Active Learning in Introductory Physics: Assessing the Benefits

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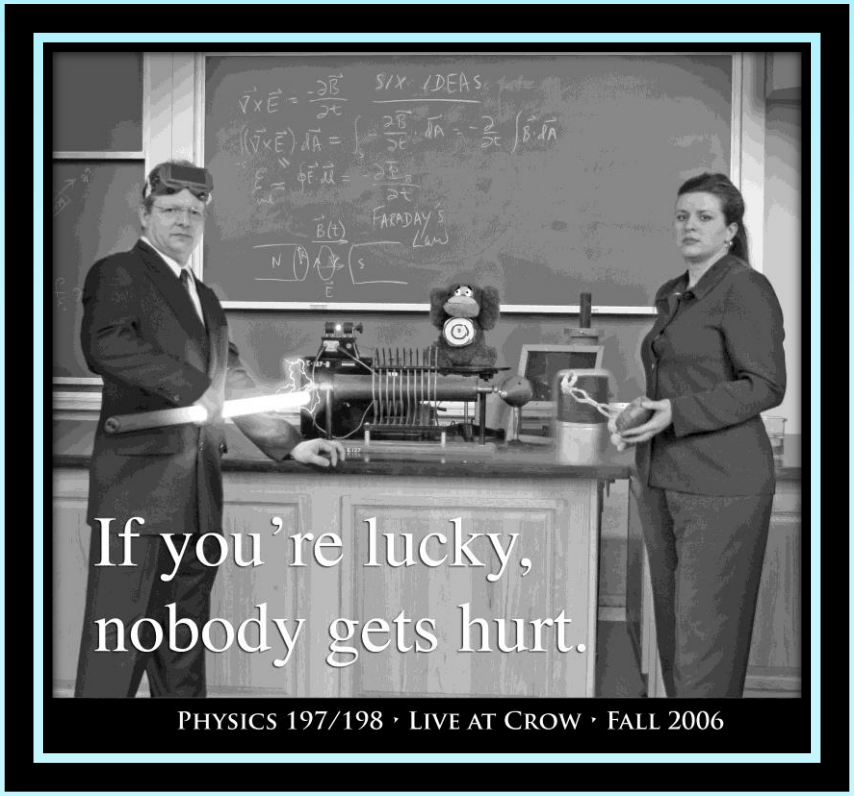


Intro Physics Background

- From time immemorial – Fall 2003: Traditional(Lecture) Physics (Physics 117/118) is only offering for intro physics at WU

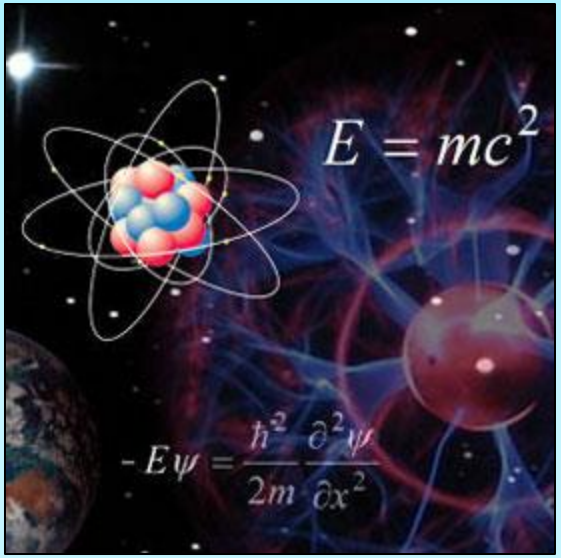
- Fall 2004: Active Physics (Physics 197/198) introduced as an alternative to Traditional Physics
  - Geared towards students with an interest in physics (e.g., majors, minors)
  - 3 sections of Traditional Physics (87% of physics students)
  - 1 section of Active Physics (13% of physics students)

- Fall 2006 – Fall 2010: Active Physics expands at the expense of Traditional Physics (roughly equal proportions in Fall 2010)

- Fall 2011 – Fall 2013: Active Physics dominates
  - 1 section of Traditional Physics (18.5 – 21.5% of physics students)
  - 5 sections of Active Physics (81.5 – 78.5% of physics students)
  - Planned 6th section for Fall 2014

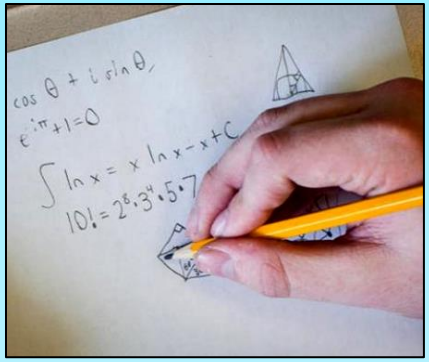
Traditional and Active Physics: The Similarities

- 4.0 credit calculus-based general introduction to physics
  - Taught by full-time faculty
  - Large class size (100 – 180 students)
- Cover comparable material
  - Minor differences in curriculum exist
- Three non-comprehensive exams
- Identical laboratory experiments
- Similar student demographics



Traditional and Active Physics: The Differences

- Preparation before class
  - Traditional: reading
  - Active: reading and homework

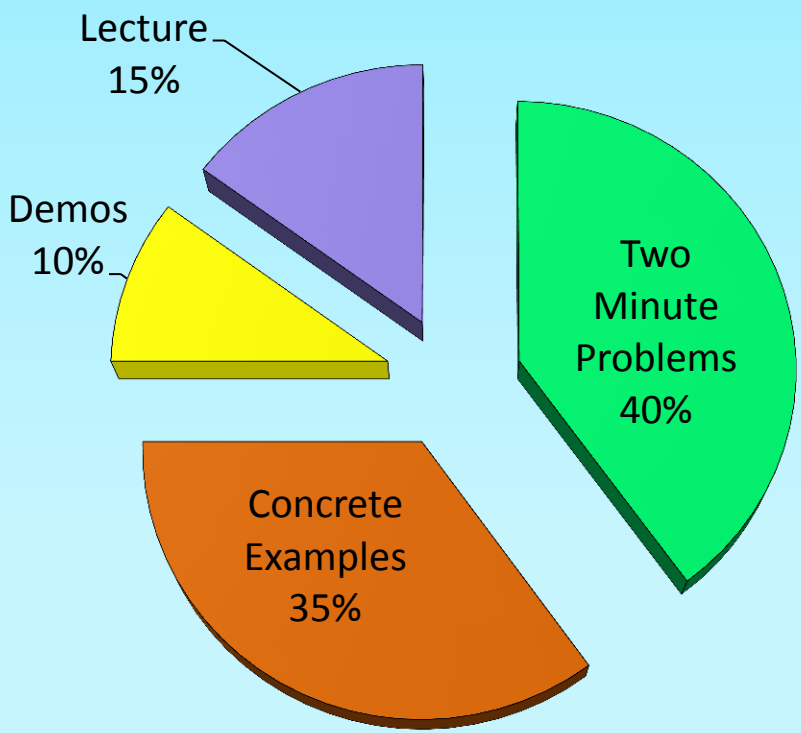


- Homework
  - Traditional: weekly assignment; no chance for revisions
  - Active: daily and weekly assignments; revisions accepted

