Interactive Engagement Strategies for ALL Classes

Dr. Edward Prather

University of Arizona

Center for Astronomy Education (CAE)

http://astronomy101.jpl.nasa.gov

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*

Facilitating Active Learning – How to promote students' intellectual engagement and critical problem solving in LECTURE!

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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

astro101

http://astronomy101.jpl.nasa.gov/ — stephen brookfield skillful teacher

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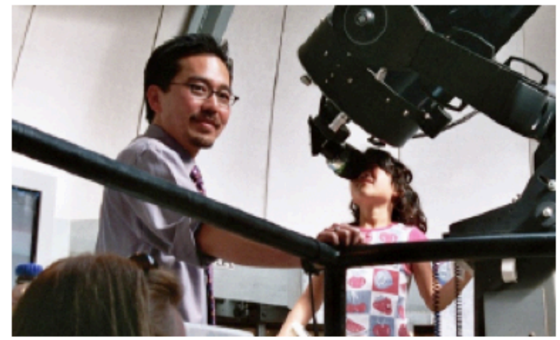
Moderation Continues to Grow by Leaps & Bounds

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



Teaching Excellence Workshops >> | Collaboration of Astronomy Teaching Scholars >> | Astrolrner@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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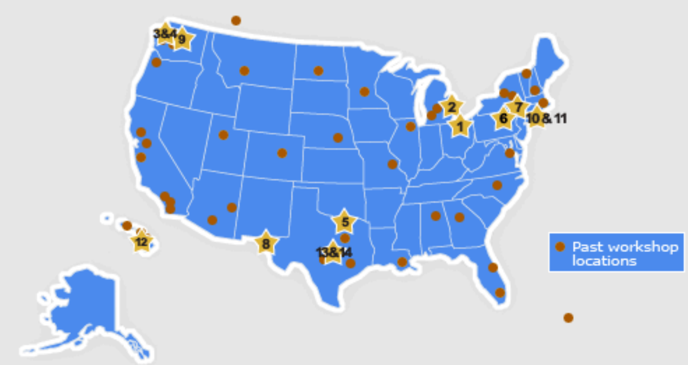
Home > Workshops

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
   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

adapted from “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 the interrelationships among facts and ideas in the context of a conceptual framework, and (3) organize knowledge in ways that facilitate retrieval, application, and critical thinking*
- A “metacognitive” approach to instruction can help students learn to take control of their own learning and monitor progress.

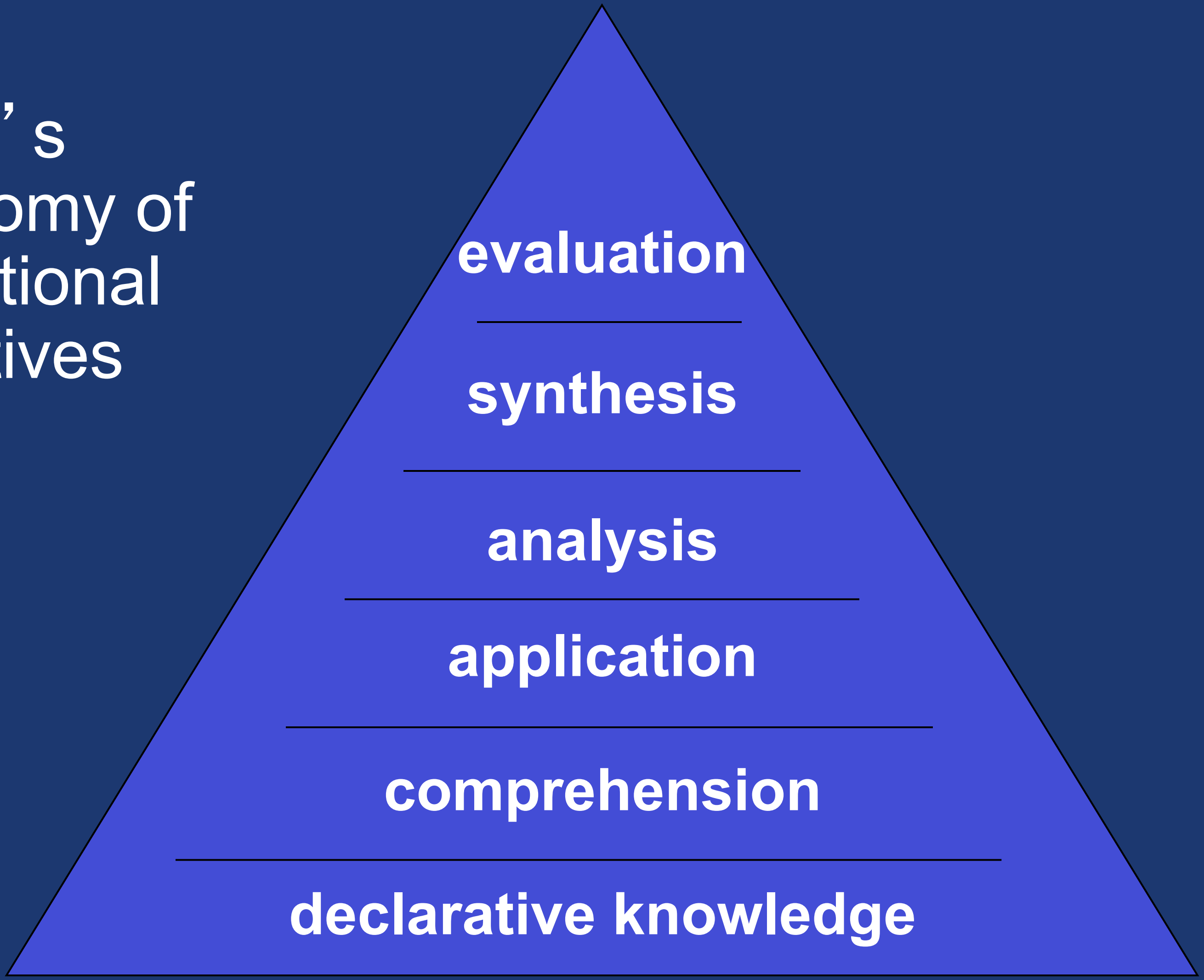
How People Learn: Brain, Mind, Experience, and School (Expanded Edition), National Research Council, National Academy Press, 2000.

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 PeerInstruction
- Small Group Interactions
  - Concept Maps
  - Case Studies
  - Sorting Tasks
  - Ranking Tasks
  - Lecture-Tutorials
  - Collaborative Problem Solving
- Student Debates (individual/group)
- Whole Class Discussions

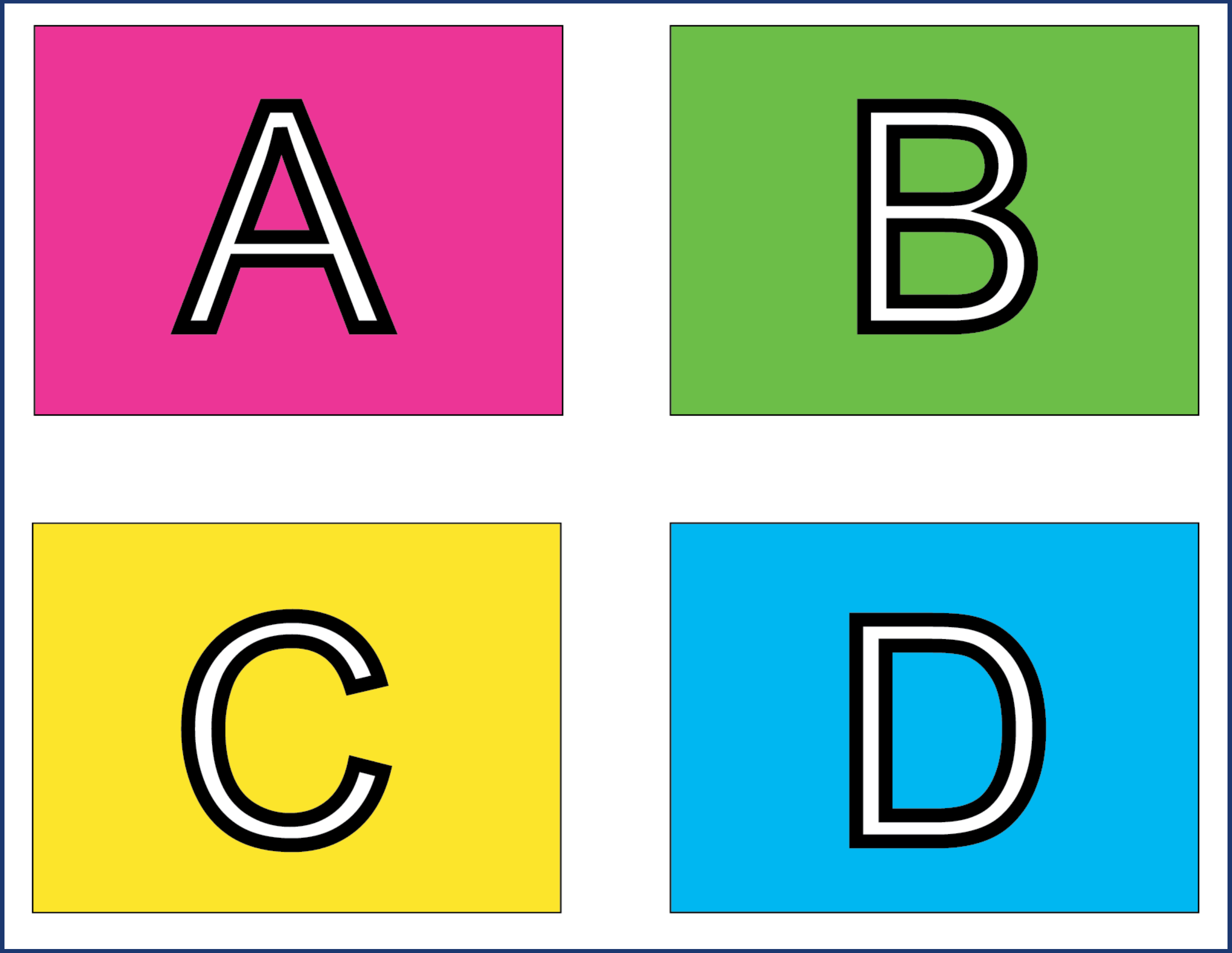
Does your class intellectually engage your students and deepen their conceptual understanding and critical thinking ability or does it re-enforce the memorization of facts and declarative knowledge?

Bloom’s Taxonomy of Educational Objectives

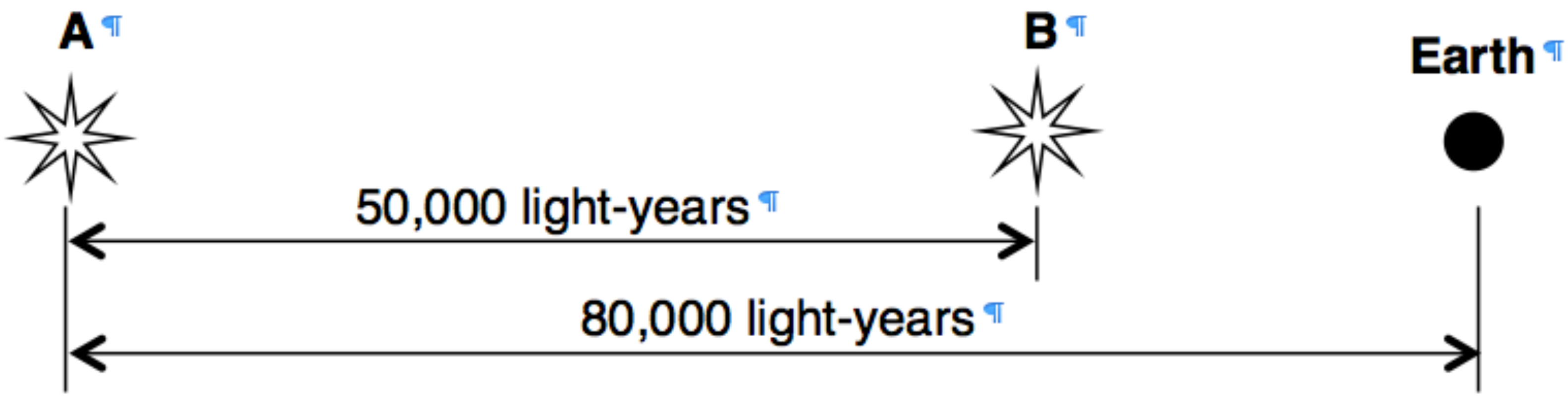


The Role of Assessment in the Development of the College Introductory Astronomy Course A "How-to" Guide for Instructors. Astronomy Education Review, 1(1), 1-24, 2002. G. Brissenden, T.F. Slater, and R. Mathieu.

Class Response System—Medium Tech



The drawing below (not to scale) shows Star A, Star B, and Earth all in a line. Star B is 50,000 light-years from Star A, while Earth is 80,000 light-years from Star A.



When an observer on Earth can first see Star A, how old would Star A appear to an observer orbiting Star B?

a. 30,000 years old
b. 50,000 years old
c. 80,000 years old
d. 130,000 years old

What would the phase of the moon be?

A. Waxing crescent

B. Third Quarter

C. Waxing Gibbous

D. Waning Crescent

E. Waning Gibbous

Centennial Hall Performing Arts Theater at University of Arizona

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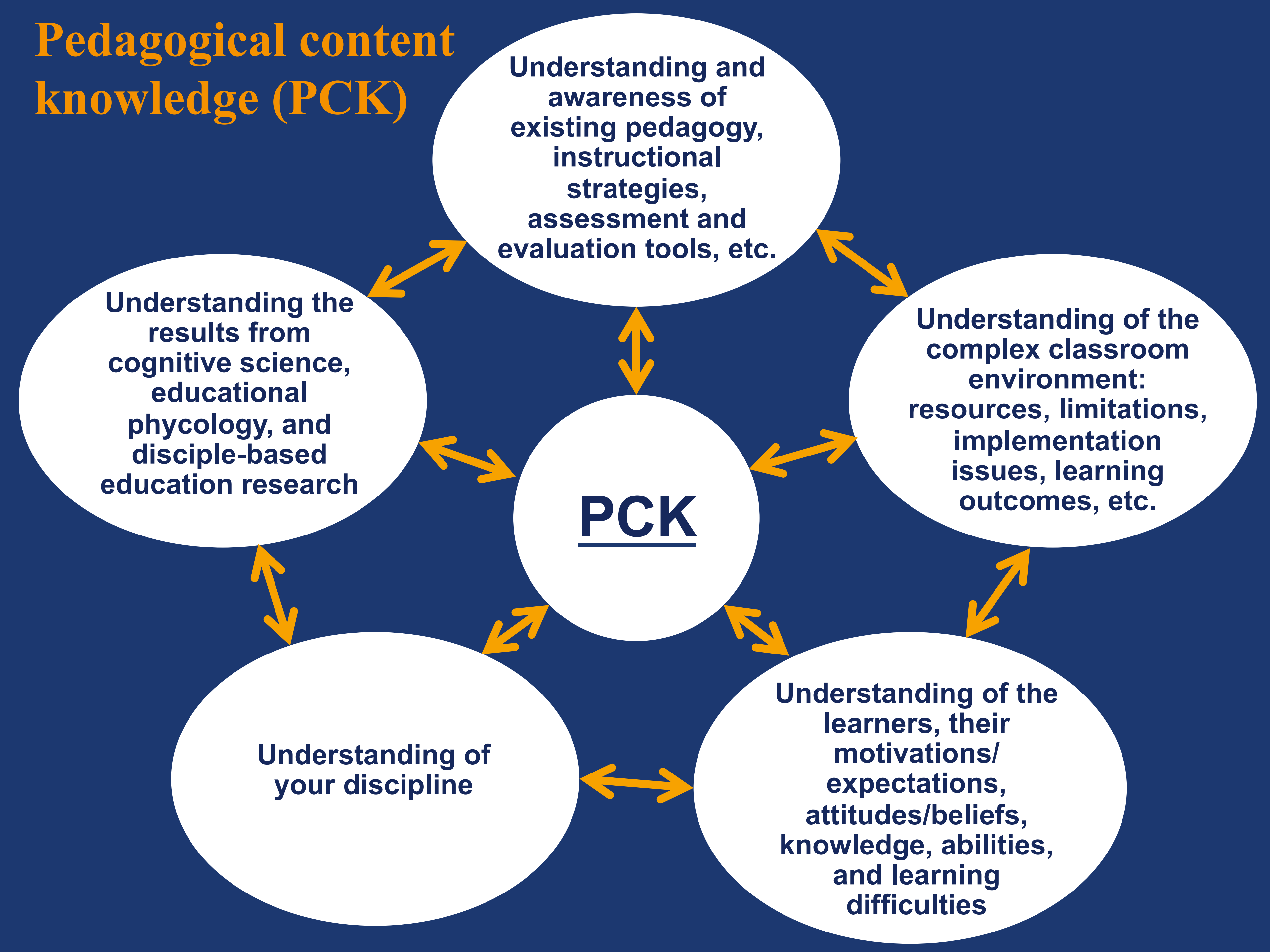
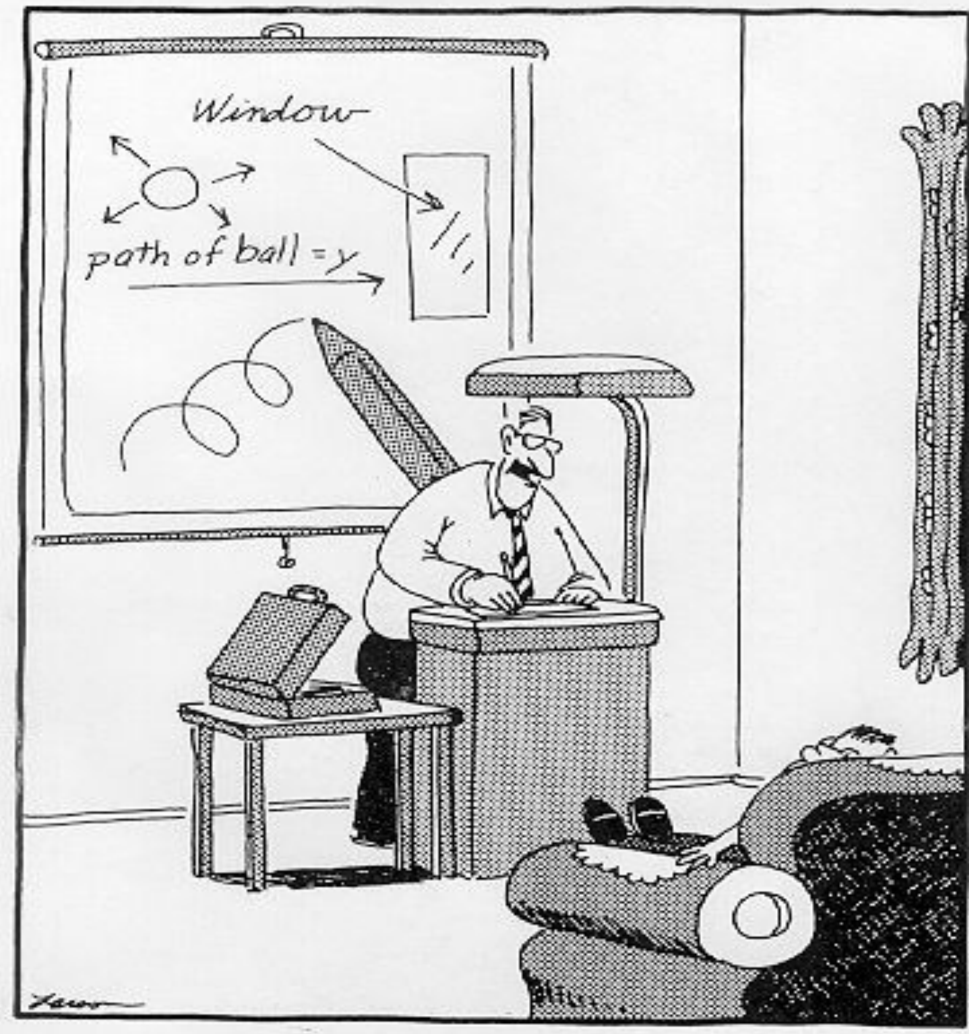
The best learners … often make the worst teachers. They are, in a very real sense, perceptually challenged. They cannot imagine what it must be like to struggle to learn something that comes so naturally to them.

