



Performance of 5000 Students in Introductory Mechanics

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Introductory Mechanics at Georgia Tech

Two Courses taught at Tech

- A “standard” course based on Knight (TRAD)
- The Matter and Interactions course based on Chabay and Sherwood (M&I)

Demographics

- ~800 students per semester take introductory mechanics
- 83% engineering, 17% science majors
- Large classroom setting (150-250 students)
- Labs/Recitations (15-25 students)

The “Standard” Course (TRAD)

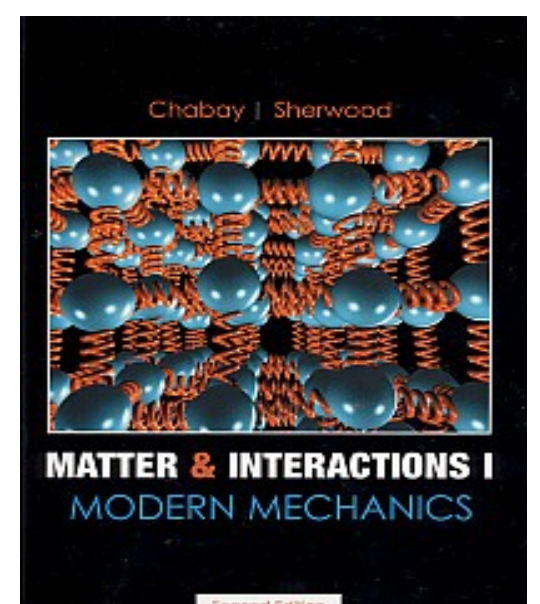
- Covers the usual topics (projectile motion, friction, statics, circular motion, etc.)
- Usual organization of topics (kinematics, dynamics, energy, angular momentum, etc.)
- Emphasis placed on force and motion concepts: constant force motion, kinematic equations, free body diagrams

Boundary Conditions

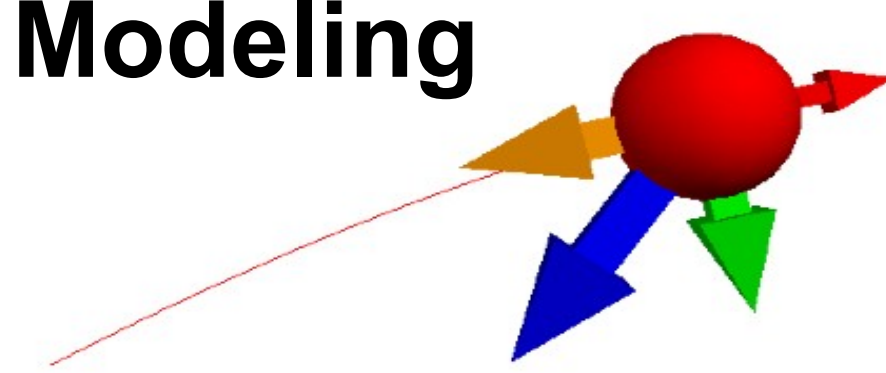
- 3 hour lecture (with “clicker” questions)
- 2 hour laboratory, 1 hour recitation
- Online homework system - Mastering Physics

The Matter and Interactions Course (M&I)

- Emphasizes on a principle based approach (Impulse-Momentum Theorem, Energy Principle, Angular Momentum Principle)
- Introduces the ball and spring model of solids and connects microscopic to macroscopic measurements
- Uses modern tools (simulation and visualization)



Computer Modeling



Boundary Conditions

- 3 hour lecture (with “clicker” questions)
- 3 hour combined lab/recitation
- Online homework system - WebAssign

Assessing Performance

Courses have markedly different curricula (course content, structure)

- Comparison is 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 small infrastructure, easy to score

