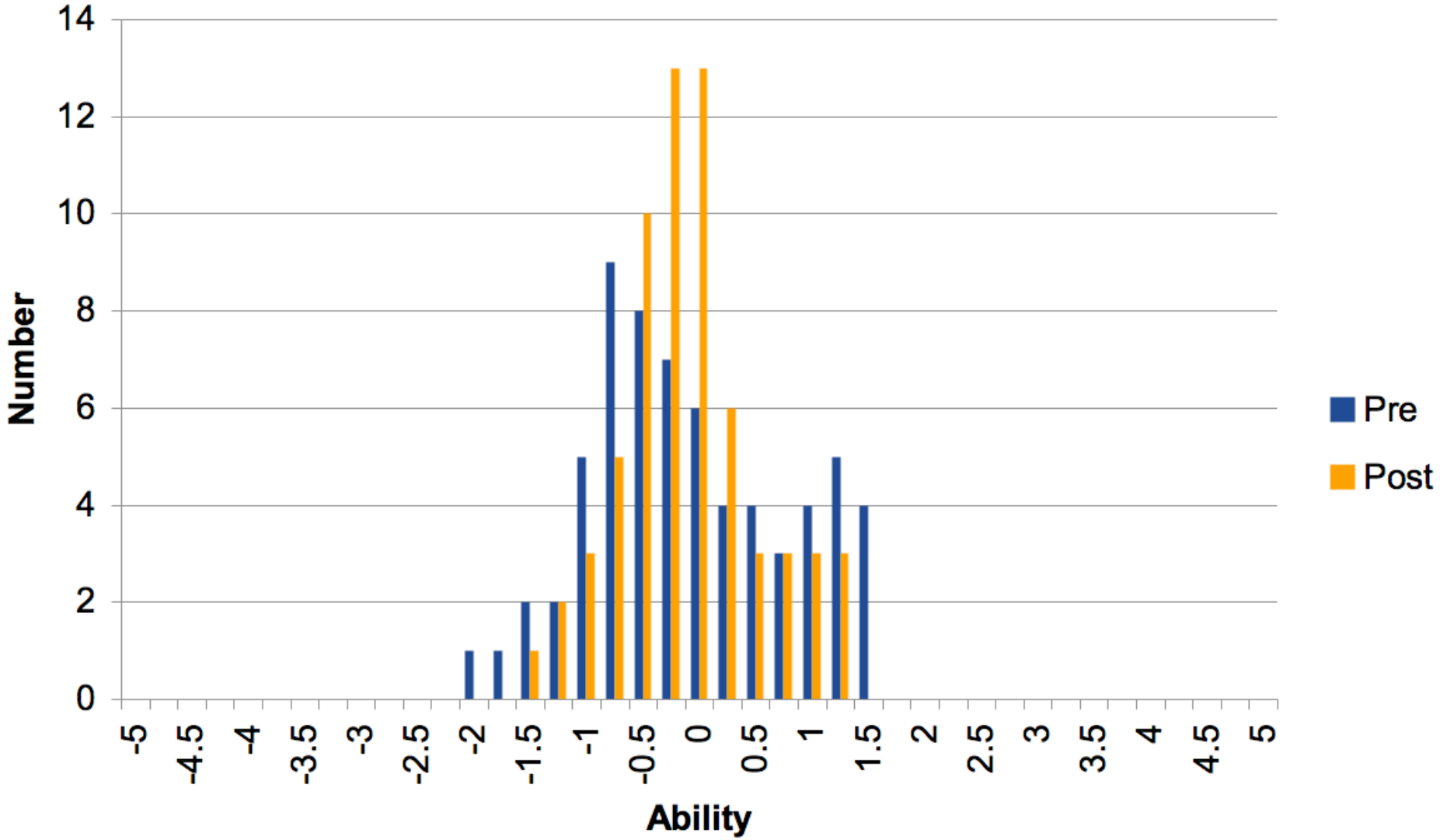
60.0

