Implementing Curricular Reform in a Large Lecture Course at Georgia Tech

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Introductory Physics @ Georgia Tech

+ Two-semester sequence
  Semester 1—Mechanics, Semester 2—E&M

+ ~1600 students per semester
+ 83% engineering, 17% science majors
+ Three lecture hours per week
  (200 students per lecture section)
+ One weekly lab/recitation (3 contact hours)
  (20 students per lab/recitation section)

Shortcomings of Traditional Curriculum

+ Content unchanged for decades
  - -19th century (or earlier) concepts
  - - Focus on analytic solutions of special cases

+ Difficulties at GT
  - -GPA lower than other intro courses
  - -High D/F/W rate (as high as 25%)
  - -Unpopular with students
  - -External review criticized structure, outcomes

Reform Curriculum:
Matter and Interactions (M&I)

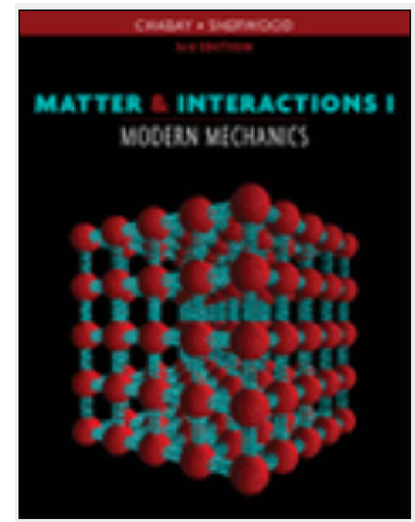
(R. Chabay & B. Sherwood, Wiley, 2010)

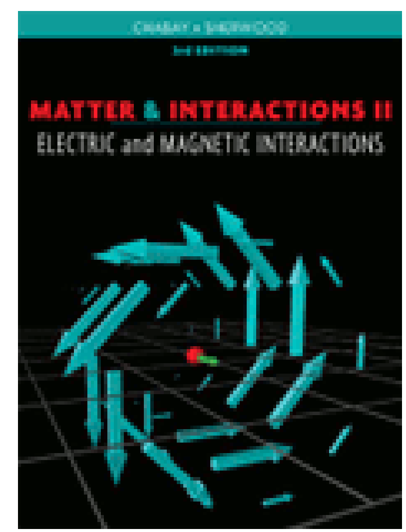
Modern content

- + Fundamental principles
- + Atoms and structure of matter
- + Relativity and quantum physics
- + Macro/micro connections

Modern tools/techniques

- + Computer modeling





Infrastructure Preparation

+ Local expert: Hire Postdoc (1/06-9/08)

+ Train Teaching Assistants
  (Spring 06, on-going)

+ Laboratory Equipment Purchase/Construction
  (Spring 06, Fall 07)

Faculty Preparation: Apprenticeship Model

+ Junior faculty---pair with experienced instructor, provide logistical support.

+ Senior faculty---same plus financial incentive

Gradual Implementation

Semester	M&I Semester 1	M&I Semester 2	Faculty w/M&I experience
Summer 06	40 students	None	0
Fall 06	120 students	45 students	1
Spring 07	200 students	150 students	2
Summer 07	None	150 students	3
Fall 07	150 students	300 students	4
Spring 08	300 students	300 students	4
Summer 08	150 students	150 students	4
Fall 08	300 students	450 students	6
Spring 08	500 students	300 students	6
Summer 09	250 students	None	6
Fall 09	400 students	550 students	7

Is reform doing any good?

Compare student performance
Traditional (control) vs M&I (reform)

In class measurements
- + Concept inventories
- + Common final exam problems.
- + Performance in follow-on courses.