Results from Standardized Assessment

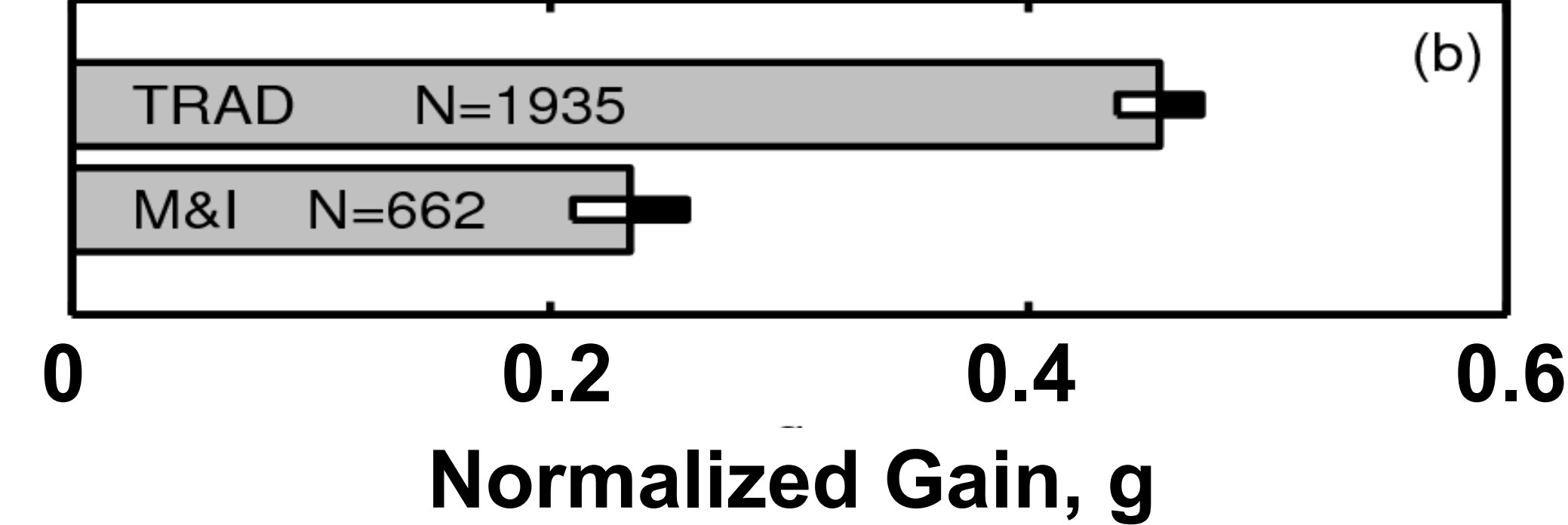