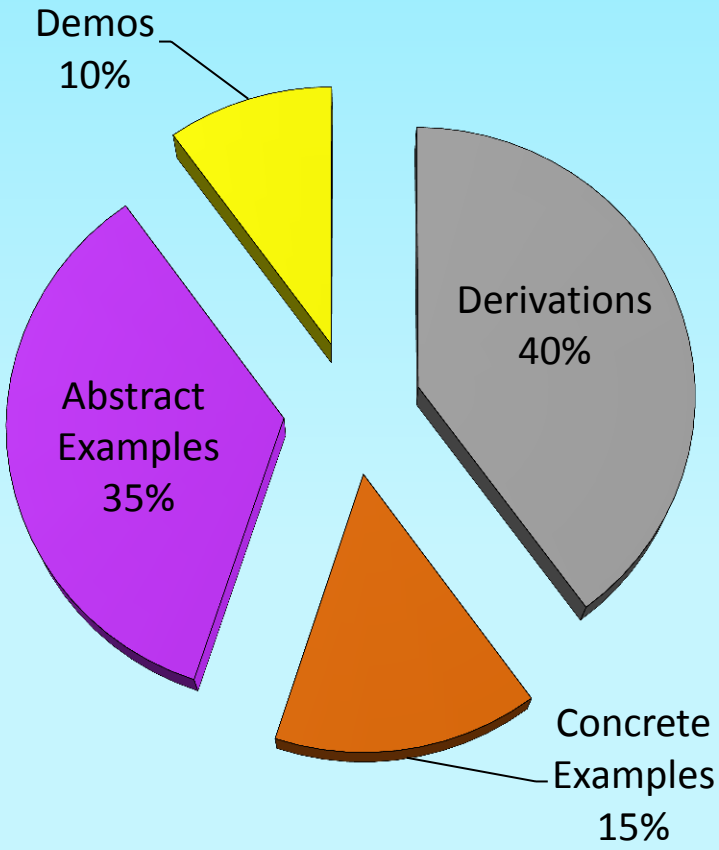
- Class structure
  - Traditional: lecture, derivations, some examples, demos
  - Active: concrete examples, small group discussion, demos, in-depth mini lectures

A Typical Class

Active Physics



Traditional Physics



Traditional and Active Physics: Major Emphases

- Traditional
  - Introduce the major ideas of intro physics
  - Develop strong problem-solving skills
  - Better understand the workings of the world around us

- Active
  - Introduce the major ideas of intro physics
  - Develop strong problem-solving skills
  - Better understand the workings of the world around us
  - Stress underlying conceptual ideas and problem-solving
  - Practice making approximations and order of magnitude estimates
  - Learn to “think like a physicist”

Two Minute Problem

- A boat carrying a large boulder floats on a lake. The boulder is thrown overboard and sinks.

  The water level in the lake (with respect to the shore)...

  A. rises.
  B. drops.
  C. remains the same.

The Explanation

- Archimedes Principle: an object floating in a liquid displaces a weight of fluid equal to its own

- A submerged object displaces a volume of fluid equal to its own

- Density = $\rho = \frac{\text{mass}}{\text{volume}}$

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- Density of water = $\rho_{water} = 1\ g/cm^3$

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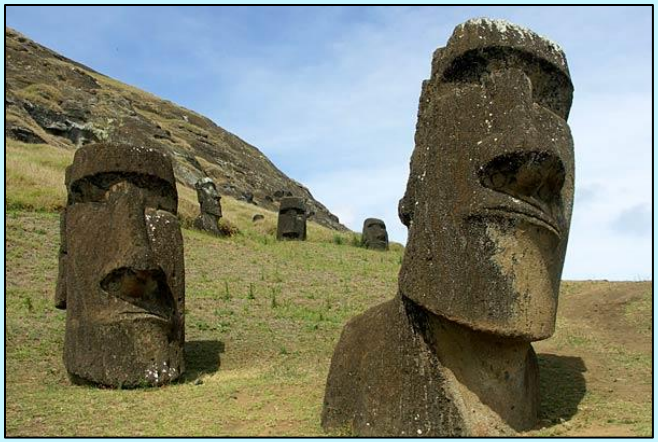


- Density of rock = $\rho_{rock} > 1\ g/cm^3$
- For the rock to sink: mass > volume

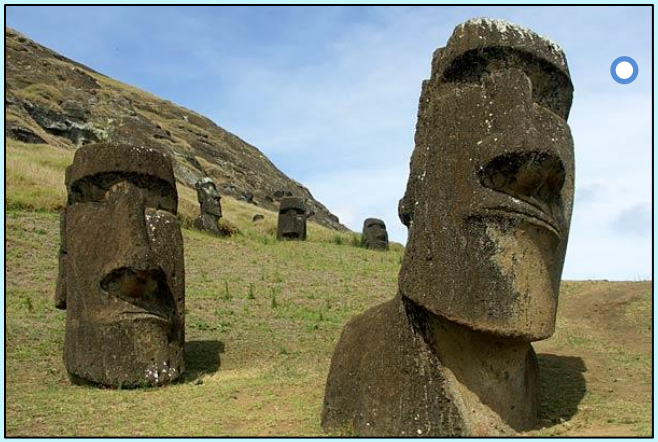
The Explanation

- Archimedes Principle: an object floating in a liquid displaces a weight of fluid equal to its own

- A submerged object displaces a volume of fluid equal to its own

- Density = $\rho = \frac{\text{mass}}{\text{volume}}$

The rock displaces more water while floating in the boat!



- Density of rock = $\rho_{rock} > 1\ g/cm^3$

- For the rock to sink: mass > volume

Study Motivation

- Overwhelming demand and very high student evaluations of Active Physics – what drives this demand?
- Is Active Physics actually more effective at helping students learn physics? Does it benefit males and females equally?
- Does emphasis on conceptual questions in Active Physics really increase conceptual understanding?
- Does Active Physics help raise student interest in physics?
- Does the effectiveness of Active Physics change with additional exposure?

Survey Logistics

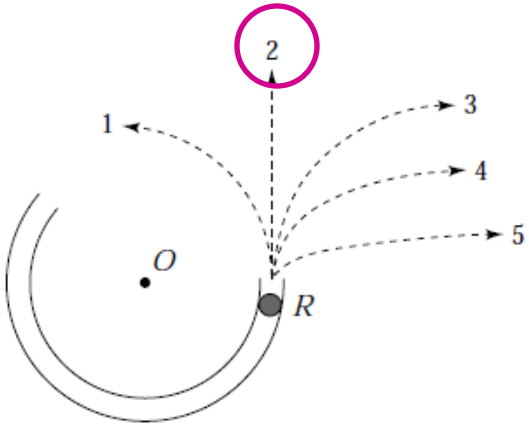
- Started in Fall 2009 and continued through present
  - Results presented here are from AY 2009, 2010, and 2011
- Students complete identical survey pre- and post-instruction surveys during Fall and Spring
  - Three components: demographics, attitudes, and problems
  - Completed online at home during a ~1 week window
- Voluntary participation from students
  - Extra credit in lab offered as an incentive
  - Raw participation rates of 50 – 76%
  - Fall only: N= 357 for Active; N = 763 for Traditional
  - Whole-Year: N = 250 for Active; N = 671 for Traditional

FCI Survey

- Force Concept Inventory
  - Developed by physicists at Arizona State University
  - Most widely-used instrument in physics education
- Used in Fall semesters only
- Consists of 30 multiple choice questions
  - Score proportional to number of correct answers
  - Assesses knowledge of Newtonian physics (~2/3 of fall semester for both courses)
  - Correct answer designed to be obvious to Newtonian thinkers with intuitive but non-Newtonian answers as alternate choices
  - False positives reduced by using multiple questions analyzing same situation

Sample FCI Questions

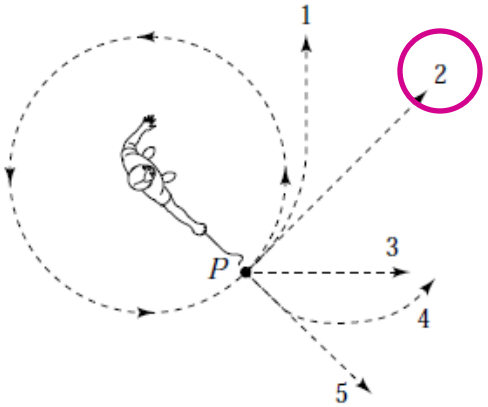
6. Which of the paths 1–5 below would the ball most closely follow after it exits the channel at R and moves across the frictionless table top?



