# The performance of 5000 students in introductory mechanics

M.D. Caballero[1], K.R. Bujak[2], M.J. Marr[2],
R. Catrambone[2], M.A. Kohlmyer[3] and M.F. Schatz[1]

[1]School of Physics
[2]School of Psychology
Georgia Institute of Technology
[3]Department of Physics
North Carolina State University

caballero@gatech.edu

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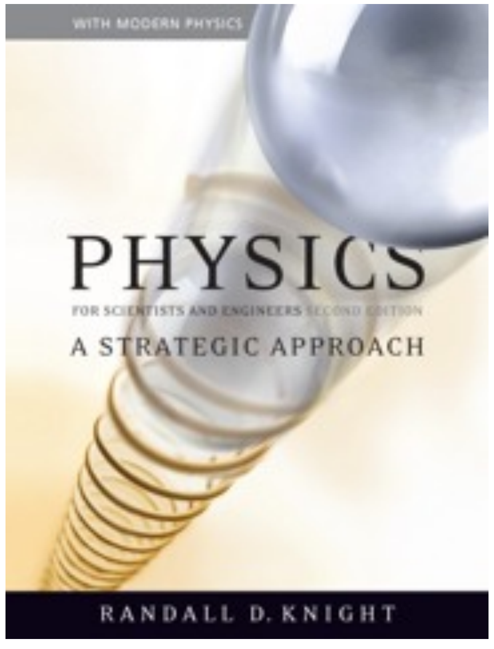
# Two Courses taught at GT

- Introductory Mechanics
  - A "standard" course based on Knight
  - The Matter and Interactions course
- ~800 students per semester take introductory mechanics
- 83% engineering, 17% science majors
- Large classroom setting (150-250 students)
- Labs/Recitations (15-25 students)

# A Standard Mechanics Course

- Covers the usual topics (projectile motion, friction, statics, circular motion, etc.)
- Usual organization of topics (kinematics, dynamics, energy, angular momentum, etc.)
- Emphasis during force and motion section - constant force motion, kinematic equations, free body diagrams
- At GT, use the Knight text
  3 hour lecture (with "clicker" questions)
  2 hour laboratory, 1 hour recitation
  Online homework system - Mastering Physics