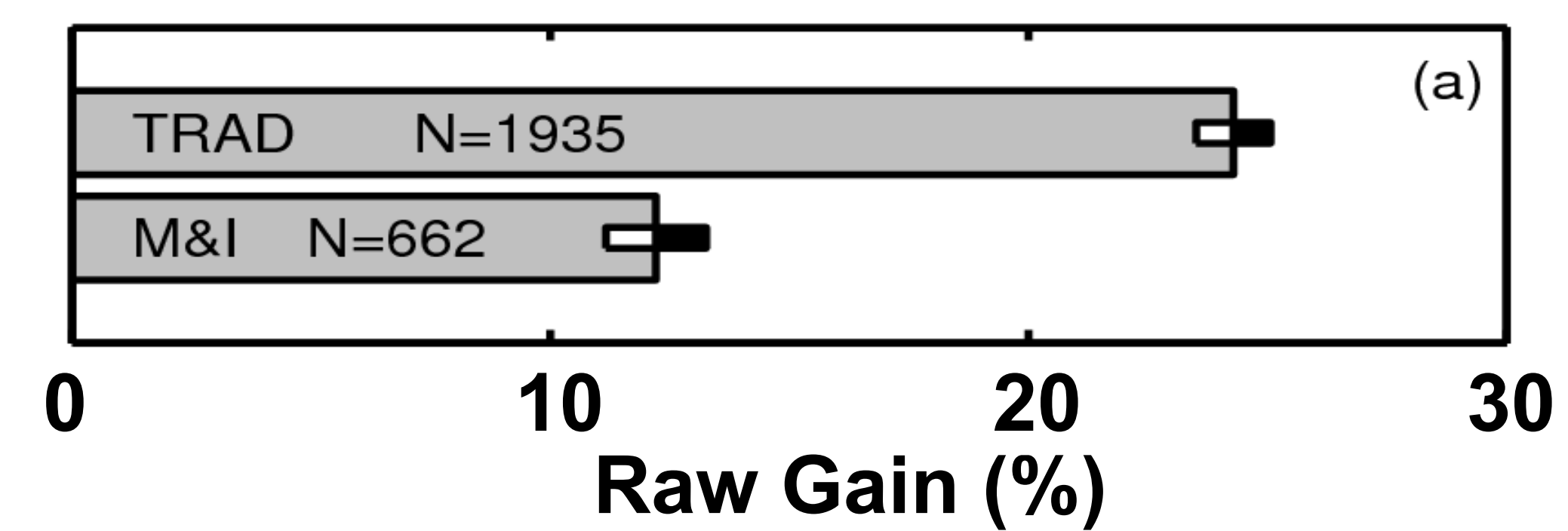
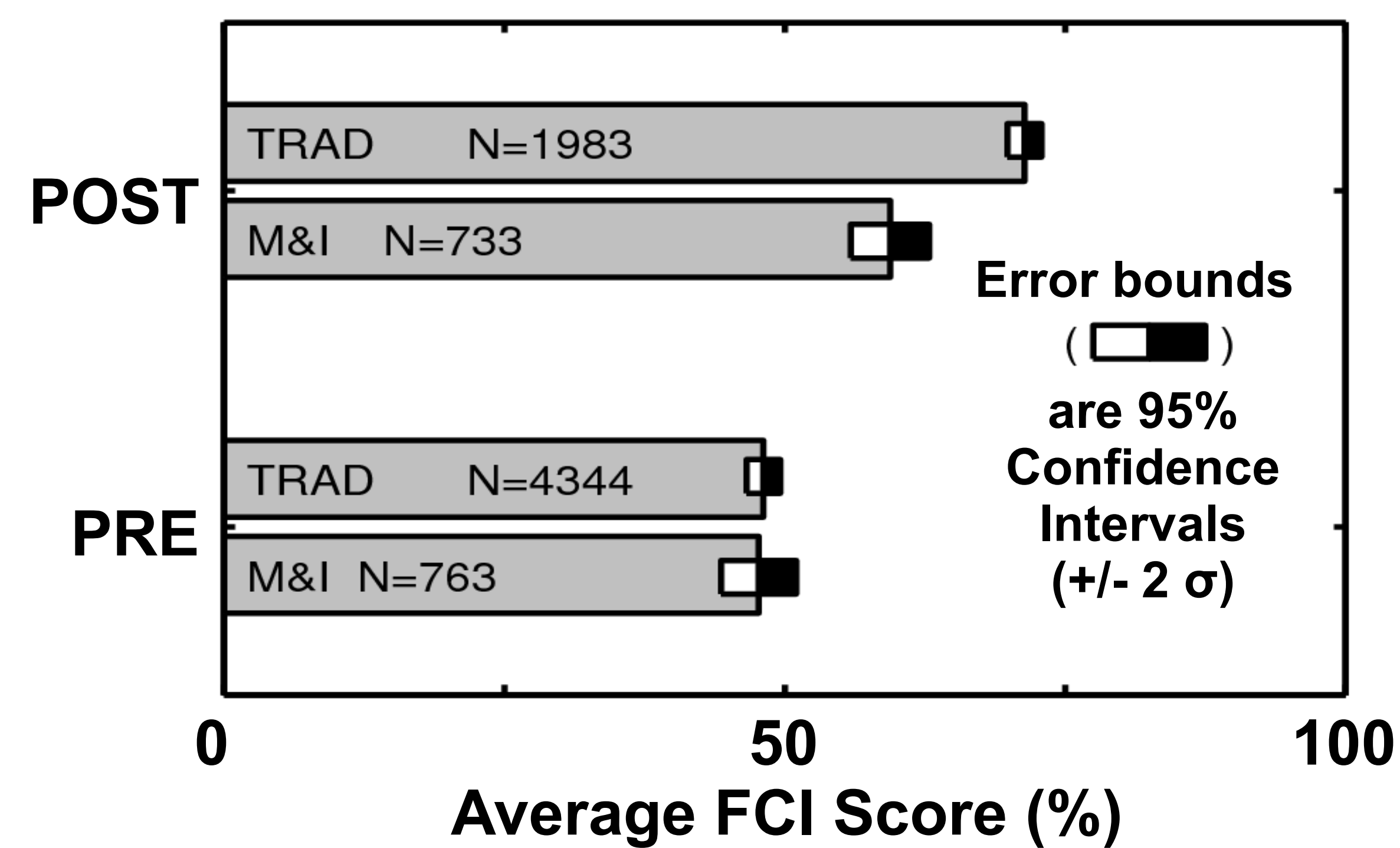
Force Concept Inventory (FCI)