Out of class measurements
- + Think aloud protocol studies

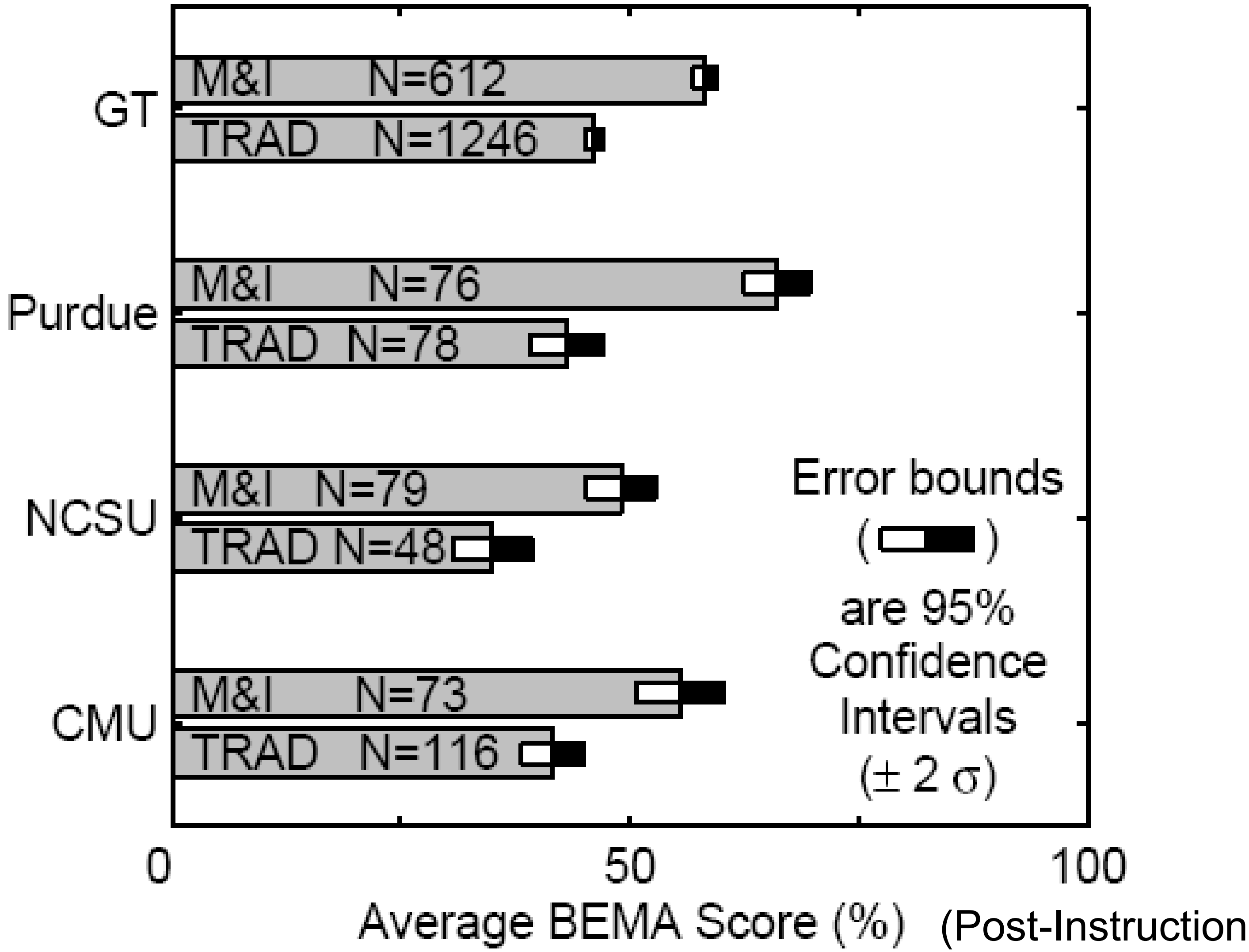
Concept Inventory—Semester 2 (E&M)

Brief Electricity & Magnetism Assessment (BEMA)

- Standardized multiple choice test
  - (31 questions)
- Qualitative and short quantitative questions
- Covers topics *common to both M&I and traditional course*
- Administer "pre-test" at beginning of course, "post-test" at end, measure gains