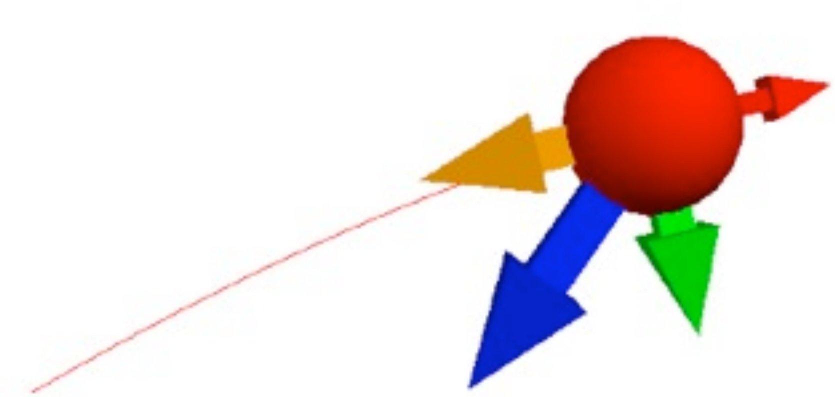


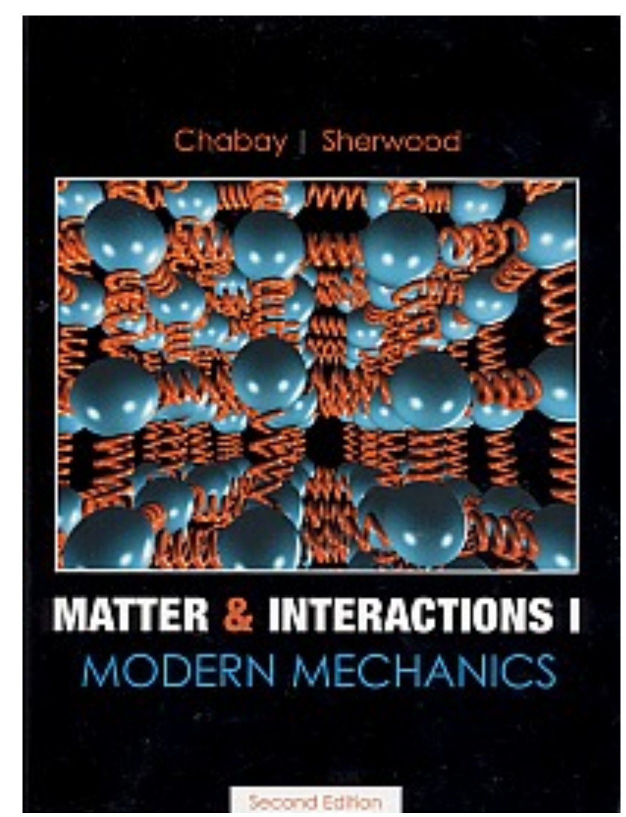
# Matter and Interactions

www.matterandinteractions.org

- Emphasizes on a principle based approach (Impulse-Momentum Theorem, Energy Principle, Angular Momentum Principle)
- Introduces the ball and spring model of matter and connects microscopic to macroscopic
- Uses modern tools (simulation and visualization)
- 3 hour lecture (with "clicker" questions)
  3 hour lab/recitation
  Online homework system - WebAssign

