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
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Summary of Results

All Institutions

Comparison of Post-test Scores

Comparison of Normalized Gains

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

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

M&I outperforms TRAD at All Institutions
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GT Performance

Distribution of BEMA Scores - Georgia Tech

Pre-test

\[ \bar{X}_{\text{MI}} = 25.9\%, \quad \bar{X}_{\text{TRAD}} = 24.8\% \]

\[ N_{\text{MI}} = 321, \quad N_{\text{TRAD}} = 1319 \]

Post-test

\[ \bar{X}_{\text{MI}} = 58.2\%, \quad \bar{X}_{\text{TRAD}} = 46.1\% \]

\[ N_{\text{MI}} = 612, \quad N_{\text{TRAD}} = 1246 \]
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Purdue Performance

Distribution of BEMA Scores - Purdue

Pre-test
\[ \bar{X}_{MI} = 31.7\%, \, \bar{X}_{TRAD} = 27.2\% \]
\[ N_{MI} = 76, \, N_{TRAD} = 78 \]

Post-test
\[ \bar{X}_{MI} = 66.1\%, \, \bar{X}_{TRAD} = 43.2\% \]
\[ N_{MI} = 76, \, N_{TRAD} = 78 \]
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NCSU and CMU Performance

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)
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Sectional Analysis

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”, $\bar{X}_{\text{TRAD}} = 51.3\%$
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Sectional Analysis

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, \( \Delta G_i / \Delta G \)
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Item Analysis

Difference in Performance per Question

Fractional Difference illustrates Strengths of M&I Curriculum

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)

\[ N_{MI} = 73, \quad N_{TRAD} = 116 \]
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)