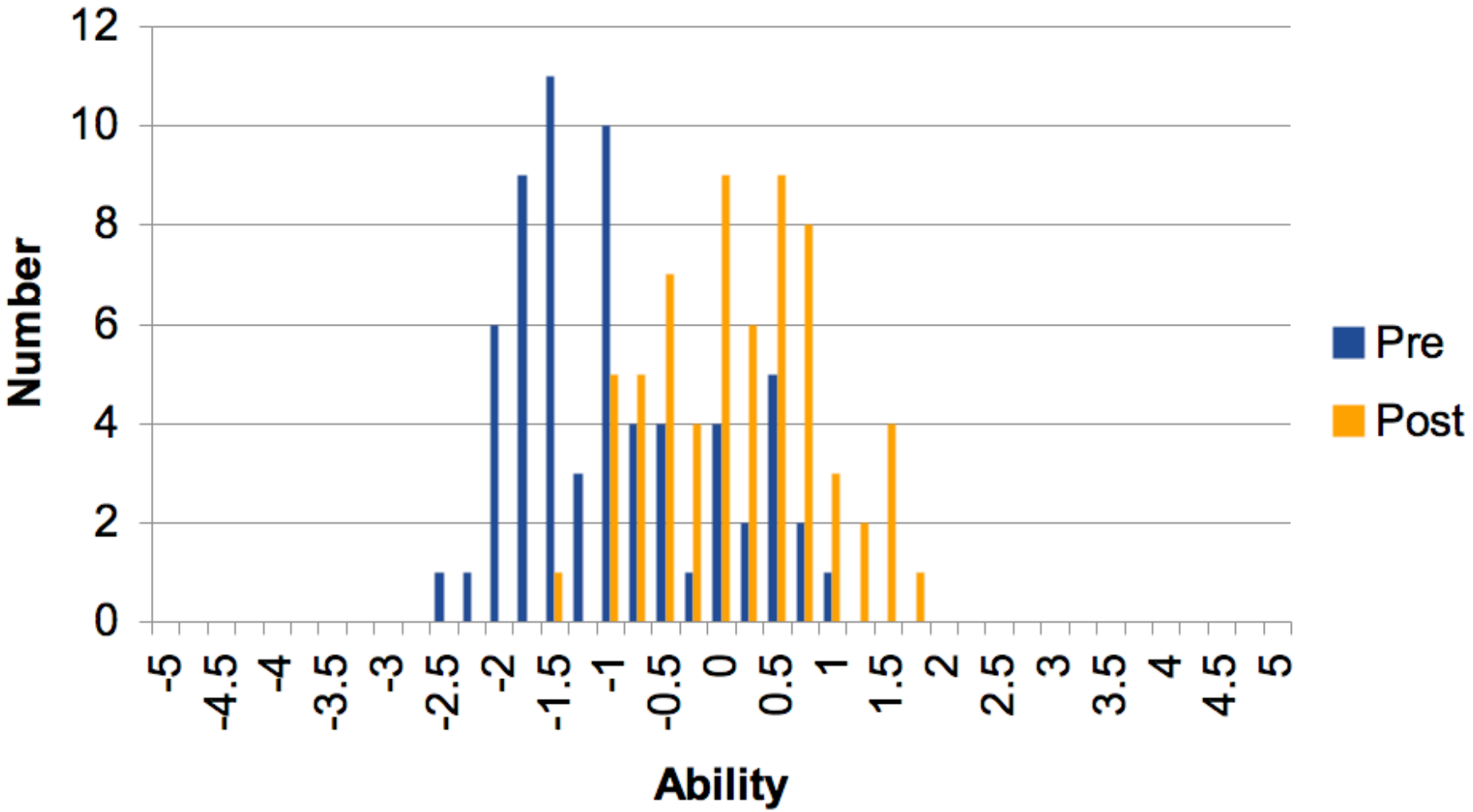
Item Response Theory (IRT)

