Education Research on Active Learning Techniques

Dr. Melissa N. Hayes-Gehrke
Astronomy Dept., UMD

2016 GROWTH Education Workshop

With thanks to Ed Prather and....

astronomy101.jpl.nasa.gov

XEROX ColorQube - Print | gmail (personal) | Google Images | Google Maps | Google Drive | AAS Member Directory | NPR | CAE Workshop Reg on AAS

astro101

Jet Propulsion Laboratory
California Institute of Technology

JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | SCIENCE & TECHNOLOGY

BRING THE UNIVERSE TO YOU: JPL Email News | RSS | Podcast | Video

CAE
Center for Astronomy Education

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

- Home
- Workshops
- Instructional & Workshop Materials
- AstroImer@CAE
- Teaching Strategies
- CATS
- College Locator
- CAE AAS Plenary Talk
- Publications
- CAE on Facebook
- Seeing the Universe
- Outside Resources
- About Us
- Contacts
- Join Our Mailing List

Think-Pair-Share:
A Revised "How-To" Guide

Faculty often ask us what they can do to "get out of lecture mode" in their classrooms. After completing a CAE Teaching Excellence Workshop, participants commonly report back that Think-Pair-Share is the technique they plan to try first. We agree it's a great place to start! So how do you effectively implement Think-Pair-Share in the classroom? Through years of classroom experimentation, we've come up with a set of steps and phrases we find motivate students to earnestly engage with your TPS ...
More >>

Teaching Excellence Workshops >>

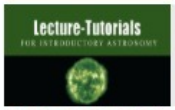
Collaboration of Astronomy Teaching Scholars >>

AstroImer@CAE >>

Who Teaches Astro 101? >>

» More Teaching Strategies

Hot Reading to Help You
Have a Cool Summer While Preparing for Fall
In our Teaching Excellence Workshops, we mention many articles and books worth reading—or, as we like to tell our students, articles and books "worth knowing"—related... More >>



Lecture-Tutorials: A How-To Guide
In This Month's Teaching Strategy, we are highlighting our expanded Lecture-Tutorials How-To Guide with a more comprehensive set of guidelines originally published... More >>

Think-Pair-Share:
A Revised "How-To" Guide
Faculty often ask us what they can do to "get out of lecture mode" in their classrooms. After completing a CAE Teaching Excellence Workshop, participants commonly... More >>

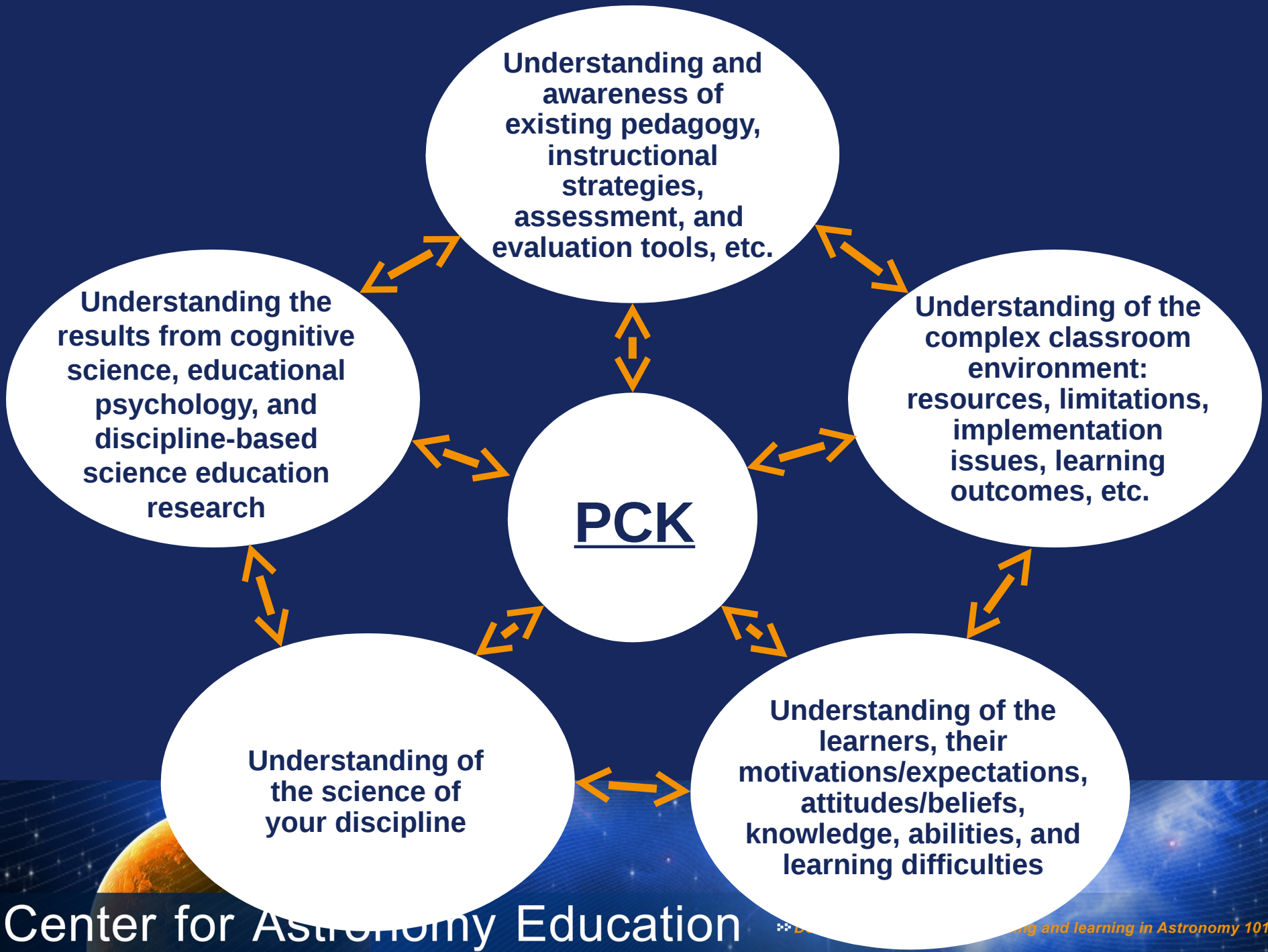
Additional Teaching Strategies >>

» Seeing the Universe through NASA's Eyes

NASA's Image of the Day Gallery
Light Toned Deposit in the Aureum Chaos Region on Mars
The High Resolution Imaging Science Experiment (HiRISE) camera aboard NASA's Mars Reconnaissance Orbiter acquired this closeup image of a light-toned deposit in Aureum Chaos, a 368 kilometer (229 mile) wide area in the eastern part of Valles Marineris, on Jan. 15, 2015, at 2:51 p.m. local Mars time.... Read More >>

NSF: 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 Hornstein, CU Boulder
- David Hudgins, Rockhurst Univ.
- Chris Impey, 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


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

Education is the formal process by which society deliberately passes on its accumulated knowledge, skills, customs and values from one generation to another.*

*** Adapted from: Don, Berg. "Definition of Education." teach-kids-attitude-1st.com. N.p., n.d. Web. 30 Sep 2011.**

Goals of the modern classroom….

- Helping to prepare citizens to be productive members of society.
- Discipline knowledge and discipline literacy
- Critical thinking and problem solving skills
- Ability to communicate effectively about complex ideas
- Ability to work with information and data
- Etc……

A Commonly Held Inaccurate Model of Teaching and Learning

Your discipline content

Bill Watterson,
Calvin and Hobbs

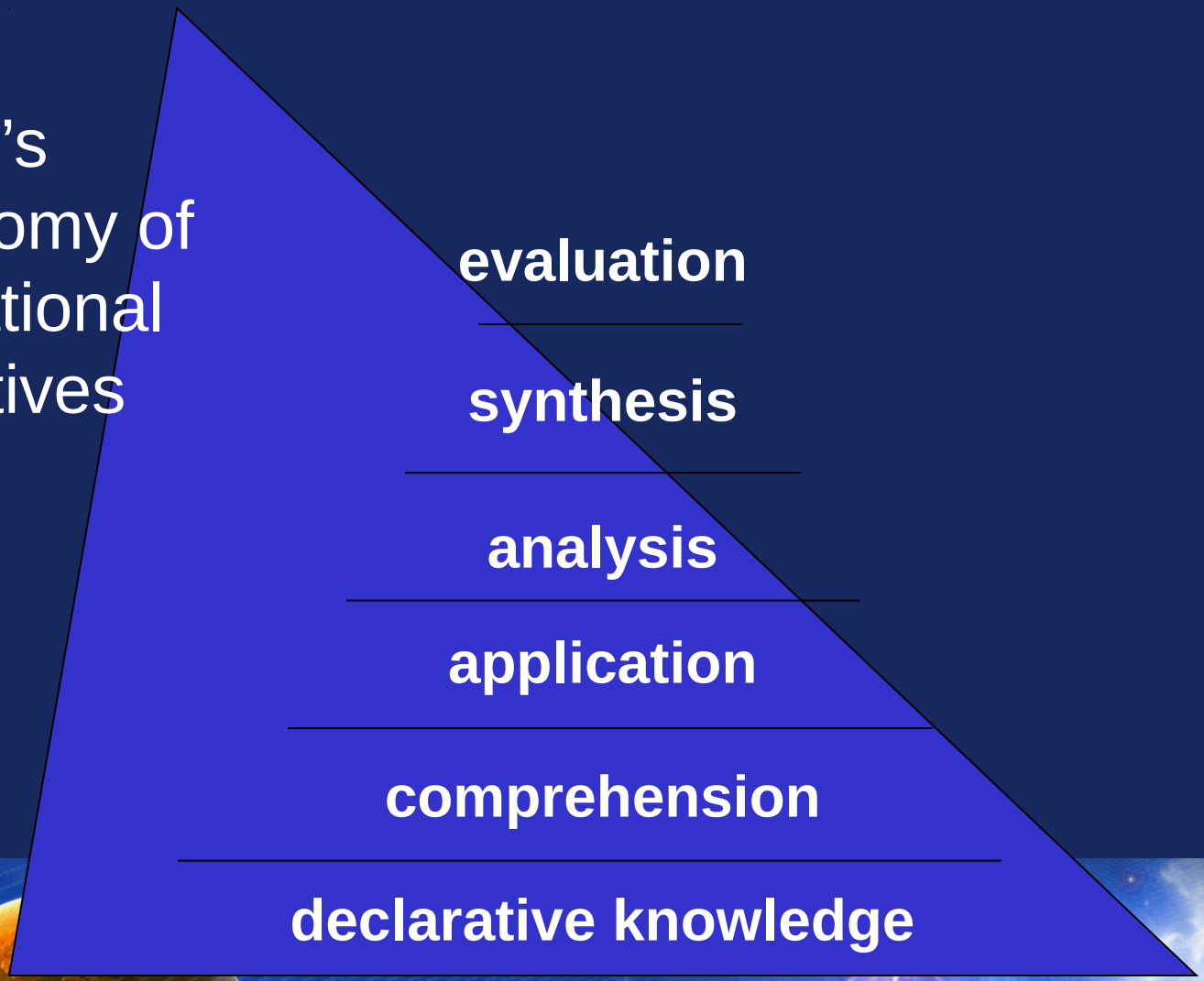
adapted from "How People Learn"

- 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 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.

Most traditional lecture courses do not intellectually engage the students and deepen their conceptual understanding and critical thinking ability, but re-enforces the memorization of facts and declarative knowledge.

