

A Tale of Two Curricula: Performance of 2000 E&M Students on the BEMA

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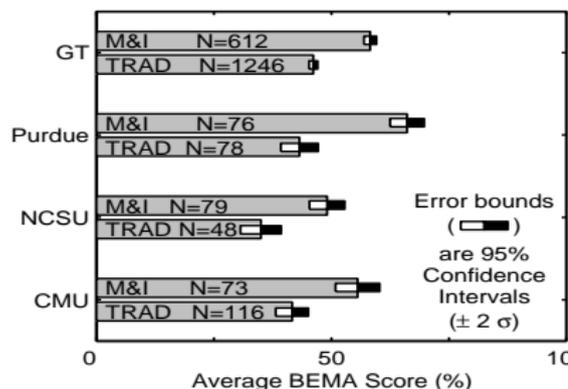
Comparing Electromagnetism Curricula

Brief E&M Assessment (BEMA)

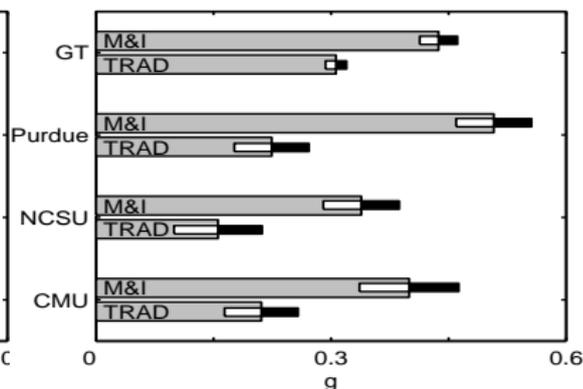
- ▶ Standardized Multiple Choice Test (31 questions)
- ▶ Qualitative and short quantitative questions
- ▶ Topics: Electrostatics (ES), DC Circuits (DC), Magnetostatics (MS), Faraday's Law and Induction (FL)
- ▶ Items common to both Matter and Interactions (M&I) and Traditional (TRAD) course

All Institutions

Comparison of Post-test Scores



Comparison of Normalized Gains



$$\text{Raw Gain, } G = \text{Post}\% - \text{Pre}\%$$

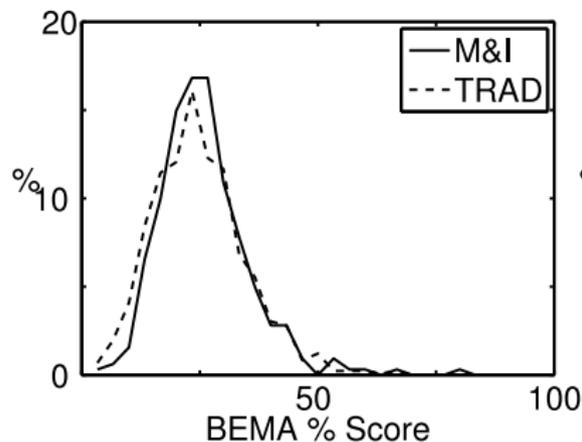
$$\text{Normalized Gain, } g = G / (100\% - \text{Pre}\%)$$

M&I outperforms TRAD at All Institutions

Distribution of BEMA Scores - Georgia Tech

Pre-test

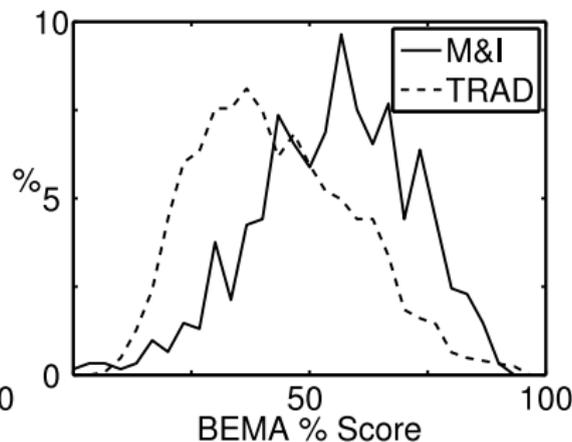
$$\bar{X}_{MI} = 25.9\%, \bar{X}_{TRAD} = 24.8\%$$