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

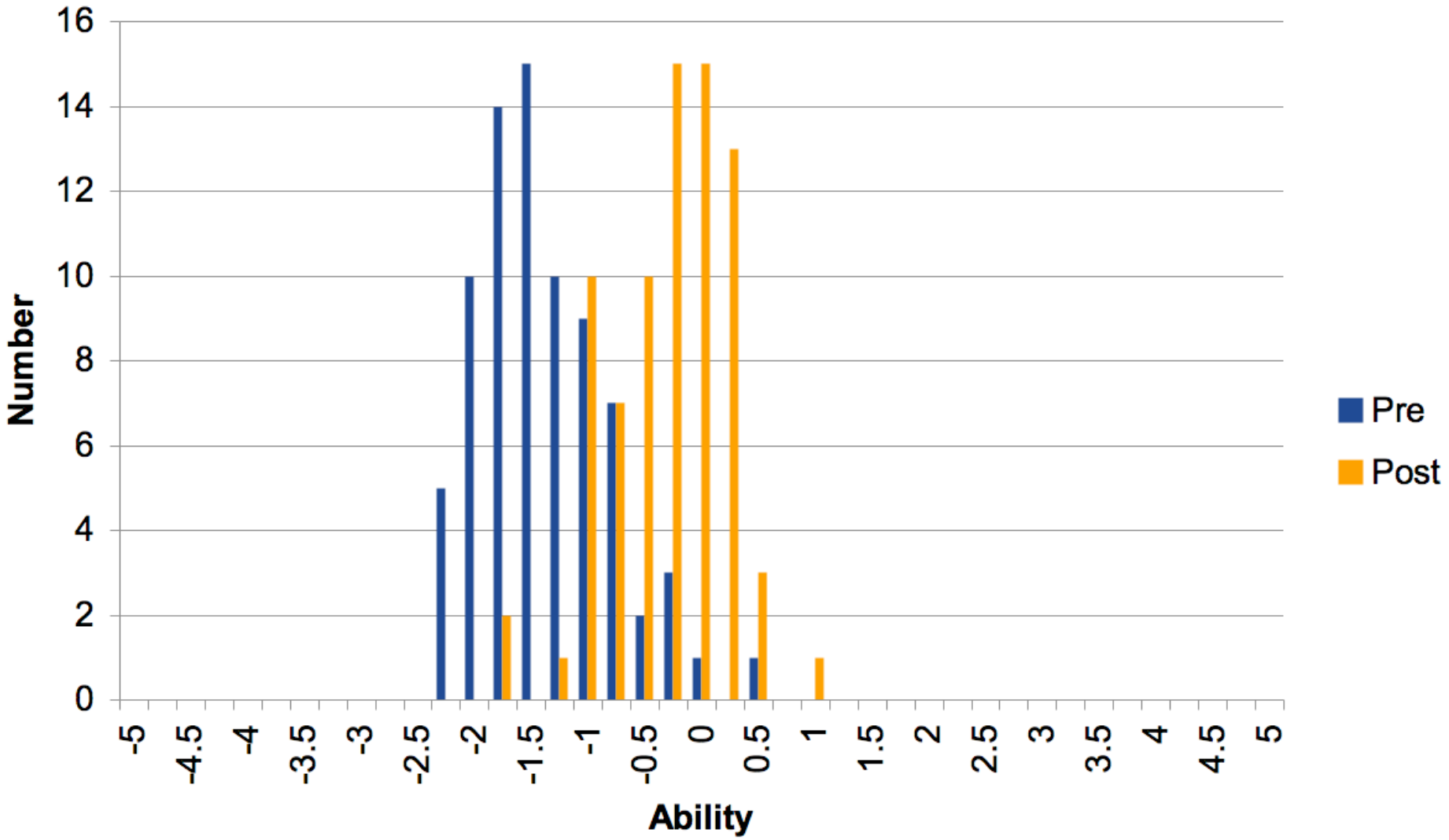
Class #1 – Student Pre and Post Ability Histogram