Computer Modeling

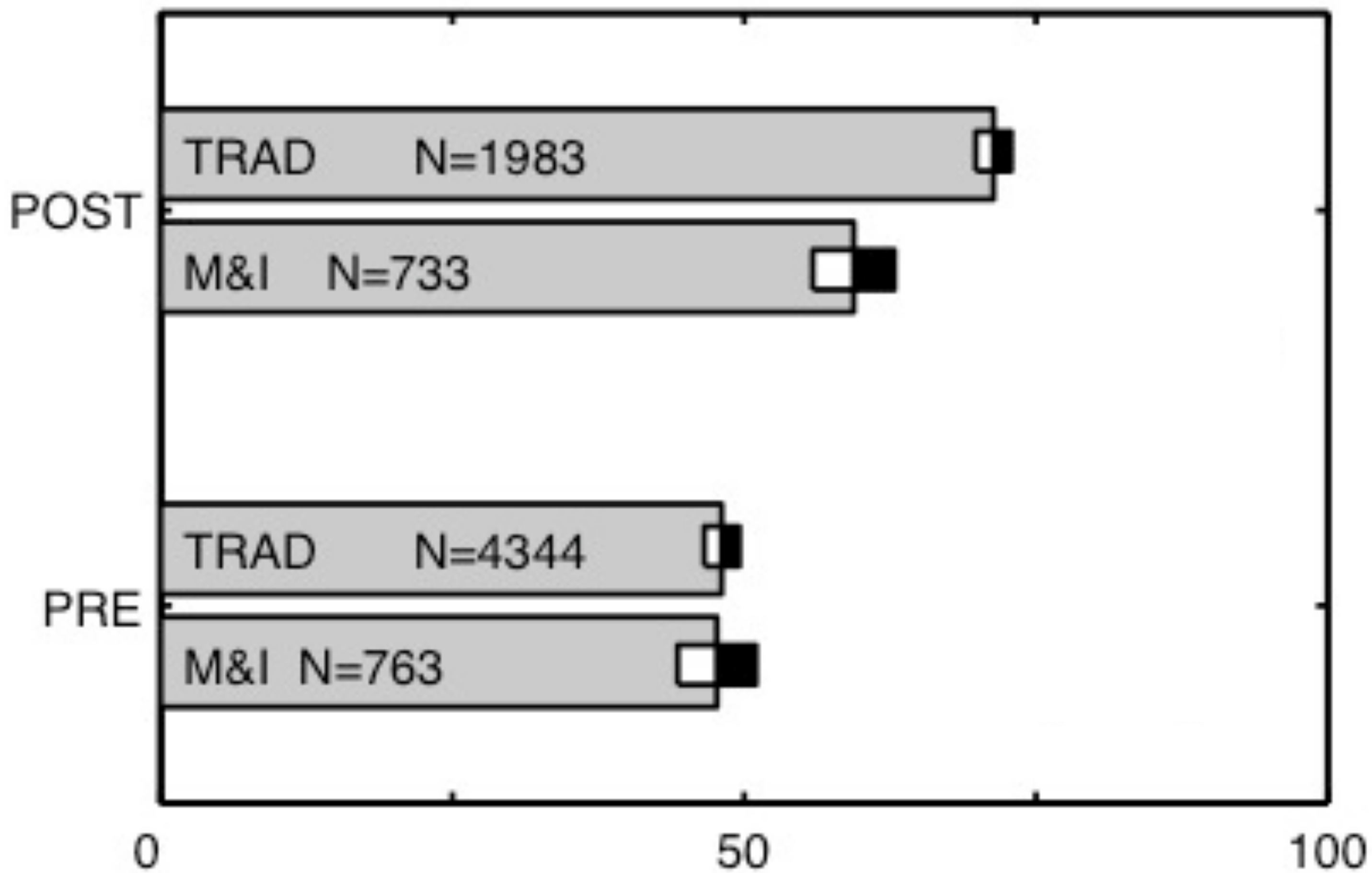




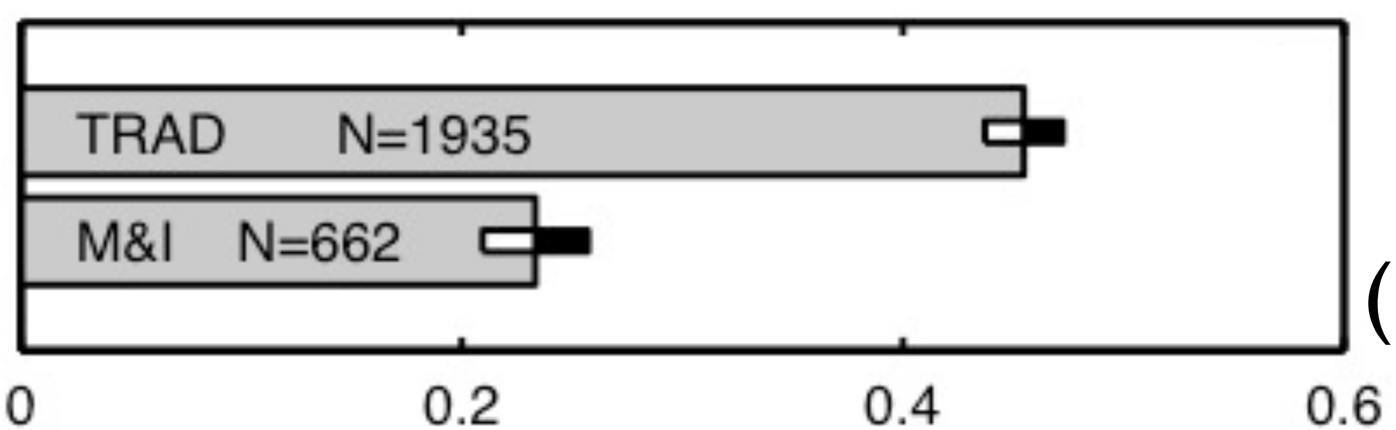
# Comparing the Courses

- Courses have markedly different curricula (course content and structure) making comparison a complex undertaking
- Proper comparison requires multiple metrics, e.g.
    - *Standardized assessments*
    - *Student interviews (think aloud)*
    - Common final exam problems
    - Complex (non-standard) problems
- Standardized assessments require smallest infrastructure, easy to score