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


Pedagogical content knowledge (PCK)
Understanding and awareness of existing pedagogy, instructional strategies, assessment and evaluation tools, etc.
Understanding the results from cognitive science, educational phycology, and disciple-based education research
Understanding of the complex classroom environment: resources, limitations, implementation issues, learning outcomes, etc.
PCK
Understanding of your discipline
Understanding of the learners, their motivations/ expectations, attitudes/beliefs, knowledge, abilities, and learning difficulties

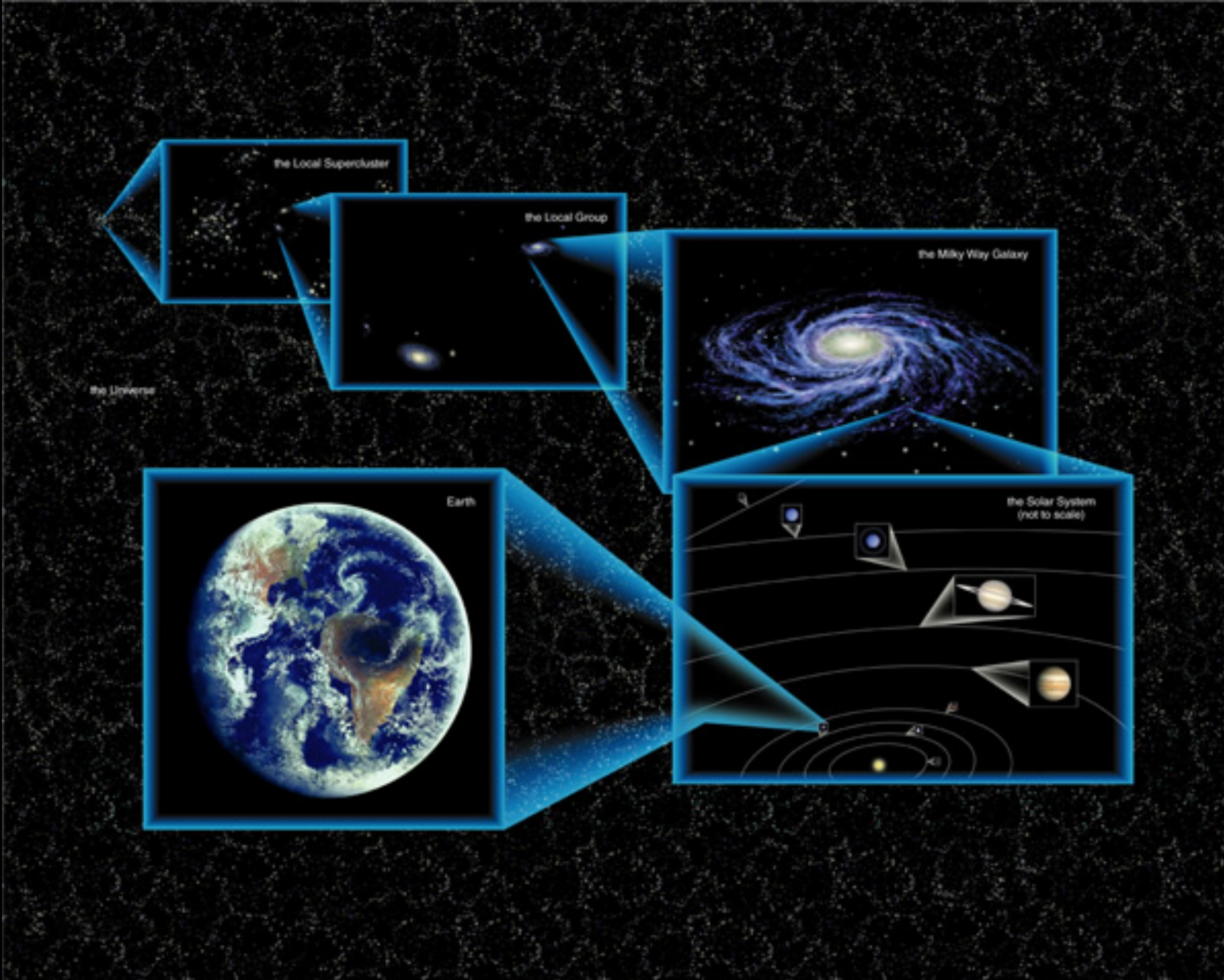
If a Picture is worth a thousand words, then what is a real-world, first-hand, experience worth?

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



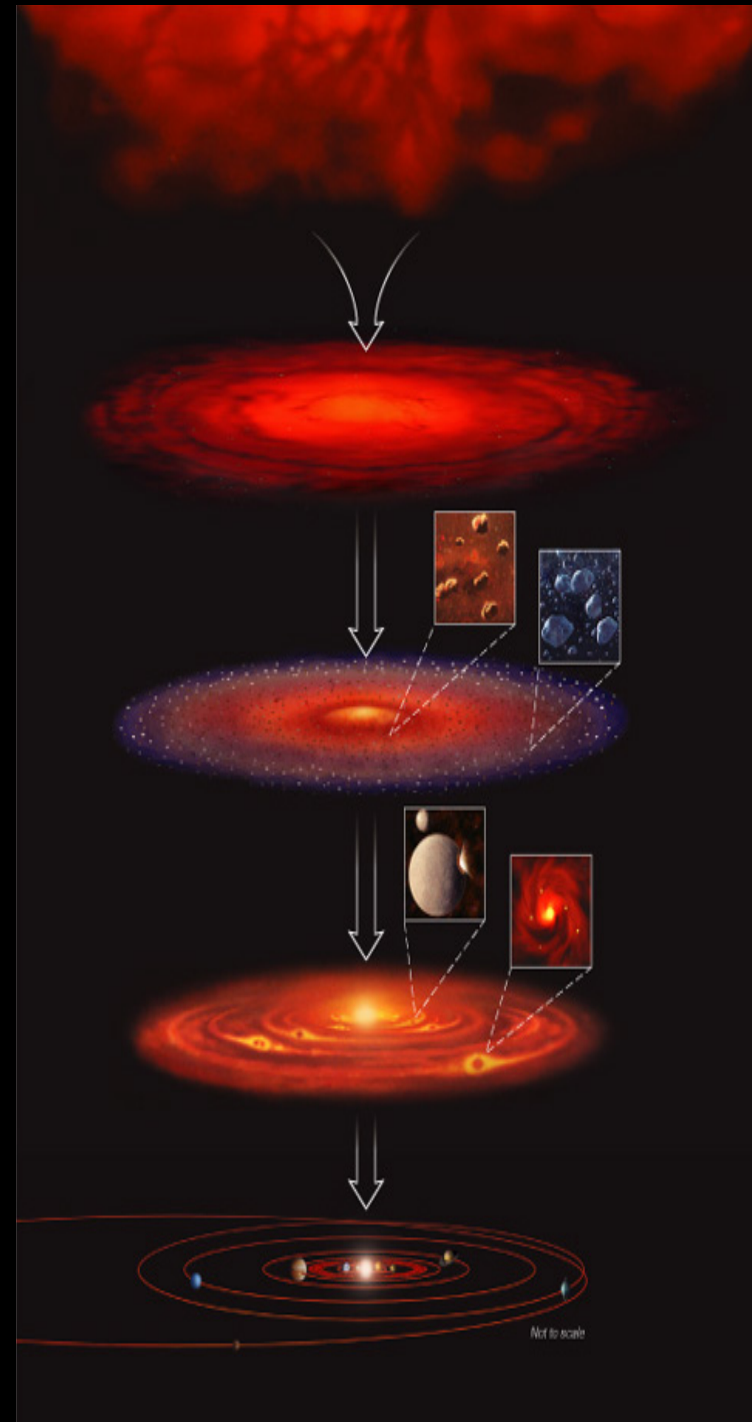
Eventually, Billy came to dread his father's lectures over all other forms of punishment.

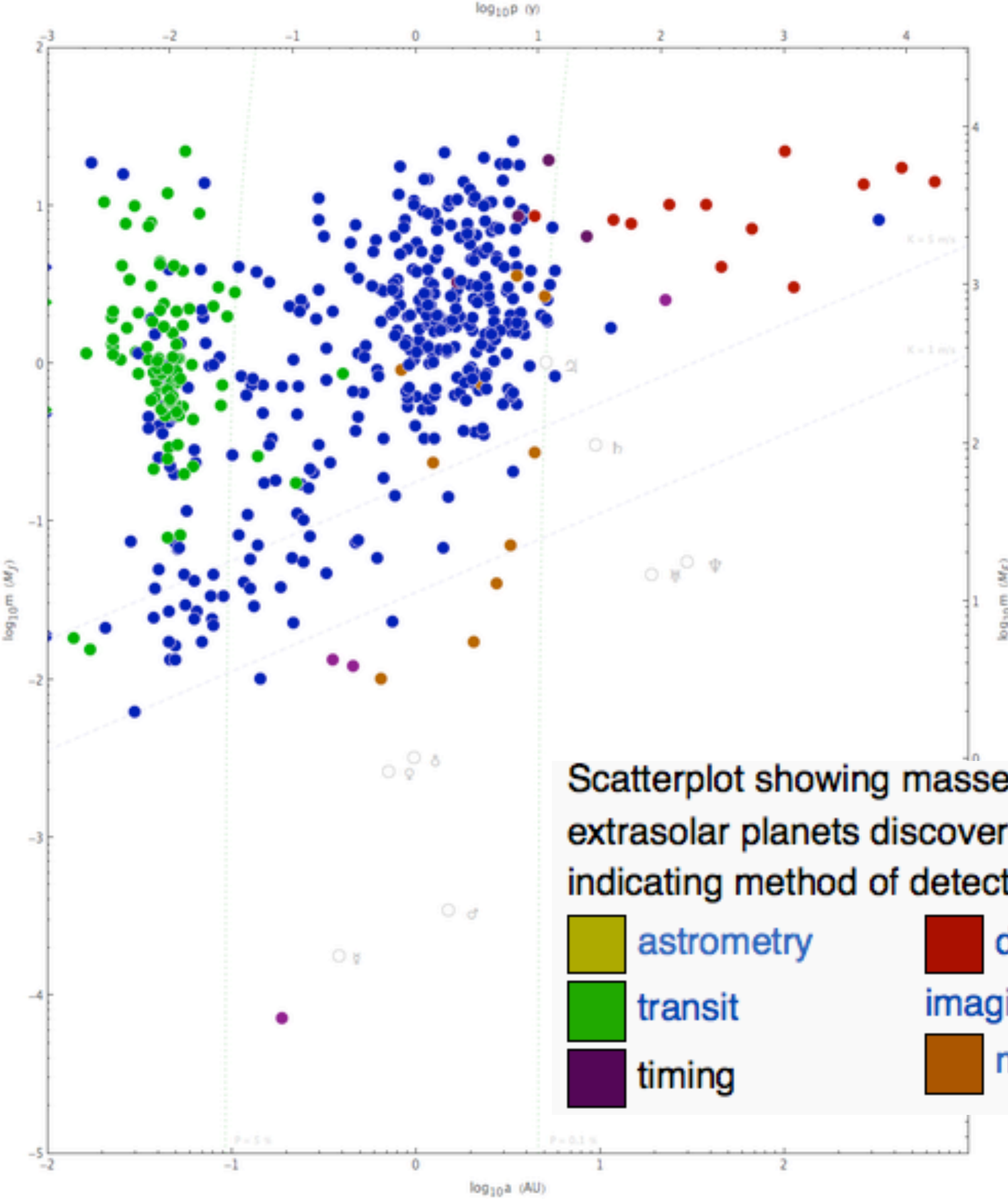
"Eventually, Billy came to dread his father's lectures over all other forms of punishment"


the Local Supercluster
the Local Group
the Milky Way Galaxy
the Universe
Earth
the Solar System
(not to scale)

… one of these?

How many of these are in ..

