Interactive Engagement Strategies for ALL Classes

Dr. Edward Prather
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Collaboration of Astronomy Teaching Scholars
An NSF Funded Center for Astronomy Education (CAE) Program
Facilitating Active Learning – How to promote students’ intellectual engagement and critical problem solving in LECTURE!

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The University of Arizona, Department of Astronomy and Steward Observatory

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An NSF Funded Center for Astronomy Education (CAE) Program

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

Image of the Day: Solar System Science
Teaching Excellence Workshops

Workshops Locations
Click a location to register for a specific workshop

Fall/Winter 2010/11

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

Spring/Summer 2011

- New Paltz, NY
  - CATS Regional Teaching Exchange
  - March 26, 2011
- El Paso, TX
  - Tier I
  - April 15 - 16, 2011
- Seattle, WA
  - CATS Regional Teaching Exchange
  - April 18, 2011
- Boston, MA
  - Tier 1, CATS
  - May 21 & 22, 2011
- Boston, MA
  - Tier II, CATS, Special Topics
  - May 22, 2011

Fall/Winter 2011/12

- Austin, TX
  - Tier II, CATS
  - January 7-8, 2012
- Austin, TX
  - Tier II, CATS, Special Topics
  - January 8, 2012
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,*
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.

*adapted from “How People Learn”*

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 reinforce the memorization of facts and declarative knowledge?

Bloom’s Taxonomy of Educational Objectives

- evaluation
- synthesis
- analysis
- application
- comprehension
- declarative knowledge
Class Response System—Medium Tech

A  B
C  D
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
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.

Pedagogical content knowledge (PCK)

Understanding of the learners, their motivations/expectations, attitudes/beliefs, knowledge, abilities, and learning difficulties

Understanding of the complex classroom environment: resources, limitations, implementation issues, learning outcomes, etc.

Understanding and awareness of existing pedagogy, instructional strategies, assessment and evaluation tools, etc.

Understanding of the results from cognitive science, educational psychology, and discipline-based education research

Understanding of your discipline

Understanding and awareness of existing pedagogy, instructional strategies, assessment and evaluation tools, etc.

Understanding of the complex classroom environment: resources, limitations, implementation issues, learning outcomes, etc.

Understanding of the learners, their motivations/expectations, attitudes/beliefs, knowledge, abilities, and learning difficulties

Understanding of your discipline

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Understanding of your discipline
Eventually, Billy came to dread his father’s lectures over all other forms of punishment.

“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
How many of these are in...

...one of these?
Rank the different methods for finding extrasolar planets from most successful to least.
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.

...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?
Amount of Doppler shift in Star’s light

\[ \approx \frac{M_p}{\sqrt{(M_s \times d)}} \]
Amount of Doppler shift in Star’s light

\[ \approx \sqrt{M_s \times d} \]
Amount of Doppler shift in Star’s light

\[ \text{Approximately} \quad \frac{M_p}{\sqrt{M_s \times d}} \]
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.

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

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• Student Debates (individual/group)
• Whole Class Discussions
“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.

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

( N ~ 100 )

Percent Correct

32% 61% 77%

Pretest Post-Lecture Post-Ranking Tasks

Post-Ranking Task:
Hake’s Normalized Gain = 0.41 ("moderately large effect")
Cohen’s d = 0.62 ("Large effect")

Ranking Tasks: Gender Effect?

Ranking Tasks benefited both groups equally.

(N ~ 100)
Ranking Tasks: High vs. Low Pretests Groups?

( N ~ 100 )

Percent Correct

Pretest  Post-Lecture  Post-Ranking Tasks

Upper Median Group

11%  64%  76%

Lower Median Group

55%  59%  76%

Ranking Tasks benefited both groups equally.
Results from a 6000 student study of Physics Students – *Hake AJP 1998*

\[ g > 0.7 \quad \text{"High"} \]

\[ g = \frac{\text{post}\% - \text{pre}\%}{100\% - \text{pre}\%} \]

- Interactive Engagement
- Traditional

\[ 0.3 < g < 0.7 \quad \text{"Medium"} \]

\[ g < 0.3 \quad \text{"Low"} \]