- 30 item multiple-choice test covers force and motion
- Emphasizes constant force motion and contains strong distractors

Initial Conditions

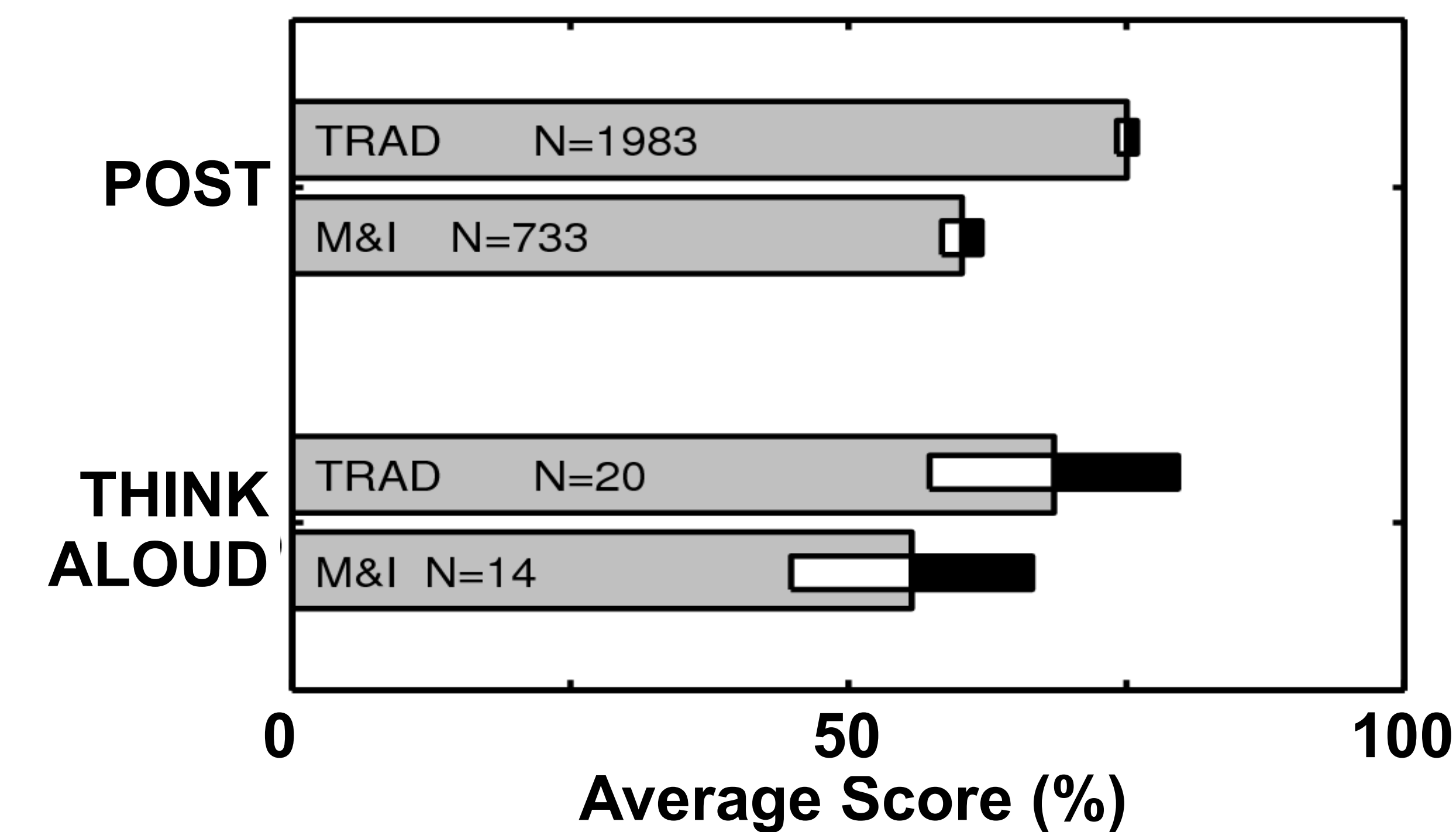
- Essential demographic data not statistically different
- Pedagogy (interactivity, presentation, etc.) very similar