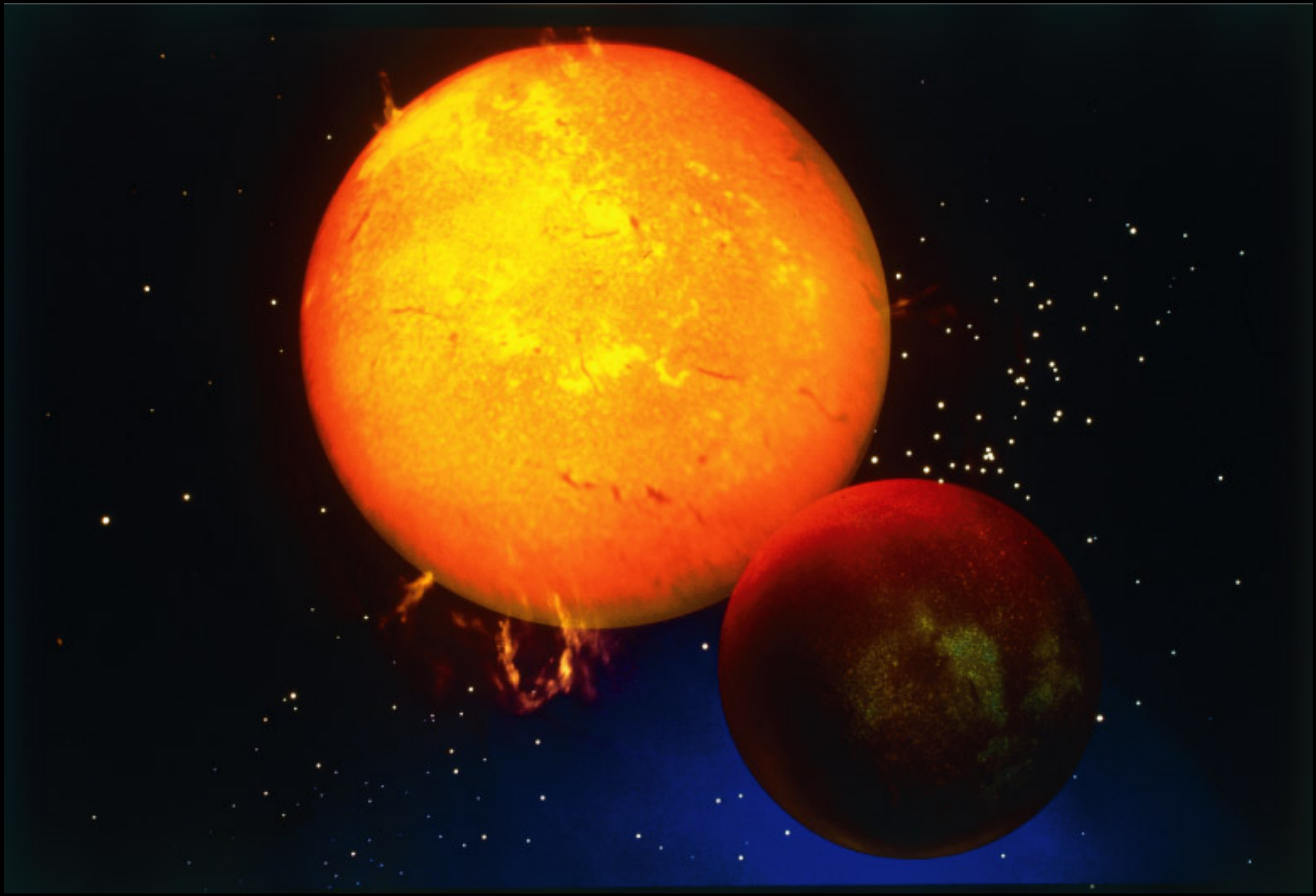


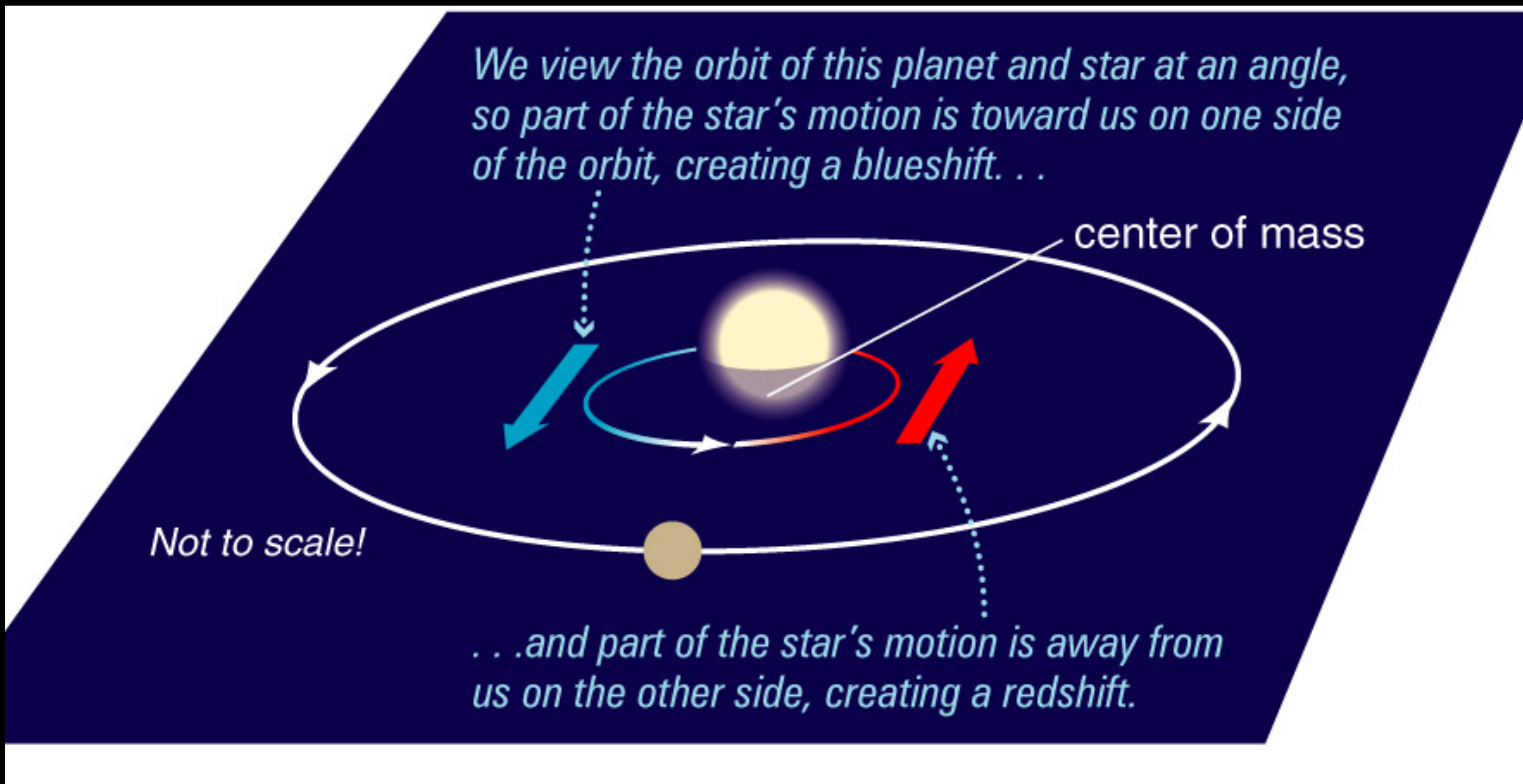


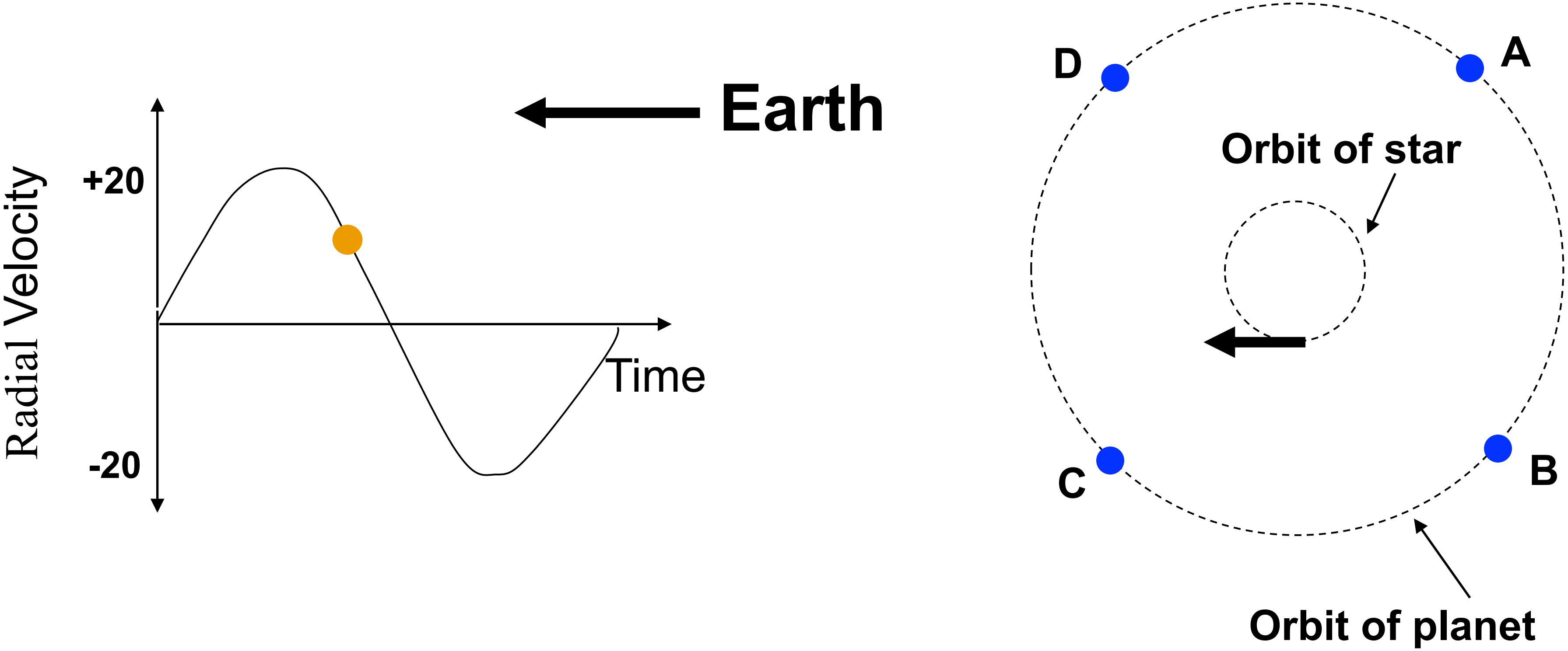
Rank the different methods for finding extrasolar planets from most successful to least.

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

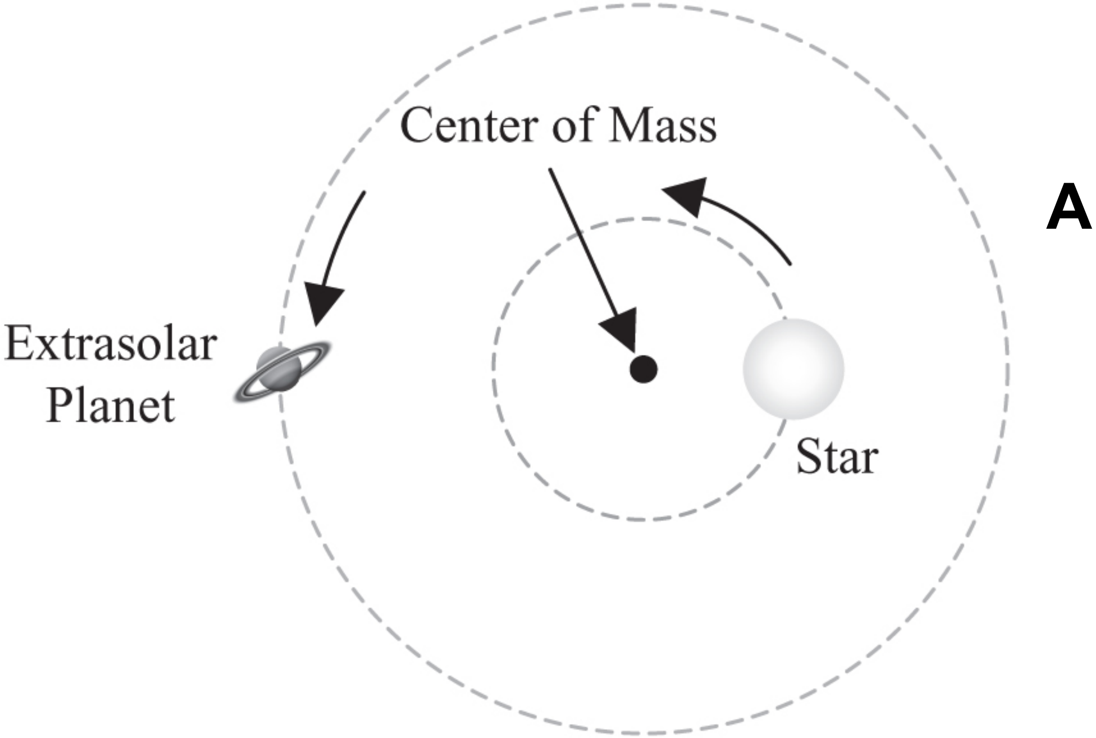
astrometry
transit
timing
direct imaging
microlensing
radial velocity
pulsar timing



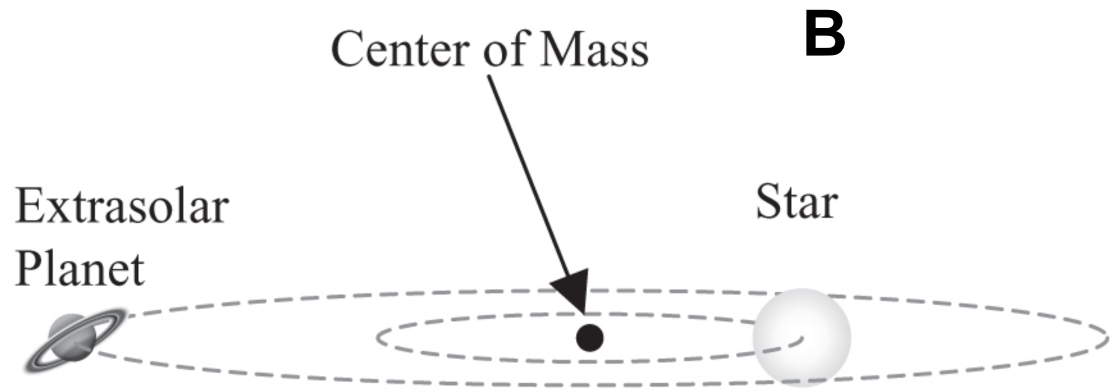

We view the orbit of this planet and star at an angle, so part of the star's motion is toward us on one side of the orbit, creating a blueshift. . .
center of mass
Not to scale!
. . .and part of the star's motion is away from us on the other side, creating a redshift.



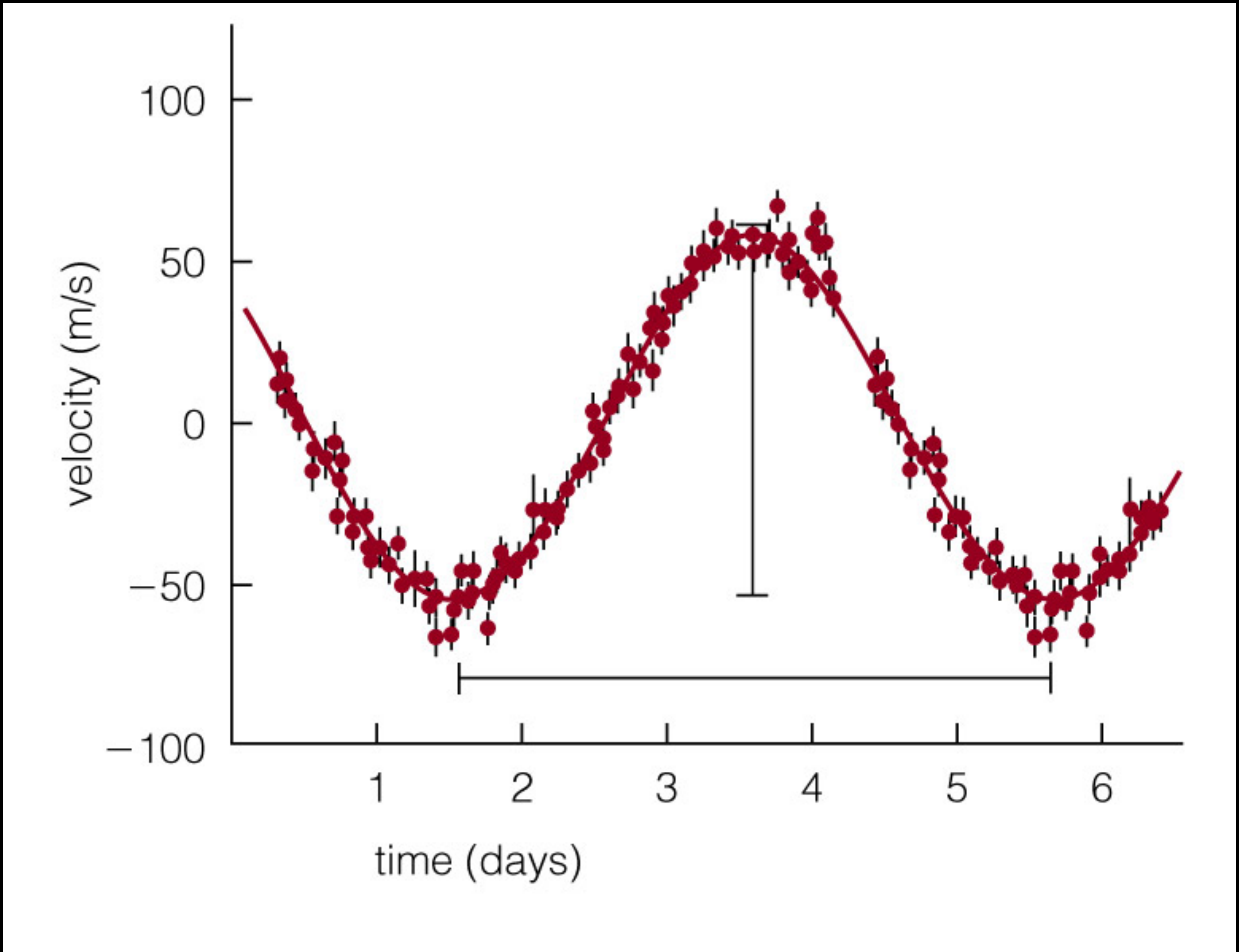
Given the location marked on the star's radial velocity curve, at which location in the planet's orbit would you expect the planet to be?



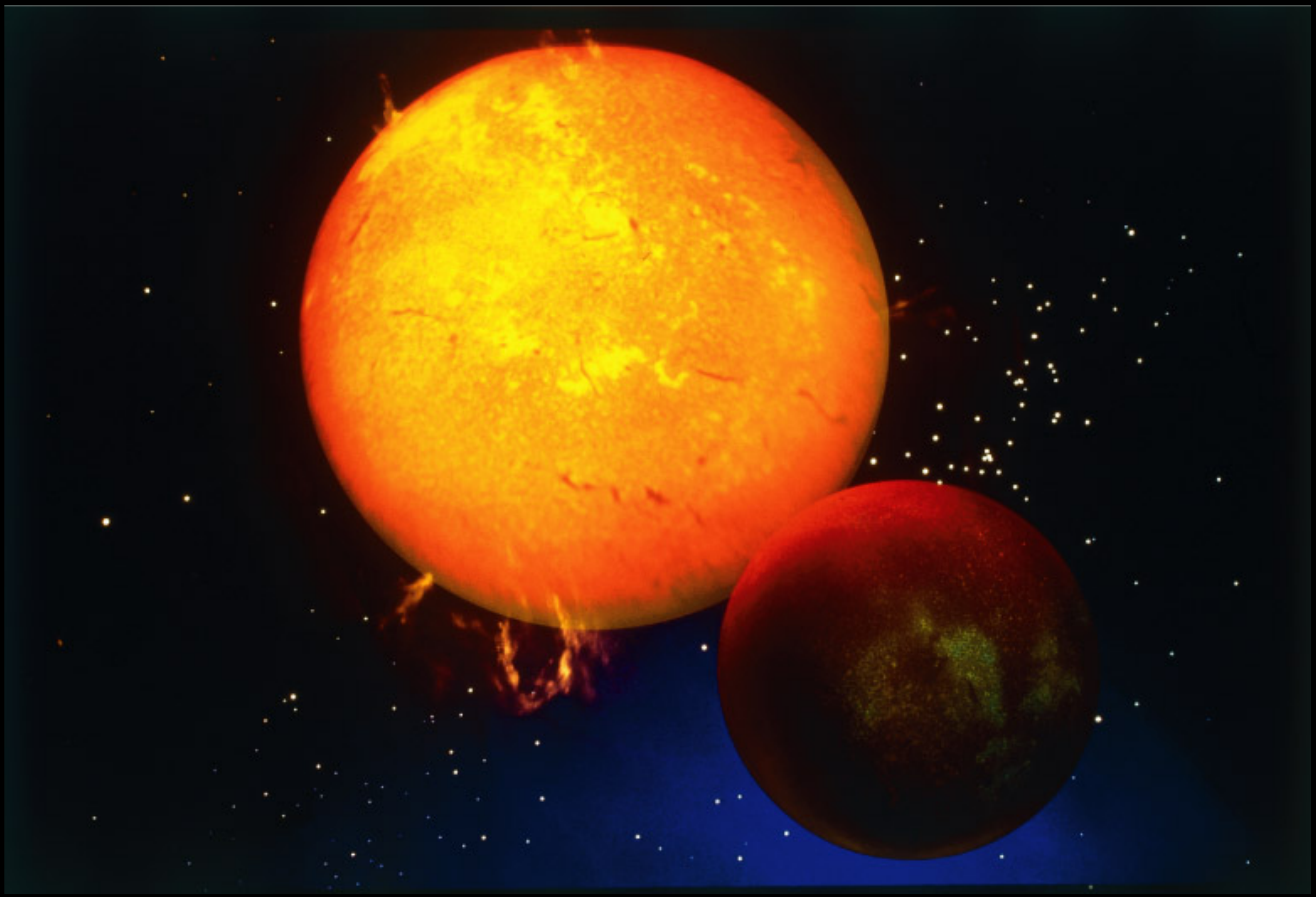
Center of Mass
A
Extrasolar
Planet
Star



Center of Mass
B
Extrasolar
Planet
Star

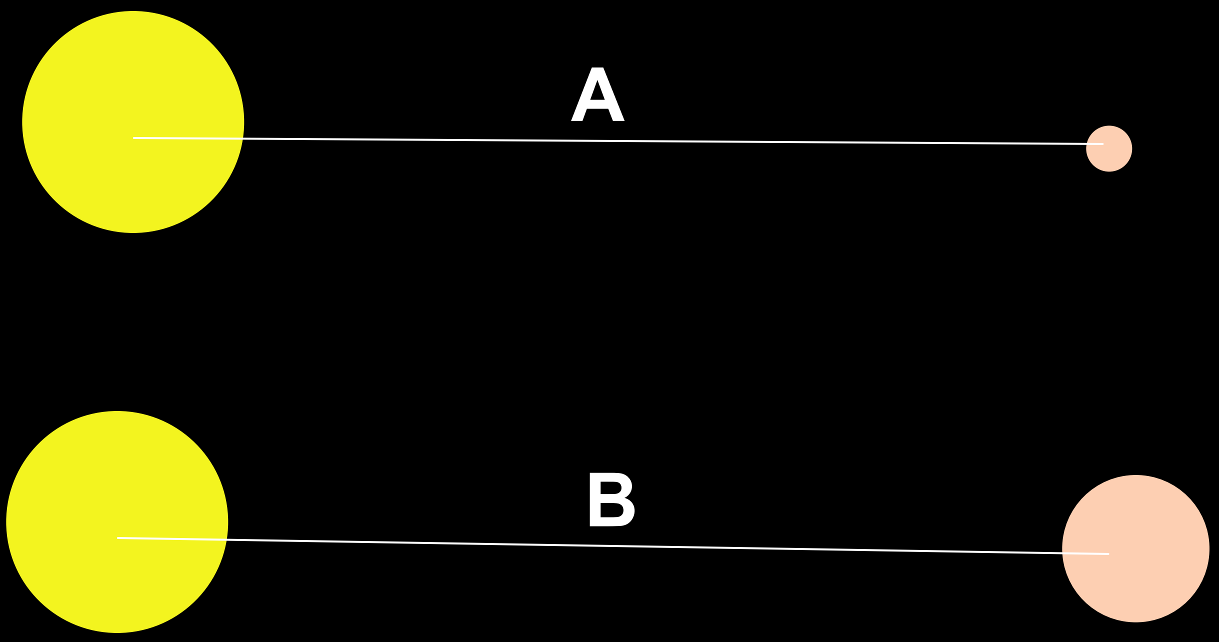

velocity (m/s)
100
50
0
−50
−100
1
2
3
4
5
6
time (days)