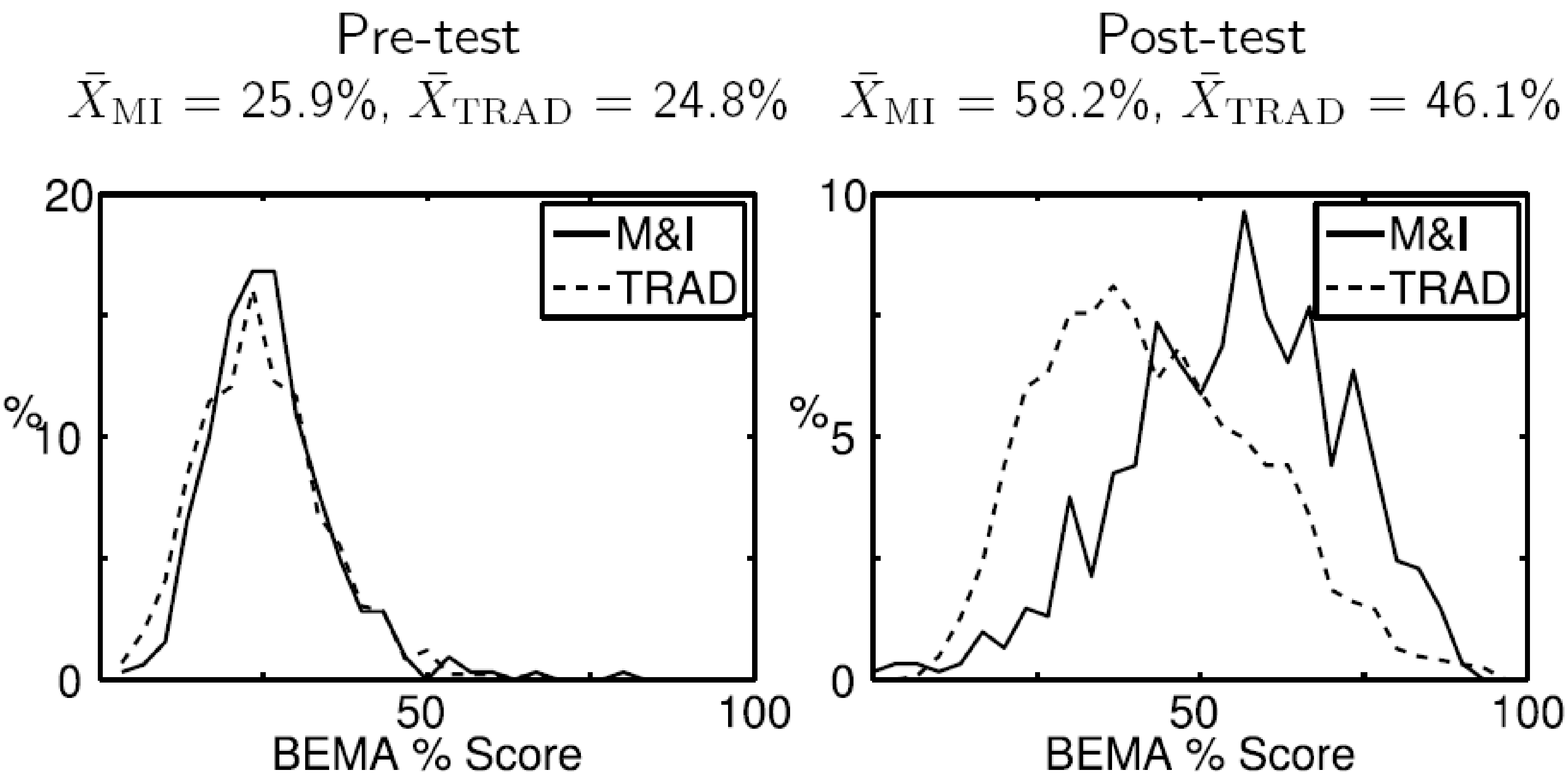
Semester 2 (E&M) Concept Inventory Reform Outperformance

Phys. Rev. ST Phys. Educ. Res. 5, 020105 (2009)