Bloom's Taxonomy of Educational Objectives



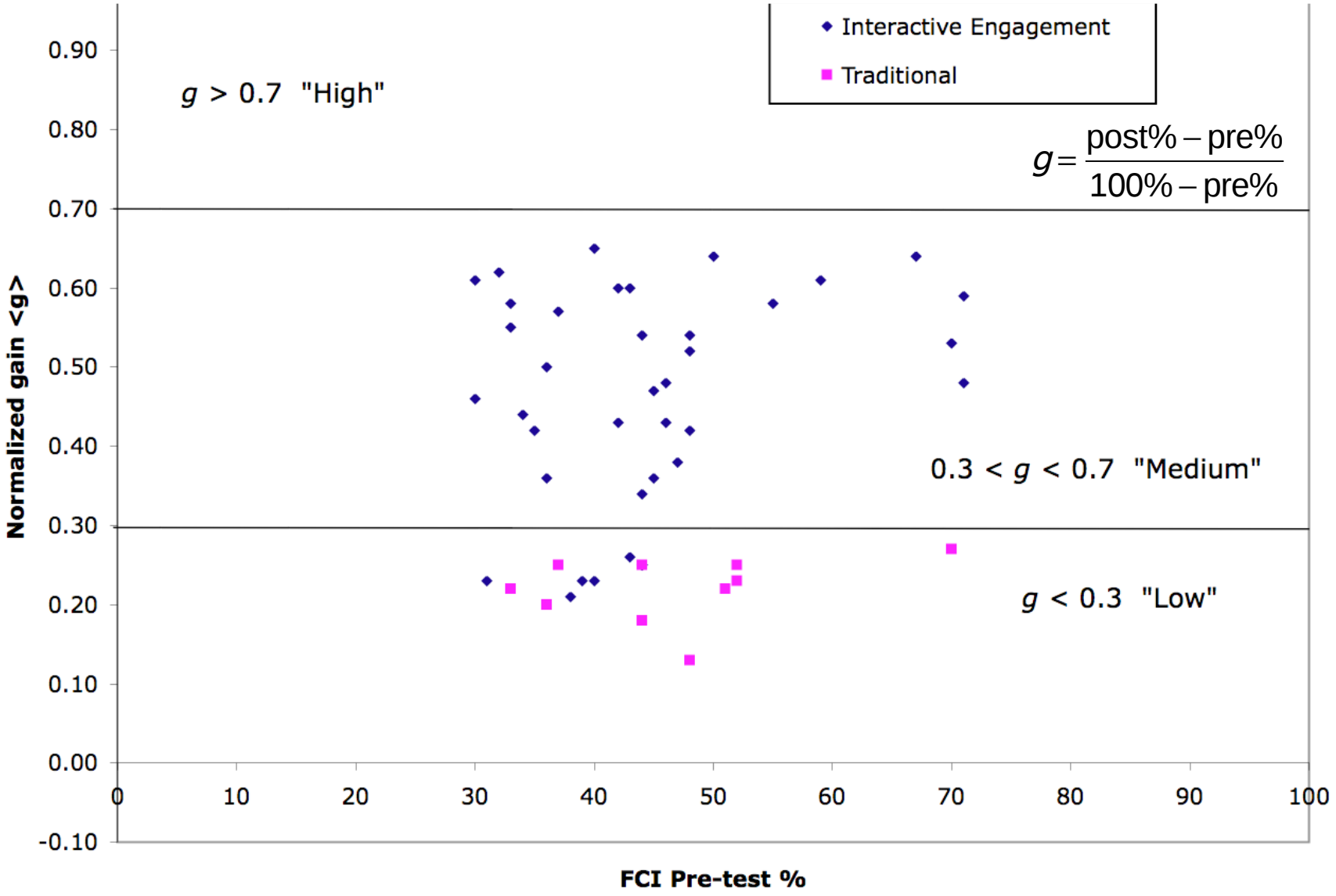
The Role of Assessment in the Development of the College Introductory Astronomy Course A "How-to" Guide for Instructors. Astronomy Education Review, 1(1), 1-24, 2002. G. Brissenden, T.F. Slater, and R. Mathieu.

What can you do instead of lecture?

Stay tuned: next section of this session is about active learning activities!

But first – evidence that they are effective!