Class #2 – Student Pre and Post Ability Histogram



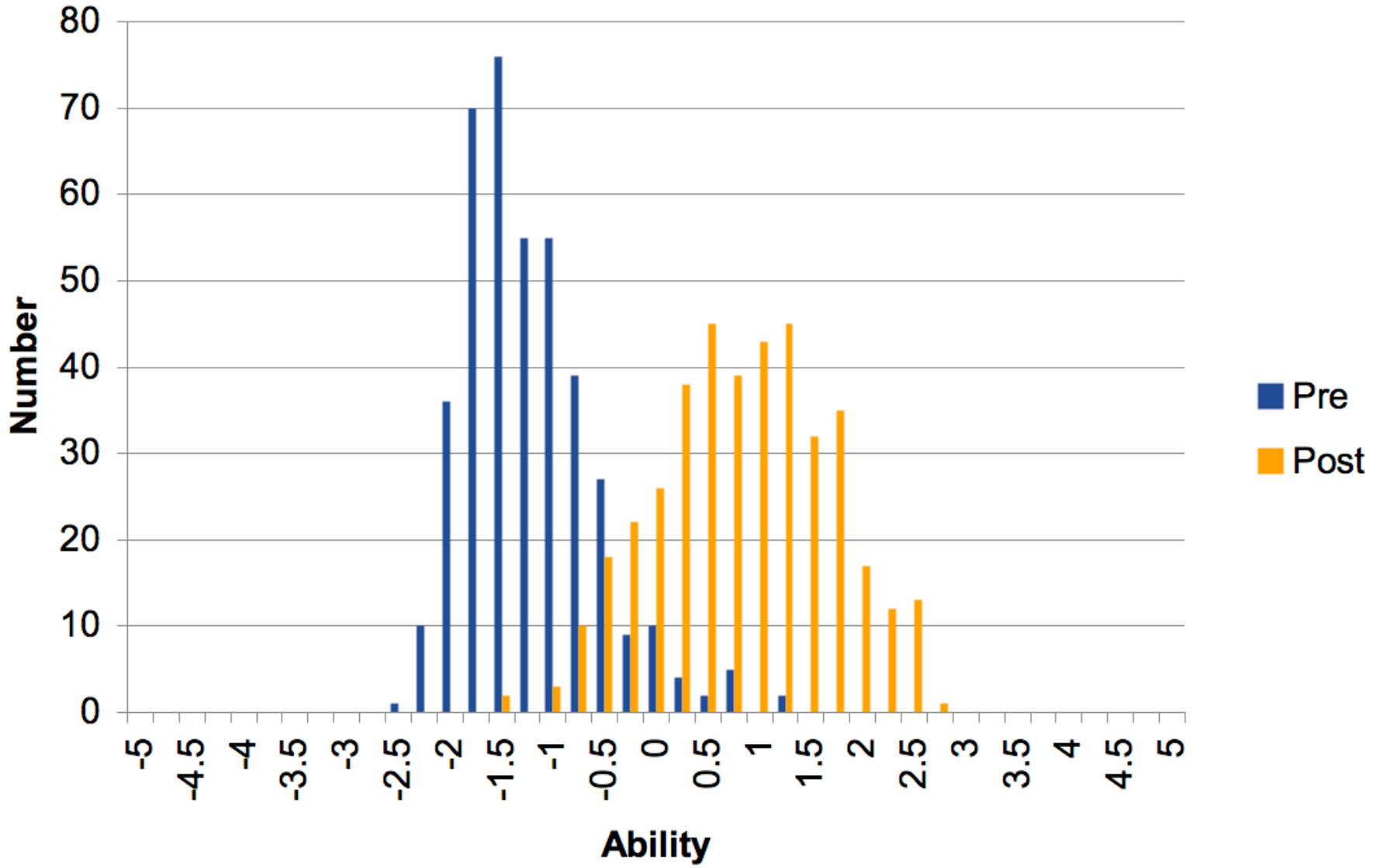
Class #3 – Student Pre and Post Ability Histogram



Techniques for all size classes

Ambassadors – of science in my class and in our society.