Semester 2 (E&M) Concept Inventory Reform Outperformance

Score Distributions at Georgia Tech

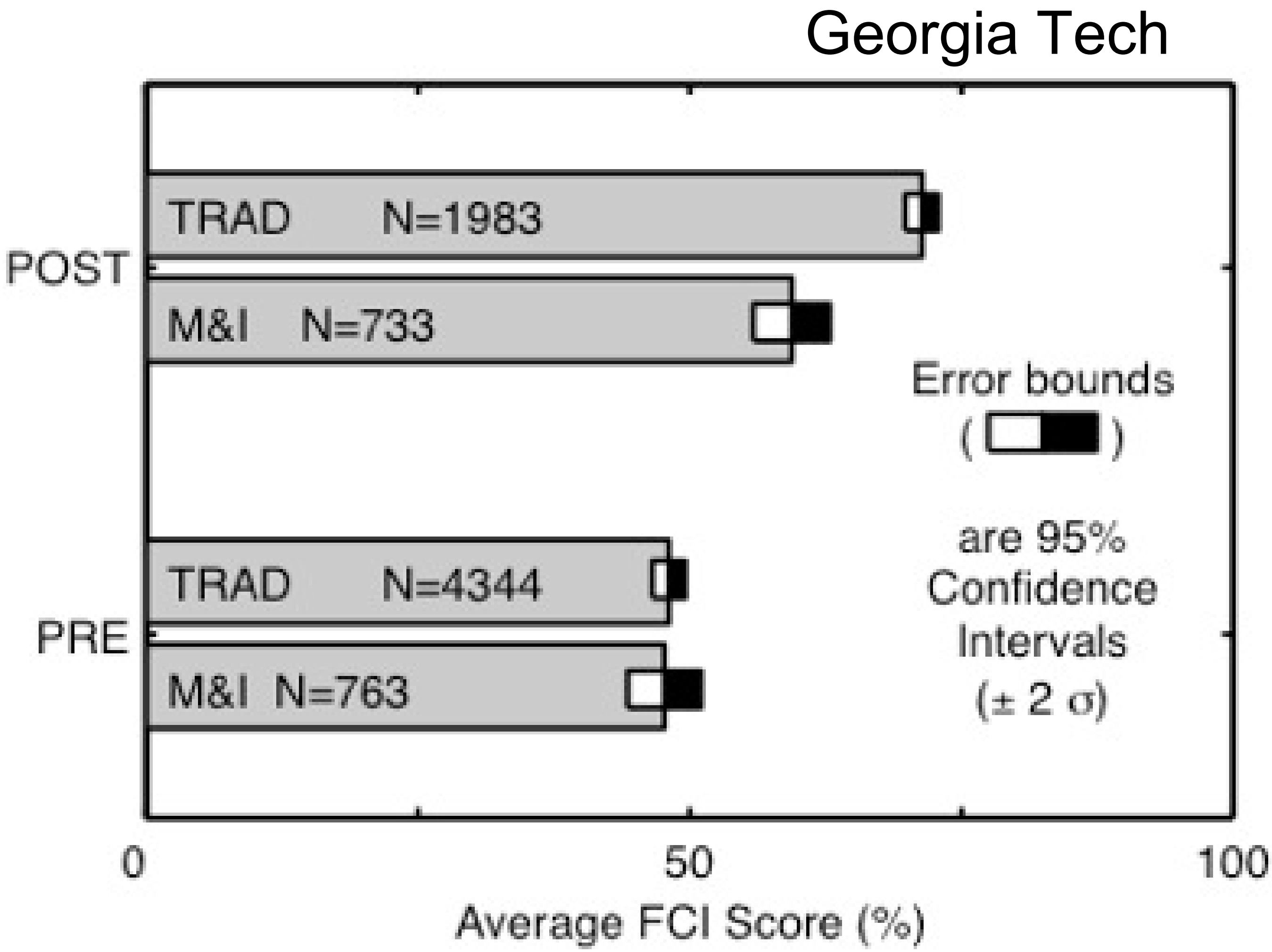


Concept Inventory—Semester 1 (Mechanics)

Force Concept Inventory (FCI)

- Standardized multiple choice test
  - (30 questions)
- Qualitative questions
- Administer “pre-test” at beginning of course, “post-test” at end, measure gains

Semester 1 (Mech.) Concept Inventory Traditional Outperformance



Common Final Exam Questions Similar (Dismal) Performance

Percentage of “Mostly Correct” Responses

Question	TRAD.	M&I
Mech. 1	13%	26%
Mech. 2	29%	24%
Mech. 3	7%	8%
Mech. 4	21%	17%
Mech. 5	59%	49%
E&M 1	10%	17%
E&M 2	22%	39%
E&M 3	20%	29%