7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the figure below.

At point P, the string suddenly breaks near the ball.

If these events are observed from directly above, which of the paths 1–5 below would the ball most closely follow after the string breaks?

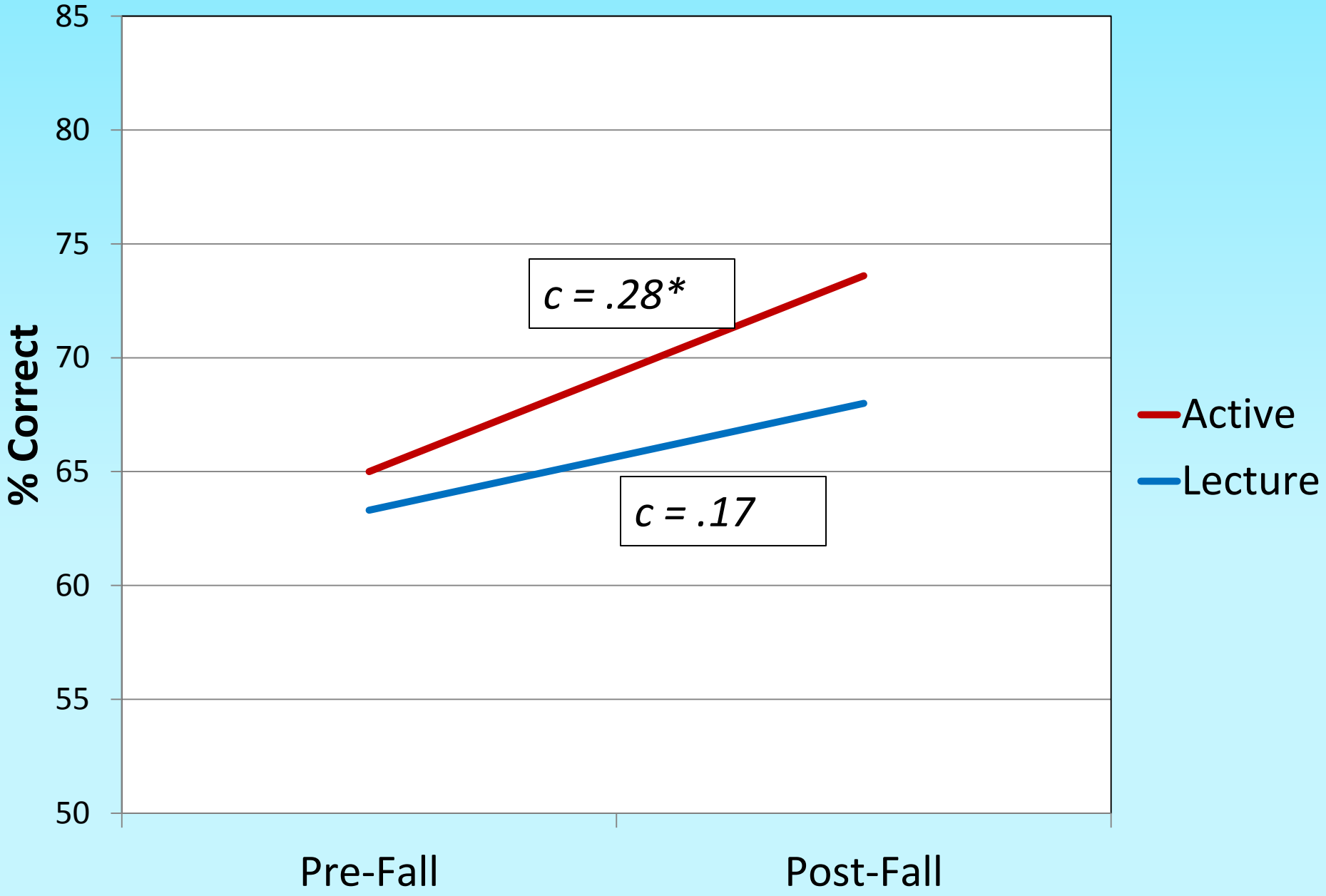


Scoring the FCI

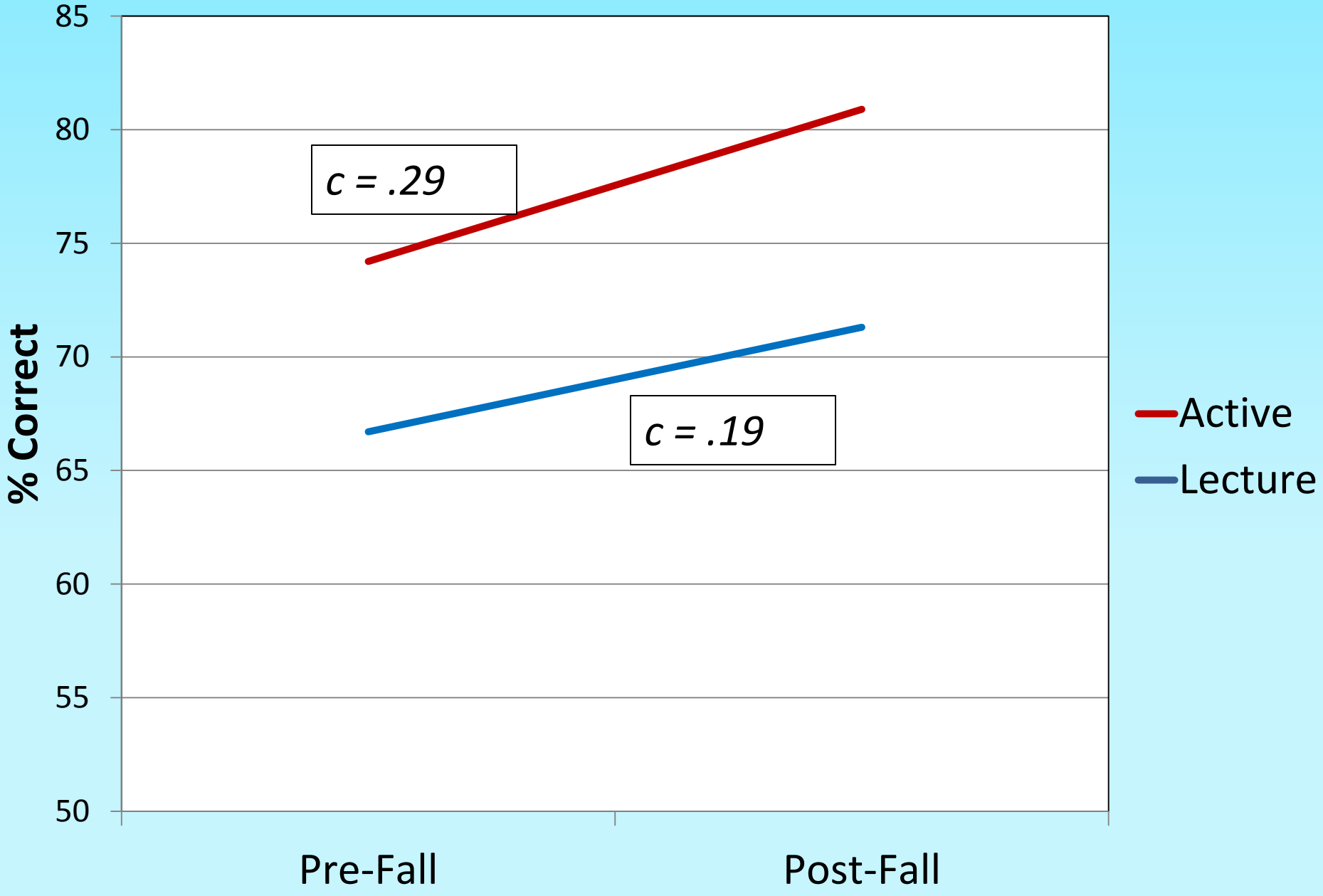
- Following previous literature (Hake 1998; Marx & Cummings, 2007), our primary FCI measure was *normalized change* (*c*)