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



Amount of Doppler shift in Star’s light

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



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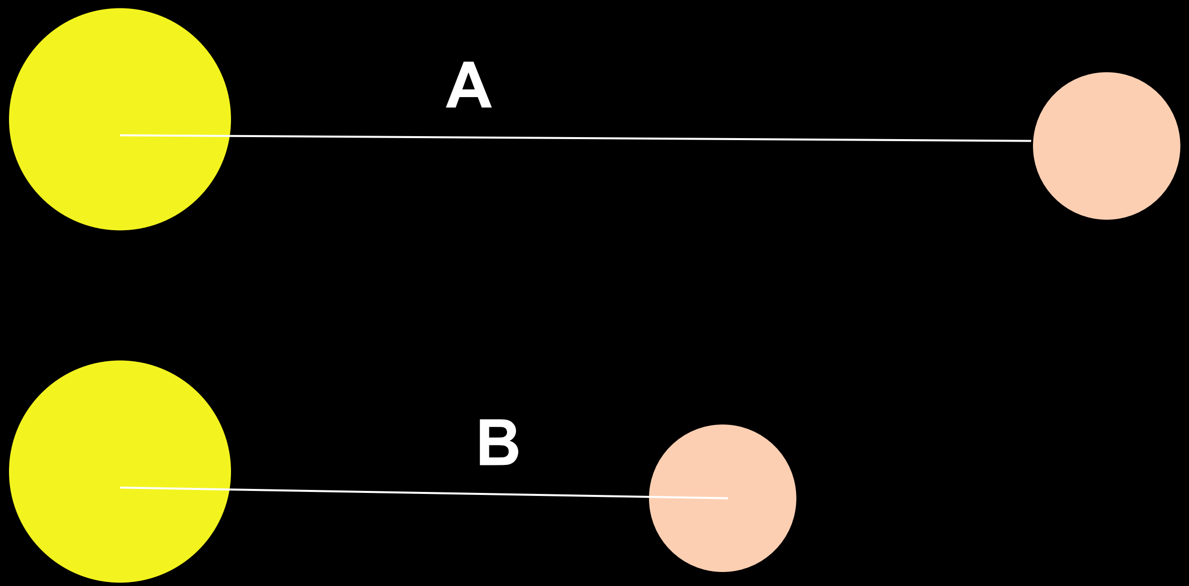
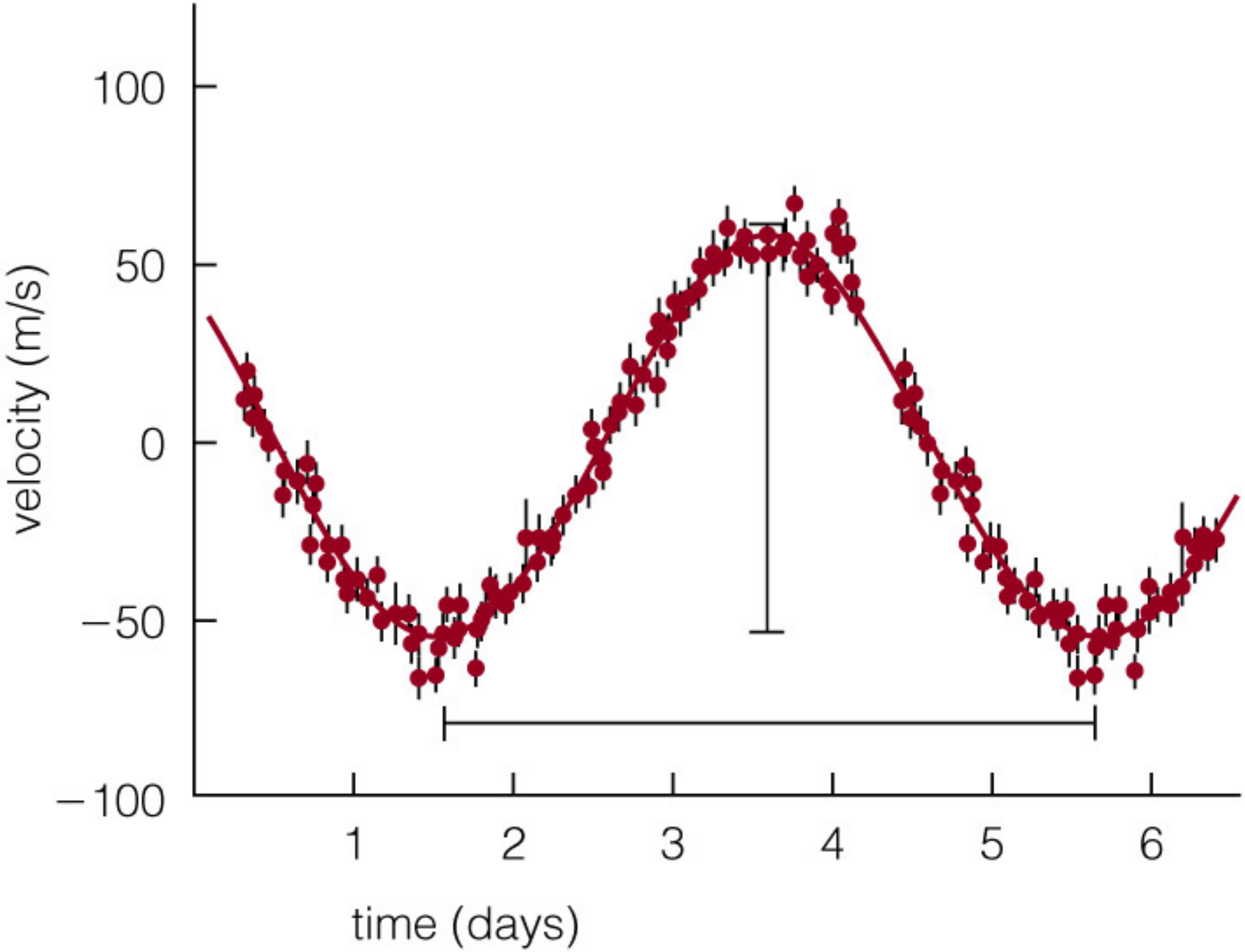
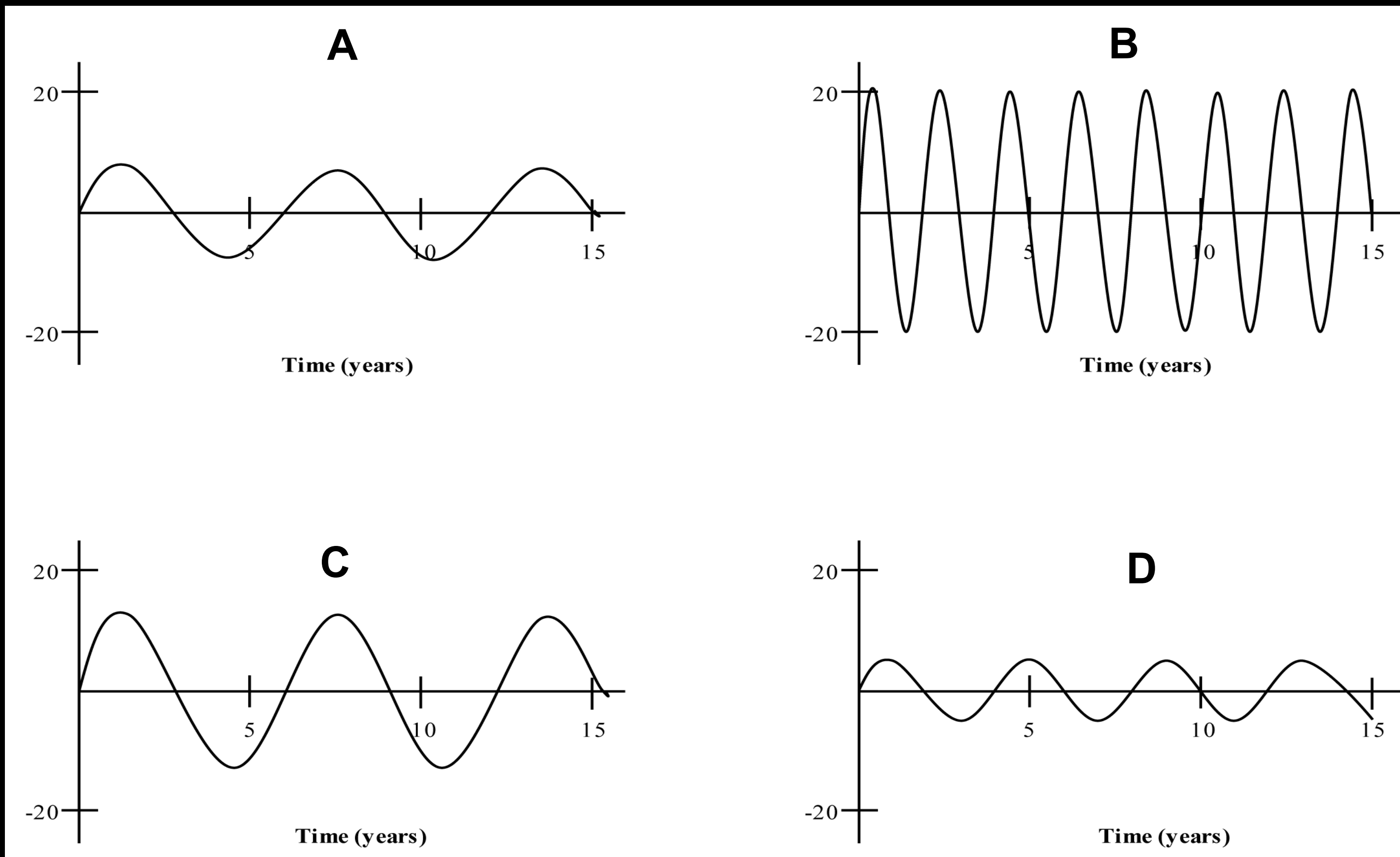




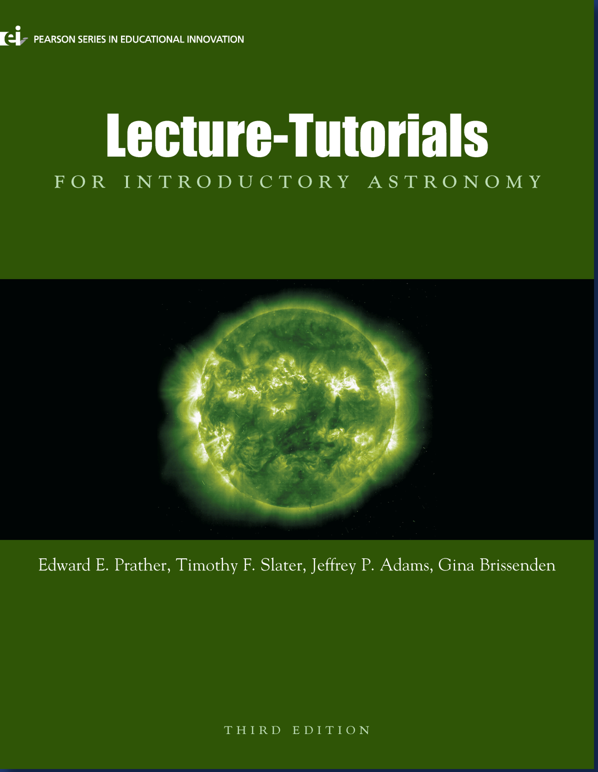
100
50
0
−50
−100
velocity (m/s)
1
2
3
4
5
6
time (days)

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



Lecture-Tutorials:

Post-lecture, pencil and paper activities, that use a Socratic-dialogue driven, highly-structured collaborative learning methodology to help students elicit, confront and resolve their naïve beliefs and reasoning difficulties, and improve their critical thinking skills and develop scientifically robust conceptual models.

Research on a Lecture-Tutorial Approach to Teaching Introductory Astronomy for Non–Science Majors, Prather, E. E.; Slater, T. F.; Adams, J. P.; Bailey, J. M.; Jones, L. V.; Dostal, J. A., Astronomy Education Review, 3(2) 2005

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

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

A Commonly Held Inaccurate Model of Teaching and Learning

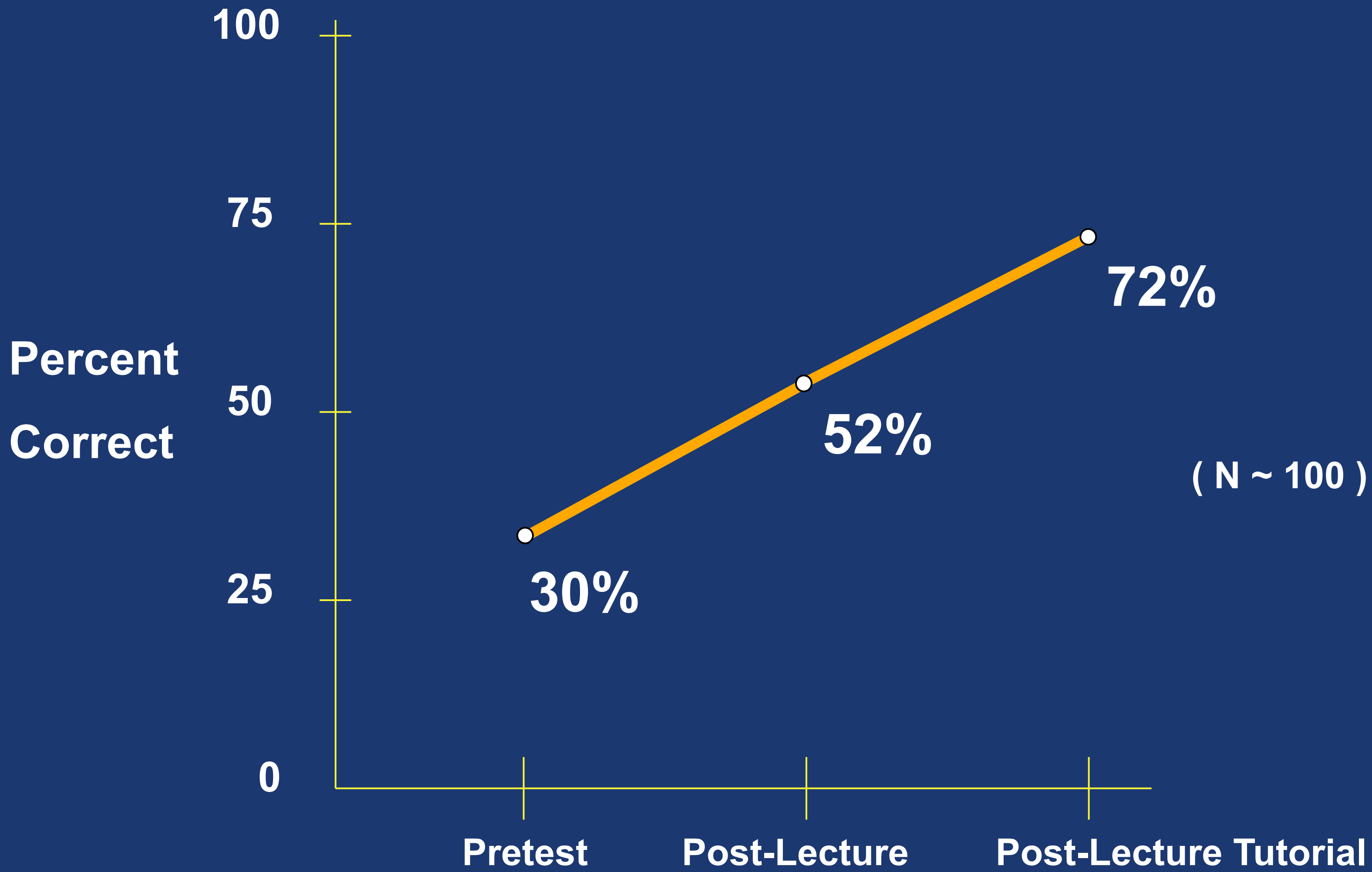
Your discipline content

Bill Watterson, *Calvin and Hobbs*

Are you really teaching if no one is learning?

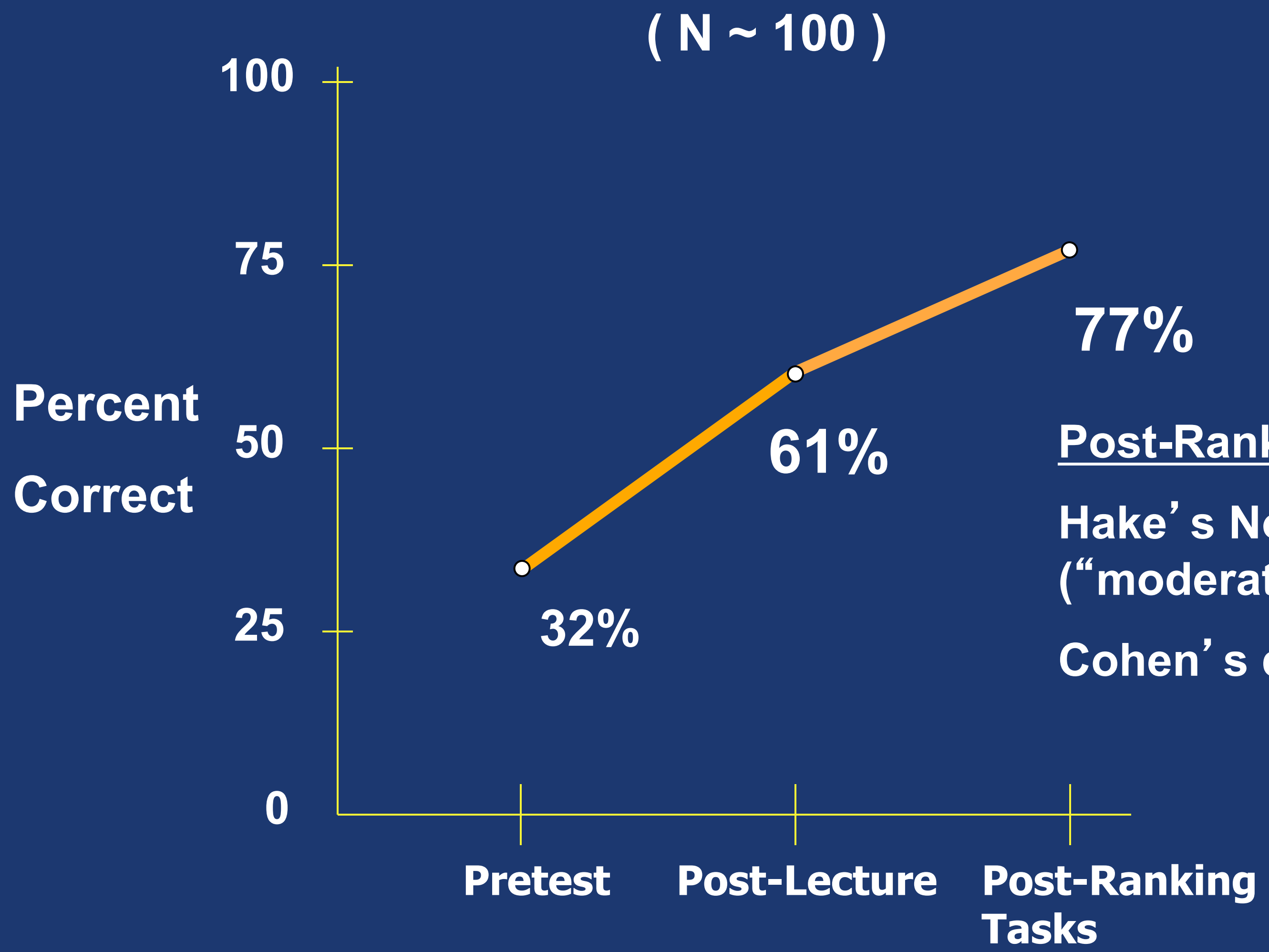
And How would you know?

The Results from our Research to Validate the Effectiveness of Lecture-Tutorials.