$$N_{MI} = 321, N_{TRAD} = 1319$$

Post-test

$$\bar{X}_{MI} = 58.2\%, \bar{X}_{TRAD} = 46.1\%$$

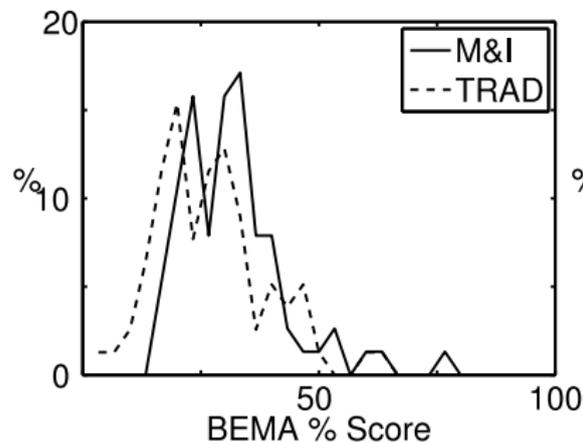


$$N_{MI} = 612, N_{TRAD} = 1246$$

Distribution of BEMA Scores - Purdue

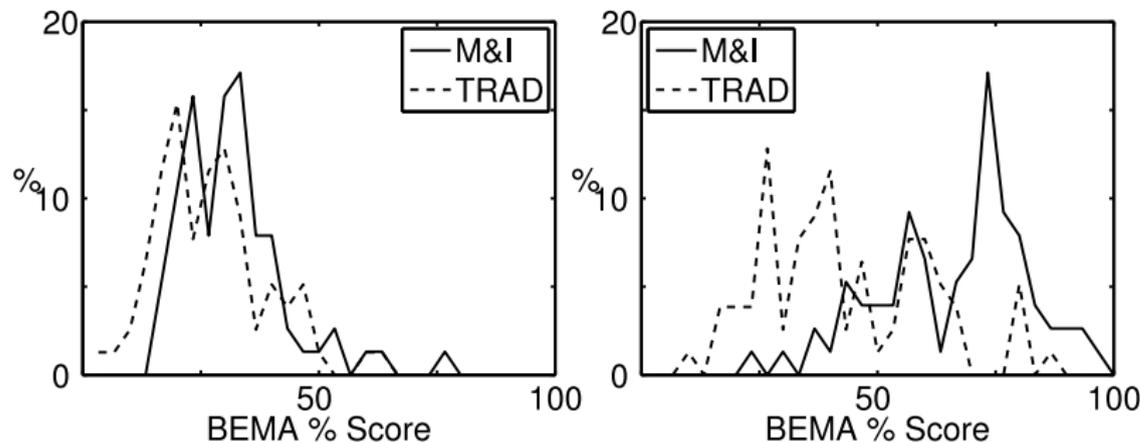
Pre-test

$$\bar{X}_{MI} = 31.7\%, \bar{X}_{TRAD} = 27.2\% \quad \bar{X}_{MI} = 66.1\%, \bar{X}_{TRAD} = 43.2\%$$



$$N_{MI} = 76, N_{TRAD} = 78$$

Post-test

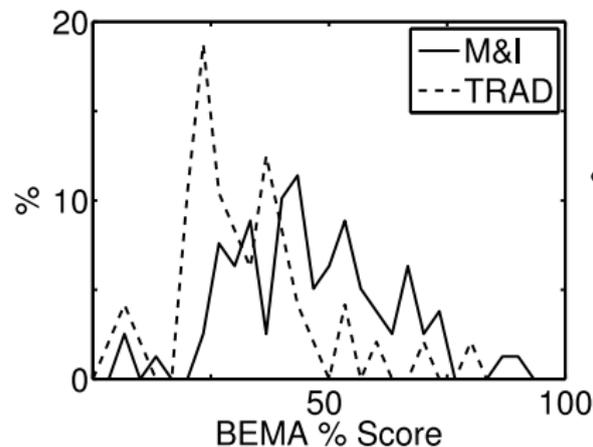


$$N_{MI} = 76, N_{TRAD} = 78$$

Distribution of BEMA Scores - NCSU and CMU

NCSU Post-test

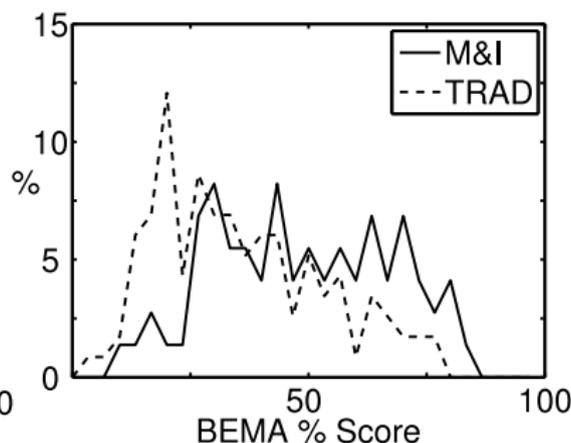
$$\bar{X}_{MI} = 49.7\%, \bar{X}_{TRAD} = 35.0\%$$