- The amount gained (or lost) from pre- to post-test relative to the amount of possible gain (or loss) from pre- to post-test
  - For those who gained, $c = \frac{\text{Post} - \text{Pre}}{100 - \text{Pre}}$
  - For those who decreased, $c = \frac{\text{Pre} - \text{Post}}{\text{Pre}}$

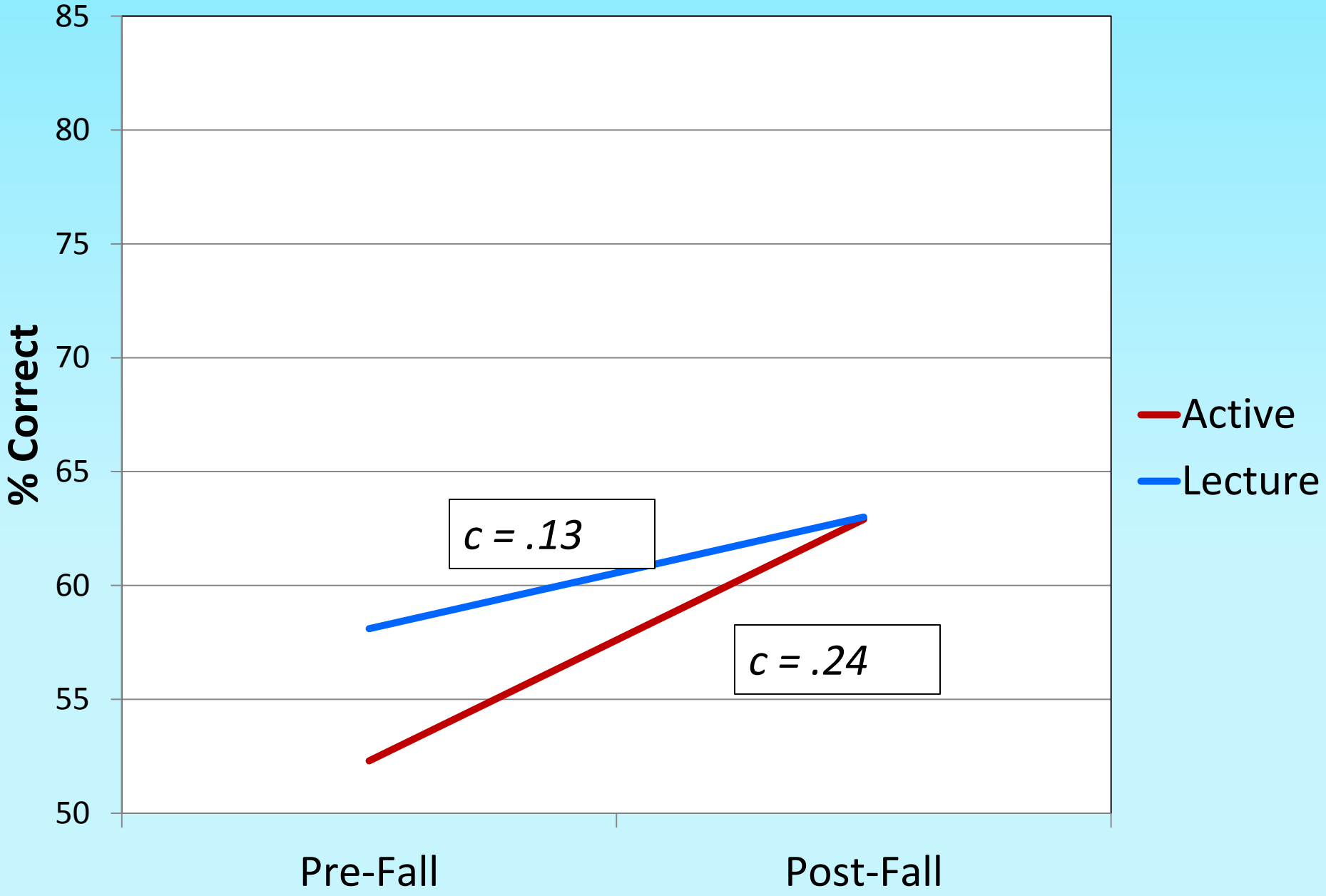
Force Concept Inventory- Overall



Force Concept Inventory- Males



Force Concept Inventory- Females

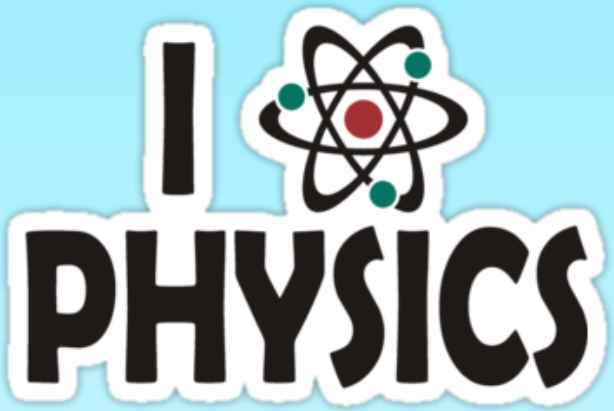


CLASS Survey

- Colorado Learning Attitudes about Science Survey
  - Developed at University of Colorado Boulder
- Used in both Fall and Spring semesters
- Consists of 42 statements grouped into sub-categories
  - Designed to asses student beliefs about physics and learning physics
  - Measures how expert-like student perceptions are
  - Student responses measured on Likert scale (5 point strongly agree to strongly disagree)
  - Takes ~10 minutes

CLASS Survey

- Student responses compared to those of experts in the following categories:
  - Real world connections
  - Personal interest
  - Sense making/effort
  - Conceptual connections
  - Applied conceptual understanding
  - Problem solving
  - Problem solving sophistication
  - Problem solving confidence



- Alternative categorization scheme (orthogonal factor analysis with current data set)
  - Learning Approach (rote vs. conceptual)
  - Solving Approach (algorithmic vs. concept-based)

Sample CLASS Questions

- **I enjoy solving physics problems.**
  - Problem Solving – General, Problem Solving Sophistication, Personal Interest
  - Experts would strongly agree

- **If I get stuck on a physics problem on my first try, I usually try to figure out a different way that works.**
  - Problem Solving – General, Problem Solving Confidence
  - Experts would strongly agree