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

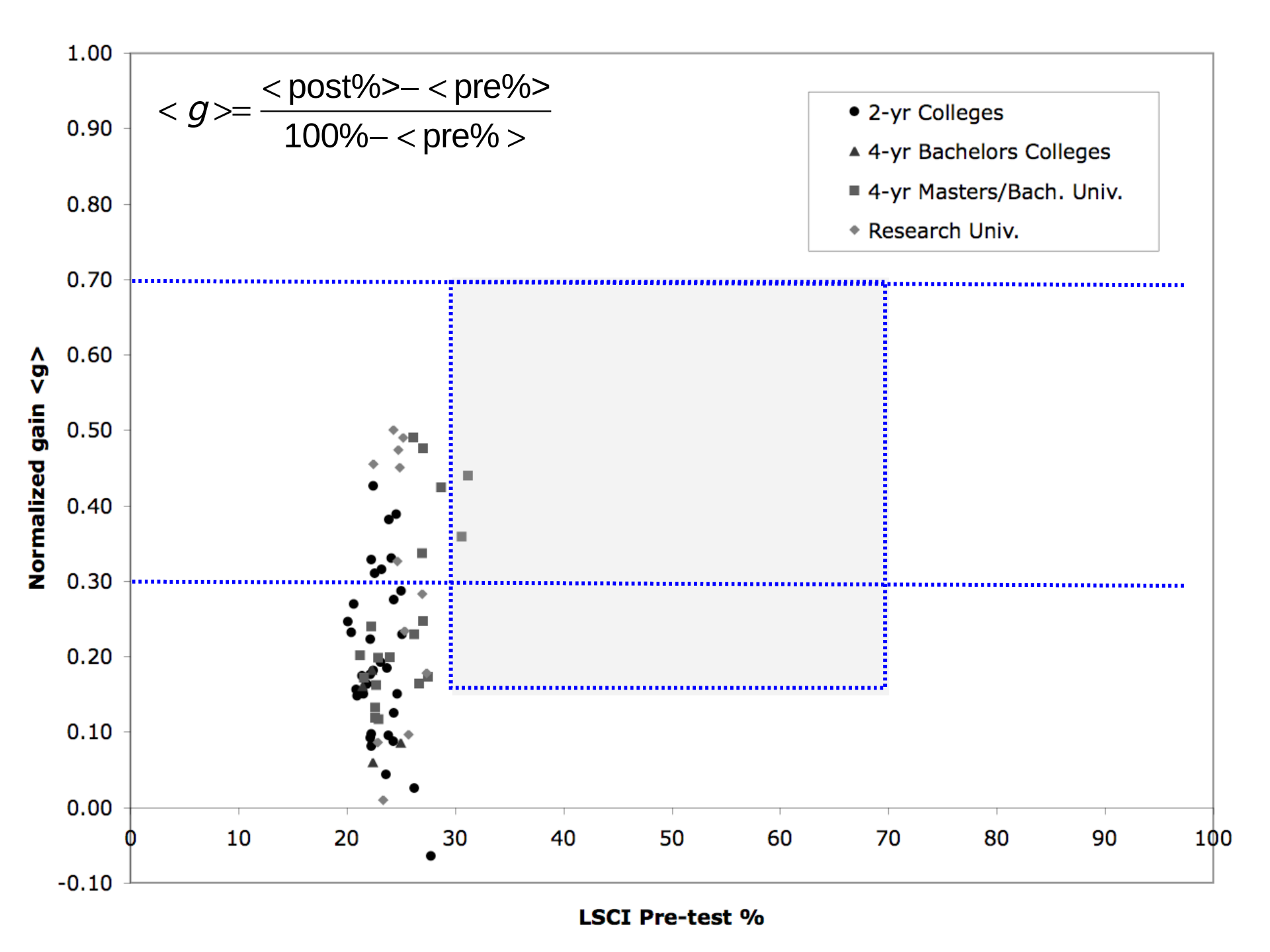


R. Hake, "...A six-thousand-student survey..." AJP 66, 64-74 (1998).

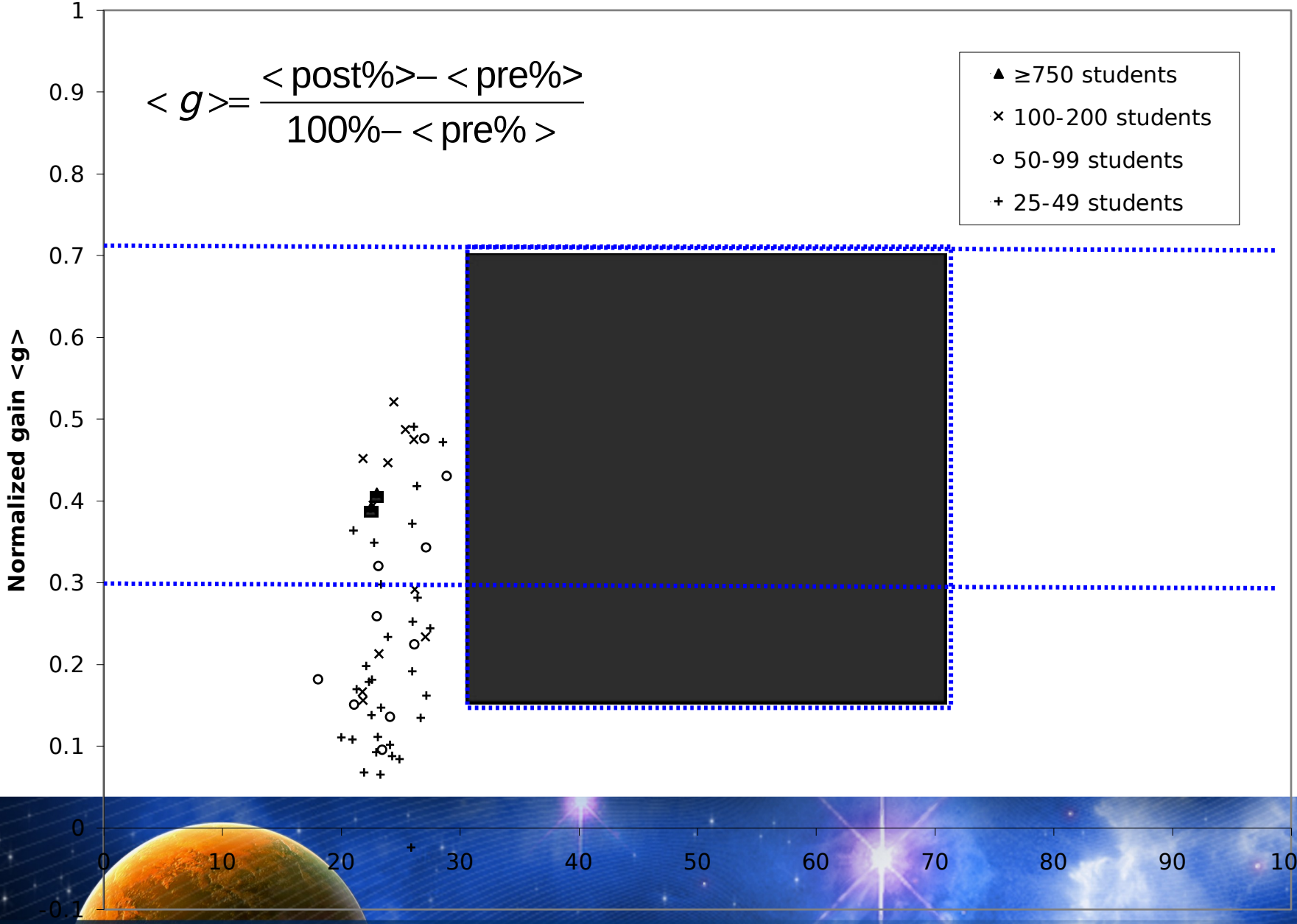
CAE National Study

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

This was a truly national study

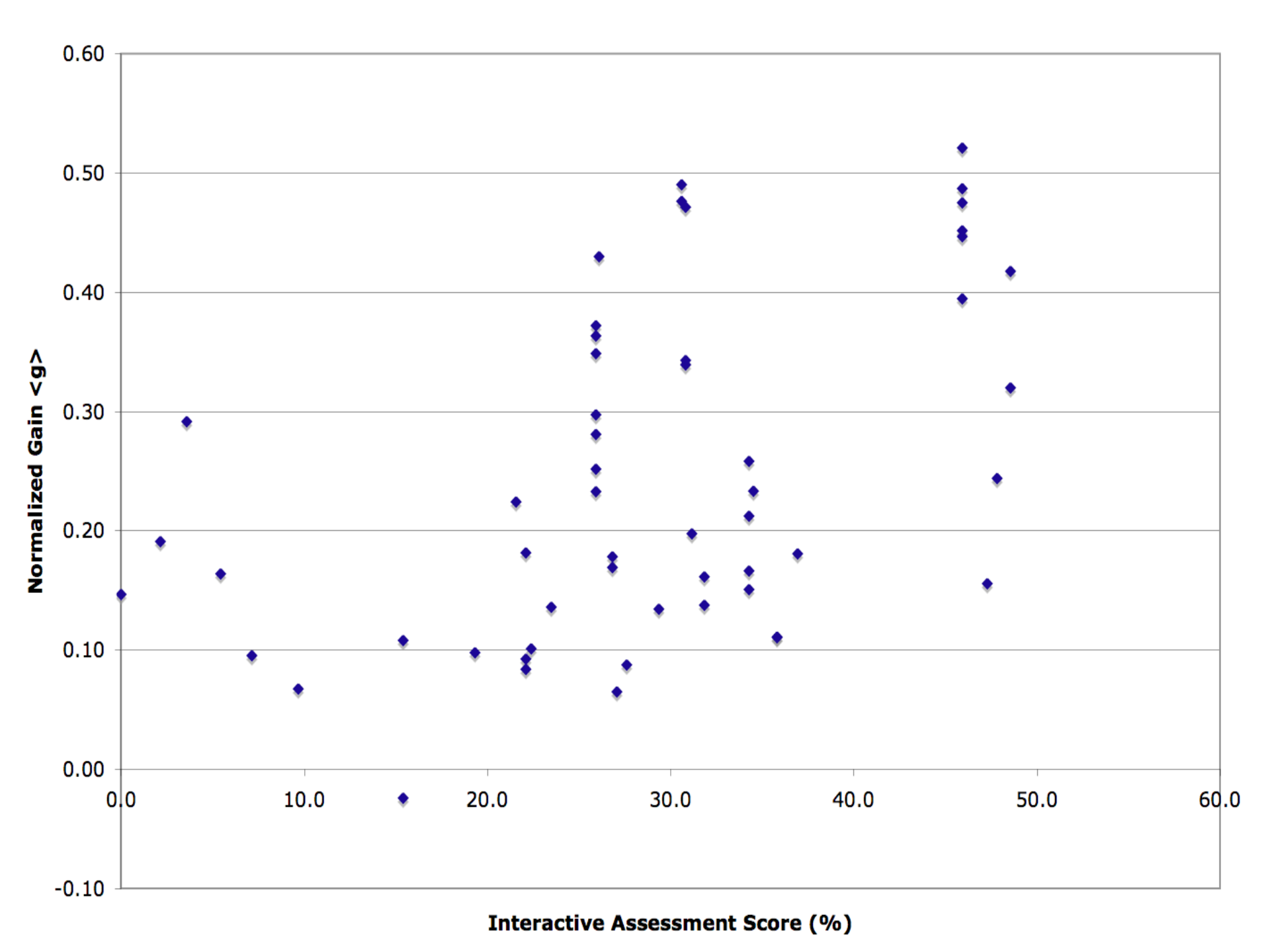

$< g >= \frac{< \text{post\%} > - < \text{pre\%} >}{100\% - < \text{pre\% } >}$
2-yr Colleges
4-yr Bachelors Colleges
4-yr Masters/Bach. Univ.
Research Univ.
Normalized gain <g>
LSCI Pre-test %
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
-0.10
0
10
20
30
40
50
60
70
80
90
100

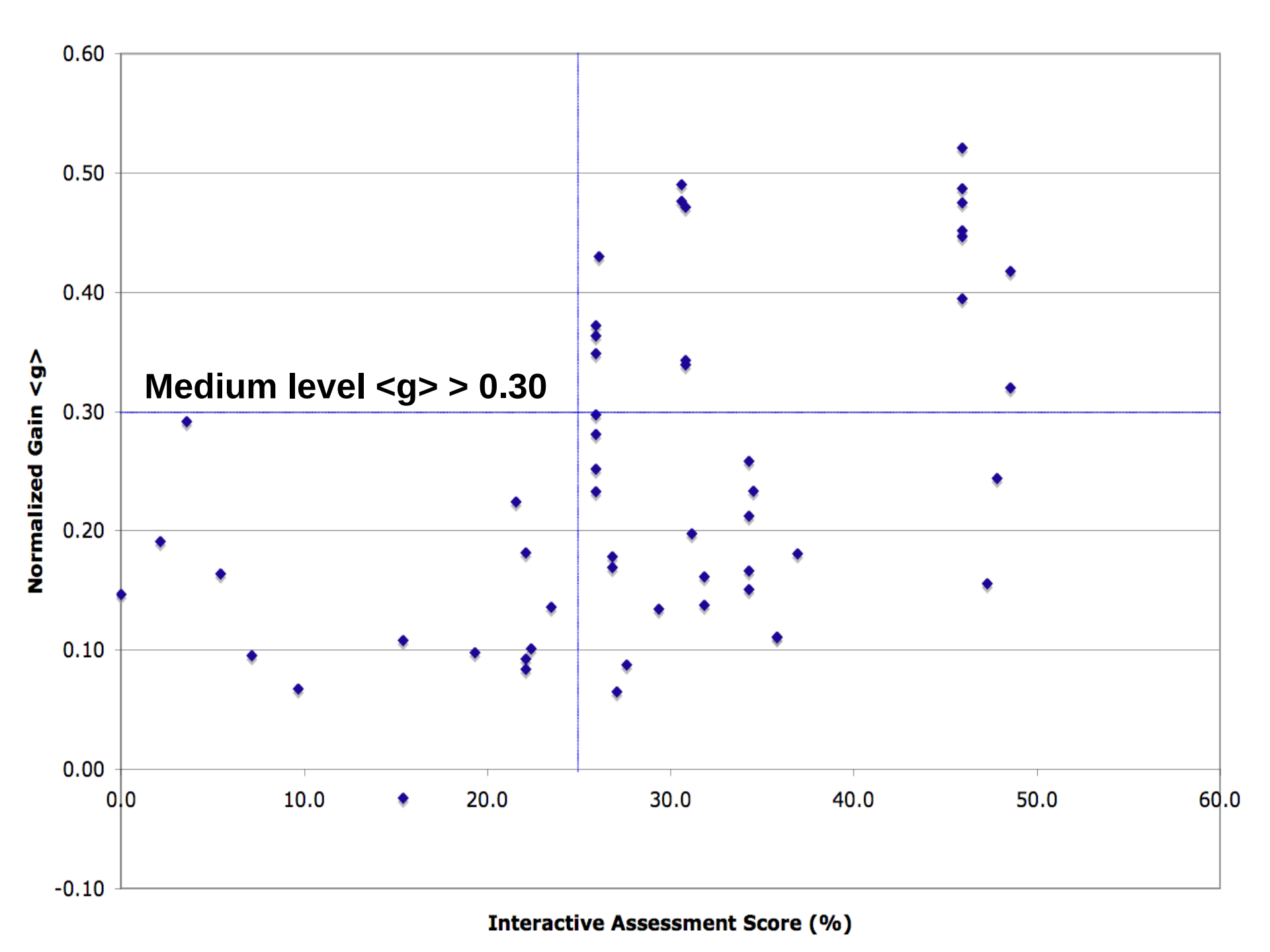
$$< g >= \frac{< \text{post\%} > - < \text{pre\%} >}{100\% - < \text{pre\%} >}$$

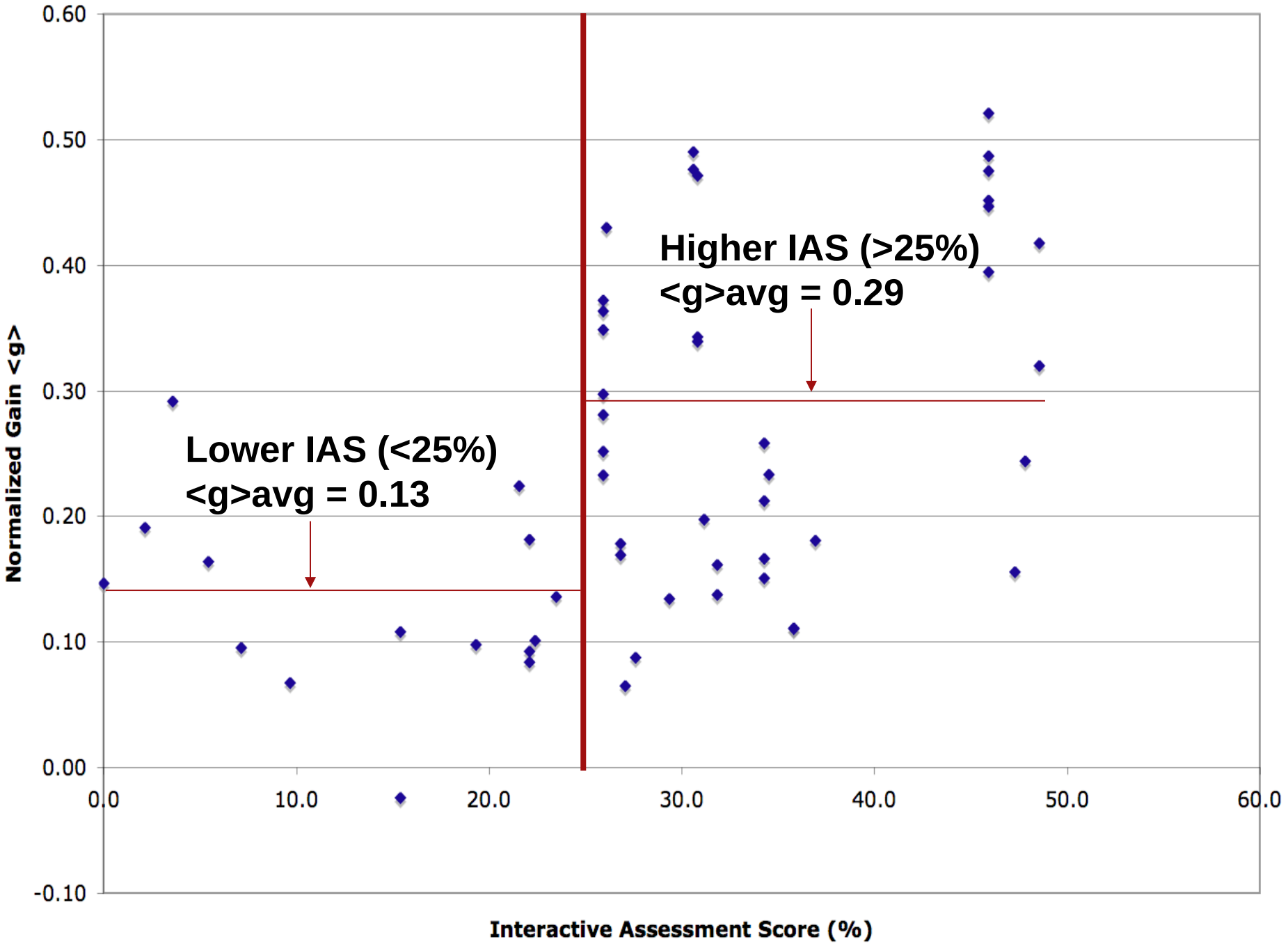


Instructor Surveys

- 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 (%)


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


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

	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 (0.059)		-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.