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
\[ <g> = \frac{<\text{post}\%> - <\text{pre}\%>}{100\% - <\text{pre}\%>} \]
\[ <g> = \frac{<\text{post}\%>- <\text{pre}\%>}{100\%- <\text{pre}\%>} \]
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.
Lower IAS (<25%)  
<\text{avg} = 0.13

Higher IAS (>25%)  
<\text{avg} = 0.29

Interactive Assessment Score (%)
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
<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Coefficients 1 Standardized Coefficients</th>
<th>Coefficients 2 Standardized Coefficients</th>
<th>Coefficients 3 Standardized Coefficients</th>
<th>Coefficients 4 Standardized Coefficients</th>
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<tbody>
<tr>
<td>Constant</td>
<td>-0.070</td>
<td>-0.235**</td>
<td>-0.266*</td>
<td>-0.206**</td>
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<td></td>
<td>(0.036)</td>
<td>(0.130)</td>
<td>(0.041)</td>
<td>(0.036)</td>
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<td>Male</td>
<td>0.093**</td>
<td>0.183**</td>
<td>0.087**</td>
<td>0.170**</td>
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<td>(0.016)</td>
<td>(0.015)</td>
<td>(0.015)</td>
<td>(0.015)</td>
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<td>White</td>
<td>0.019</td>
<td>0.013</td>
<td>0.019</td>
<td>0.006</td>
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<td></td>
<td>(0.029)</td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.020)</td>
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<td>Native English speaker</td>
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<td>0.015</td>
<td>0.011</td>
<td>0.013</td>
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<tr>
<td></td>
<td>(0.029)</td>
<td>(0.020)</td>
<td>(0.020)</td>
<td>(0.020)</td>
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<tr>
<td>Father with Bachelor's degree or higher</td>
<td>0.008</td>
<td>0.015</td>
<td>0.002</td>
<td>0.006</td>
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<td></td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td>(0.014)</td>
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<tr>
<td>Natural log of Family Income</td>
<td>0.002</td>
<td>0.008</td>
<td>0.002</td>
<td>0.003</td>
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<td>(0.010)</td>
<td>(0.008)</td>
<td>(0.008)</td>
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<td>Class year</td>
<td>0.018*</td>
<td>0.073*</td>
<td>0.024**</td>
<td>0.092**</td>
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<td>(0.036)</td>
<td>(0.036)</td>
<td>(0.036)</td>
<td>(0.036)</td>
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<tr>
<td>College GPA</td>
<td>0.036**</td>
<td>0.106**</td>
<td>0.037**</td>
<td>0.109**</td>
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<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.010)</td>
<td>(0.010)</td>
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<td>Arts, Humanities, or Social Science major</td>
<td>0.101**</td>
<td>0.176**</td>
<td>0.194**</td>
<td>0.181**</td>
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<tr>
<td></td>
<td>(0.018)</td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.017)</td>
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<tr>
<td>Last math class taken</td>
<td>0.031**</td>
<td>0.214**</td>
<td>0.054**</td>
<td>0.230**</td>
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<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
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<tr>
<td>Number of previous physical science course</td>
<td>0.044**</td>
<td>0.338**</td>
<td>0.024**</td>
<td>0.320**</td>
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<td></td>
<td>(0.006)</td>
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<td>(0.006)</td>
<td>(0.006)</td>
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<tr>
<td>Previous Astrophysics course</td>
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<td>-0.039</td>
<td>-0.028</td>
<td>-0.031</td>
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<td></td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.022)</td>
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<tr>
<td>Pretend Percent Correct</td>
<td>-0.005**</td>
<td>-0.224**</td>
<td>-0.005**</td>
<td>-0.213**</td>
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<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td>(0.001)</td>
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<tr>
<td>Interactivity Score</td>
<td>0.0051**</td>
<td>0.258**</td>
<td>0.0062</td>
<td>0.214**</td>
</tr>
<tr>
<td></td>
<td>(0.0006)</td>
<td>(0.0006)</td>
<td>(0.0006)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Cross term: Interactivity score X Arts,</td>
<td>0.0092*</td>
<td>0.183*</td>
<td>0.0092*</td>
<td>0.183*</td>
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<tr>
<td>Humanities, Soc Sci Major</td>
<td>(0.0003)</td>
<td>(0.0033)</td>
<td>(0.0003)</td>
<td>(0.0033)</td>
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<td>Cross term: Interactivity score X Male</td>
<td>0.0001</td>
<td>0.004</td>
<td>0.0001</td>
<td>0.004</td>
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<tr>
<td>Cross term: Interactivity score X White</td>
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<td>-0.044</td>
<td>-0.0006</td>
<td>-0.044</td>
</tr>
<tr>
<td>Cross term: Interactivity score X Native</td>
<td>0.0022</td>
<td>0.129</td>
<td>0.0022</td>
<td>0.129</td>
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<tr>
<td>English speaker</td>
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<td>(0.007)</td>
<td>(0.007)</td>
<td>(0.007)</td>
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<td>Cross term: Interactivity score X College</td>
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<td>-0.182</td>
<td>-0.0030</td>
<td>-0.182</td>
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<td>GPA</td>
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<td>(0.0006)</td>
<td>(0.0006)</td>
<td>(0.0006)</td>
</tr>
<tr>
<td>Cross term: Interactivity score X Last</td>
<td>-0.0002</td>
<td>-0.057</td>
<td>-0.0002</td>
<td>-0.057</td>
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<td>math class taken</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
<td>(0.0004)</td>
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<tr>
<td>Cross term: Interactivity score X Number</td>
<td>0.0001</td>
<td>0.016</td>
<td>0.0001</td>
<td>0.016</td>
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<tr>
<td>of previous physical science courses</td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.0005)</td>
<td>(0.0005)</td>
</tr>
<tr>
<td>F Value</td>
<td>18.2**</td>
<td>24.3**</td>
<td>26.2**</td>
<td>23.0**</td>
</tr>
<tr>
<td>N</td>
<td>910</td>
<td>910</td>
<td>910</td>
<td>910</td>
</tr>
<tr>
<td>Adjusted R-Square</td>
<td>0.383</td>
<td>0.250</td>
<td>0.250</td>
<td>0.253</td>
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</tbody>
</table>