$$N_{MI} = 79, N_{TRAD} = 48$$

CMU Post-test

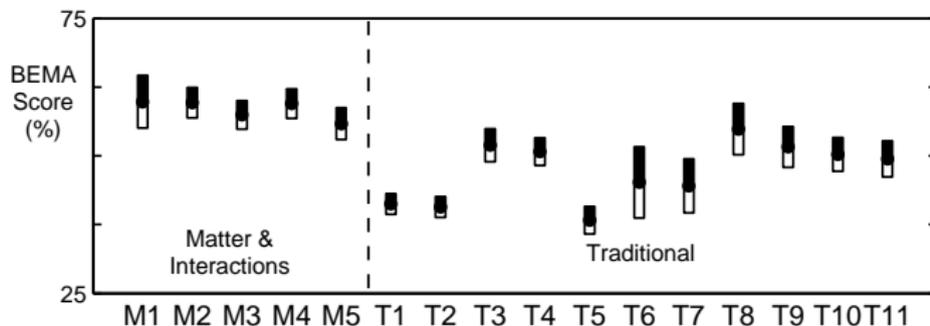
$$\bar{X}_{MI} = 55.6\%, \bar{X}_{TRAD} = 41.6\%$$



$$N_{MI} = 73, N_{TRAD} = 116$$

Post-test BEMA Results by Section at GT

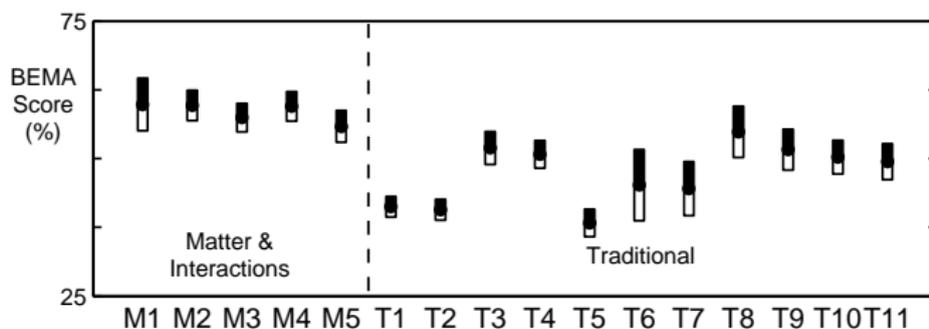
$$\bar{X}_{MI} = 58.2\% \quad \bar{X}_{TRAD} = 46.1\%$$



Large variation for TRAD (pedagogy, instructor)

Post-test BEMA Results by Section at GT

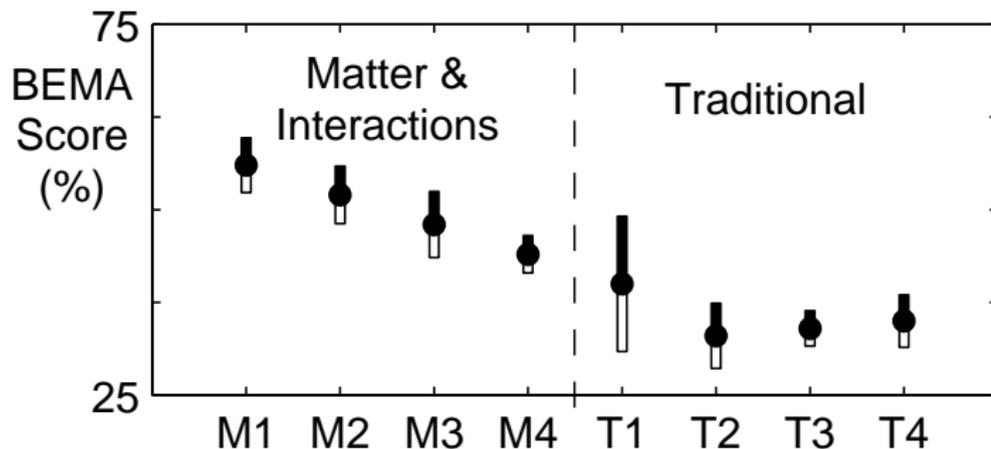
Consider TRAD Instructors using Active Engagement,
i.e. “clickers” (Sections T3,T4,T8,T9,T10,T11)