# Measuring Performance using the Force Concept Inventory




Avg. FCI Score (%)



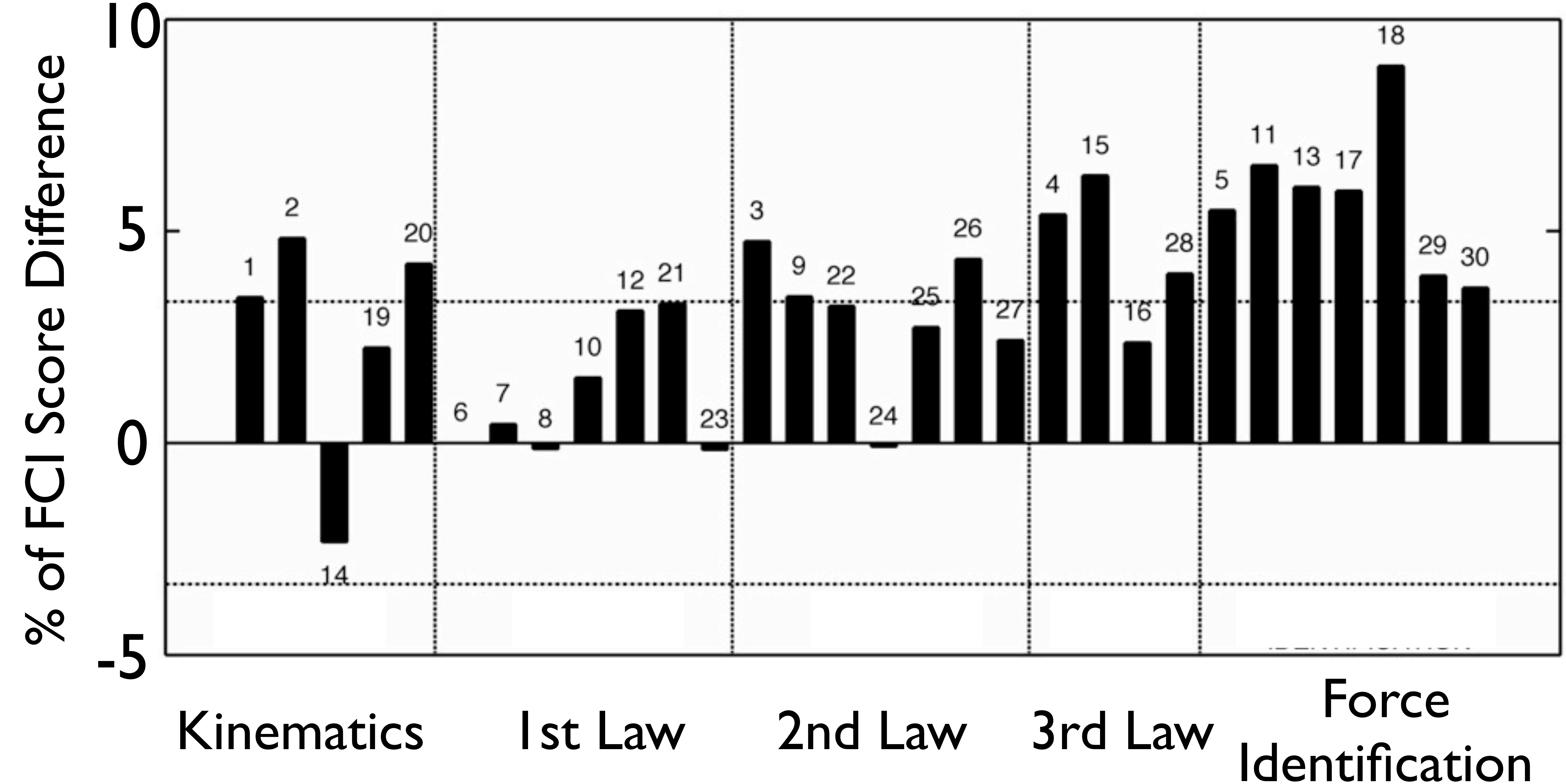

Normalized Gain

- 30 item multiple-choice test covers force and motion
- Emphasizes constant force motion and contains strong distractors
- Essential demographic data not statistically different
- Pedagogy (interactivity, presentation, etc.) very similar

TRAD outperforms M&I
(Mean FCI score: 71.3% vs 59.3%)