Research on a Lecture-Tutorial Approach to Teaching Introductory Astronomy for Non–Science Majors, Prather, E. E.; Slater, T. F.; Adams, J. P.; Bailey, J. M.; Jones, L. V.; Dostal, J. A., Astronomy Education Review, 3(2) 2005

The Results from our Research to Validate the Effectiveness of Ranking Tasks



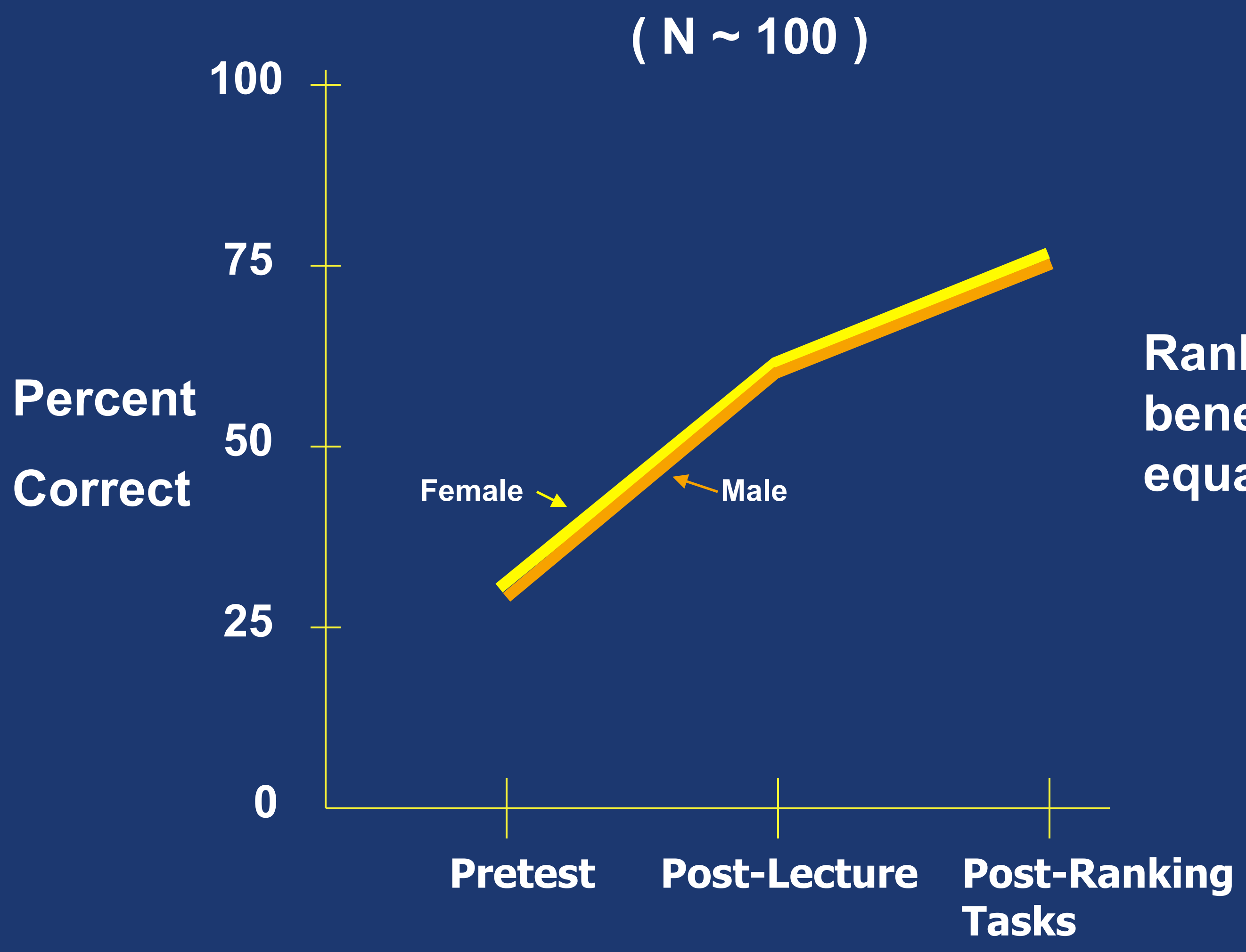
Post-Ranking Task:

Hake's Normalized Gain = 0.41 ("moderately large effect")

Cohen's d = 0.62 ("Large effect")

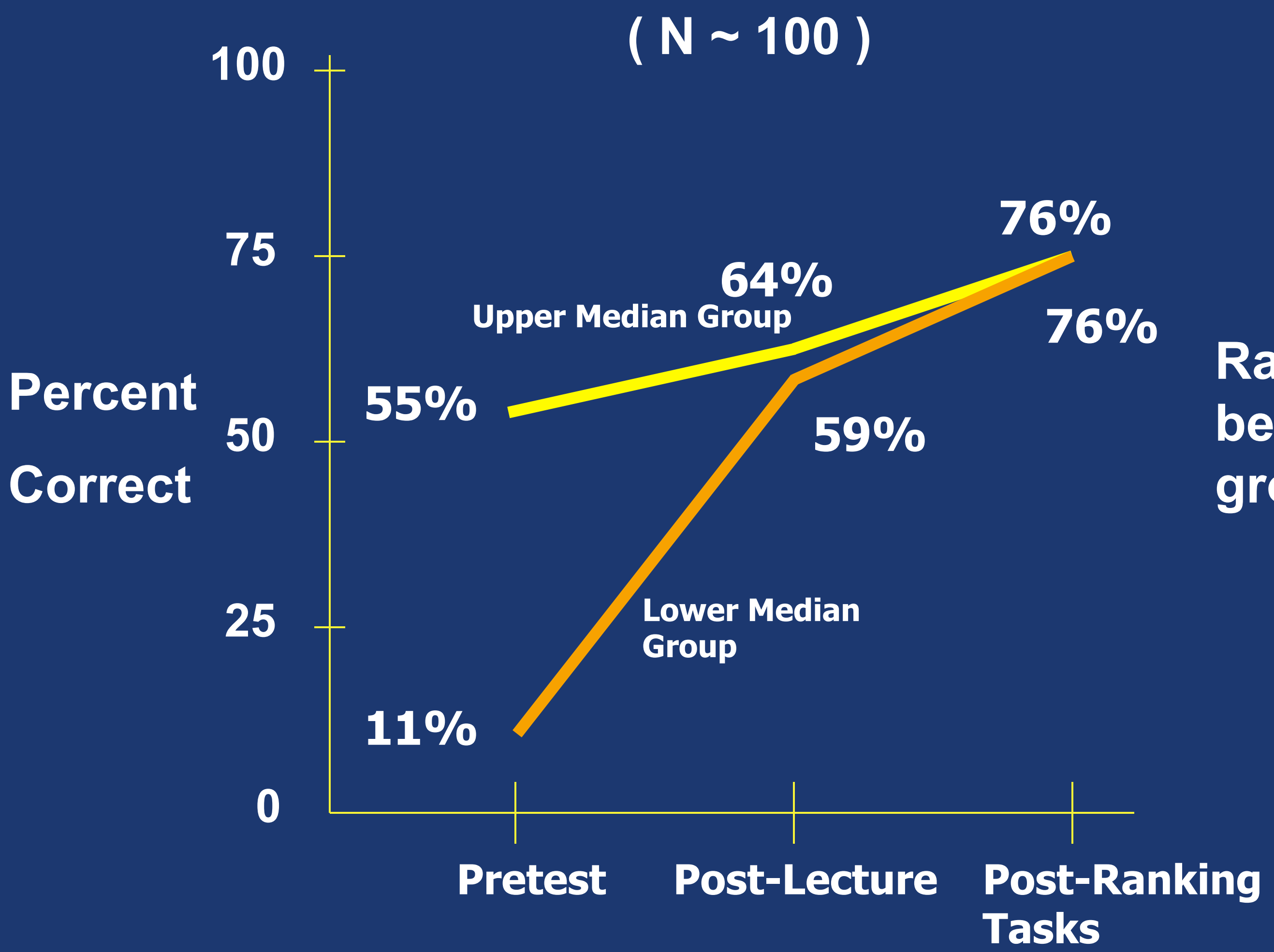
Effectiveness of Collaborative Ranking Tasks on Student Understanding of Key Astronomy Concepts, Hudgins, D. W., Prather. E. E., Grayson, D.J. and Smits, D. P. Astronomy Education Review, 5(1), 2006

Ranking Tasks: Gender Effect?



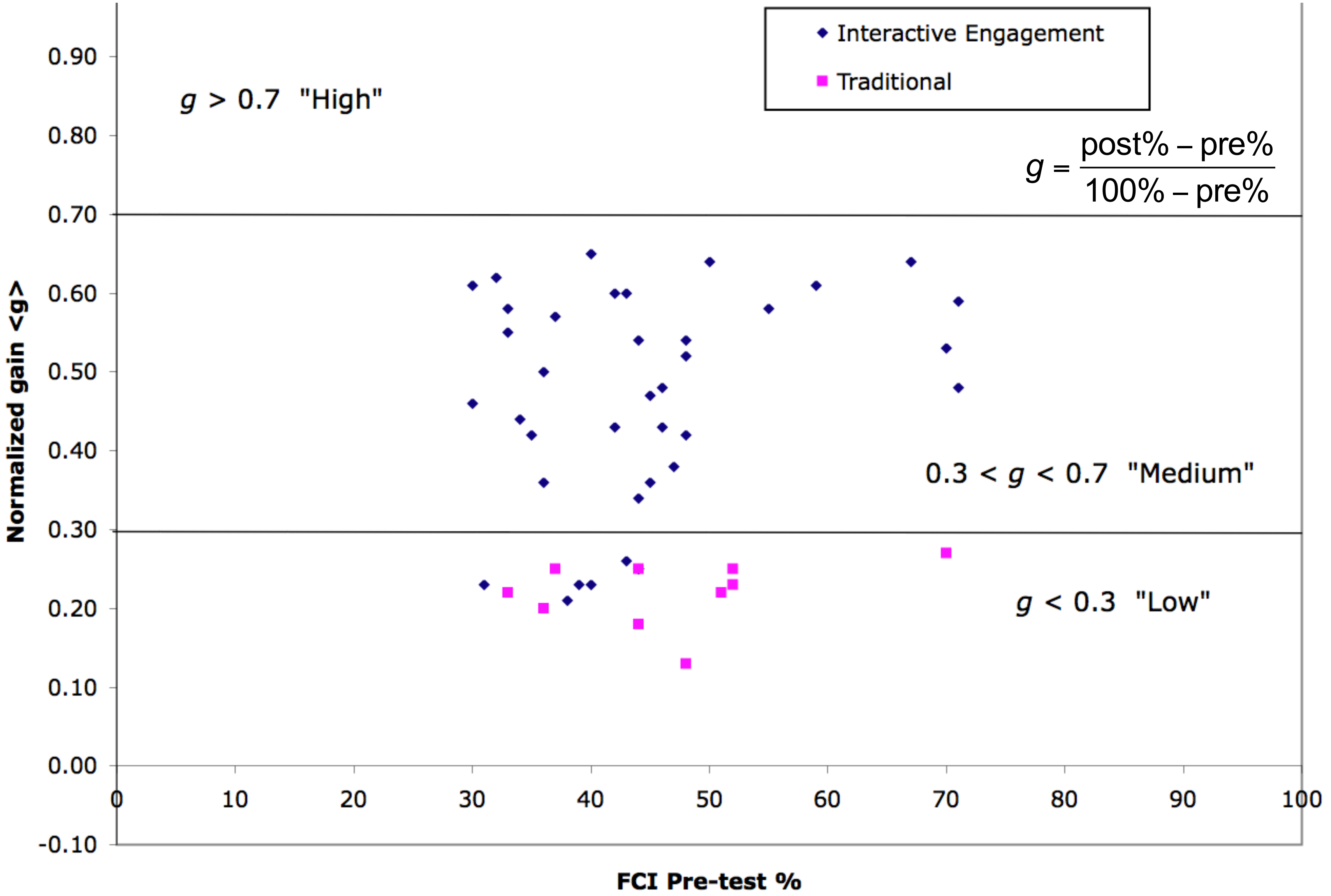
Ranking Tasks benefited both groups equally.

Ranking Tasks: High vs. Low Pretests Groups?



Ranking Tasks benefited both groups equally.

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

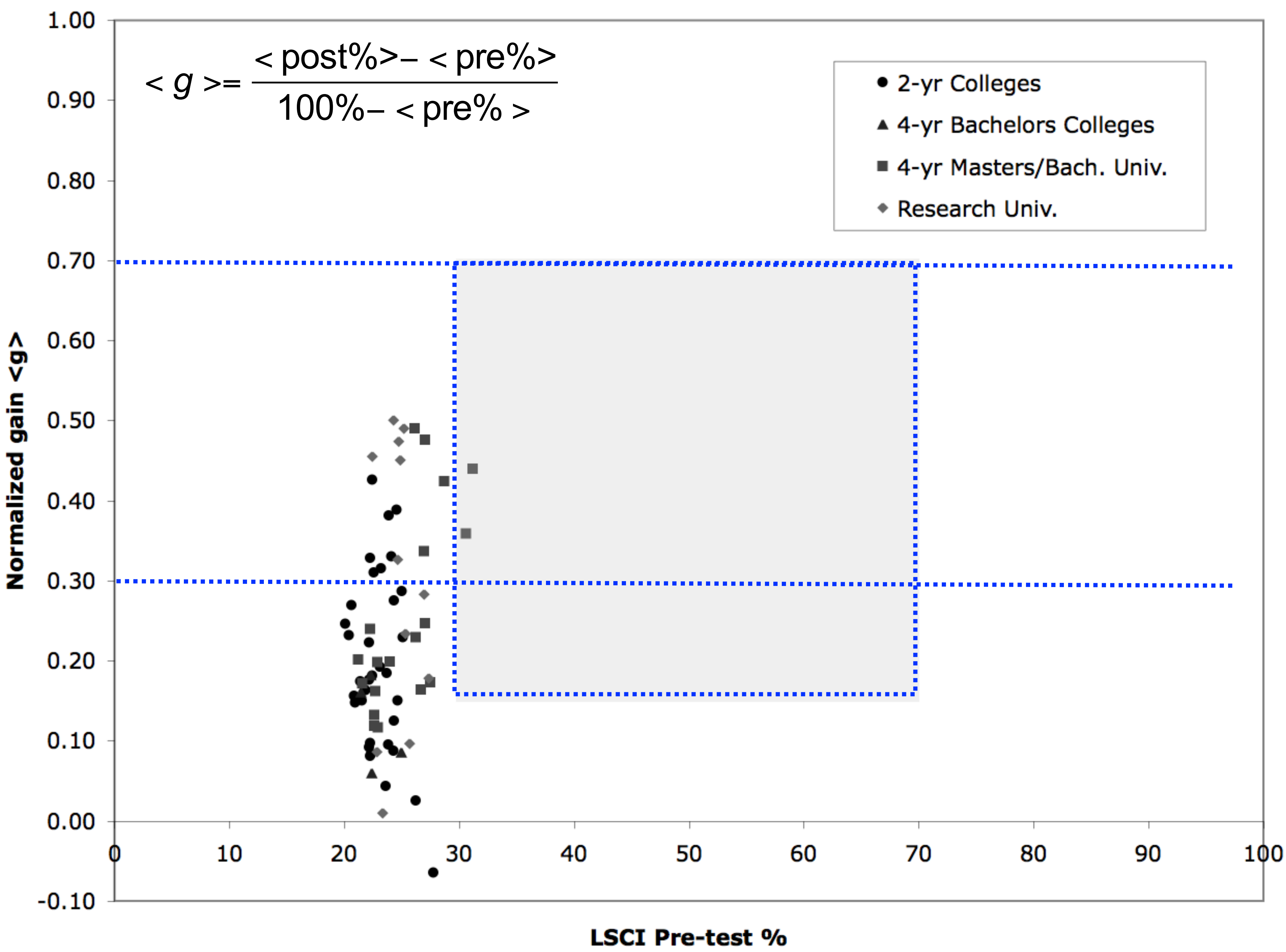


R. Hake, "…A six-thousand-student survey…" AJP 66, 64-74 (1998).

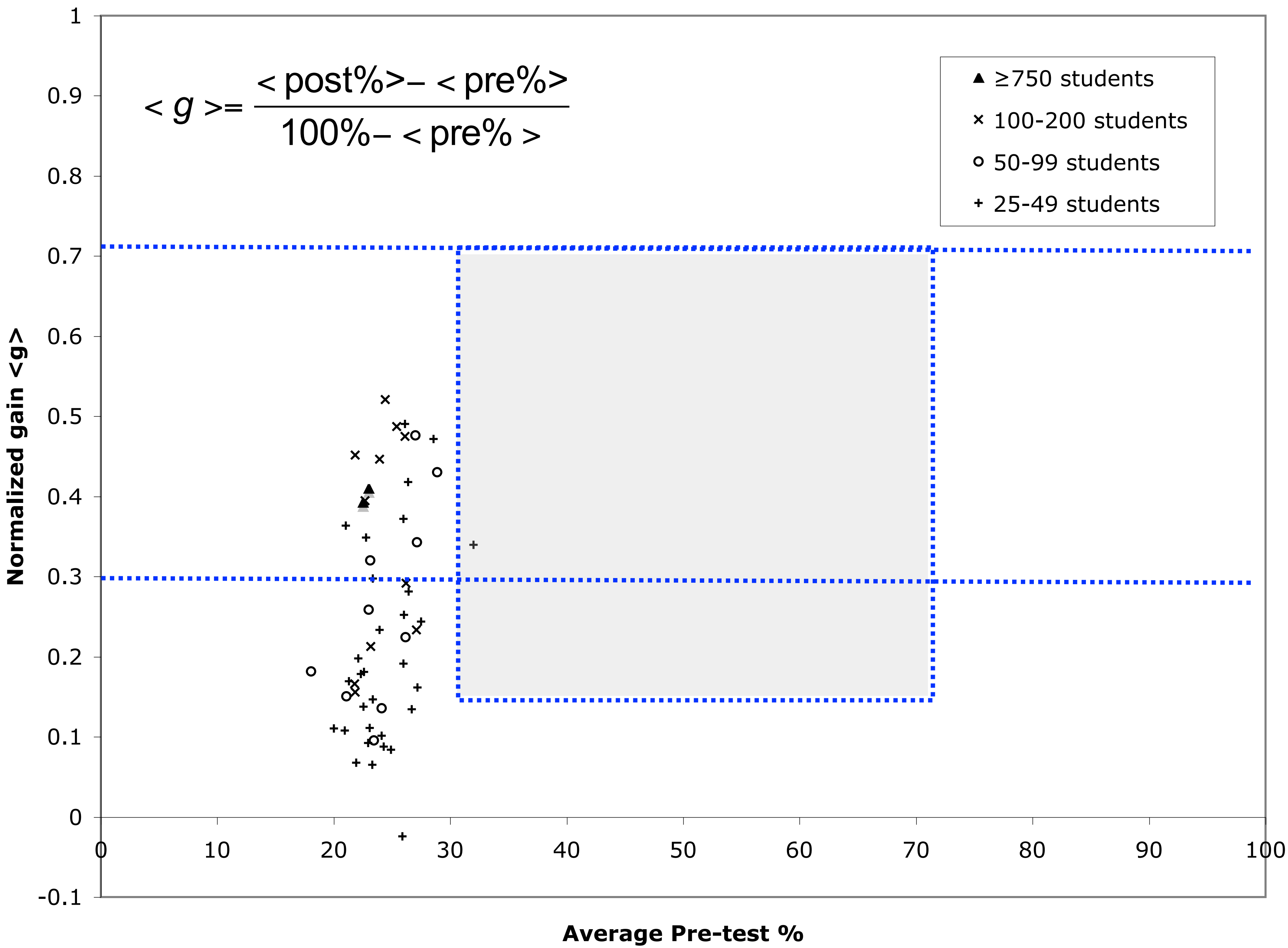
CAE National Study

- 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



$$< g >= \frac{< post\% > - < pre\% >}{100\% - < pre\% >}$$
2-yr Colleges
4-yr Bachelors Colleges
4-yr Masters/Bach. Univ.
Research Univ.
Normalized gain <g>
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
LSCI Pre-test %