TRAD Instructors using “clickers”, $\bar{X}_{\text{TRAD}} = 51.3\%$

Post-test BEMA Results by Section at NCSU

$$\bar{X}_{MI} = 49.0\% \quad \bar{X}_{TRAD} = 35.0\%$$



Superior performance by M&I
Used Controlled Laboratory study, Small N

Computing Differences in Performance

Compare Performance per Question

- ▶ Performance is gauged by Raw Gain

$$G = \text{Post}\% - \text{Pre}\%$$

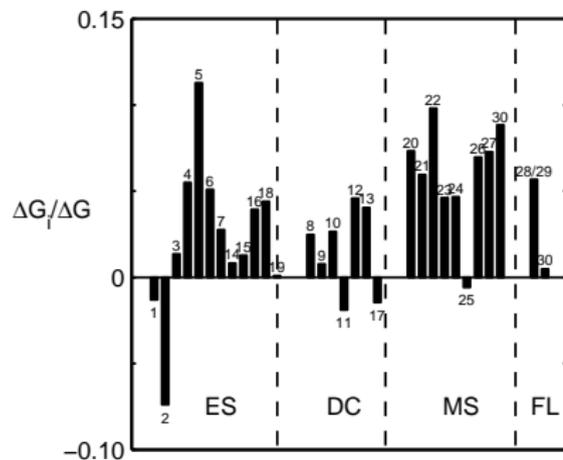
- ▶ Questions can be grouped by Topic

Computing Fractional Differences

- ▶ Overall Difference, $\Delta G = G_{\text{MI}} - G_{\text{TR}}$
- ▶ Item Difference, $\Delta G_i = G_{i,\text{MI}} - G_{i,\text{TR}}$
- ▶ Fractional Difference, $\Delta G_i / \Delta G$

Difference in Performance per Question

Fractional Difference illustrates Strengths of M&I Curriculum

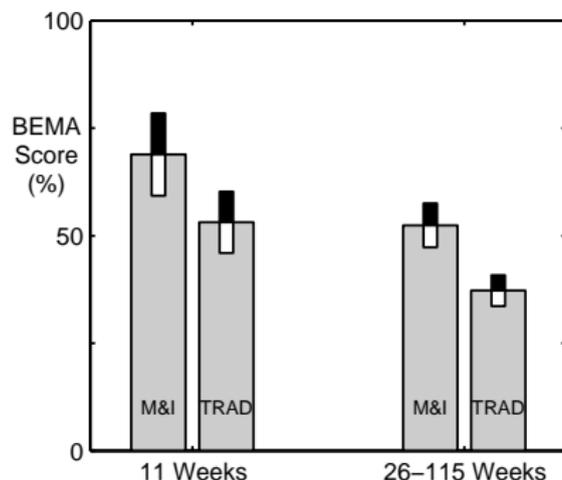


By Topic	
$\sum_{ES} \Delta G_i / \Delta G$	0.2782
$\sum_{DC} \Delta G_i / \Delta G$	0.1118
$\sum_{MS} \Delta G_i / \Delta G$	0.5485
$\sum_{FL} \Delta G_i / \Delta G$	0.0616

Electrostatics (ES), DC Circuits (DC),
Magnetostatics (MS), Faraday's Law (FL)

Electromagnetism Retention Study

M&I Students perform better than TRAD
Even 26-155 Weeks after course



Controlled Laboratory Setting (CMU)

$N_{MI} = 73, N_{TRAD} = 116$

Conclusions

- ▶ BEMA Post-tests scores significantly higher for M&I
(Even compared against TRAD sections using “clickers”)
- ▶ M&I outperforms across topics
(Electrostatics, DC circuits, Magnetostatics, Faraday’s Law)
- ▶ M&I very effective with Magnetostatics and Faraday’s Law
(difficult concepts, highly abstract)
- ▶ M&I students retain E&M knowledge longer
(CMU Retention Study)
- ▶ Incoming classes are the same
(Demographics: GPA, Course GPA, SATs & Pre-test Scores)