Average GPA in Advanced Courses Similar Performance

COE 2001(Engineering Statics)

(Requires Mechanics Prerequisite)

Trad: 2.79 (+/- 0.05) (N=1695)

M&I: 2.81(+/- 0.11) (N=359)

ECE 3025(Electromagnetics)

(Requires E&M Prerequisite)

Trad: 2.93 (+/- 0.15) (N=144)

M&I: 2.95(+/- 0.28) (N=24)

GT Faculty Decision
Adopt or Discard Reform?

Adopt Semester 2 reform,
Hybridize Semester 1 (Final Decision Pending)

+ Faculty Discussion:
  * Not (strongly) data-driven
  * Testimony of participating faculty given significant consideration.
  * Computation/Visualization: accepted prima facie as significantly positive

Lessons Learned: Implementing Sustainable Reform in Large Lecture Courses

More and Better Measurements NEEDED

+ Measurements are difficult

+ Beware of overreliance on particular measurements (Concept Inventories)

E&M Concept Inventory: BEMA

Reform Outperformance

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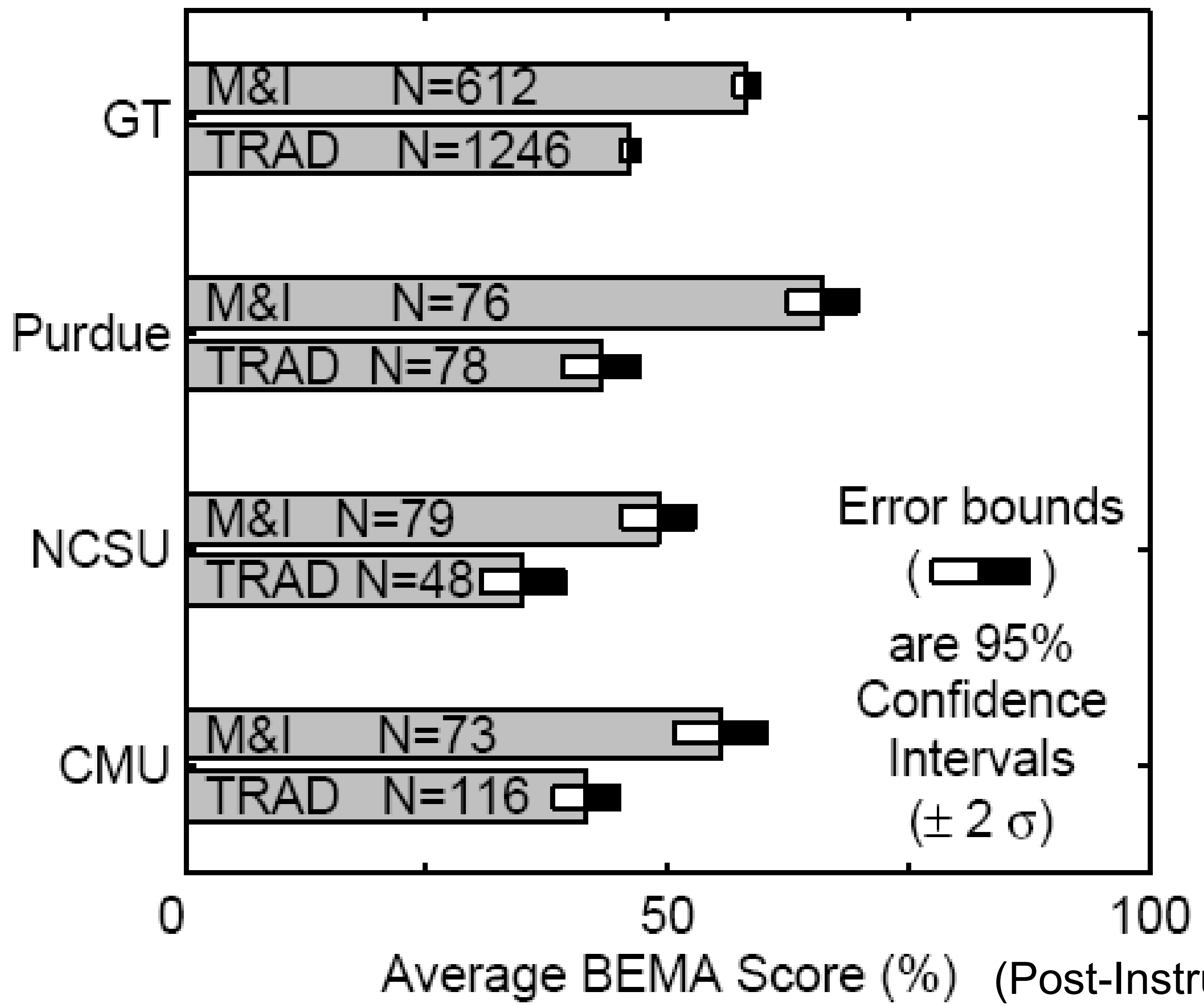
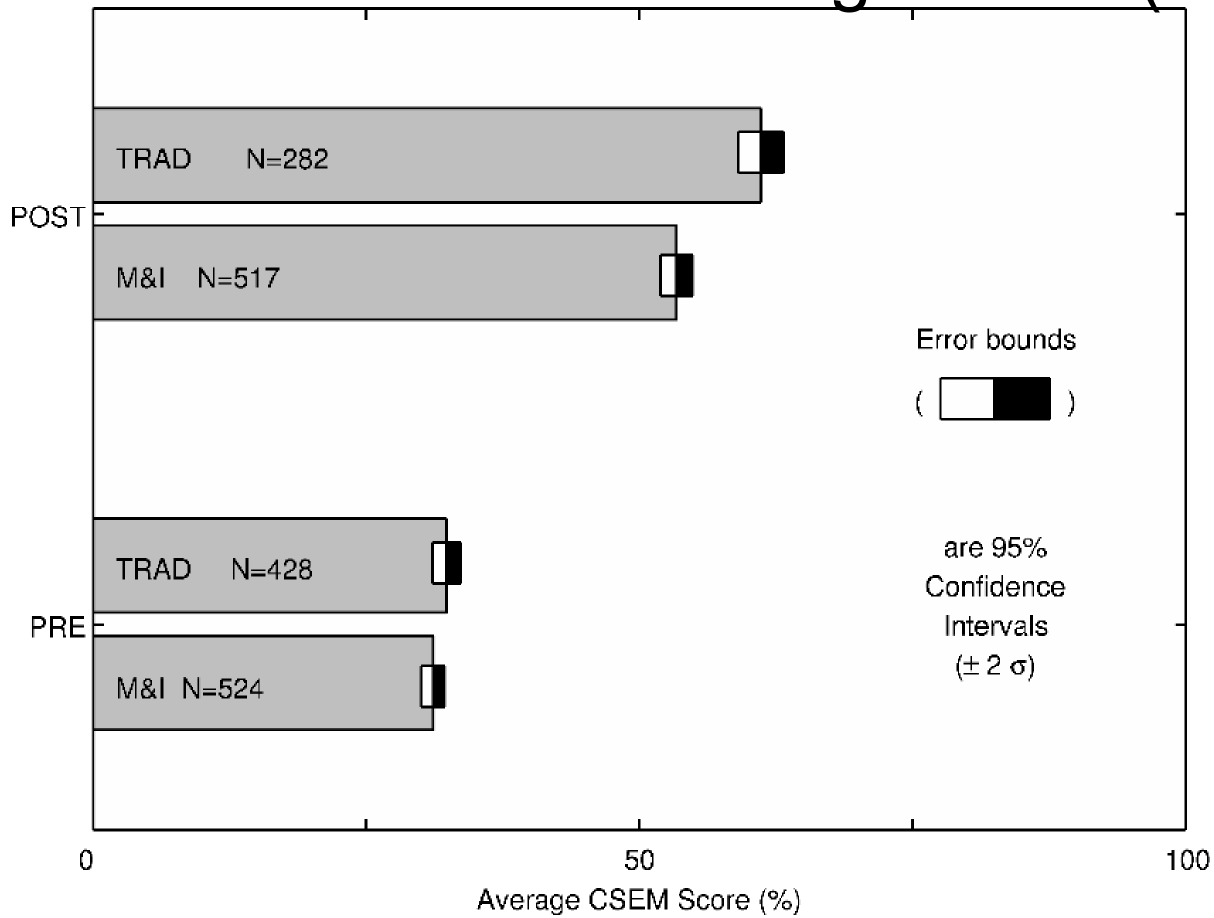


(Post-Instruction)

E&M Concept Inventory: CSEM
Traditional Outperformance

Georgia Tech (Fall 09)



Are BEMA & CSEM Equivalent?