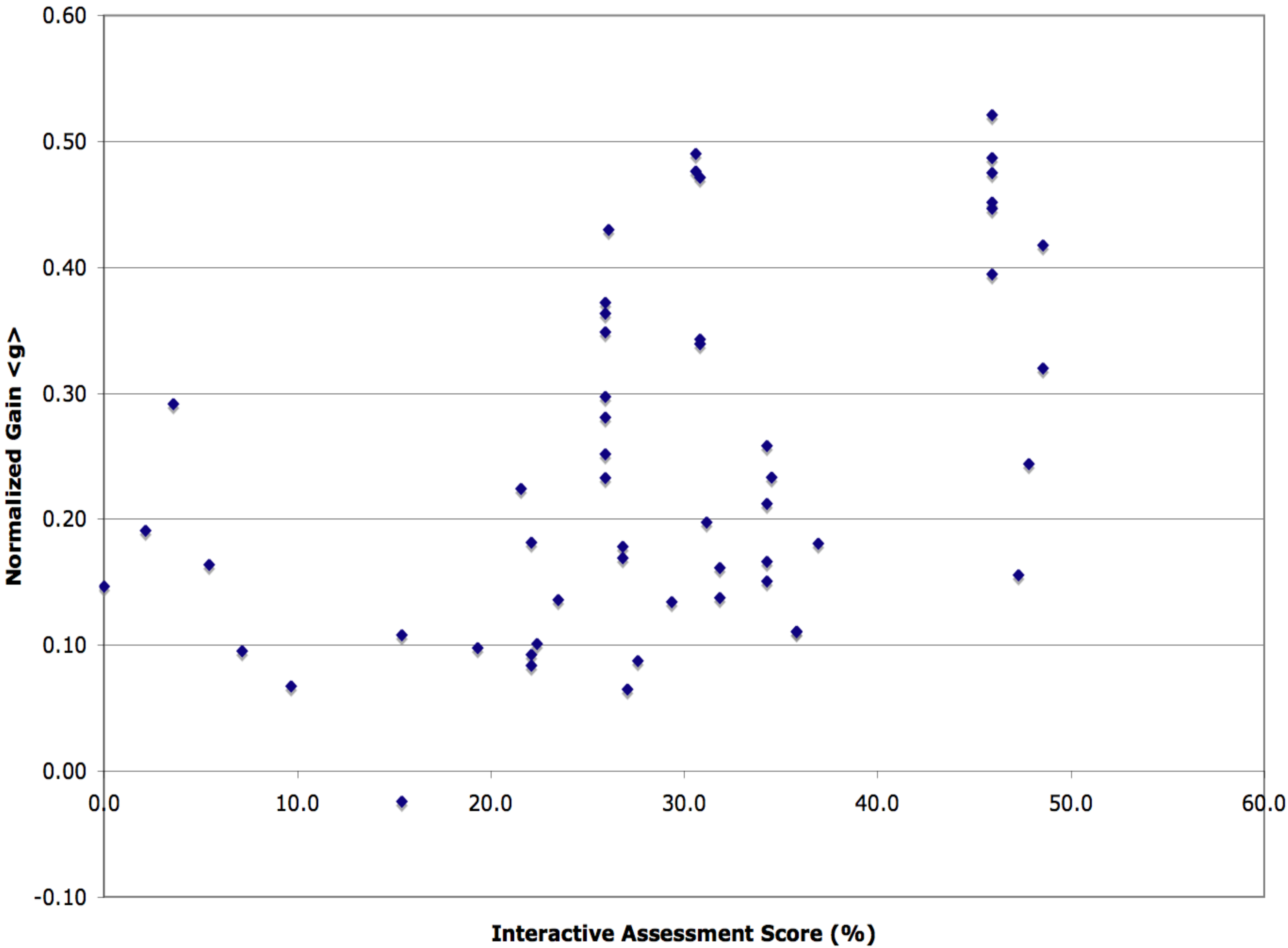


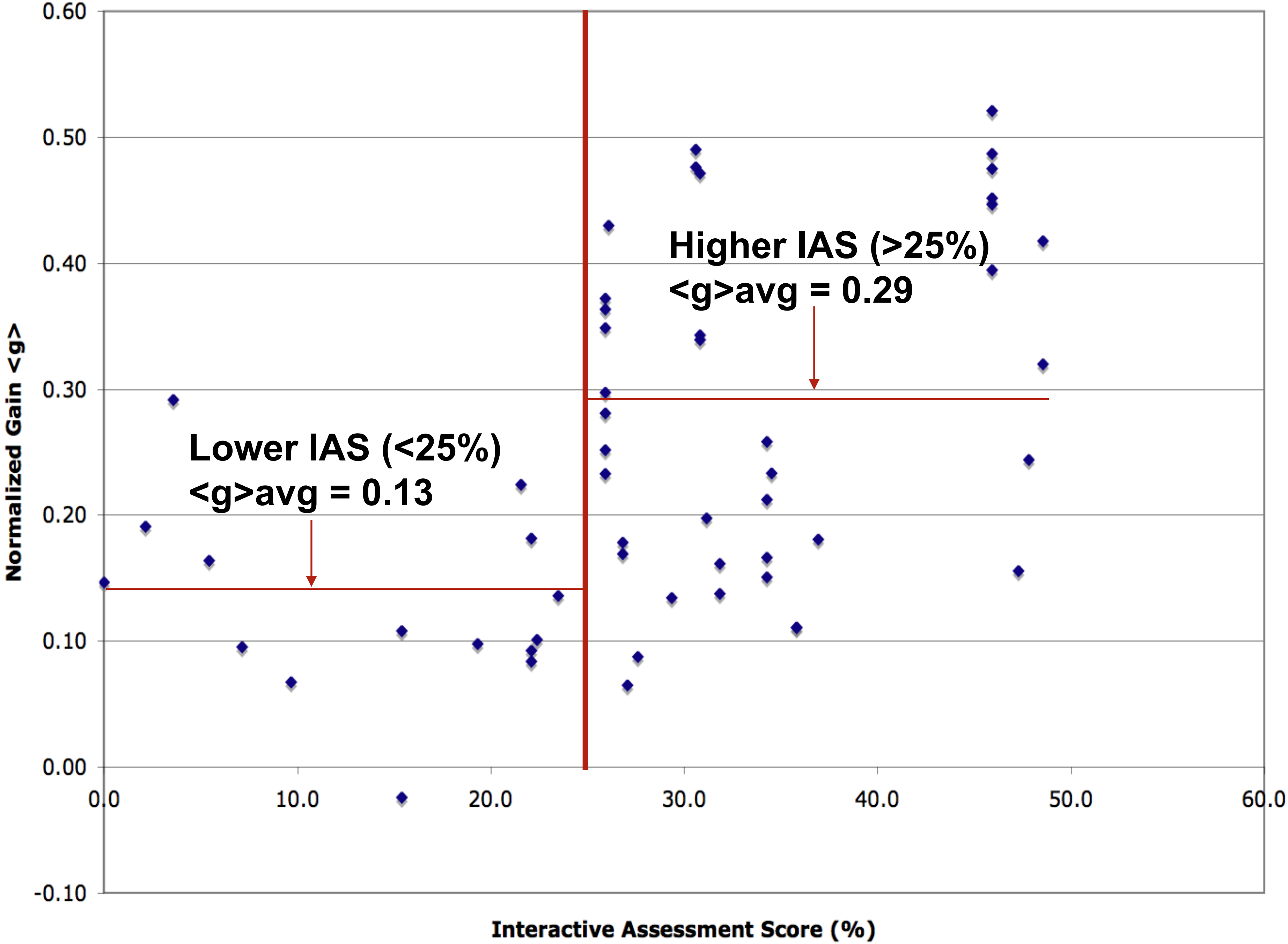
$$< g >= \frac{< post\% > - < pre\% >}{100\% - < pre\% >}$$
≥750 students
100-200 students
50-99 students
25-49 students
Normalized gain <g>
Average Pre-test %
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
10
20
30
40
50
60
70
80
90
100

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

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

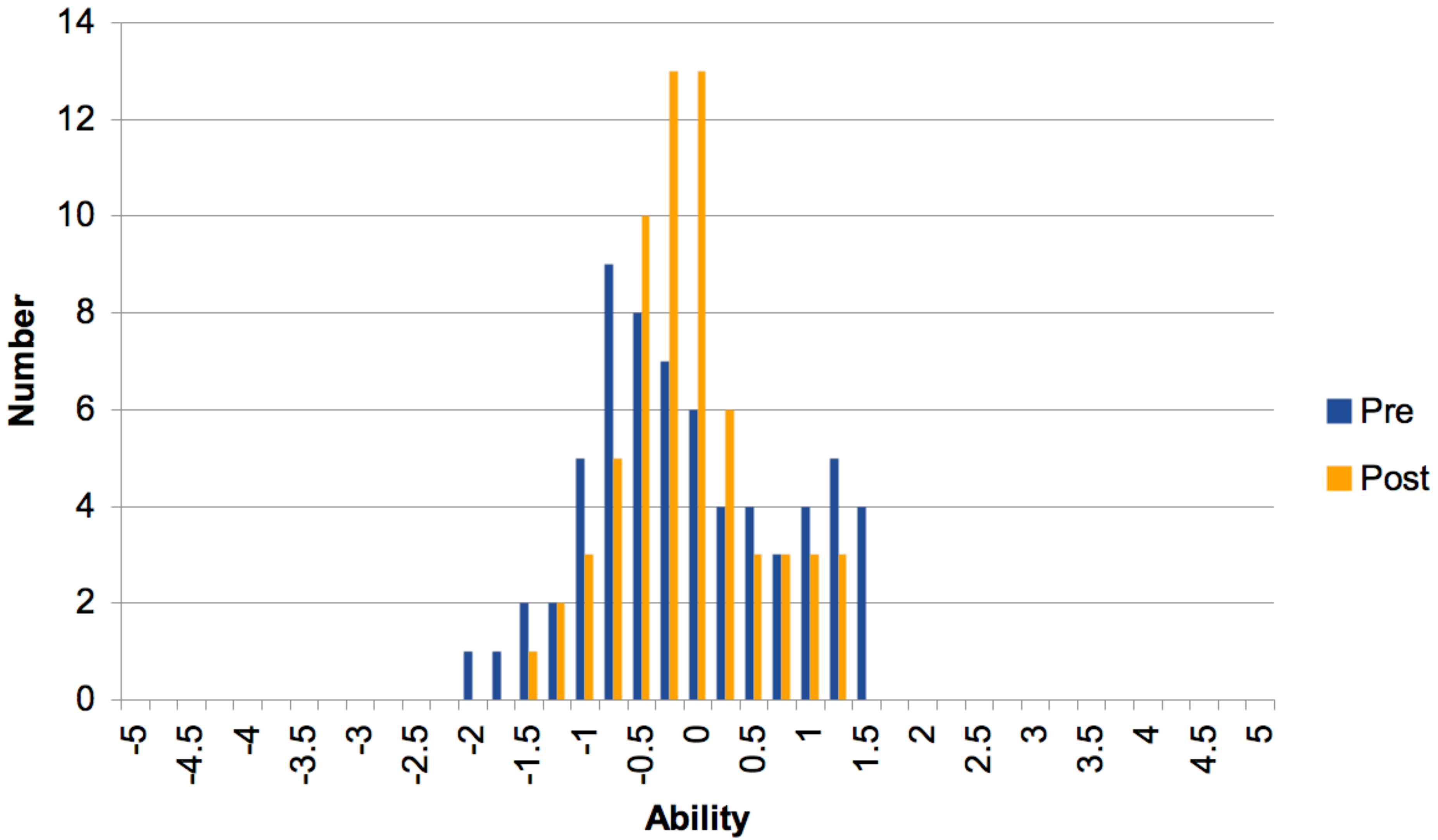
Implementation is the most important factor to success in student learning.

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.

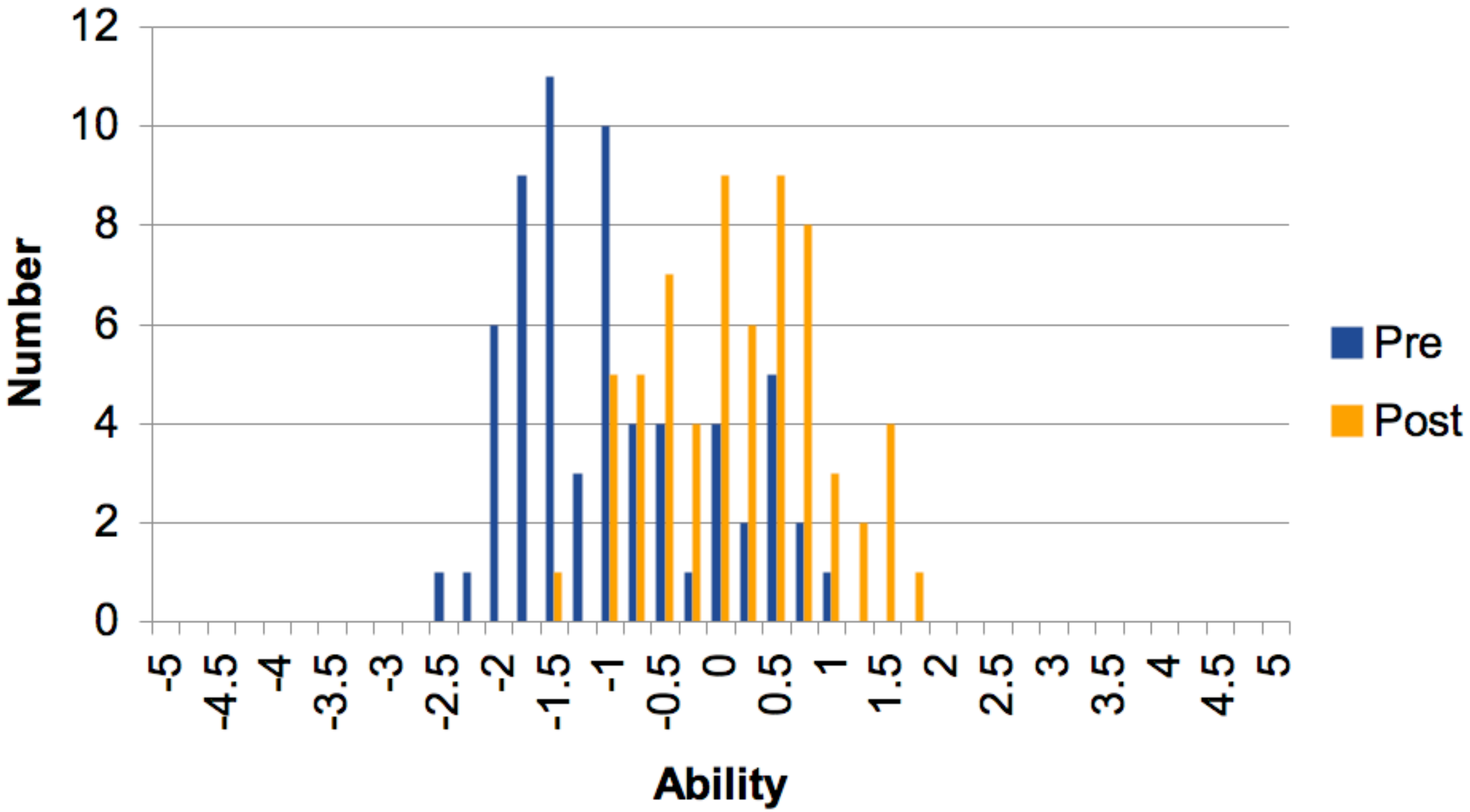
Item Response Theory (IRT)