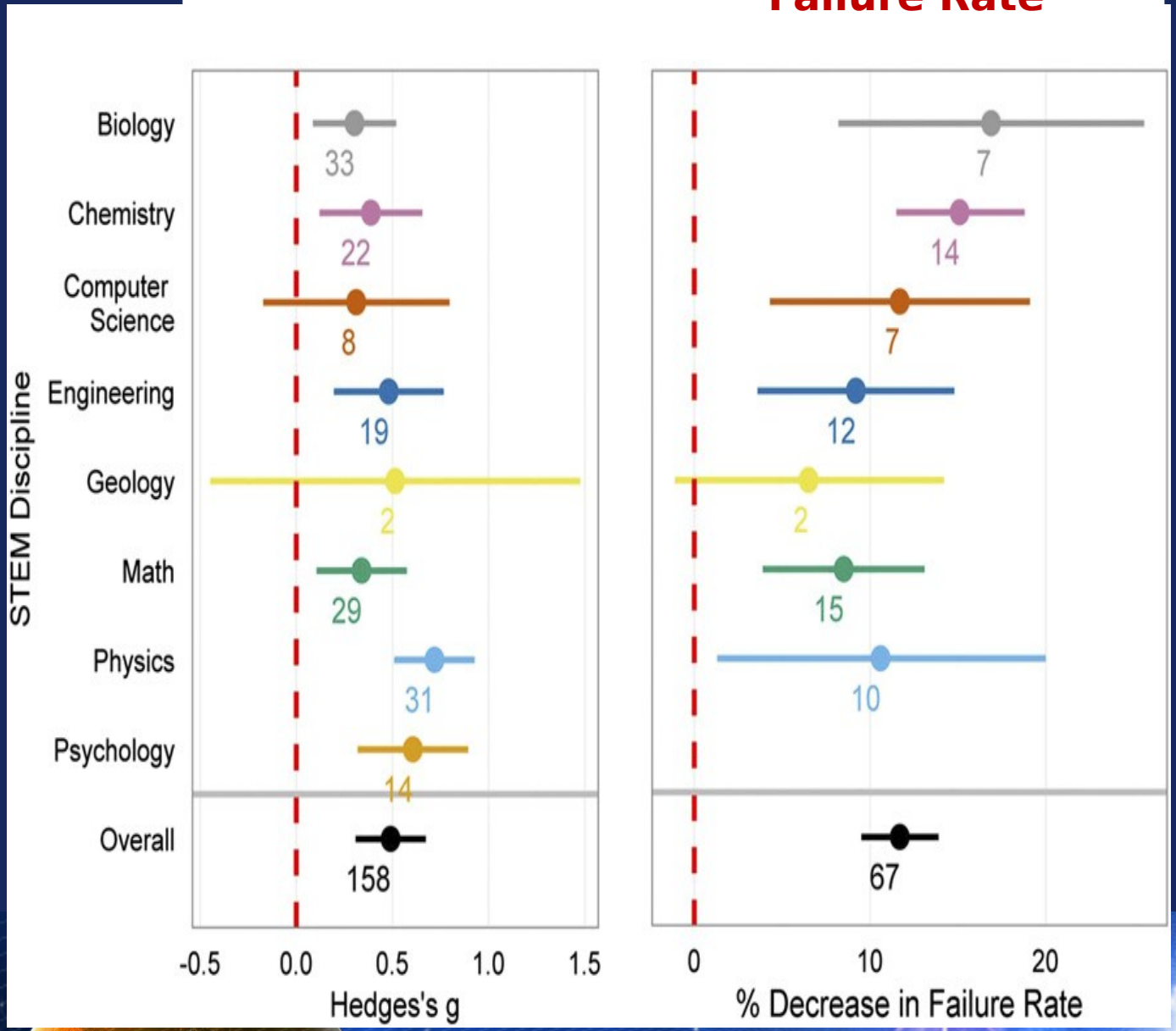
The take home message Part II

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.

Learning Gains

% Decrease in Failure Rate



Numbers indicate # of studies reviewed

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

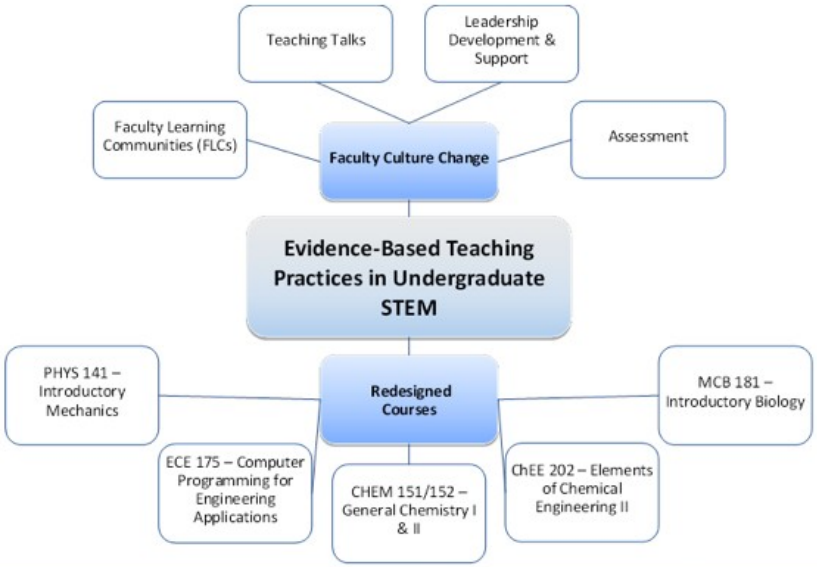
UA-AAU Undergraduate STEM Education Project

Welcome

Transforming Undergraduate STEM Education

Our Central Goals:

The UA-AAU STEM Education Project seeks to provide thousands of science and engineering majors at the University of Arizona with solid understanding in core STEM disciplines. For this purpose, we are engaged in the redesign of three foundational science courses (general chemistry, introductory biology, and introductory physics/mechanics) and two introductory engineering courses (elements of chemical engineering II and computer programming for engineering applications). The course redesigns are using student-centered and active learning pedagogy to enhance discipline knowledge and conceptual understanding. Three common themes cut across all redesign efforts: 1) promotion of information and quantitative literacy, 2) use of real-life applications in problem solving, and 3) use of models to develop conceptual understanding. The topics covered in the courses are being critically examined to emphasize core disciplinary ideas, problem-solving abilities, critical thinking, and teamwork, to ensure students are provided with a solid foundational understanding.



News

Coming Soon! STEM Teaching Award

A Call for Nominations for the **Undergraduate STEM Teaching Excellence Award** for Sping, 2015 is Coming Soon!

FLCs Spring 2015

The first meeting of the four FLC groups for Spring 2015 will take place on Wednesday, January 21st.

View More>>

staff login

Insights from the Univ. of Arizona AAU STEM reform effort in Physics

Reformed Class

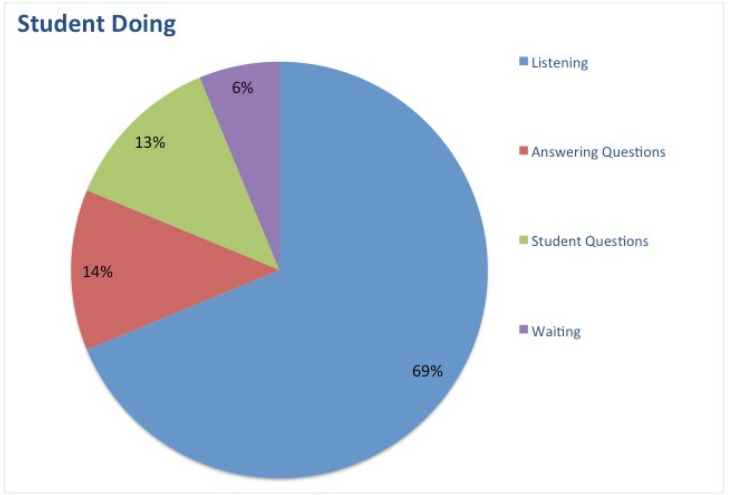
- Two 50 minute lectures per week
  - Focused on introducing concepts using active engagement instructional strategies and on collaborative group problem solving
  - Minimal derivations of equations
- Each student also attends a 50 minute recitation sections per week
  - Led by graduate TA with assistance 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

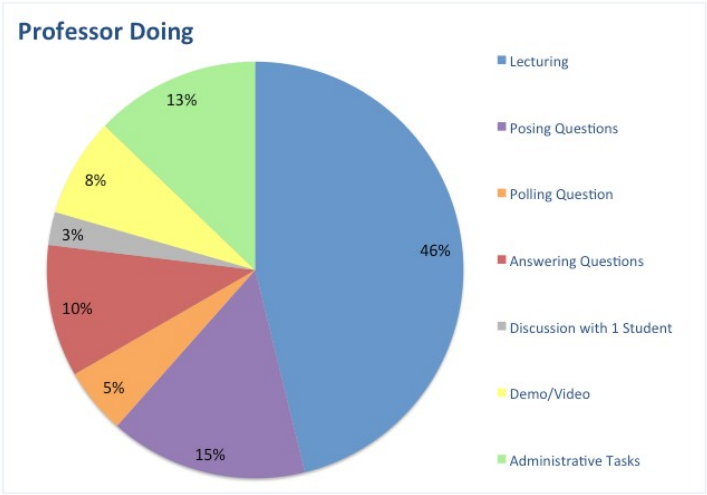
Traditional Class

- 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

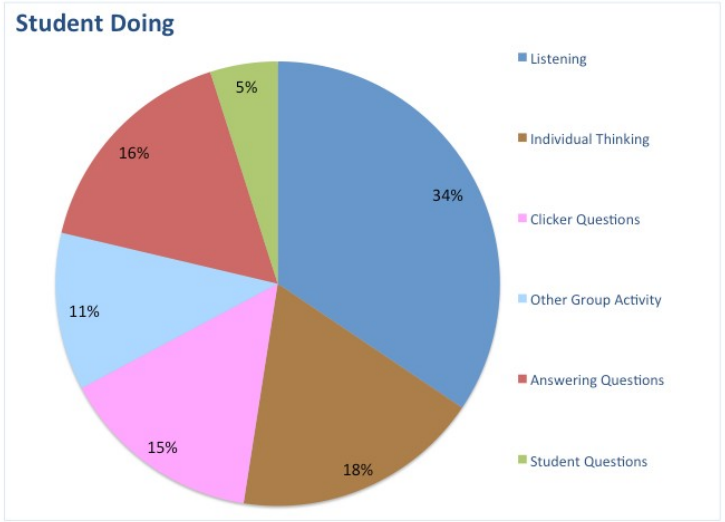
COPUS data from UA Calc-Physics Course Reforms