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



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



An Example

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:

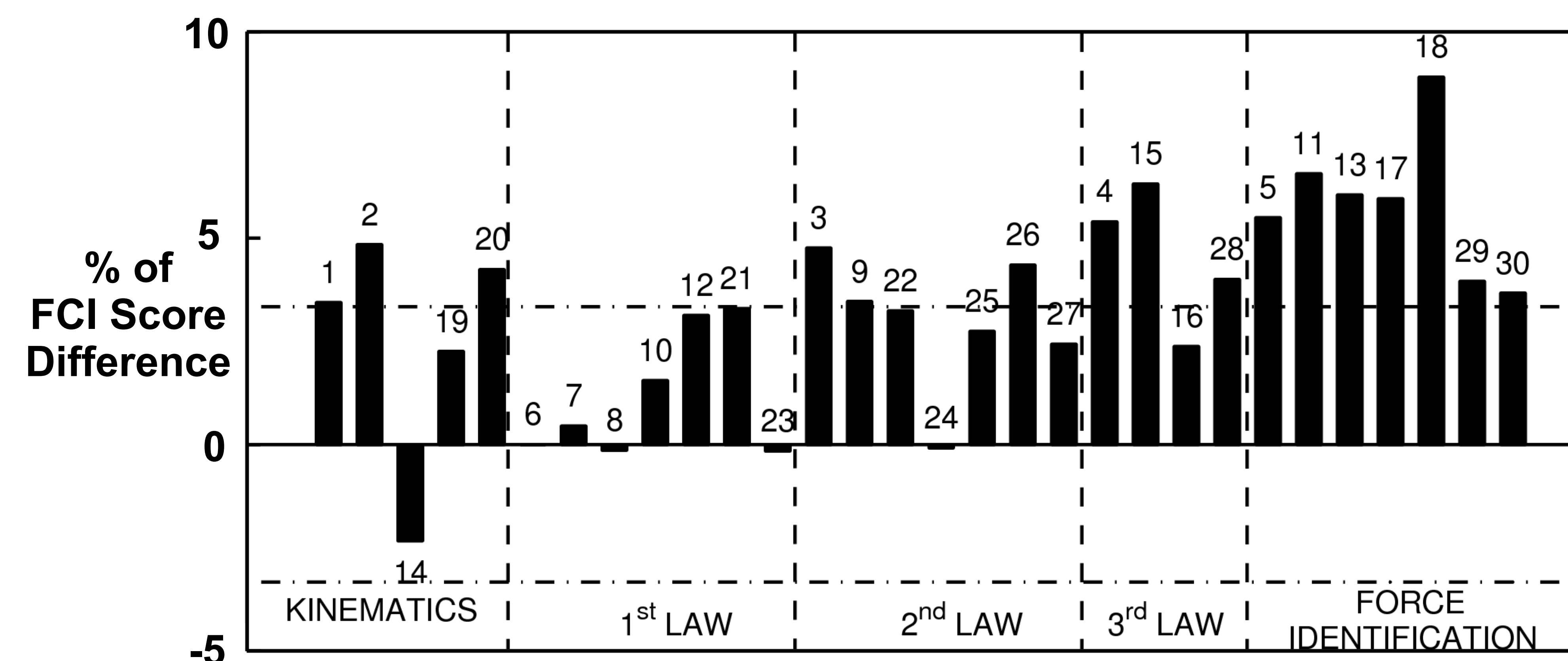
- (A) about half as long for the heavier ball as for the lighter one.
- (B) about half as long for the lighter ball as for the heavier one.
- (C) about the same for both balls.
- (D) considerably less for the heavier ball, but not necessarily half as long.
- (E) considerably less for the lighter ball, but not necessarily half as long.