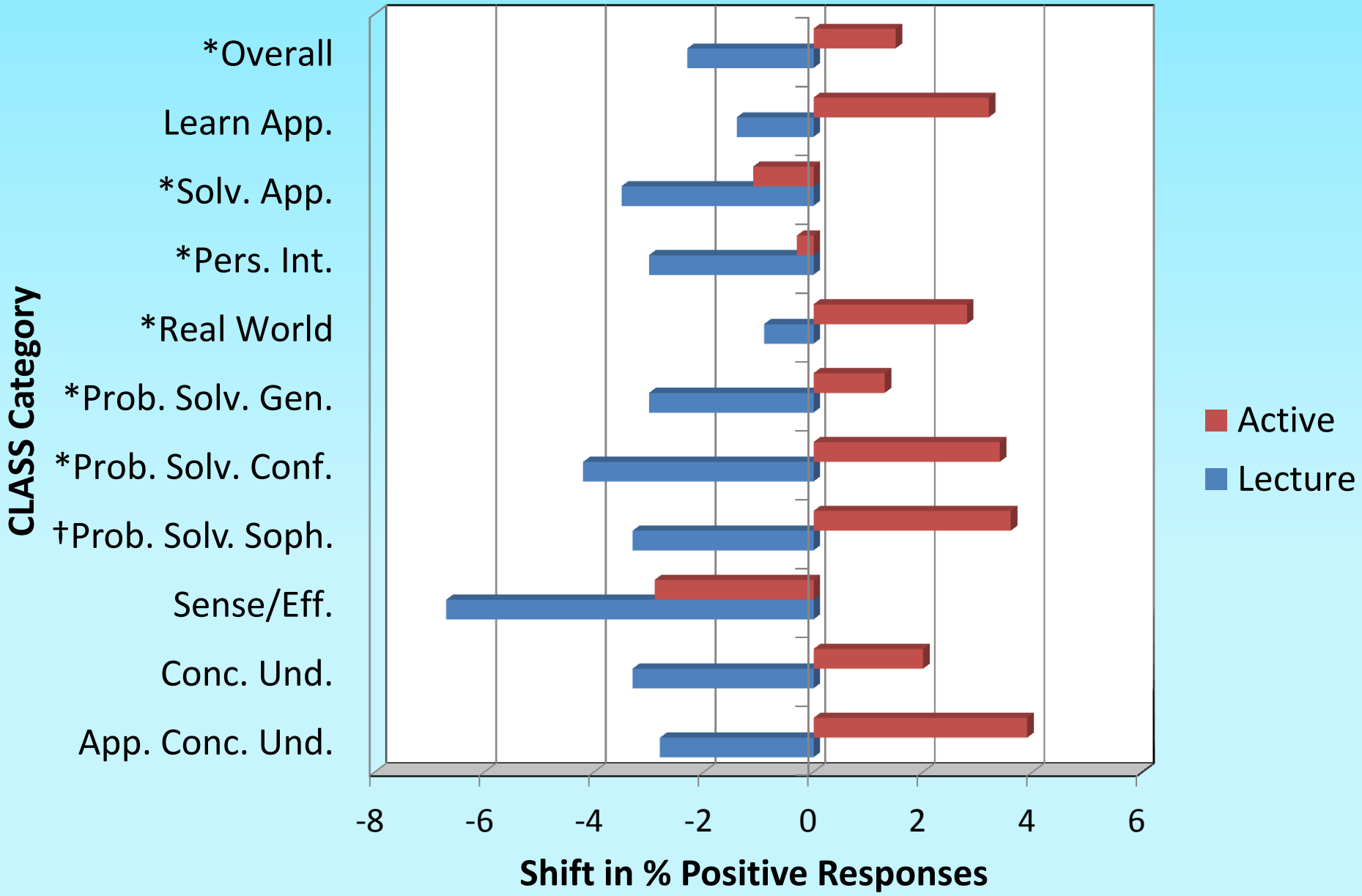
- **If I want to apply a method used for solving one physics problem to another problem, the problems must involve very similar situations.**
  - Problem Solving – General, Applied Conceptual Understanding
  - Experts would strongly disagree - requires reverse scoring

Scoring the CLASS

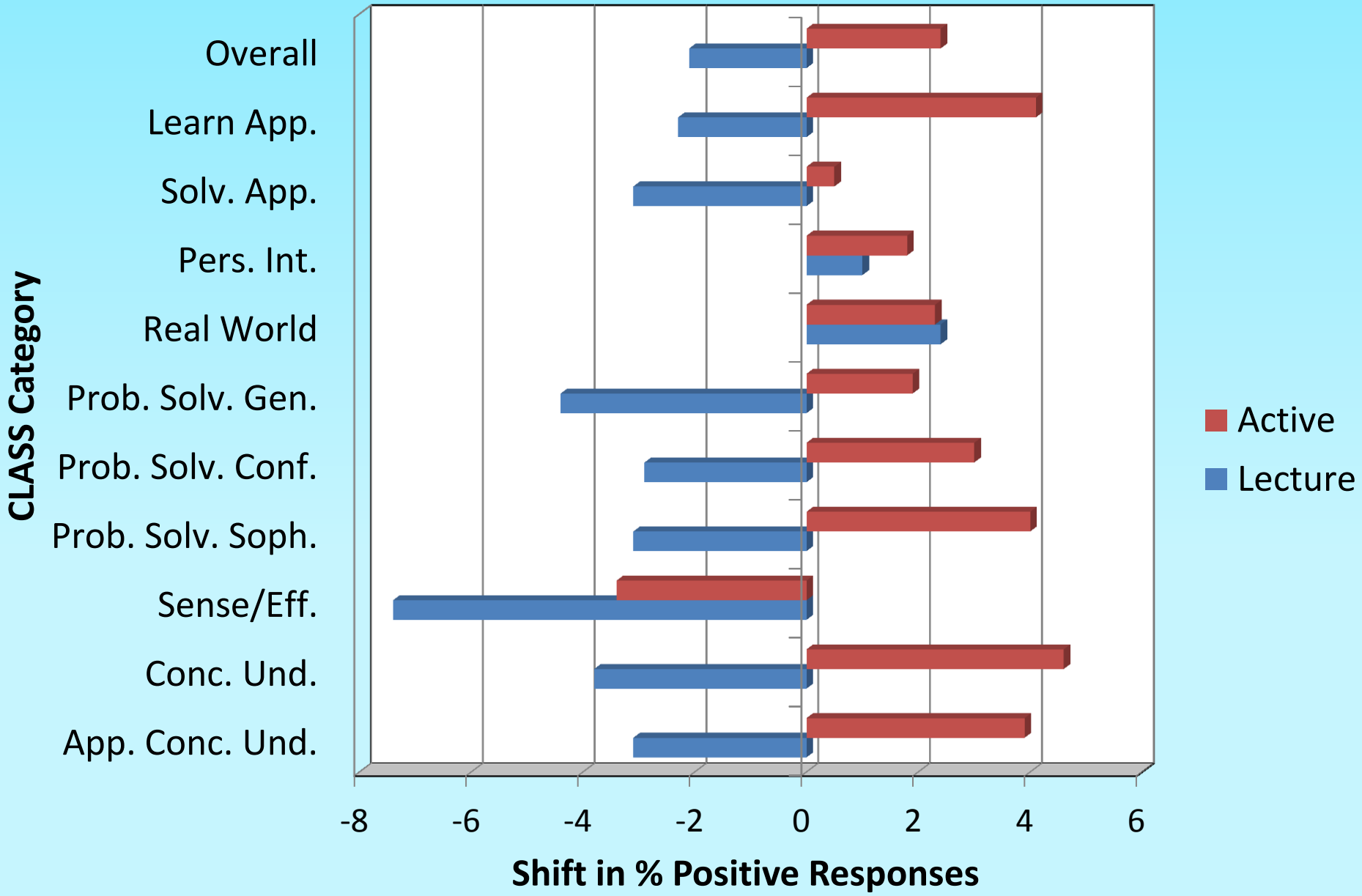
- Following the literature, 5-point responses were converted to dichotomous responses
  - Agree with expert (4/5 or 1/2 for reverse-coded items)
  - Not agree with expert (all other responses)

- The score is the percentage of items that agree with an expert, either overall or within the given subscale
  - Overall score derived from all 36 items with expert consensus
  - Subscale scores