Professor #1 Traditional

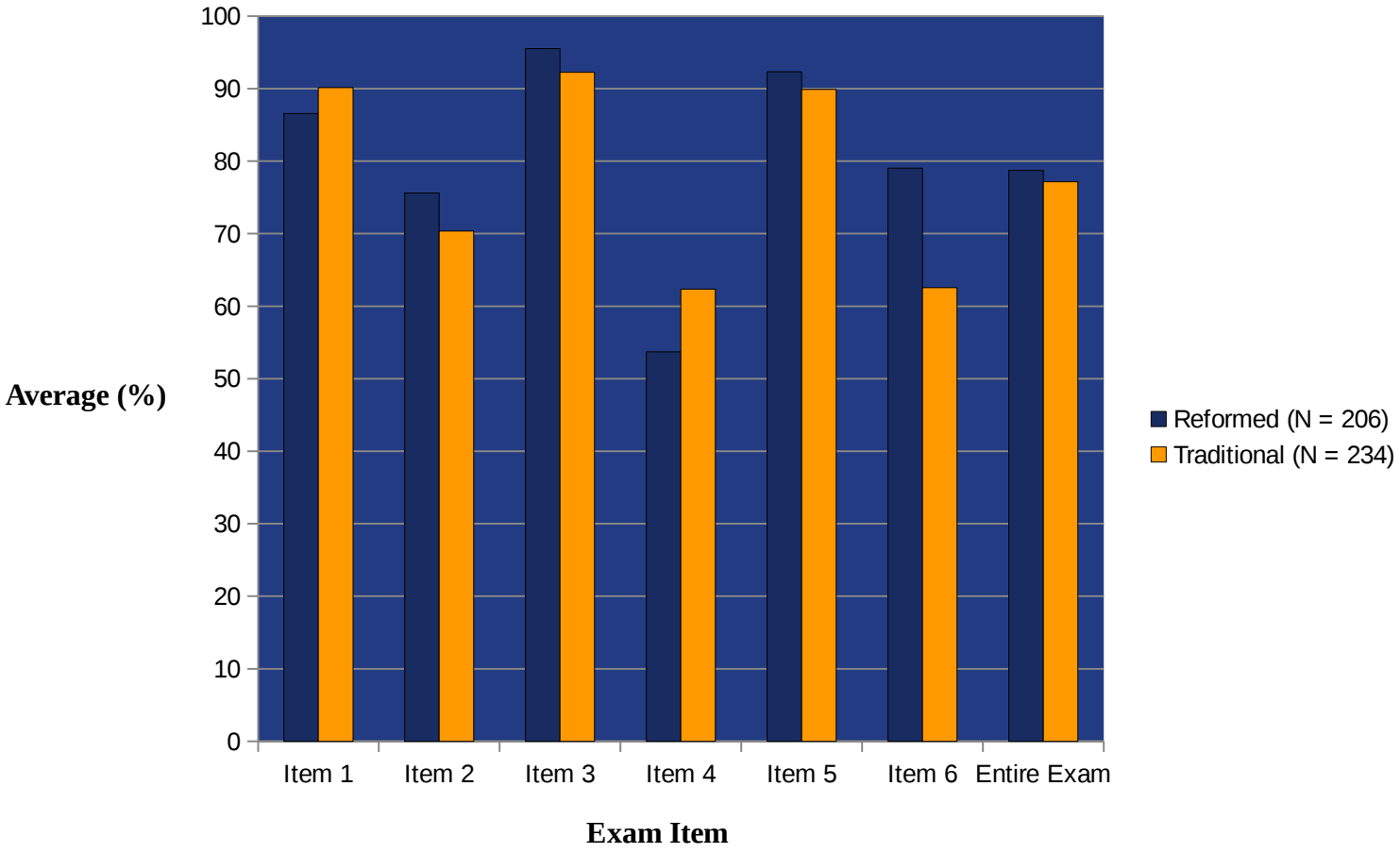




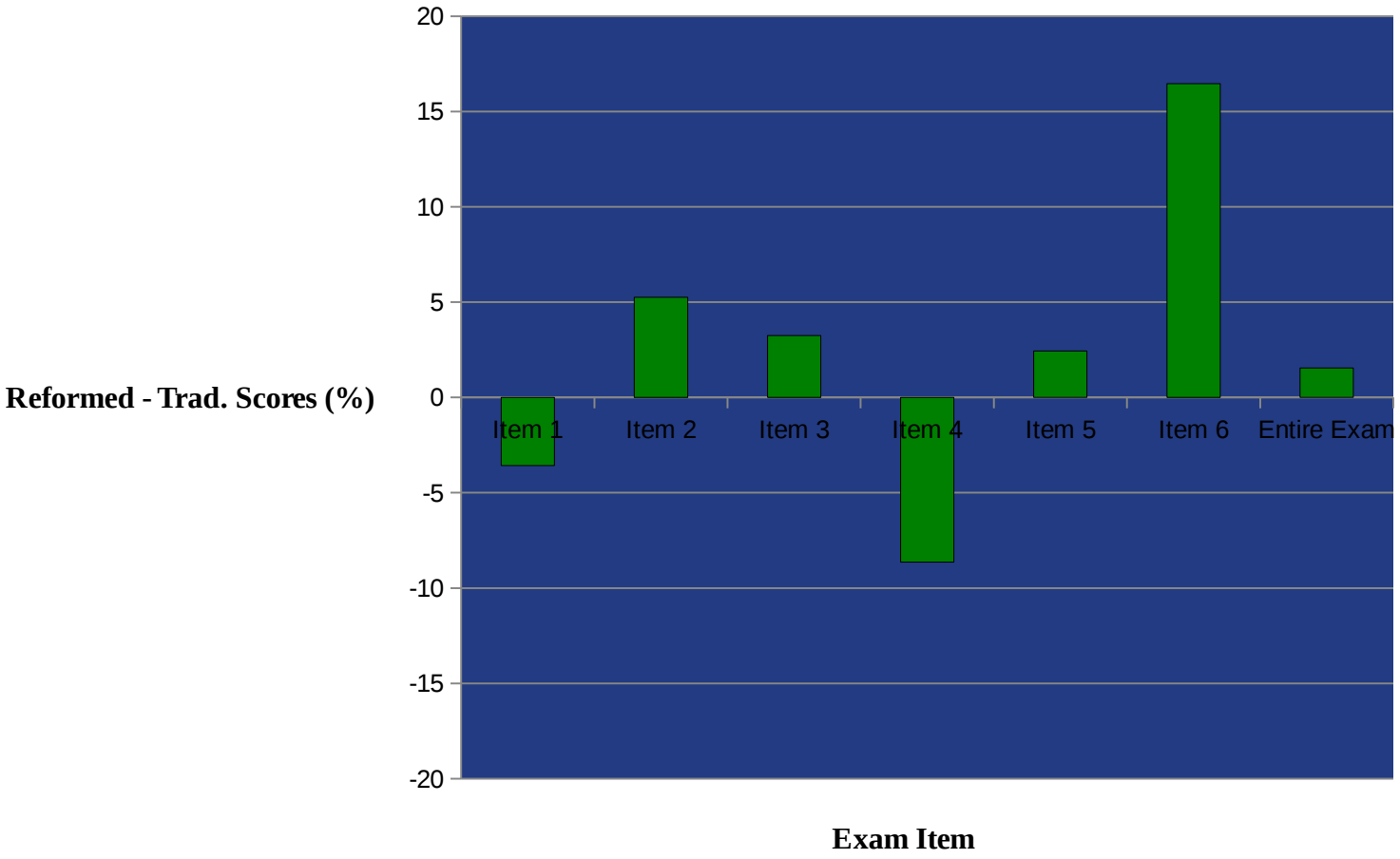
Professor #2 Reformed



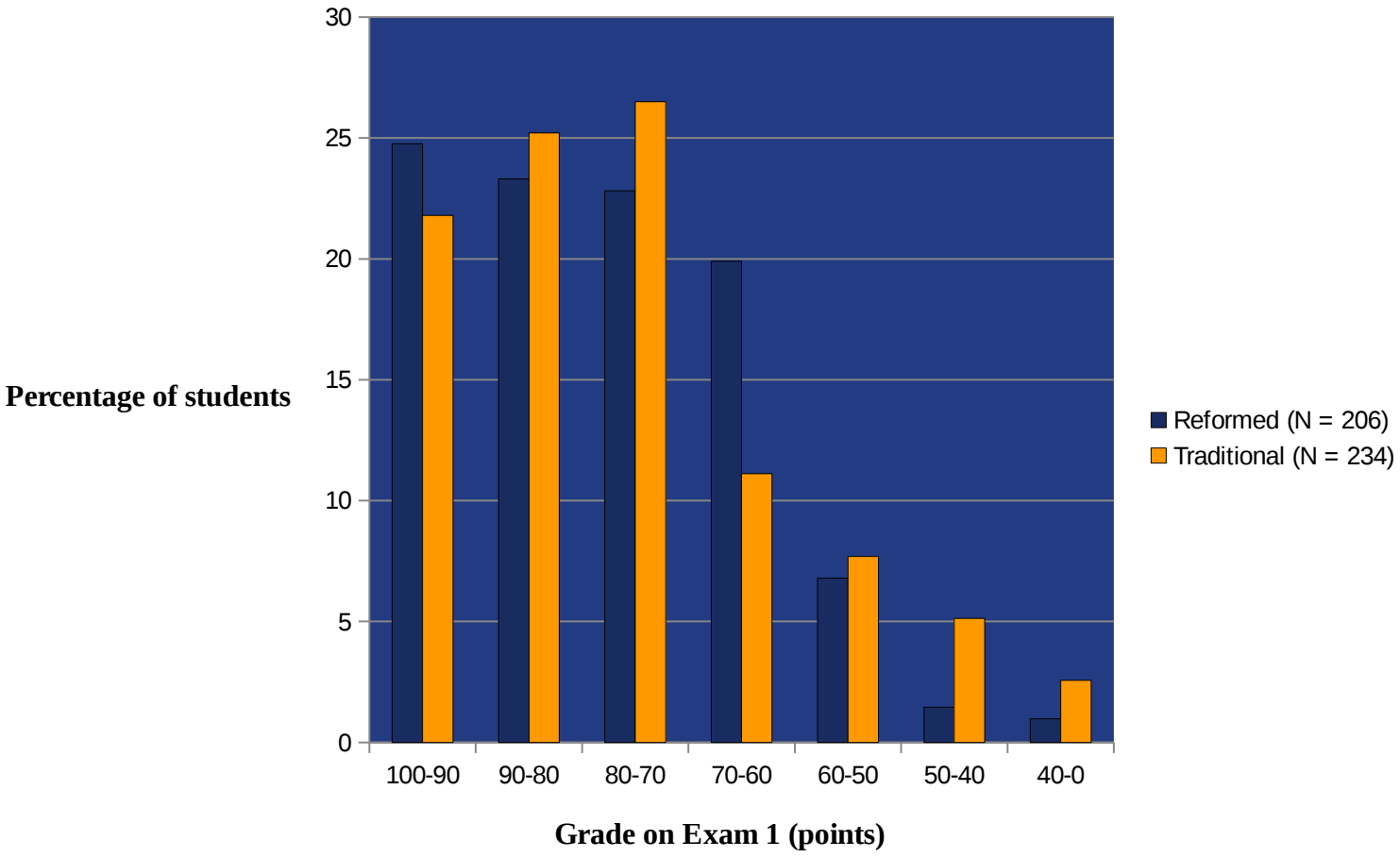
Exam 1


Average (%)
100
90
80
70
60
50
40
30
20
10
0
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item
Reformed (N = 206)
Traditional (N = 234)

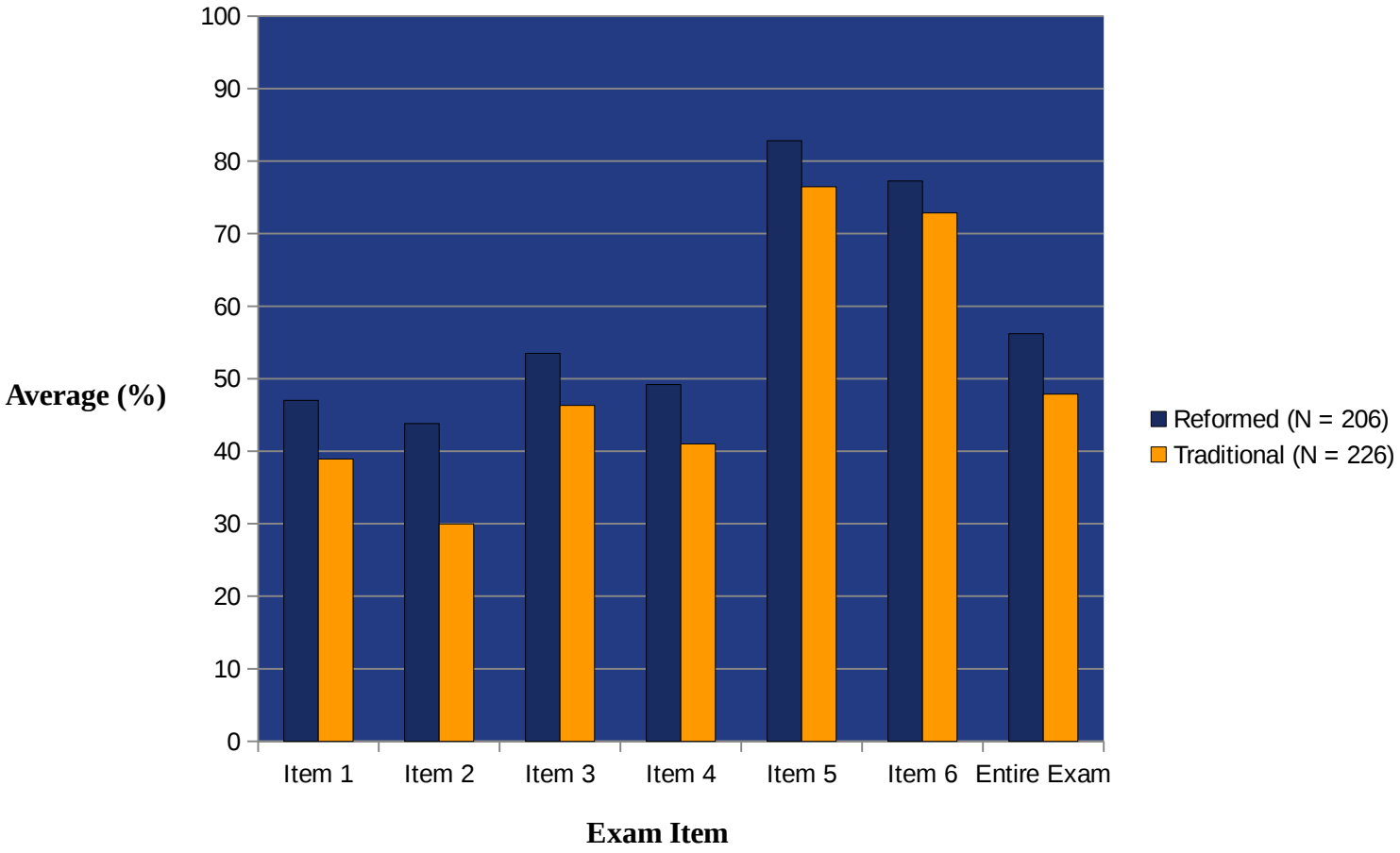
Exam 1


Reformed - Trad. Scores (%)
20
15
10
5
0
-5
-10
-15
-20
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item