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

Solution	TRAD (%)	M&I (%)
Determined accel. was constant	0	36
“Mass doesn't matter”	60*	21
Use of kinematic equations	40	0
Recall from previous exercise	20	0

*Half of these students also used kinematic equations

Item Analysis reveals superior TRAD performance across topics



Further Investigation

Suggestions about 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
- Both groups revert to naive or incorrect notions of force and motion
- Both groups 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%

Efforts in Numerical Computation and Visualization

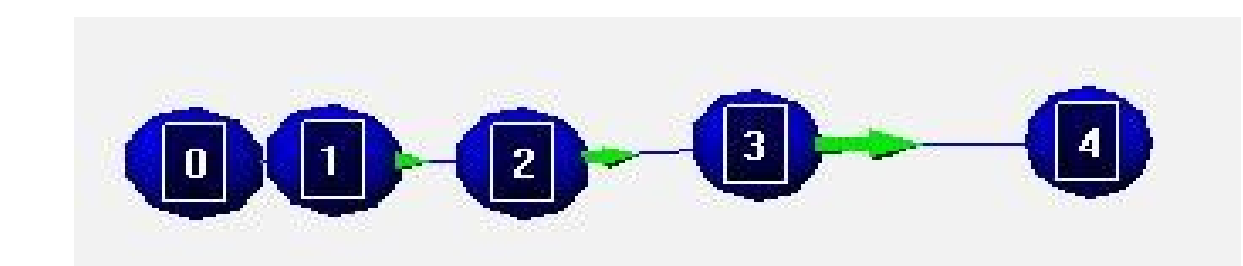
Beginning in Spring 2009, homeworks using the computer modeling component have been developed.

Students are exposed to finite differencing early on

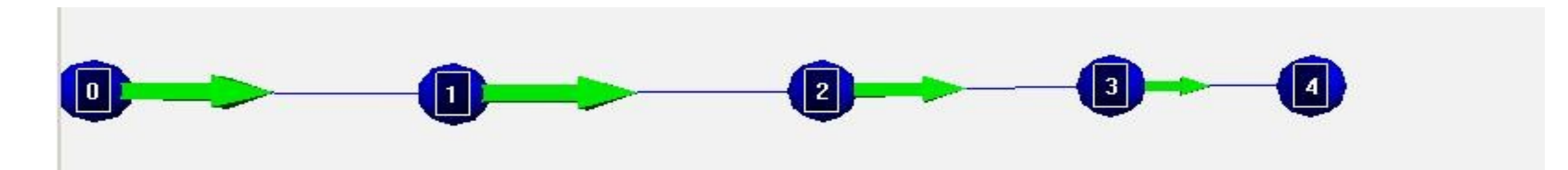
- Create trajectory
- Determine average velocity
- Determine average net force
- Visualize trajectory, velocity and force vectors.

Student submitted work

Object speeding up (1D)



Object slowing down (1D)



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

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