S. Pollock, PERC Proceedings (2008):
Yes, (for same (Traditional) curriculum)

Equivalent for different curricula?

More (and different) measurements needed

More Interdisciplinary Work NEEDED

+ Content specialists largely ignorant of psychological, social, cognitive dimensions of teaching and learning

Example: Cognitive-Science-Inspired: Curricular Reform

Core Mechanics Knowledge

Motion
t, Δt, $\vec{v}$, $\Delta\vec{v}$,
a, $\vec{p}$, $\Delta\vec{p}$

$\boxed{\text{PRINCIPLES}}$

PRINCIPLES
Momentum
Energy
Angular Momentum

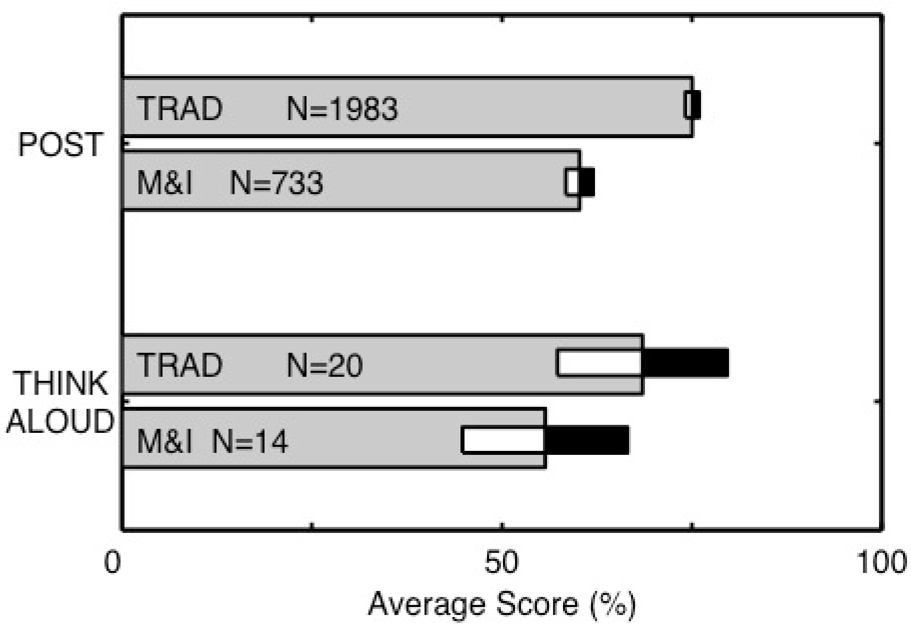
Interactions
$\vec{F}$, potential energy

Chabay & Sherwood (2010); Reif (2008)

Think-aloud protocol study
Semester 1 Concept Inventory

+ Individual interview of volunteers who work problems while narrating their thoughts