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

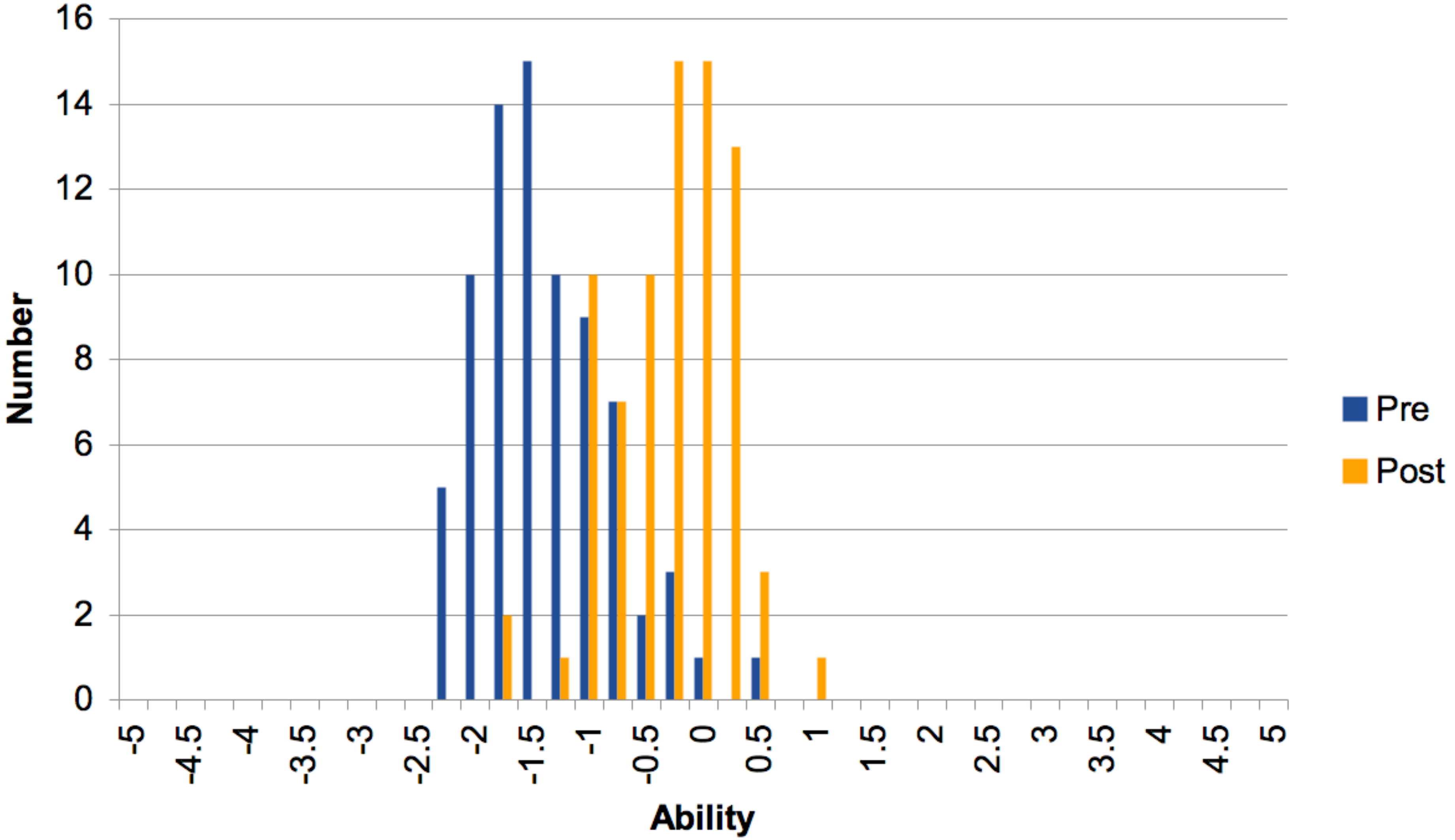
Single Course Ability Histogram



Single Course Ability Histogram

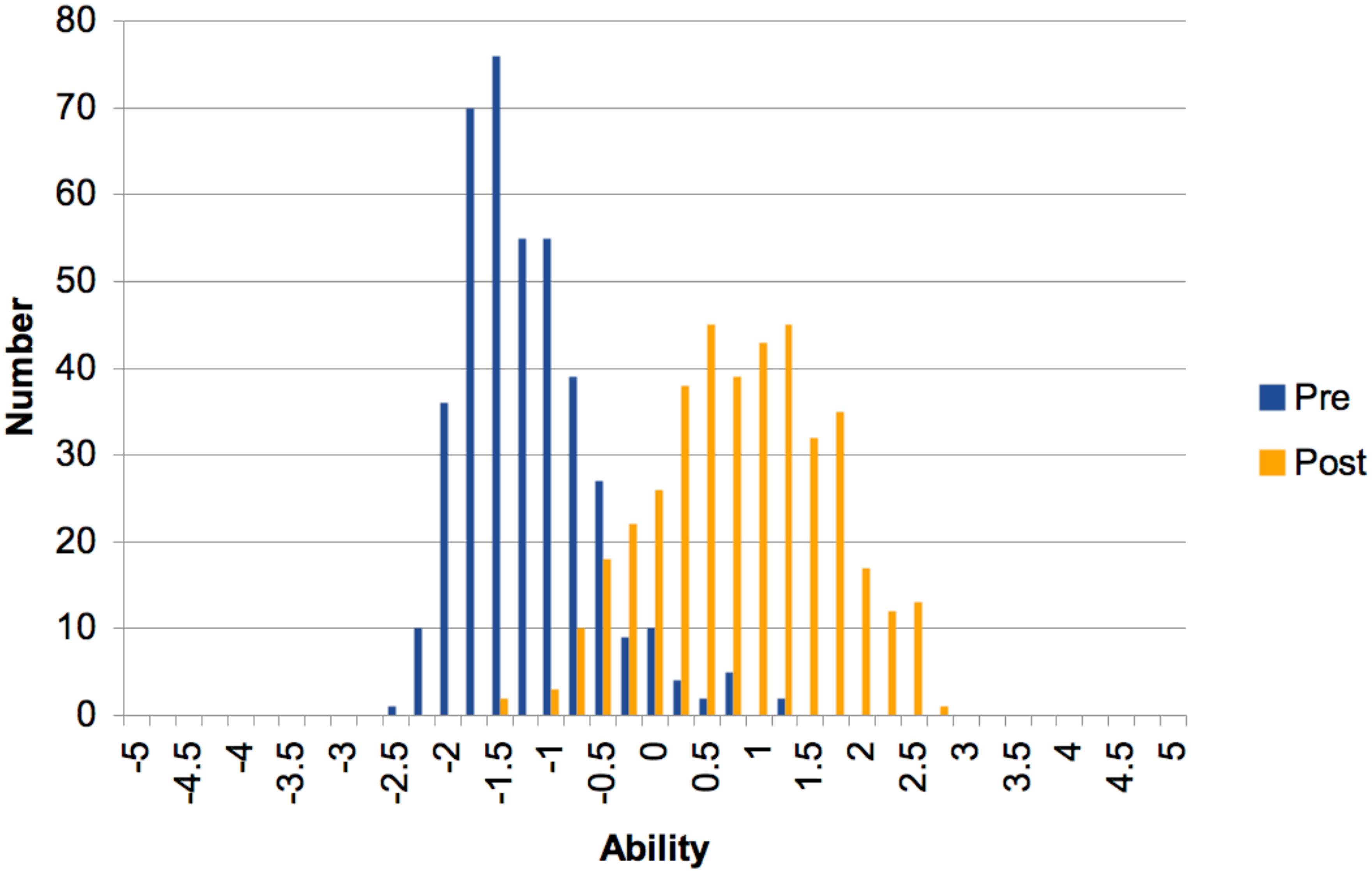


Single Course Ability Histogram



Ambassadors – of science in our society, our nations future leaders

Mega Course Ability Histogram



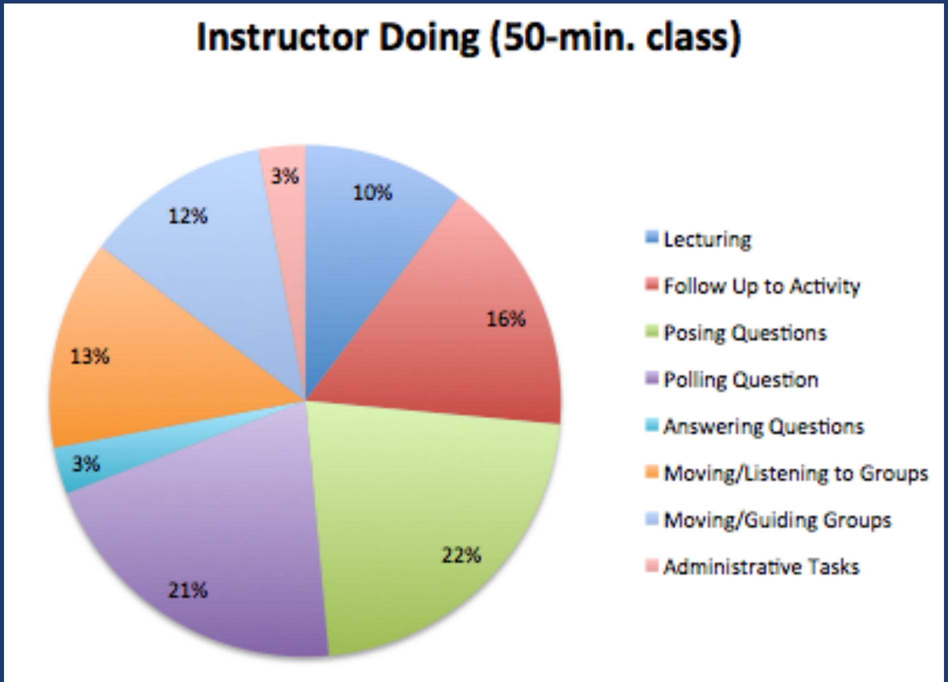
Reformed Class

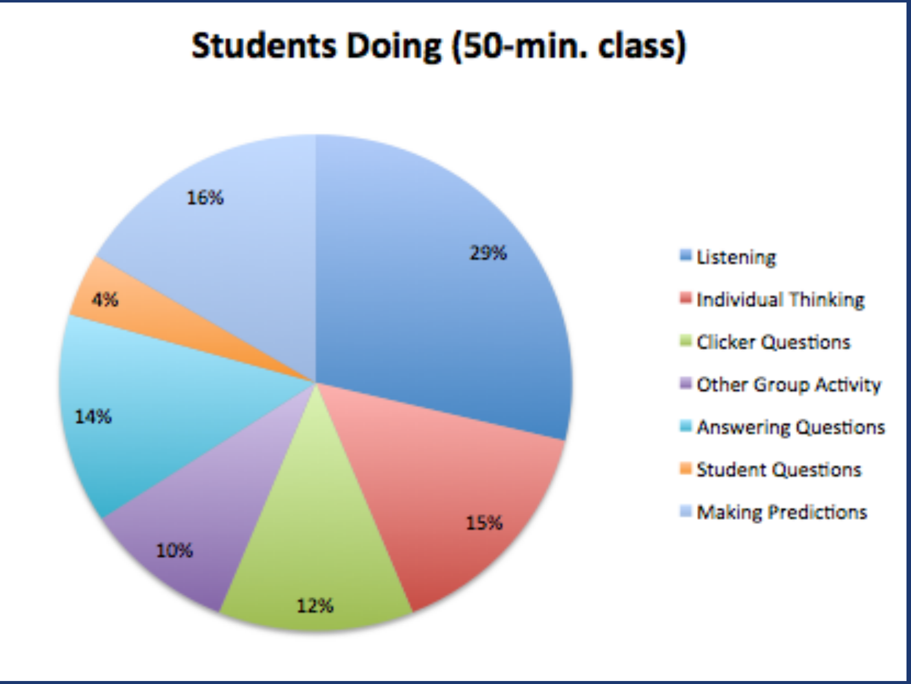
- Two 50 minute lectures per week
  - Focused on introducing concepts using active engagement instructional strategies and on interactive, collaborative problem solving
  - Minimal derivations of equations
- Each student also attends one of ten 50 minute recitation sections per week
  - Led by graduate TA with assistance from undergraduate peer instructors
  - Students work on collaborative tutorials, which promote reasoning abilities and problem solving skills
- Instructor experienced in astronomy and physics education research, but teaching PHYS 141 for the first time

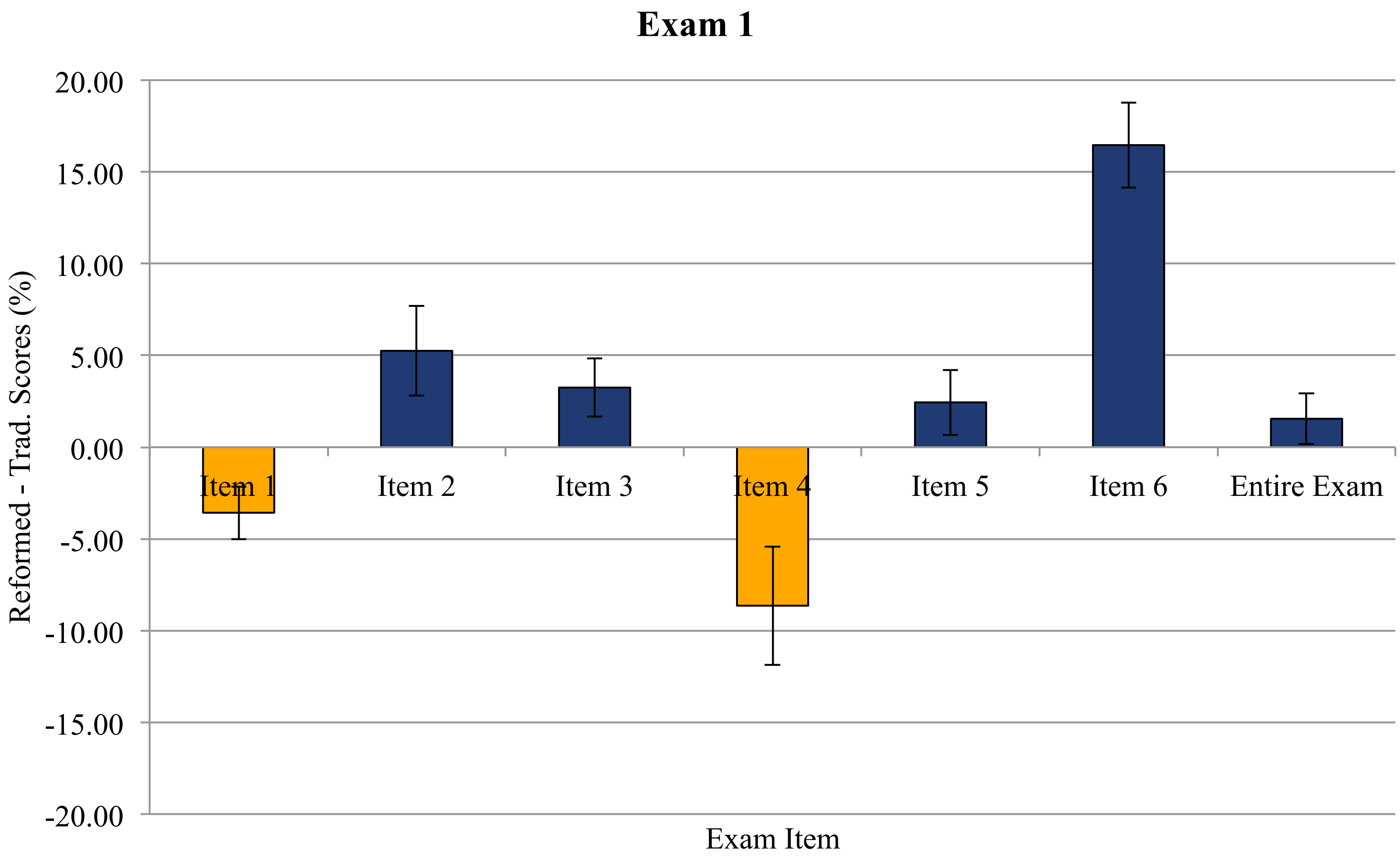
Traditional Class

- Three 50 minute lectures per week
  - Focused on introducing concepts and on instructor-led modeling of problem solving
  - Many derivations of equations
- Instructor experienced in teaching PHYS 141 and widely regarded by faculty and students as an excellent lecturer