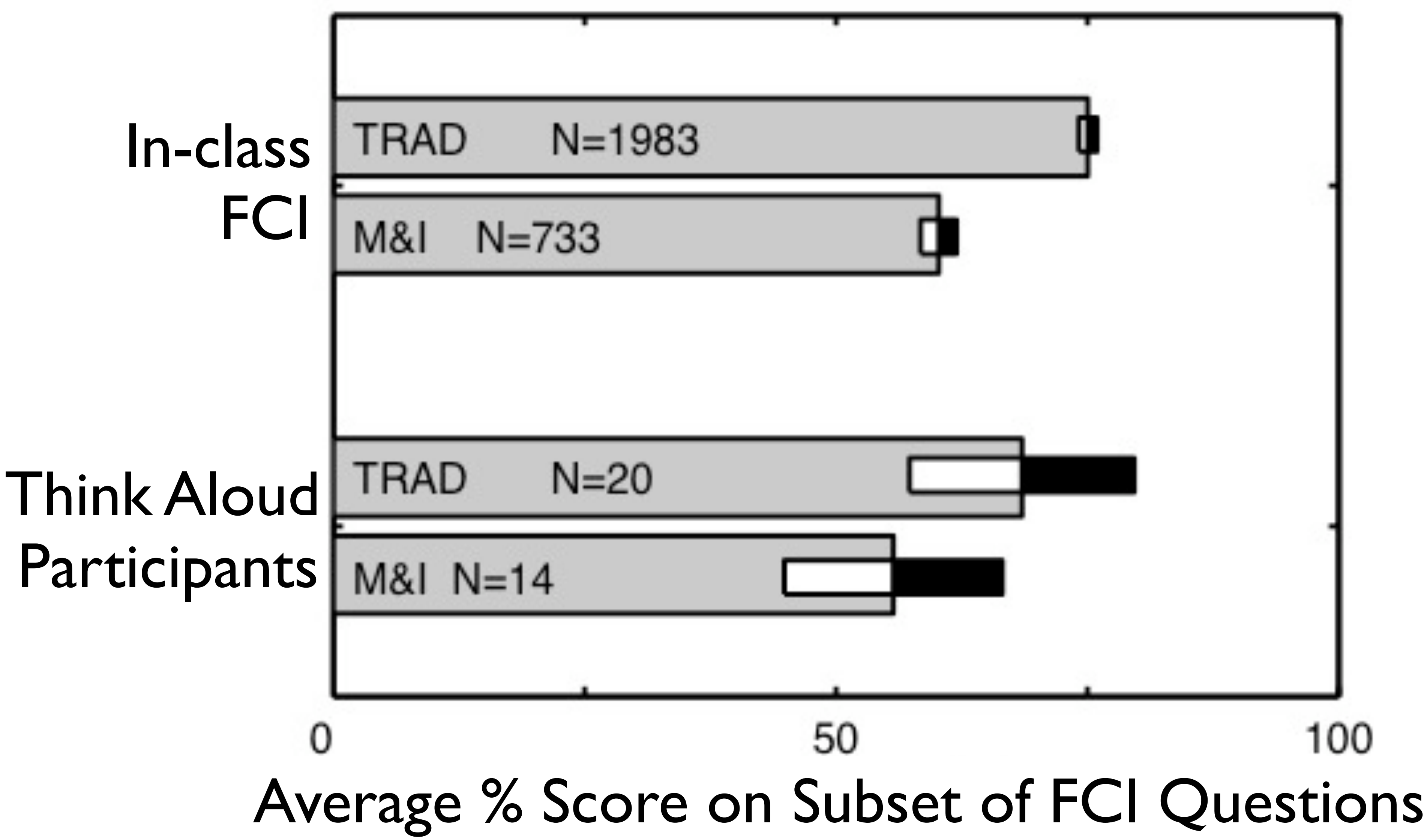
# TRAD Performs Better Across Topics

- A priori categorization of topics by experts
- Calculate % a given question contributes to total difference (TRAD-M&I)



# Think-Aloud Study

- Audio and video record subjects solving subset of 10 questions
  - Subset had higher than average contributions to the difference in scores
  - Participants: TRAD, n = 20 and M&I, n =14



# Suggestive Results from Transcript Analysis

- M&I students fail to employ the Impulse-Momentum Theorem
  (NO mention of momentum at all)
- M&I students confuse components of the net force and forces associated with agents
- Revert to naive or incorrect notions of force and motion
- Revert to (often, incorrect/incomplete) memory of high school physics

# Homework Questions

- Both courses require students to complete 3 homework assignments per week
- Questions covering FCI topics appearing in homework sets were counted
- Larger fraction of standard course items cover FCI topics
    - TRAD ~30% vs M&I ~10%

# Concluding Remarks

- TRAD students outperform M&I students on in-class FCI
- Think aloud study identifies M&I students' shortcomings
- Homework questions suggest exposure to FCI-like items in M&I is limited compared to standard course
- Other metrics currently under evaluation
- Development of materials to foster M&I students' fluency on force and motion items has begun
- More info: www.physics.gatech.edu/gtper

# Why this difference?

- Essential Demographics are identical
- M&I aims to illustrate generality of physics principles
  - De-emphasis of constant force motion
  - Analysis of systems often uses modeling (Languages different: Sherin, 1997)