MEGA course Student Pre and Post Ability Histogram



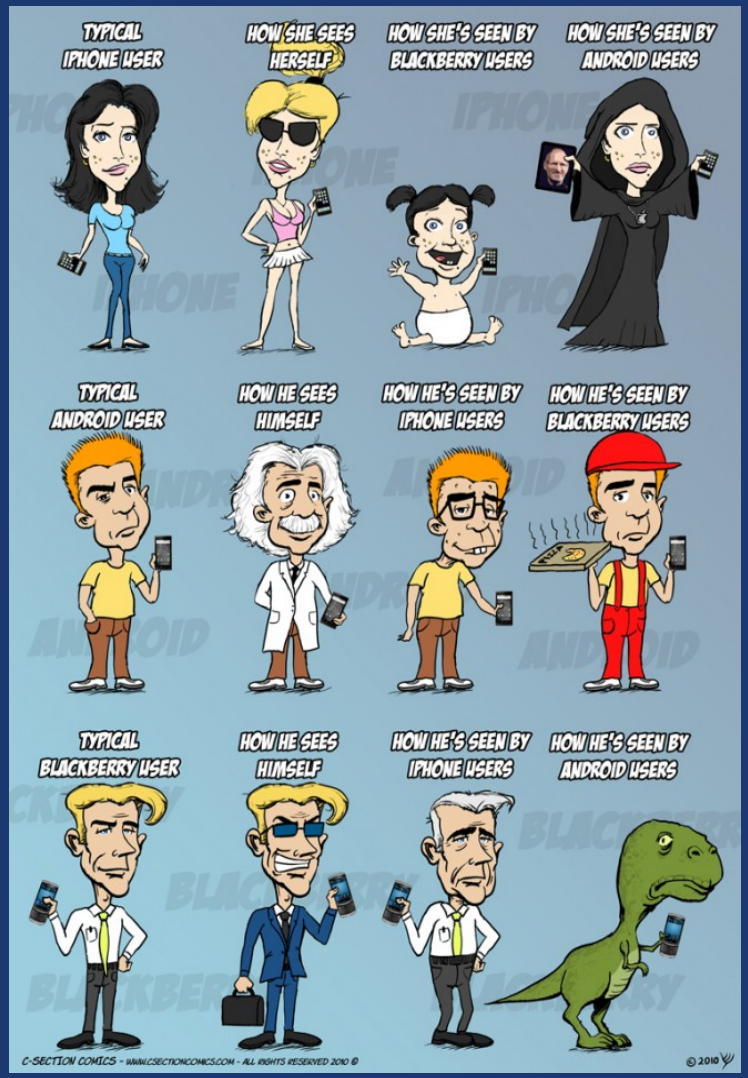
"If this were a medical study of two treatment strategies for a disease, the study would be stopped at this point for ethical reasons, so that every patient could be given the more effective treatment immediately!"

Given the incredibly large number of students being affected by our instruction in large enrollment intro. science courses, it is unethical to teach theses courses with methods proven to be ineffective at promoting transformation.

Is a traditional lecturer in a large enrollment intro. science course a danger to our society.

Come mothers and fathers
Throughout the land
And don't criticize
What you can't understand
Your sons and your daughters
Are beyond your command
Your old road is
Rapidly agin'
Please get out of the new one
If you can't lend your hand
For the times they are a-changin'.

Bob Dylan



Center for Astronomy Education

» Dedicated to the professional development of introductory astronomy instructors

Help People.

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

The Dalai Lama