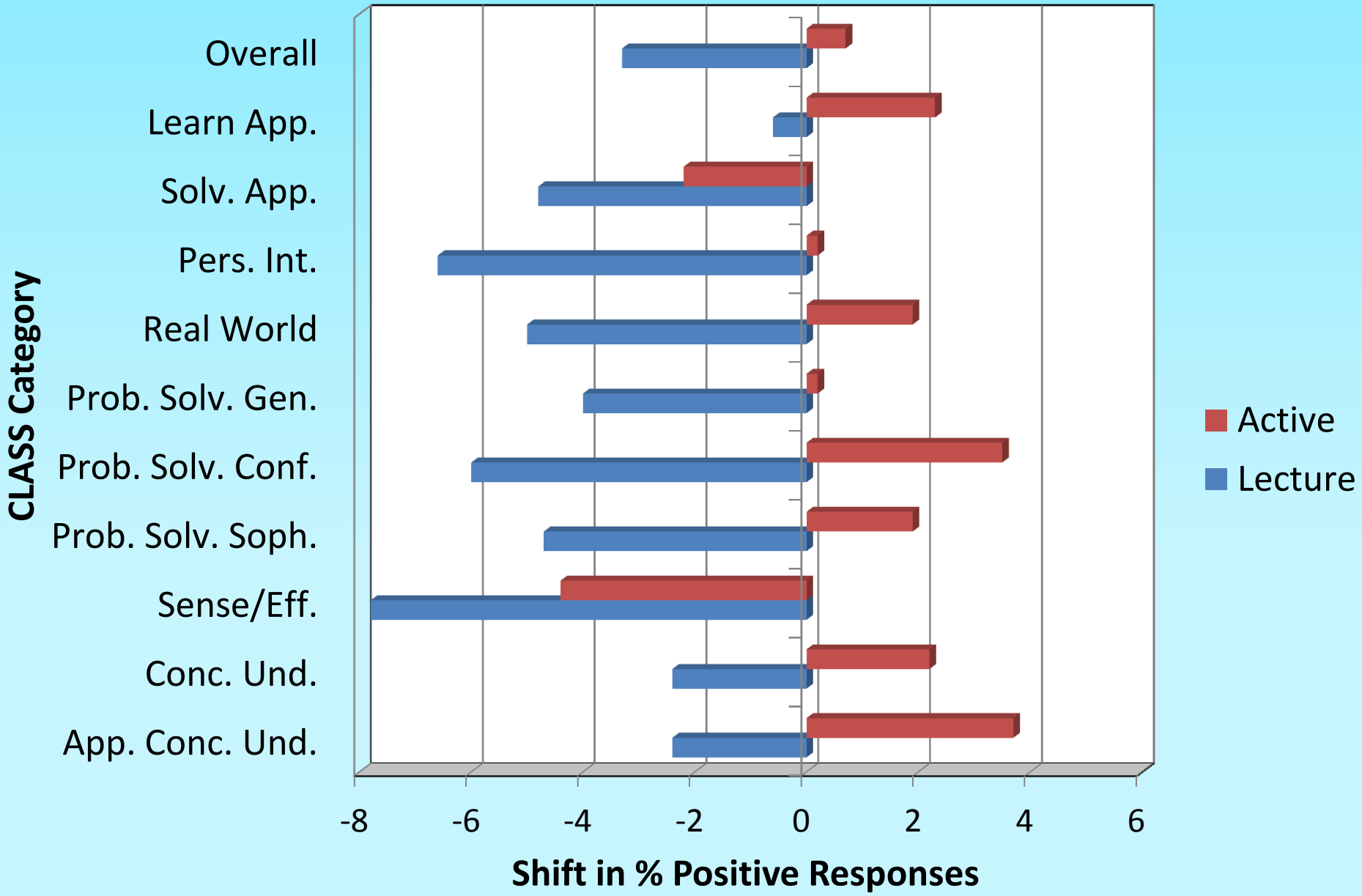
Overall CLASS Shifts- Fall Only



Male CLASS Shifts- Fall Only



Female CLASS Shifts- Fall Only



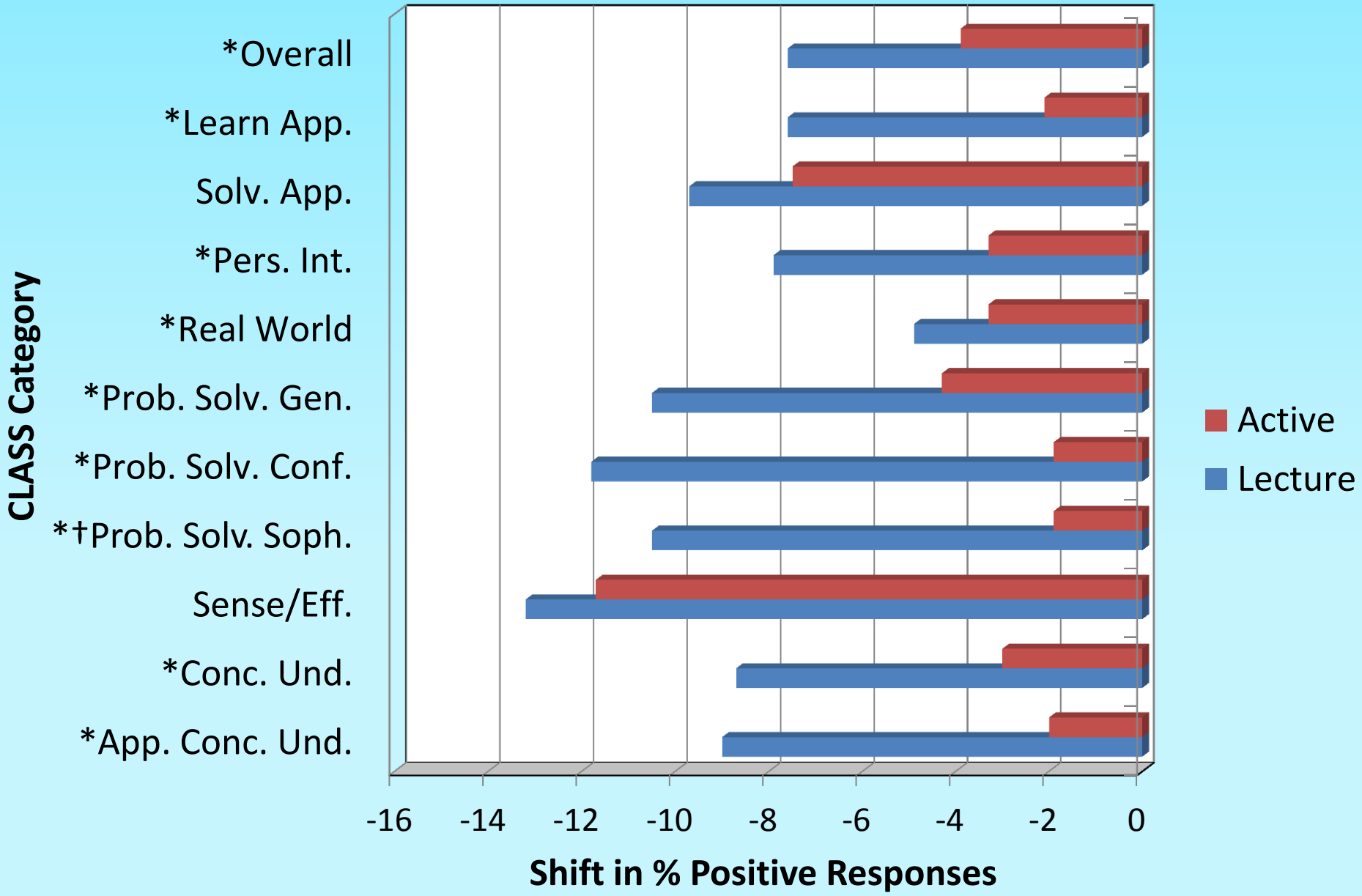
Fall Results Summary

- Active Physics produced benefits over Traditional (Lecture) Physics
  - Significantly higher conceptual gains on FCI
  - More expert-like shifts on CLASS
    - Nominal active physics advantage for all subscales
    - Significant advantage on overall scale and 5 of 10 subscales that were examined