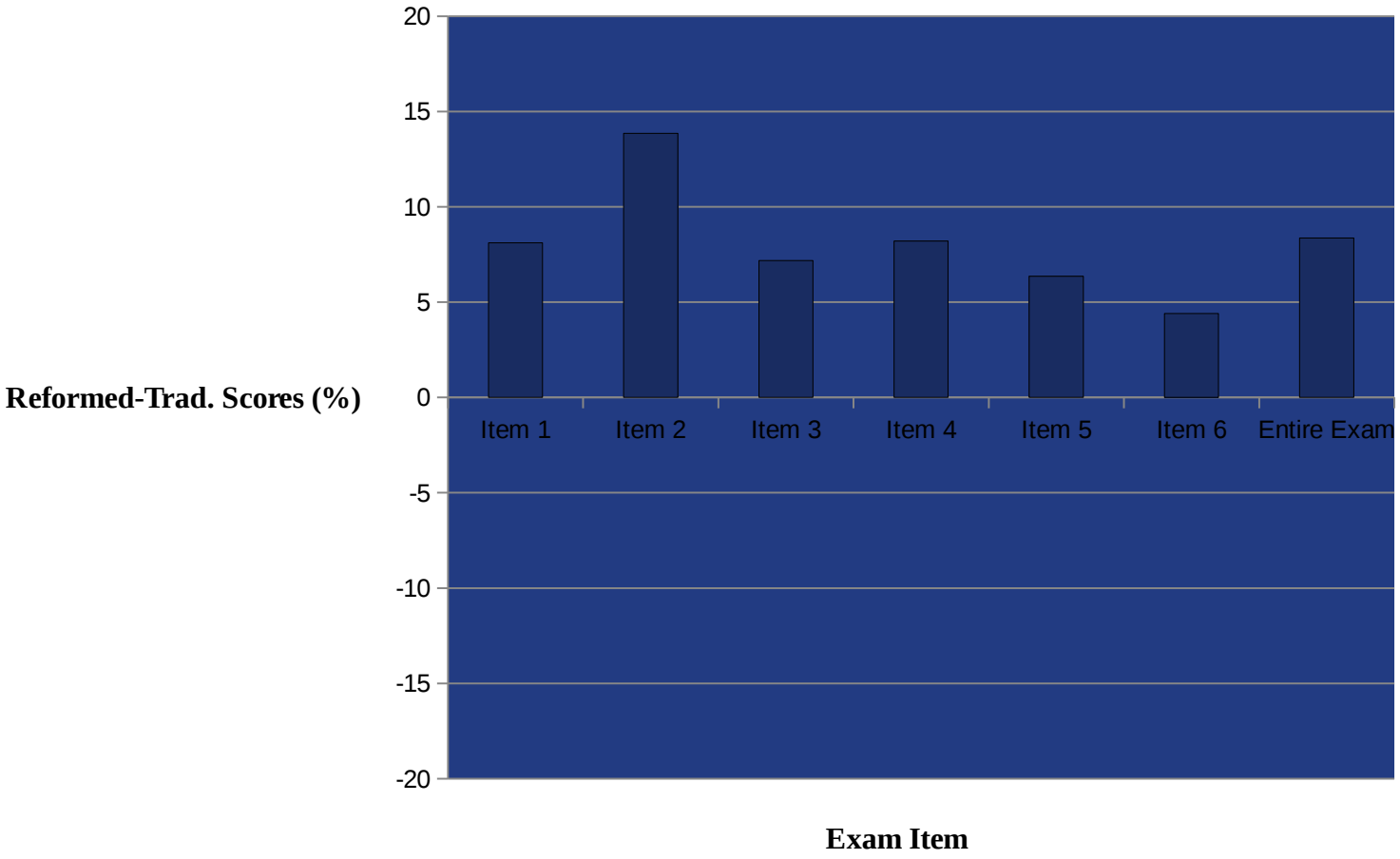
Exam 1


Percentage of students
30
25
20
15
10
5
0
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Reformed (N = 206)
Traditional (N = 234)
Grade on Exam 1 (points)

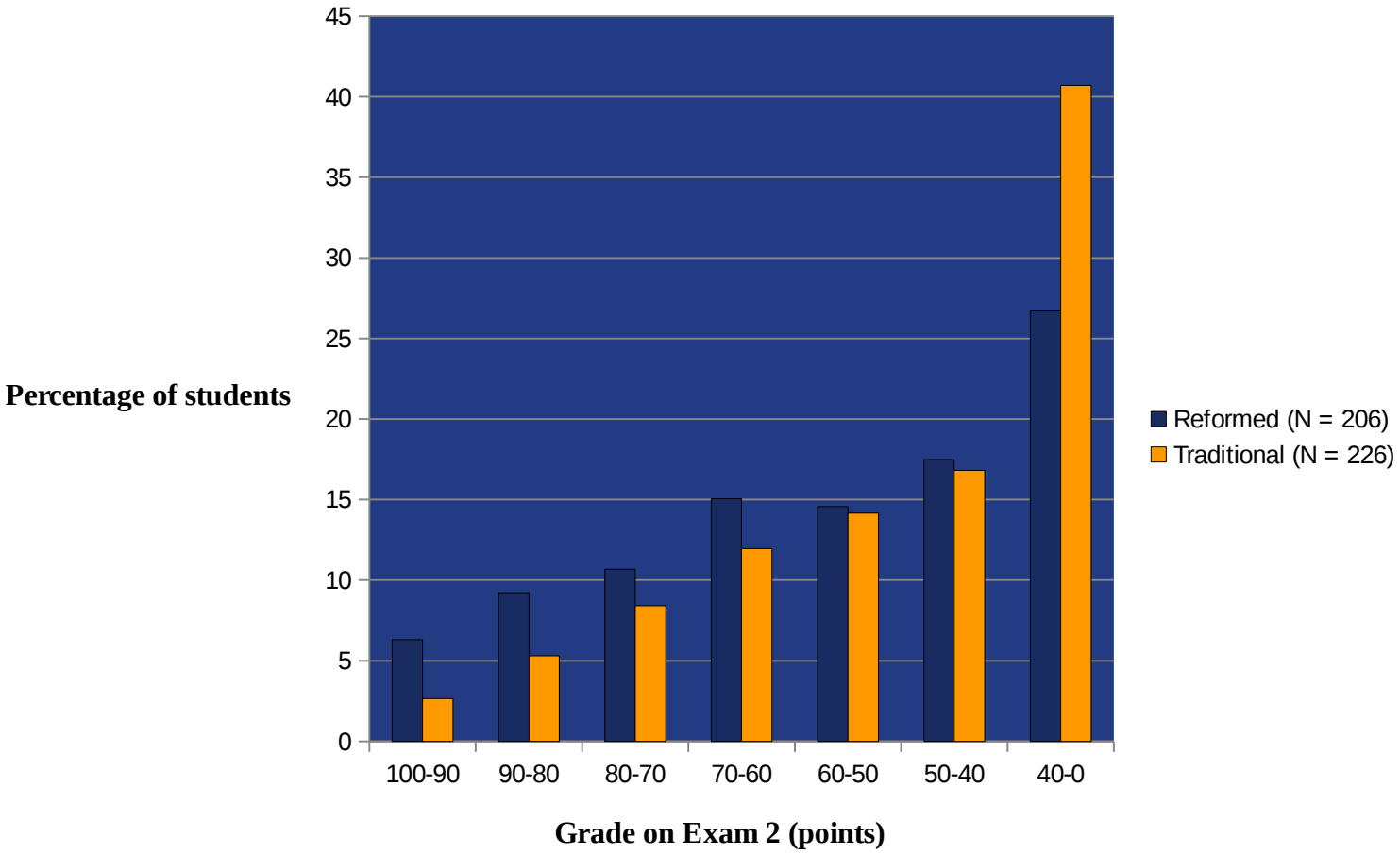
Exam 2


Average (%)
100
90
80
70
60
50
40
30
20
10
0
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item
Reformed (N = 206)
Traditional (N = 226)

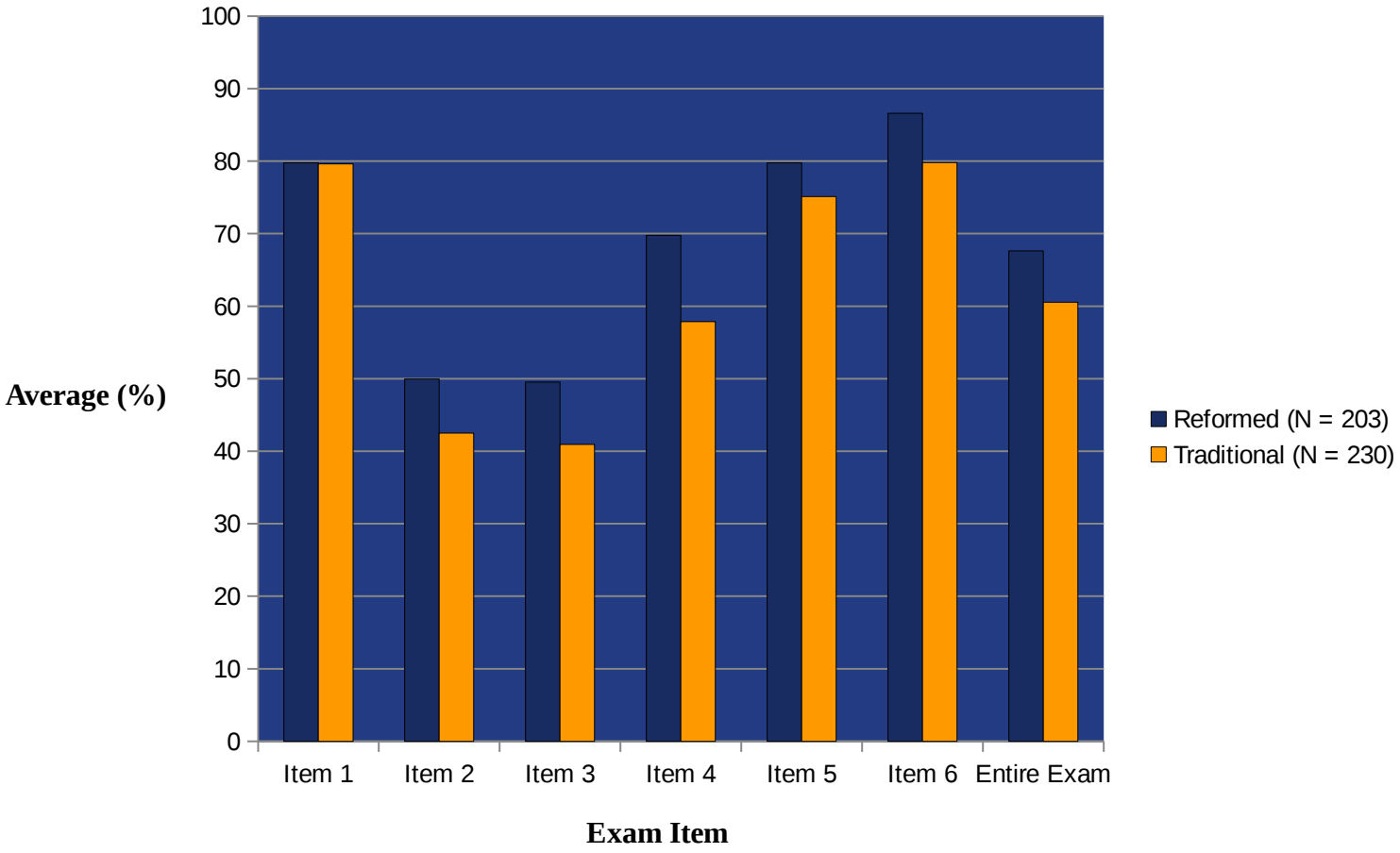
Exam 2


Reformed-Trad. Scores (%)
20
15
10
5
0
-5
-10
-15
-20
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item