  - Taught general procedures instead of being given "canned" kinematic formulae
  - More difficult to link several tasks into one goal versus using a "prescribed" method (Catrambone, 2006)
- FCI emphasizes constant force motion
  - TRAD well trained by their curriculum
  - Items similar to FCI appear on PRS, recitation, etc.
- "Think-aloud" study to illuminate underlying issues

# An Example from the Think-Aloud Study

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:

(A) about half as long for the heavier ball as for the lighter one.

(B) about half as long for the lighter ball as for the heavier one.

(C) about the same for both balls.

(D) considerably less for the heavier ball, but not necessarily half as long.

(E) considerably less for the lighter ball, but not necessarily half as long.

- Correct Response (C) - 90% TRAD, 57% M&I, Major distractors (A & D) - 10% TRAD, 36% M&I

| Solution | TRAD (%) | M&I (%) |
|---|---|---|
| Determined acceleration was constant | 0 | 36 |
| "mass doesn't matter" | 60* | 21 |
| use of kinematics equations | 40 | 0 |
| recall from previous exercise | 20 | 0 |

*Half of these students also used kinematic equations

# Item Analysis using Fractional Differences

- Comparing Performance per Question
  - Performance gauged by Raw Gain: G = Post % - Pre %
  - Questions can be grouped by Topic
- Computing Fractional Differences
  - Total Difference: $\Delta G = G_{TRAD} - G_{M\&I}$
  - Item Difference: $\Delta G_i = G_{i,TRAD} - G_{i,M\&I}$
- Ratio, $\Delta G_i/\Delta G$, gives fractional difference ($\Delta G_i/\Delta G > 0.033$, question contribution is greater than if each question contributed equally.)