* 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

- **X-axis (Ability)**: The ability level ranges from -5 to 5.
- **Y-axis (Number)**: The number of occurrences.
- **Bars**:
  - Pre: Represented in blue.
  - Post: Represented in orange.

The histogram shows the distribution of ability levels before and after an event or intervention.
Single Course Ability Histogram

![Graph showing distribution of abilities pre and post course]
Ambassadors – of science in our society, our nation's future leaders
Mega Course Ability Histogram

Number

Ability

Pre
Post
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

**Instructor Doing (50-min. class)**

- Lecturing: 16%
- Follow Up to Activity: 12%
- Posing Questions: 13%
- Polling Question: 3%
- Answering Questions: 21%
- Moving/Listening to Groups: 10%
- Moving/Guiding Groups: 22%
- Administrative Tasks: 10%

**Students Doing (50-min. class)**

- Listening: 29%
- Individual Thinking: 14%
- Clicker Questions: 12%
- Other Group Activity: 16%
- Answering Questions: 4%
- Student Questions: 15%
- Making Predictions: 10%
Exam 1

- **Grade on Exam 1 (points)**
  - 100-90
  - 90-80
  - 80-70
  - 70-60
  - 60-50
  - 50-40
  - 40-0

- **Percentage of students**

- **Reformed (N = 206)**
- **Traditional (N = 234)**

The bar chart shows the distribution of grades for Exam 1 between two teaching methods: Reformed and Traditional. The number of students in each grade range is indicated by the height of the bars.
Exam 2

Percentage of students

Grade on Exam 2 (points)

Reformed (N = 206)
Traditional (N = 226)
Exam 3

Reformed - Trad. Scores (%)

Exam Item

- Item 1
- Item 2
- Item 3
- Item 4
- Item 5
- Item 6
- Entire Exam
Exam 3

Percentage of students

Grade on Exam 3 (points)

Reformed (N = 203)

Traditional (N = 230)
Final Exam

Reformed - Trad. Scores (%)

Exam Item

-25.00 -20.00 -15.00 -10.00 -5.00 0.00 5.00 10.00 15.00 20.00 25.00

Item 1 Item 2 Item 3 Item 4 Item 5 Item 6 Item 7 Item 8 Item 9 Entire Exam