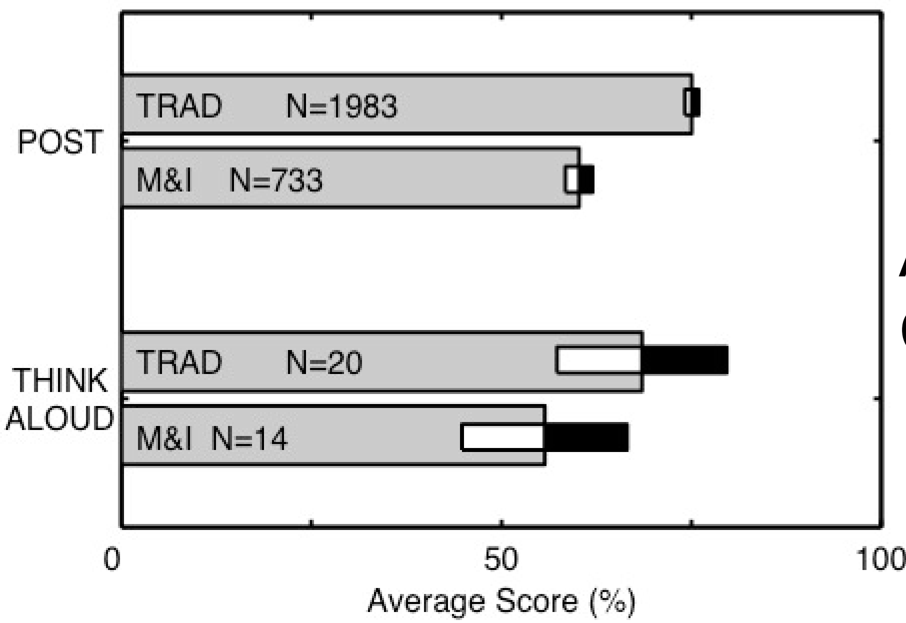
+ Analysis of interview Audio/Video records
(Work in progress)



Average % Score of
Concept Inventory Questions

Think-aloud protocol study
FCI Concept Inventory

+ RESULT:
NO M&I participants used a Fundamental Principle!



Average % Score of
Concept Inventory Questions

Principle-based Curriculum for Novices?

M&I course exercises
(homework, labs, etc)
developed in Traditional way

Develop exercises using cognitive science systematically?

Interdisciplinary work needed

Task analysis

- Determine the knowledge and procedures needed to solve classes of problems
  - May be different for novices and experts!
  - Experts may have “hidden” or “compiled” knowledge
- “Professional novice” (Catrambone)
  - Examines expert working on physics problems from *M&I* course
  - Reconstructs necessary steps
  - Builds general procedure
- Compare student problem solving to task analysis
  - Do they follow same procedure?
  - What pieces are they missing?

Tighter Integration of Computation/Visualization NEEDED

+ M&I Student Experience: Lab only

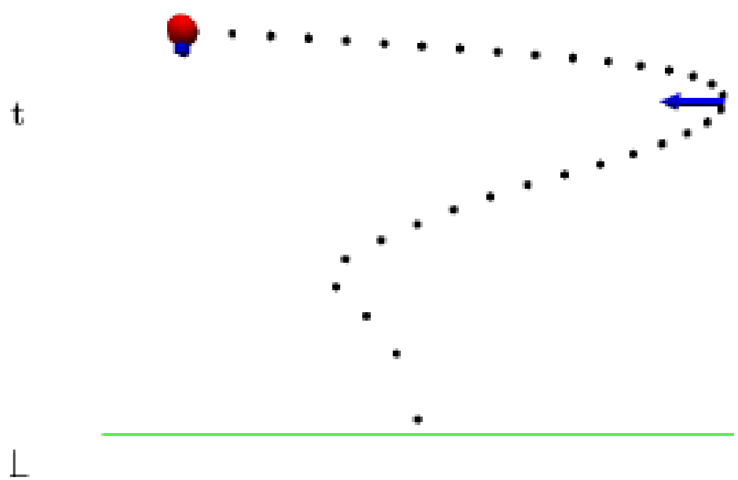
+ Significant Computational Anxiety

Computational Homework

+ Modify lab-developed code to investigate new questions

+ Problems highly-customized to each student

+ Heavy use of visualization to build student intuition



Weather Balloon Trajectory
blue arrow represents $\vec{F}_{\mathrm{net}}$

Computational Homework

For more details:

See Talk GG04: (TUESDAY 7:36pm, Washington I)
Marcos Caballero
“Computational Exercises in Introductory Mechanics”
(Session GG: Teaching with Technology III)

Summary

Curriculum Implementation Keys:

+ Local expert (teaching postdoc)
+ Go slow (build infrastructure)

Strengthen Sustainability:

+ More and better measurements
+ Improve exercises (w/ Cognitive Science)
+ Tighter integration of computation

http://www.physics.gatech.edu/gtper