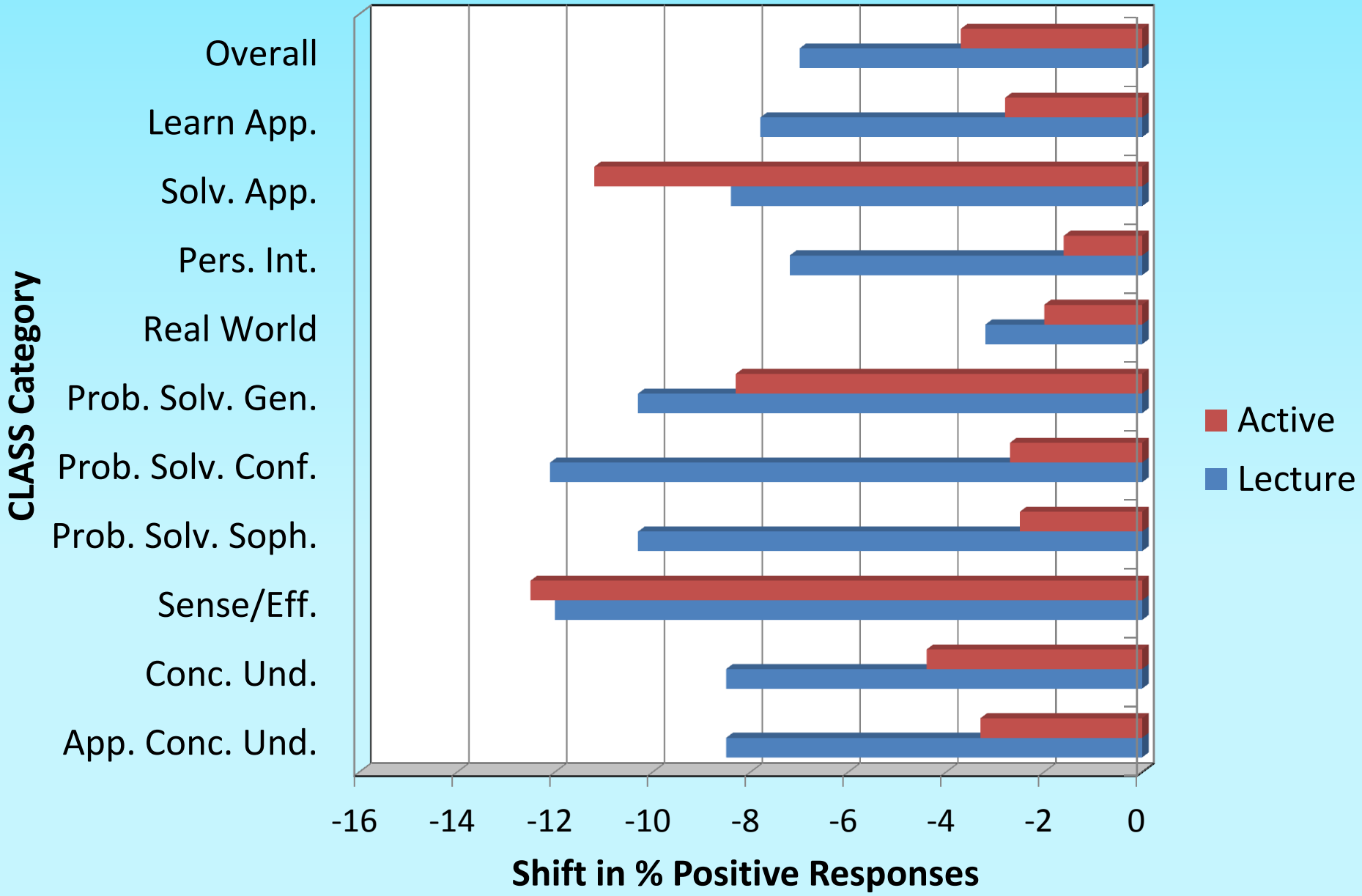
- Benefits of Active Physics were very consistent across males and females

- What are the effects of Active Physics on CLASS across the Whole Year?