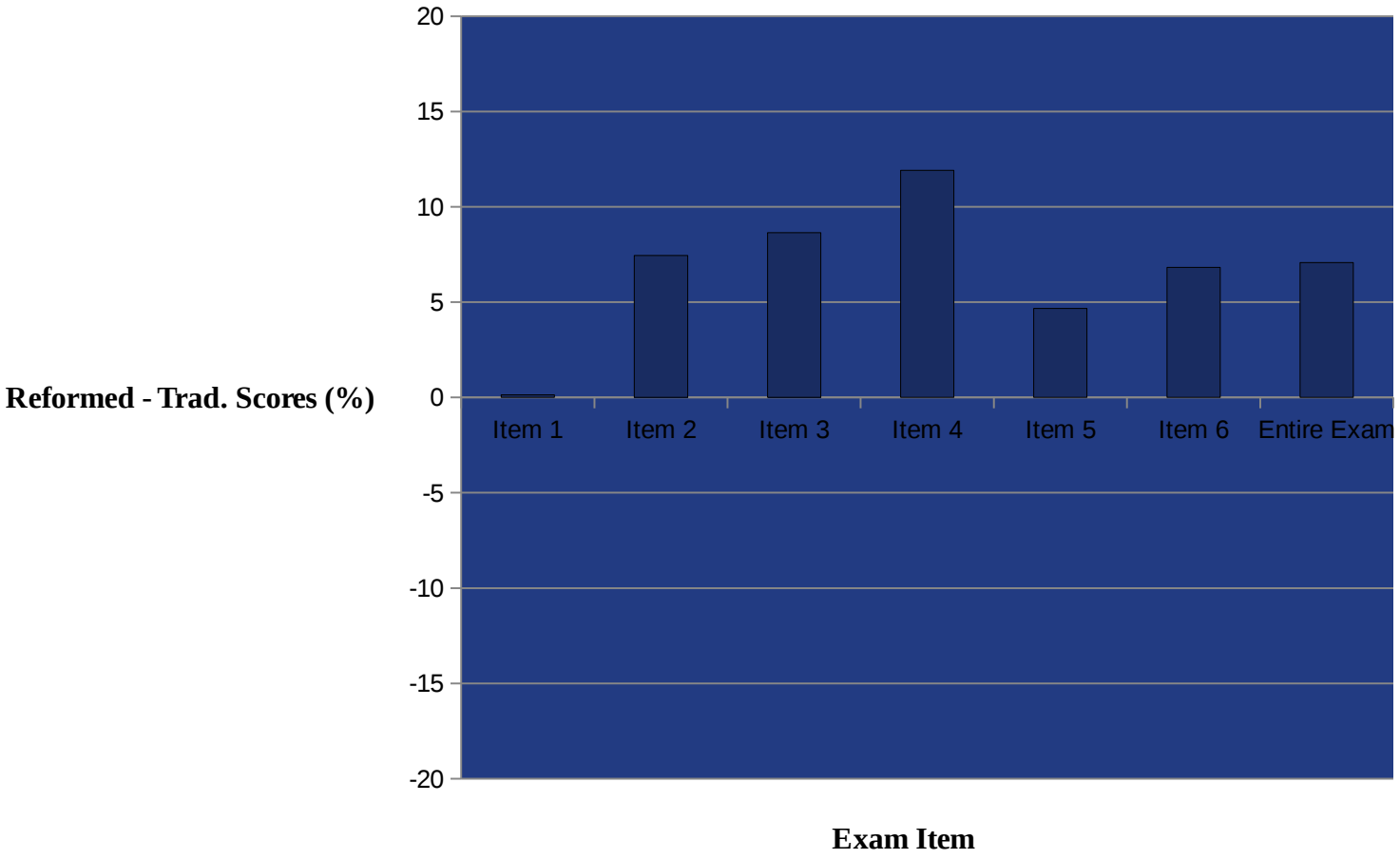
Exam 2


Percentage of students
45
40
35
30
25
20
15
10
5
0
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Reformed (N = 206)
Traditional (N = 226)
Grade on Exam 2 (points)

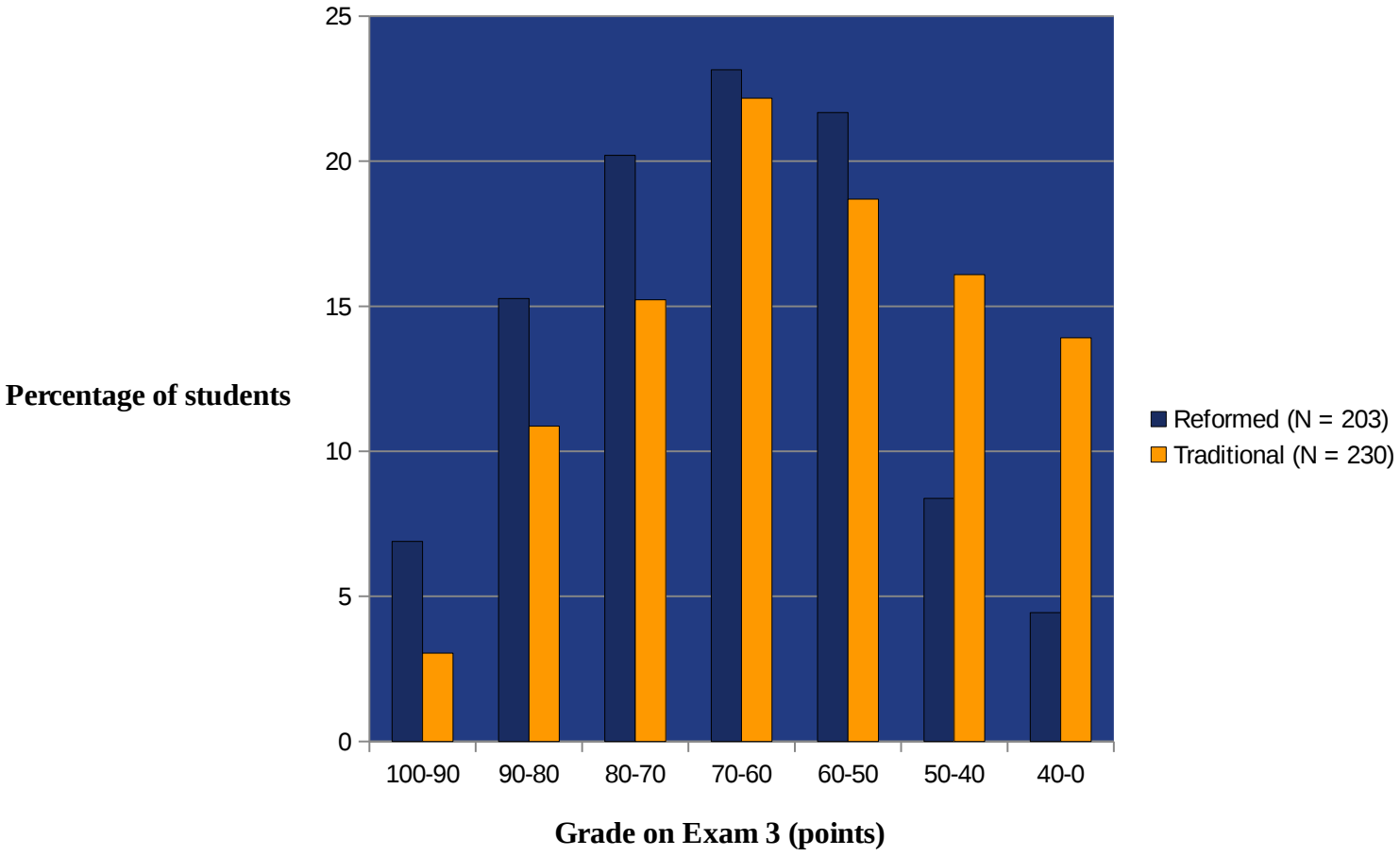
Exam 3


Average (%)
100
90
80
70
60
50
40
30
20
10
0
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item
Reformed (N = 203)
Traditional (N = 230)

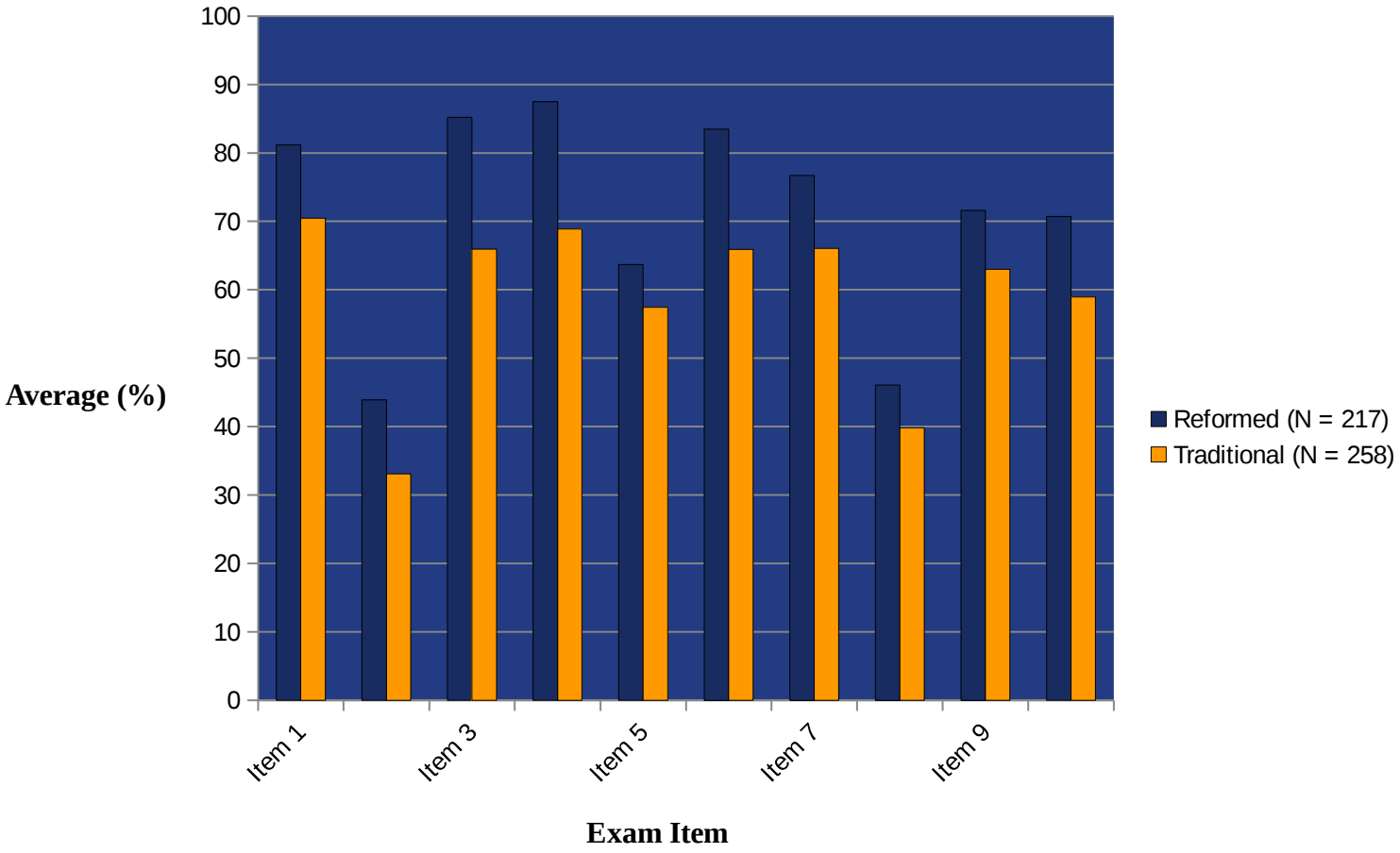
Exam 3


Reformed - Trad. Scores (%)
20
15
10
5
0
-5
-10
-15
-20
Item 1
Item 2
Item 3
Item 4
Item 5
Item 6
Entire Exam
Exam Item