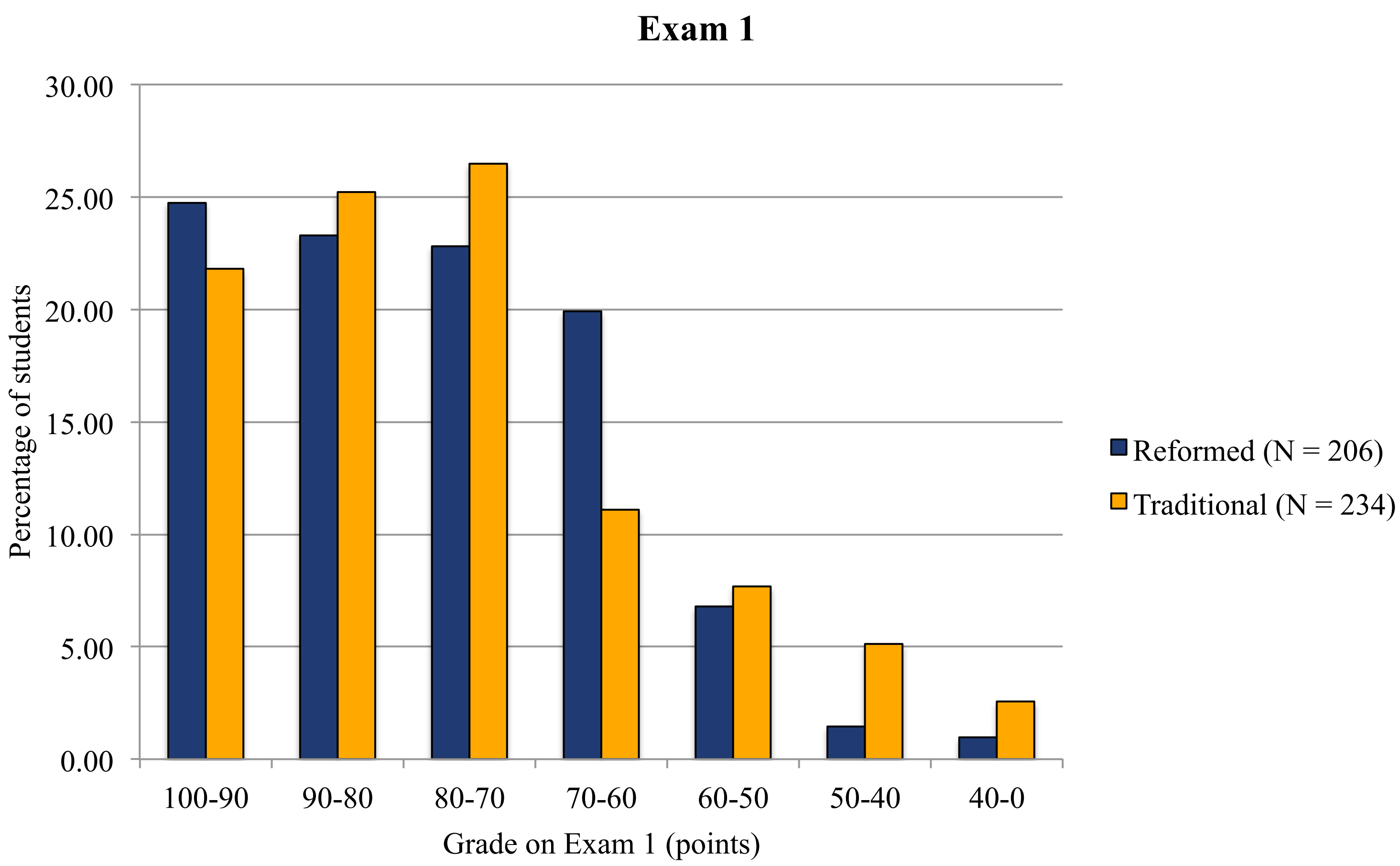
COPUS data from UA Calc-Physics Course

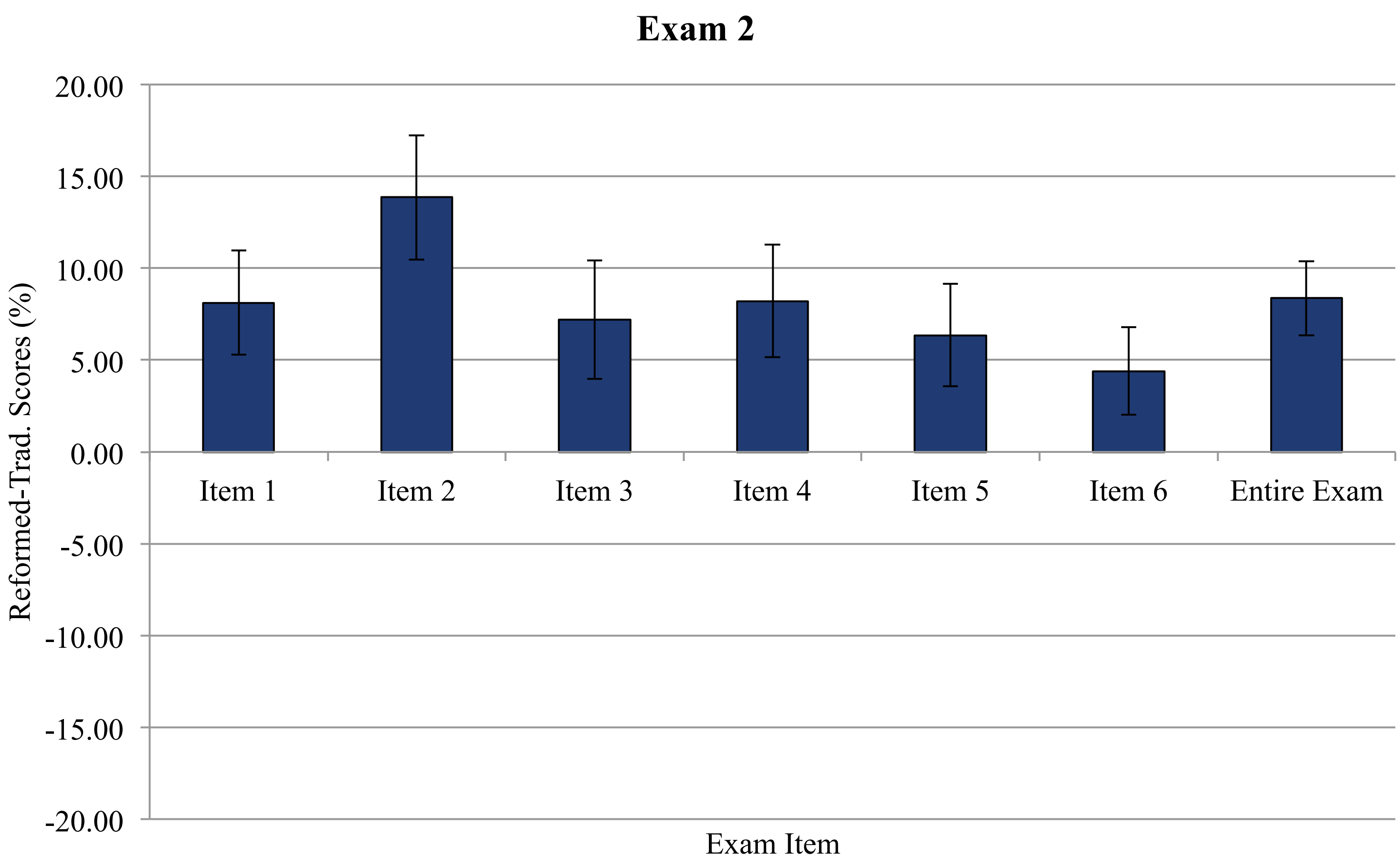


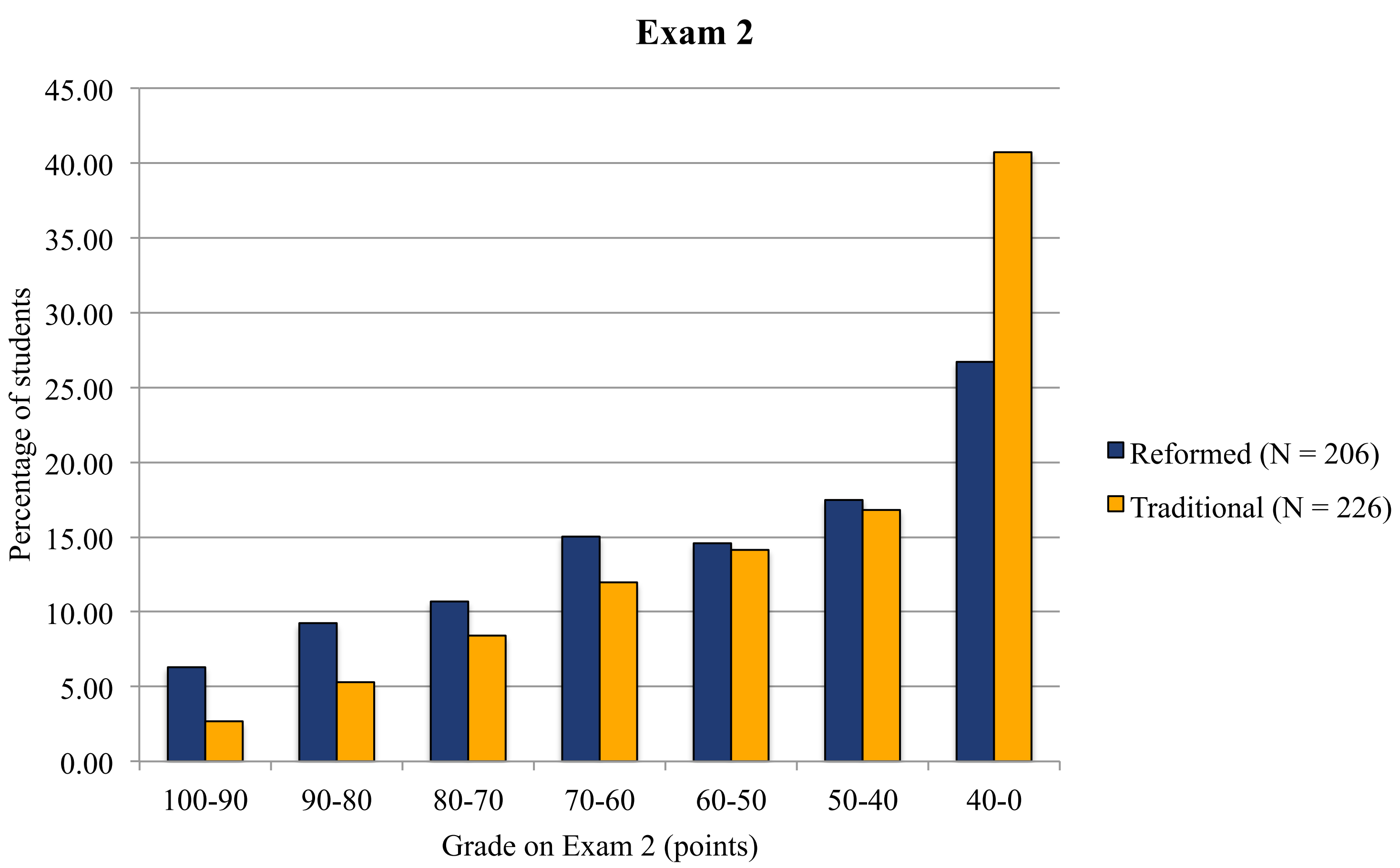


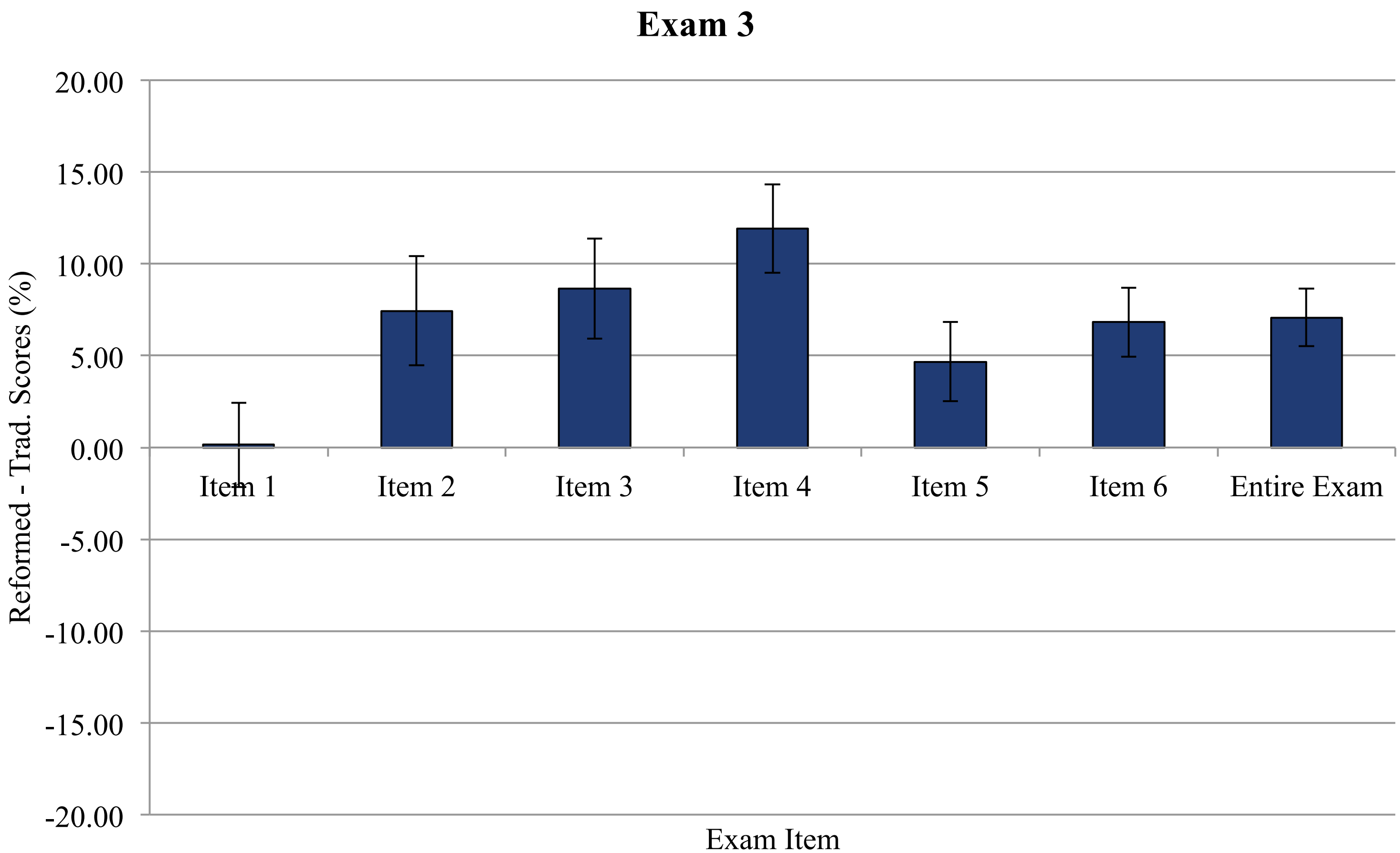


Exam 1
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
Reformed - Trad. Scores (%)
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item

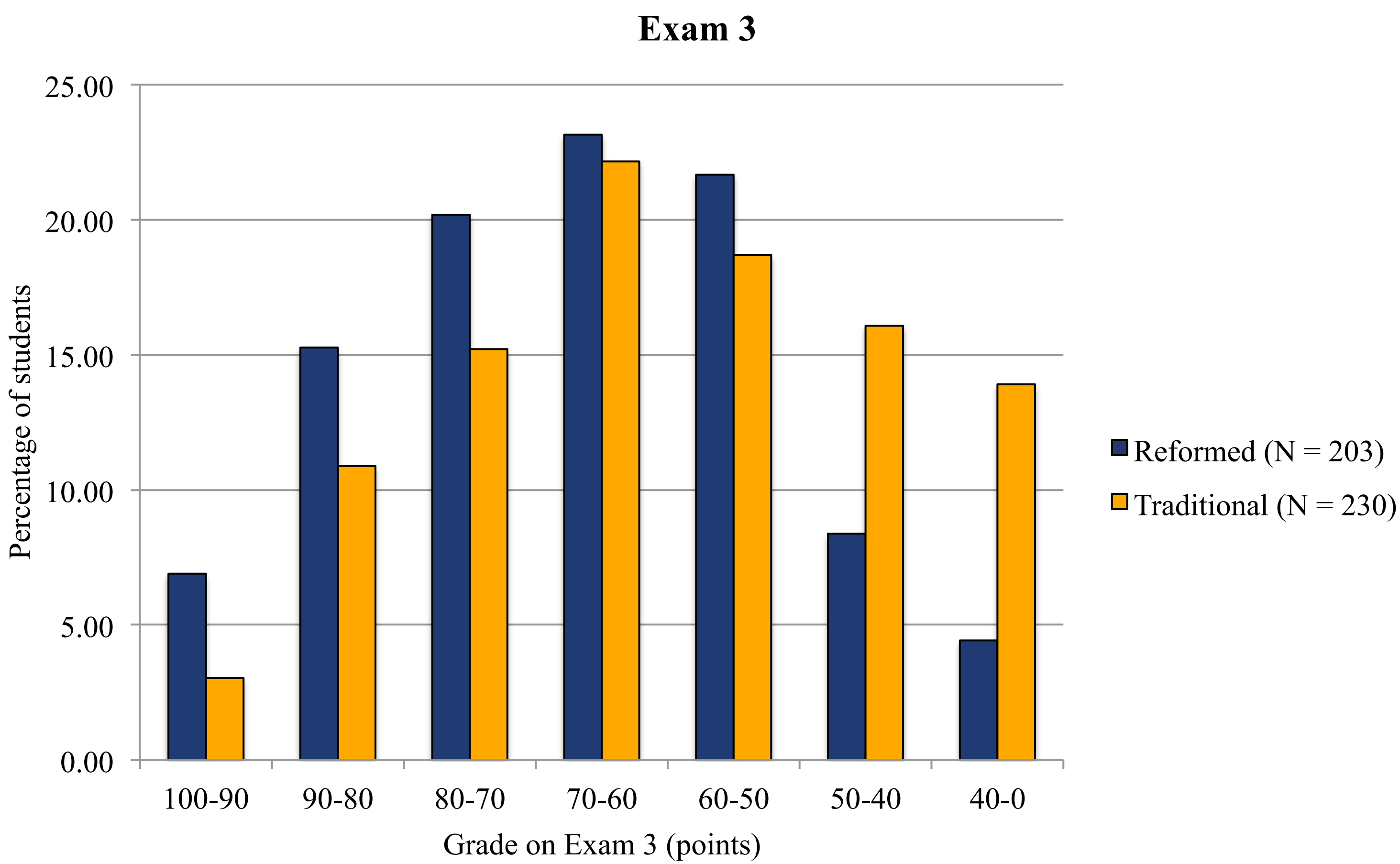

Exam 1
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Percentage of students
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Grade on Exam 1 (points)
Reformed (N = 206)
Traditional (N = 234)

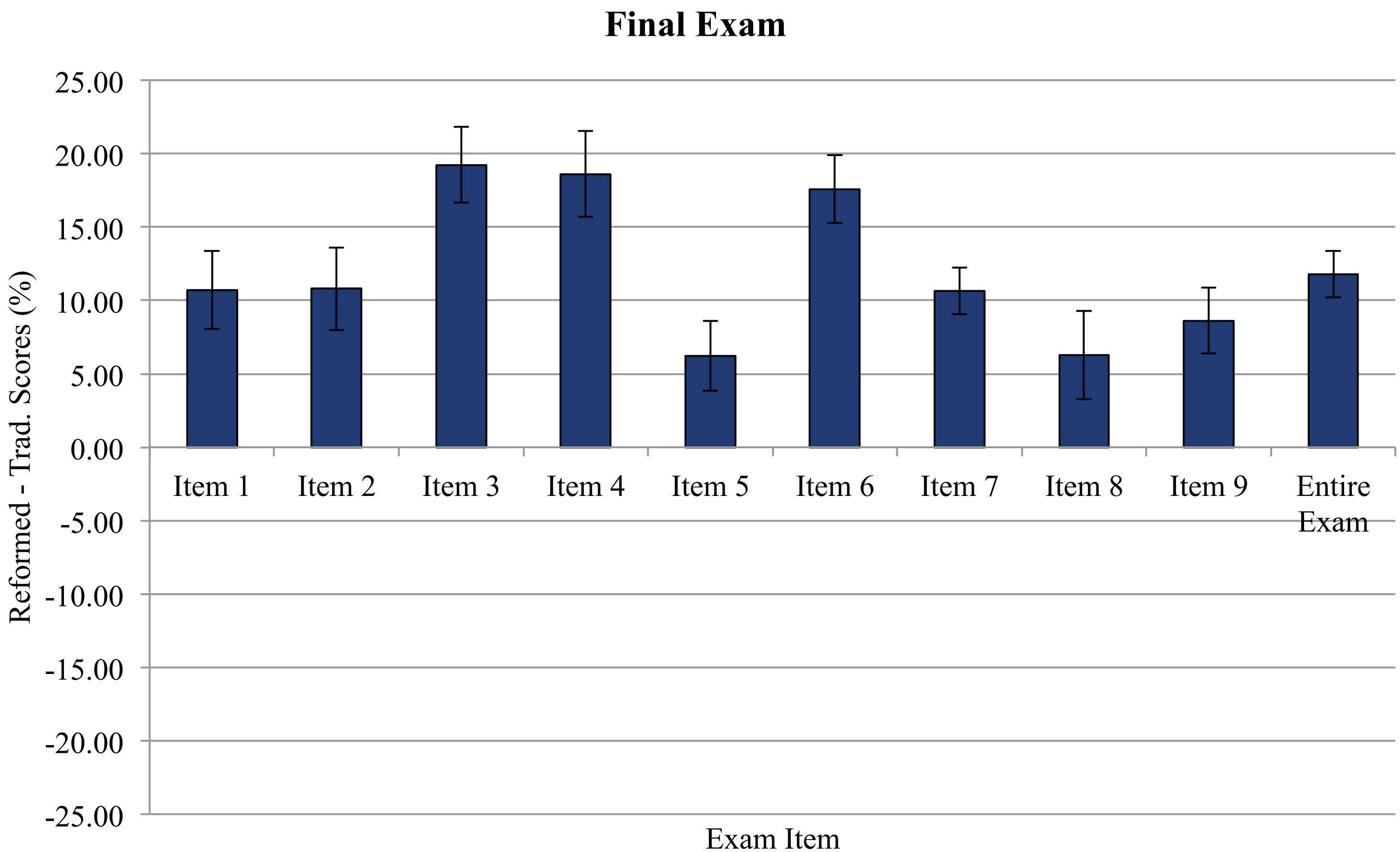

Exam 2
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
Reformed-Trad. Scores (%)
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item

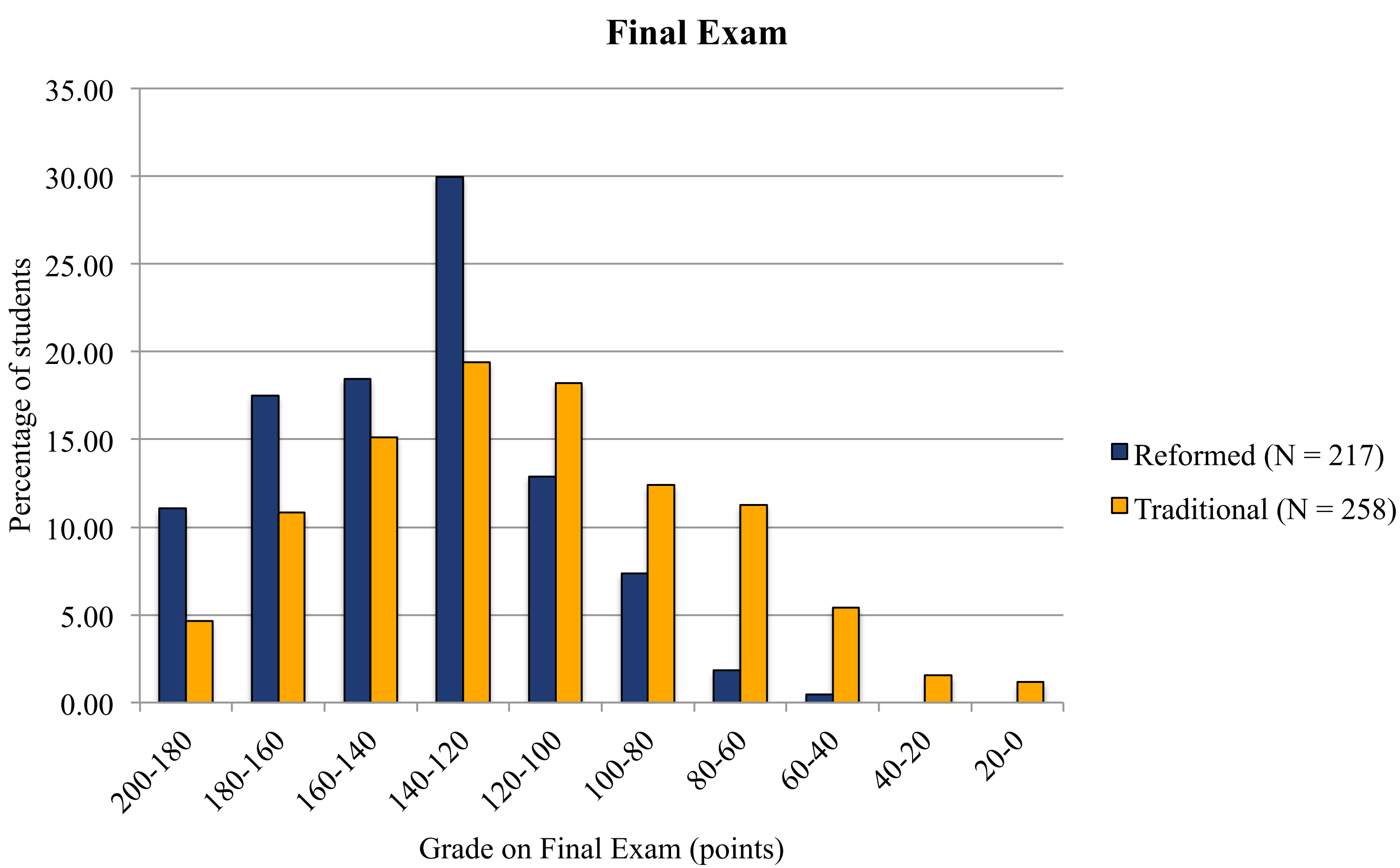

Exam 2
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Percentage of students
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Grade on Exam 2 (points)
Reformed (N = 206)
Traditional (N = 226)



Exam 3
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
Reformed - Trad. Scores (%)
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item


Exam 3
25.00
20.00
15.00
10.00
5.00
0.00
Percentage of students
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Grade on Exam 3 (points)
Reformed (N = 203)
Traditional (N = 230)


Final Exam
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-20.00
-25.00
Reformed - Trad. Scores (%)
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Item 7
Item 8
Item 9
Entire Exam
Exam Item


Final Exam
Percentage of students
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
200-180
180-160
160-140
140-120
120-100
100-80
80-60
60-40
40-20
20-0
Grade on Final Exam (points)
Reformed (N = 217)
Traditional (N = 258)