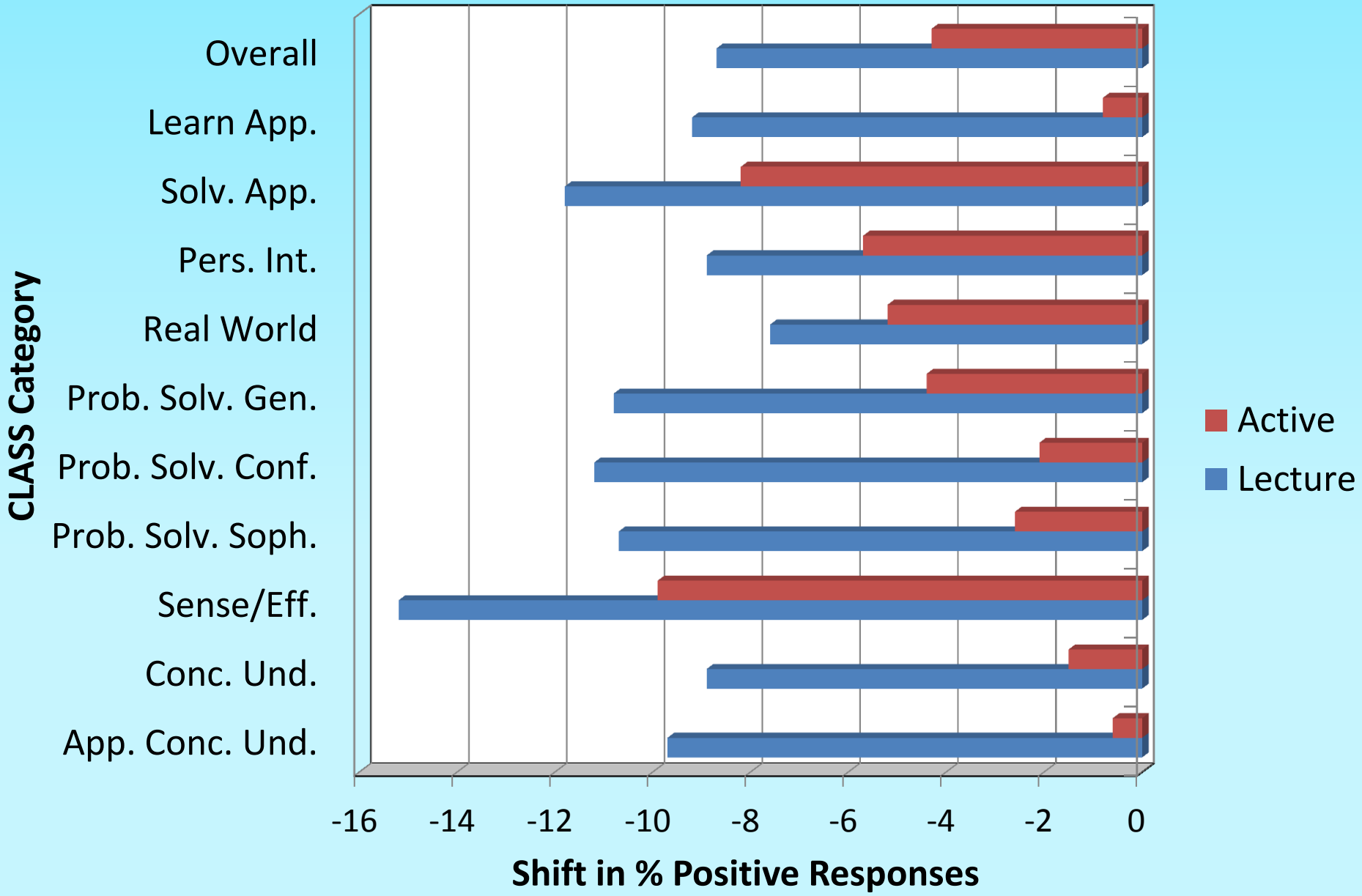
Overall CLASS Shifts- Whole Year



Male CLASS Shifts- Whole Year



Female CLASS Shifts- Whole Year



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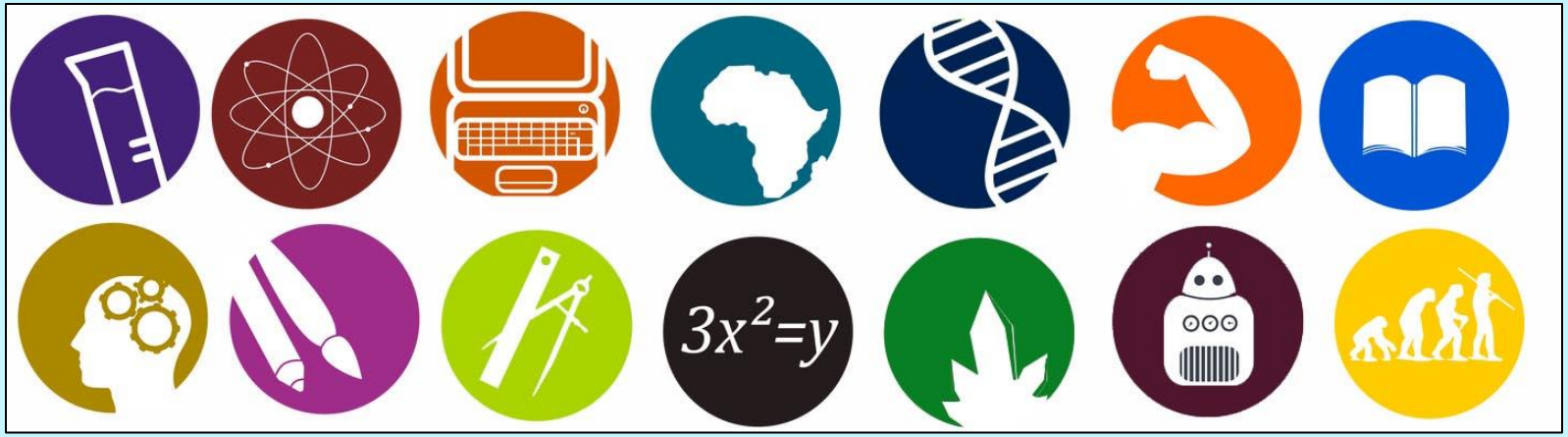
- Benefits of Active Physics were very consistent across males and females

- Despite overall decreases in CLASS scores in Spring, advantages of Active Physics were more robust across the whole year than across the first semester

What can we learn?

- The Active Physics curriculum produces benefits in Introductory Physics, but what can other courses take from this?

- With some creativity, some of the beneficial aspects of Active Physics can be incorporated into other types of classes



Translating Active Physics Techniques

- Homework both before and after class, plus revisions
- Real-world and concrete examples
- Emphasis on conceptual underpinnings
- Two minute problems
- Predict outcome of demos
- Leave derivations to the text
- Practice making approximations
- Vary activities during each class

<u>Overarching Goal:</u>
To push students toward "thinking like a physicist", rather than just learning physics content

Translating Active Physics to Other Disciplines

- Chemistry
- Engineering
- Geology
- Biology
- Anthropology
- Psychology
- Sociology
- Economics
- Political Science
- History
- Comparative Literature

Two Minute Problems in Psychology

- Psychology differs from Physics in many respects
  - Generally non-quantitative
  - No problem-solving in the traditional sense
  - Effects are probabilistic, not certain

- Still, similar techniques could produce benefits in both Physics and Psychology

- Primary purpose of Two Minute Problems:
  - Have students grapple with a concept and discuss it *prior to* knowing "the answer"
  - Link abstract concepts to concrete, real-world experience

- Can the same goals be achieved in Psychology?

Two Minute Problem

- Two chemistry courses are identical with the following exception:

  In course A, all worksheets are typed out in

  non-italicized, Times New Roman, 12-pt fonts

  In course B, all worksheets are typed out in

  italicized, Comic Sans, 12-pt. font

Which outcome is more likely?

A. Course A will outperform course B

B. Course B will outperform course A

C. The courses will perform equivalently

The Explanation

- Course B, with *Italicized Comic Sans,* is likely to perform better (Diemand-Yauman, Oppenheimer, & Vaughan, 2010)

- Desirable Difficulties: Introducing certain difficulties into the learning process can greatly improve long-term retention

- Why?
  - Familiar fonts lead to higher fluency. Fluency is a "feeling of knowing", but is a poor indicator of actual, long-term learning
  - The difficult fonts disrupt fluency, reduce the artificial "feeling of knowing", and encourage deeper processing of the material

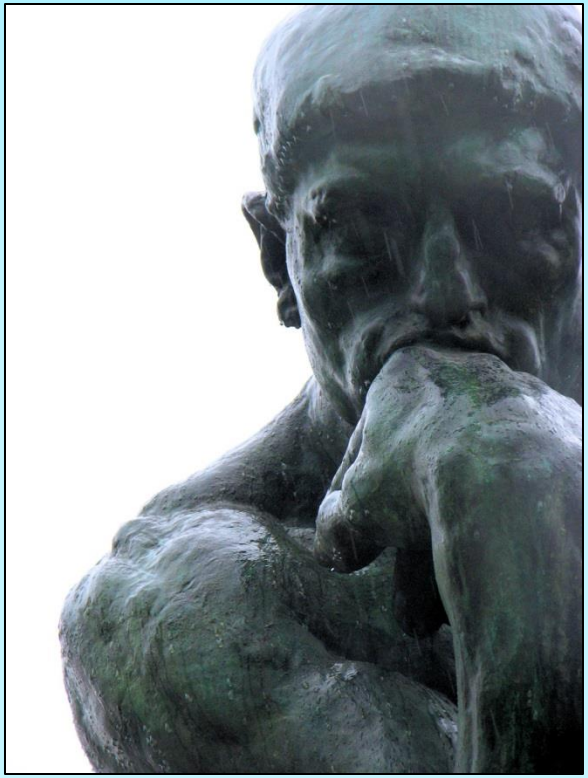
Goals of Two Minute Problems Revisited

- Have students grapple with a concept and discuss it *prior to* knowing "the answer"
  - Students had to come up with the answer by thinking and talking about their knowledge of learning

- Link abstract concepts to concrete, real-world experience
  - An abstract concept (fluency) introduced via a concrete application (text font) and an activity very familiar to students (learning from a worksheet)

Translating Active Physics

- What types of activities might achieve the similar goals of "thinking like a …."
  - Chemist
  - Engineer
  - Biologist
  - Psychologist
  - Sociologist
  - Economist
  - Historian



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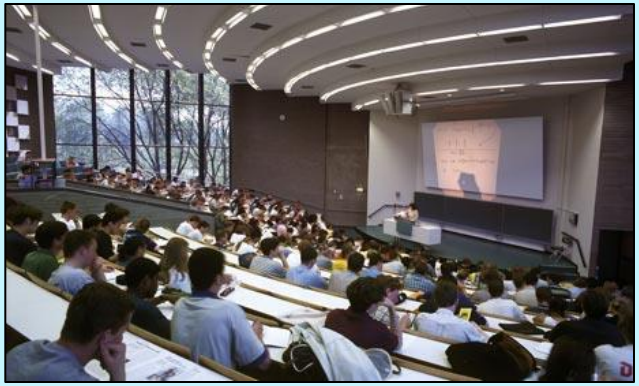
Inquiry-Based Curricula

- "Pure" Active-Learning curricula have been used, to great effect, in introductory physics

- However, these types of curricula are typically used in classes of 30 or smaller and may not be practical or effective in larger classes

- The benefits of the Active Physics have been demonstrated in relatively large courses (typically 120 – 130 students)



Utilizing Active Techniques in a Large Classroom

- Students discuss problems in small groups
- Respond with i<clickers
- Reward students with participation points
- Expand on conceptual student discussion with example worked on board
- Break complicated problems into smaller pieces with breaks in between