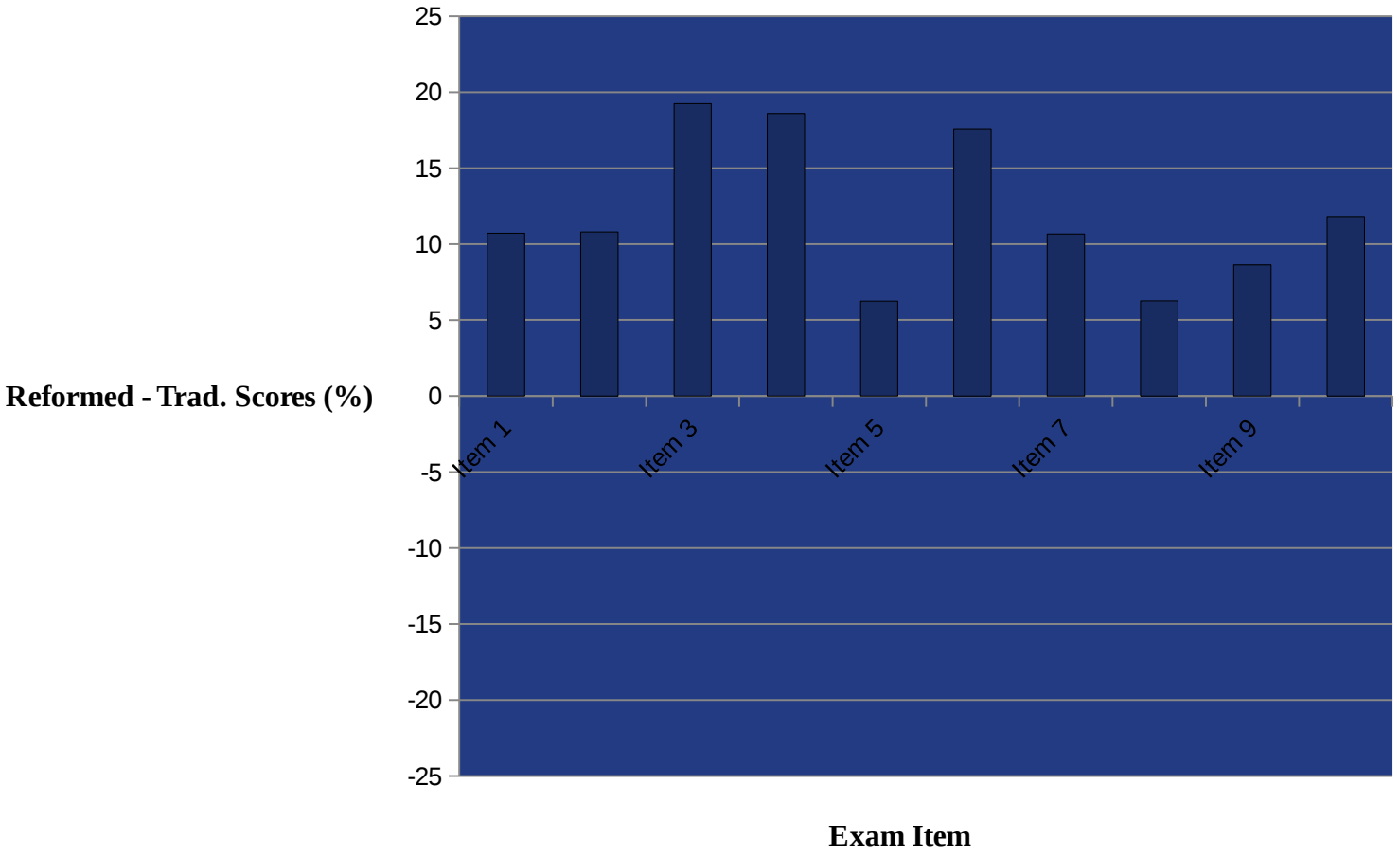
Exam 3


Percentage of students
25
20
15
10
5
0
100-90
90-80
80-70
70-60
60-50
50-40
40-0
Reformed (N = 203)
Traditional (N = 230)
Grade on Exam 3 (points)

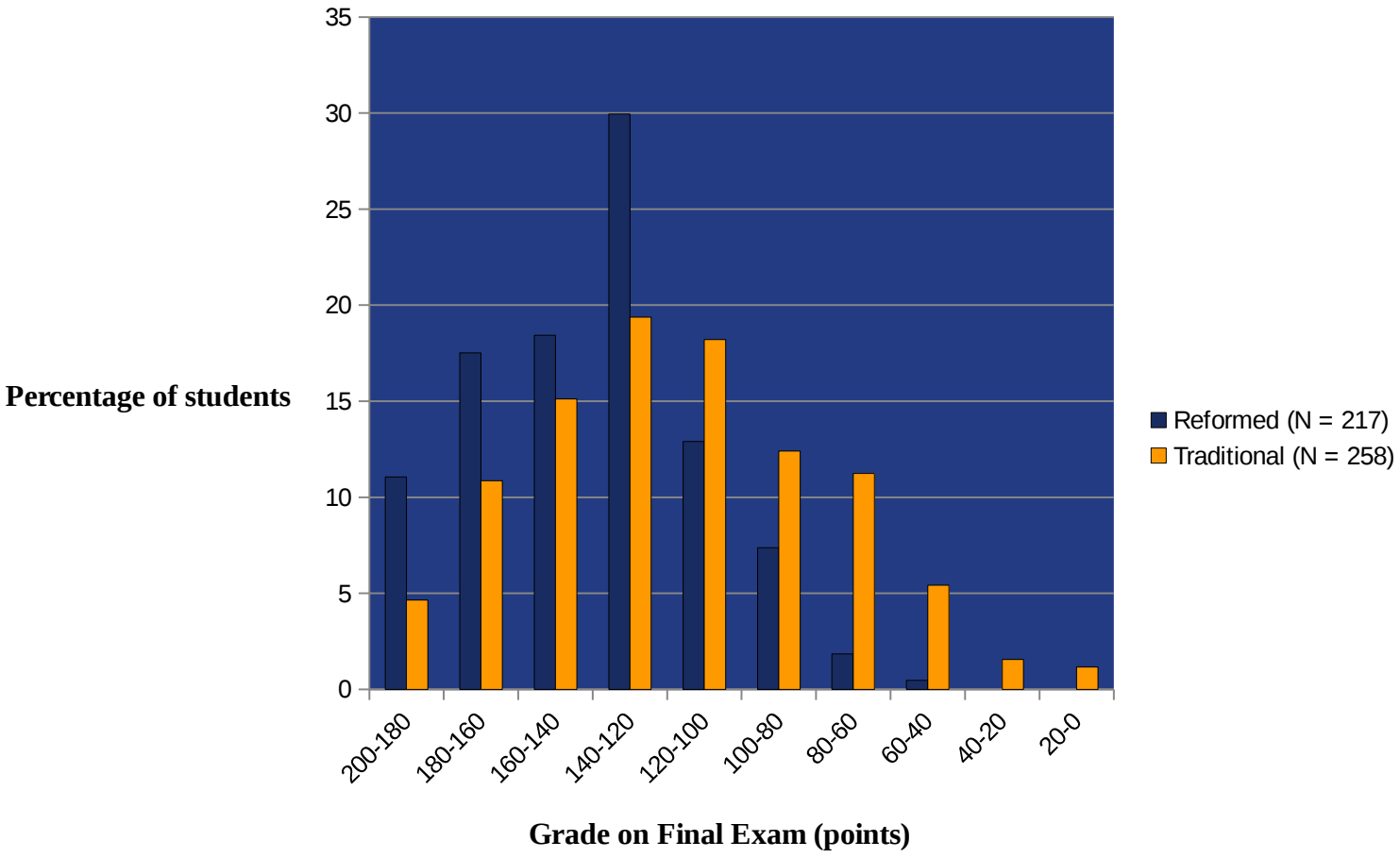
Final Exam


Average (%)
100
90
80
70
60
50
40
30
20
10
0
Item 1
Item 3
Item 5
Item 7
Item 9
Exam Item
Reformed (N = 217)
Traditional (N = 258)

Final Exam


Reformed - Trad. Scores (%)
25
20
15
10
5
0
-5
-10
-15
-20
-25
Item 1
Item 3
Item 5
Item 7
Item 9
Exam Item

Final Exam


Percentage of students
35
30
25
20
15
10
5
0
200-180
180-160
160-140
140-120
120-100
100-80
80-60
60-40
40-20
20-0
Reformed (N = 217)
Traditional (N = 258)
Grade on Final Exam (points)

astro101: Workshops

astronomy101.jpl.nasa.gov/workshops/

Reader

Google Images | untitled folder | Apple | Yahoo! | Google Maps | YouTube | Wikipedia | News | Favorites | Popular

Jet Propulsion Laboratory
California Institute of Technology

JPL HOME | EARTH | SOLAR SYSTEM | STARS & GALAXIES | SCIENCE & TECHNOLOGY

BRING THE UNIVERSE TO YOU: JPL Email News | RSS | Podcast | Video

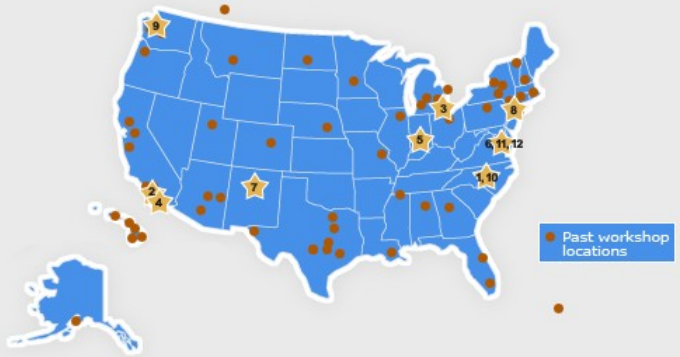
CAE
Center for Astronomy Education

Dedicated to the professional development of introductory astronomy instructors

Workshops

Teaching Excellence Workshops

Workshops Locations
Click a location to register for a specific workshop



Fall/Winter 2012/13

1. Jamestown, North Carolina
   Regional Teaching Exchange
   Planning Meeting
   October 6, 2012
2. Long Beach, California
   Tier I,CATS
   January 5-6, 2013

Spring/Summer 2013

3. Dearborn, Michigan
   Regional Teaching Exchange
   April 20, 2013
4. Oceanside, California
   Regional Teaching Exchange
   May 4, 2013
5. Indianapolis, Indiana
   Tier I,CATS
   June 1-2, 2013
6. College Park, Maryland
   New Faculty Workshop
   June 17-20, 2013
7. Albuquerque, New Mexico
   Tier I,CATS
   August 24-25, 2013

Fall/Winter 2013/14

8. New Paltz, New York
   Regional Teaching Exchange
   September, 2013
9. Seattle, Washington
   Regional Teaching Exchange
   September or October TBD, 2013
10. Jamestown, North Carolina
    Regional Teaching Exchange
    October 4 (tentative), 2013
11. College Park, Maryland
    New Faculty Workshop
    November 7-10, 2013
12. National Harbor, Maryland
    Tier I,CATS
    January 4-5, 2014

Center