



## Longer term impacts of transformed courses on student conceptual understanding of E&M

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### Overview

We used PER-based techniques to transform introductory[1] and upper-division[2] E&M, and investigate impacts of these course transformation on future physics majors.

Summary of these courses and assessments at CU

Course	Population	Pedagogy	Assessment
Physics II	Freshman E&M ~400/term, 7 terms	Transformed: UW Tutorials[5] & Peer instruction[6]	BEMA[3]
Phys 301/302	Junior-level E&M 1 and 2 ~40/term, 7 terms	Trad and transformed[7], Griffiths' text[8]	CUE [4] & BEMA

### Guiding Research Questions

Do we confirm early results showing long-term impacts of introductory reforms?

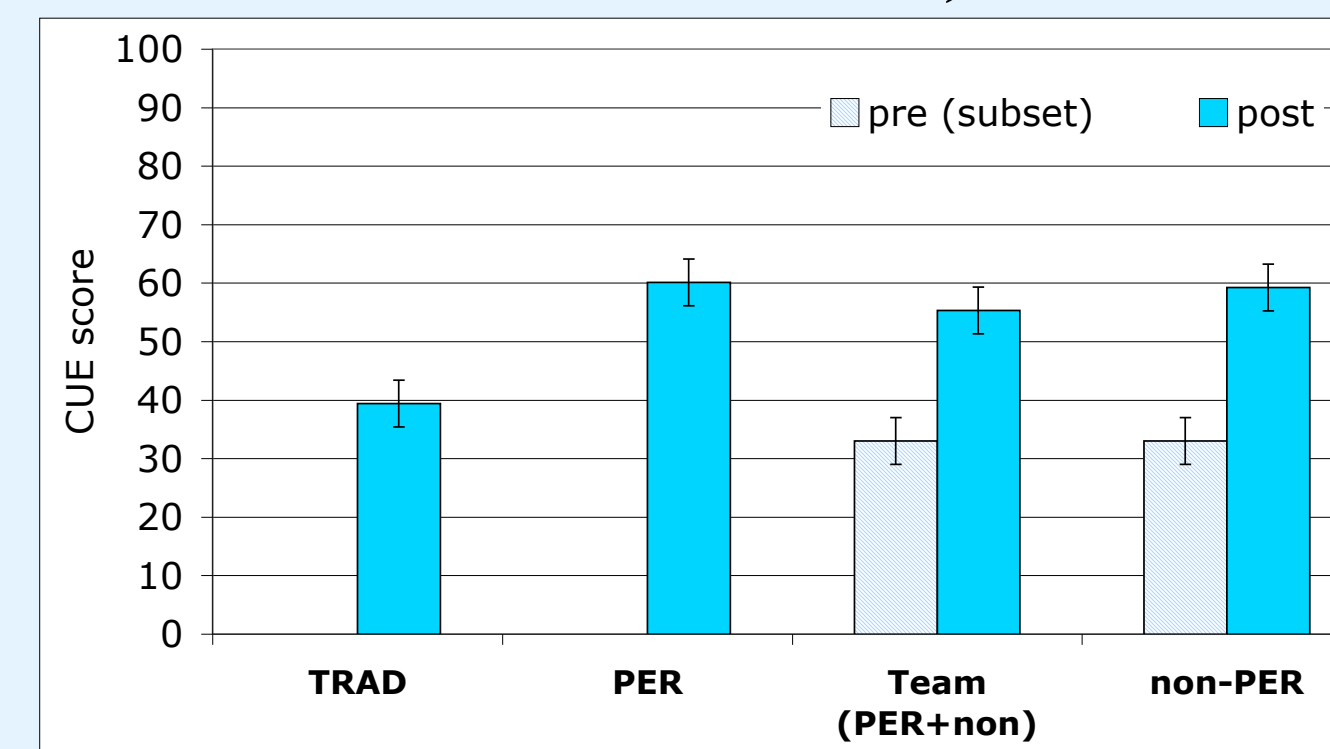
What is/are the nature and influences on the time-evolution of BEMA scores?

Are there differences in long-term retention across different topical areas?

How do upper-division courses impact freshman-level concepts? (BEMA scores)  
Upper-level concepts? (CUE scores)

### Impacts of Transformed upper-division E&M

#### CUE (Colorado Upper-division Electrostatics assessment) outcomes

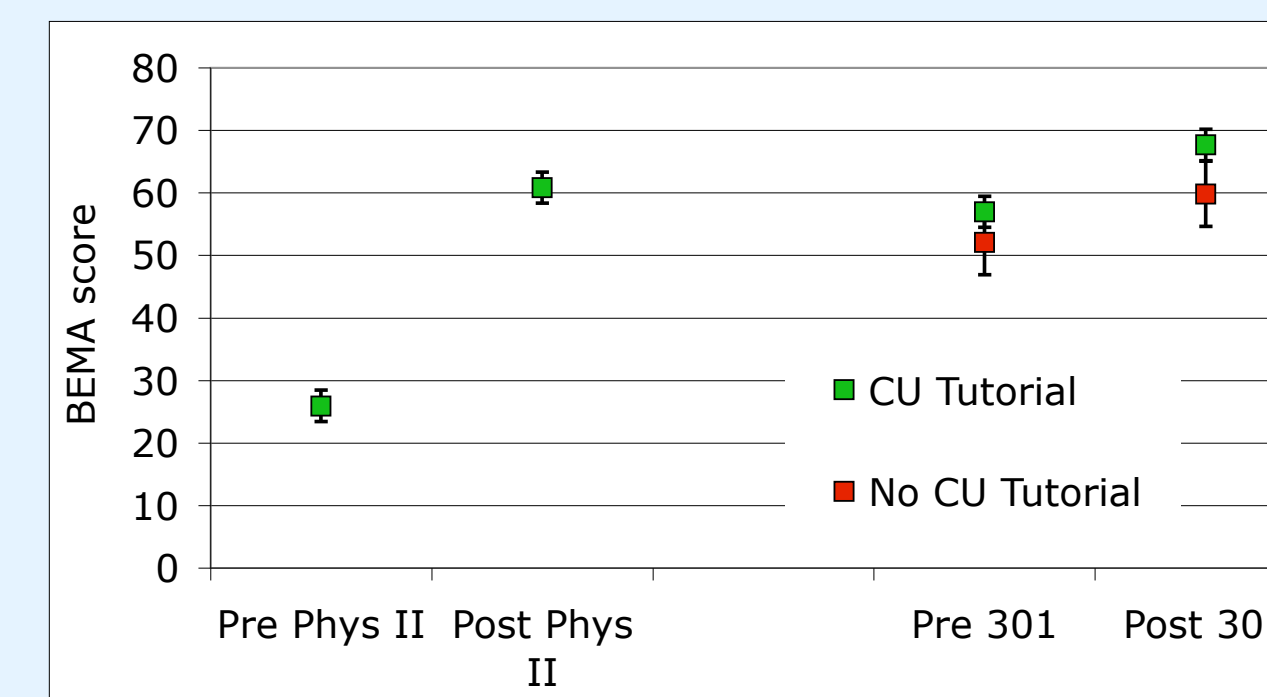


1st term : control semester, traditionally taught  
2nd term: PER faculty (curriculum designer)  
3rd term: team taught, different PER faculty + non-PER  
4th term: non-PER faculty (from previous term)

Transforming upper-division E&M significantly improves junior-level understanding (CUE scores)

#### BEMA outcomes

Shift in BEMA score for tracked students who ended up in transformed 301 (upper-division)

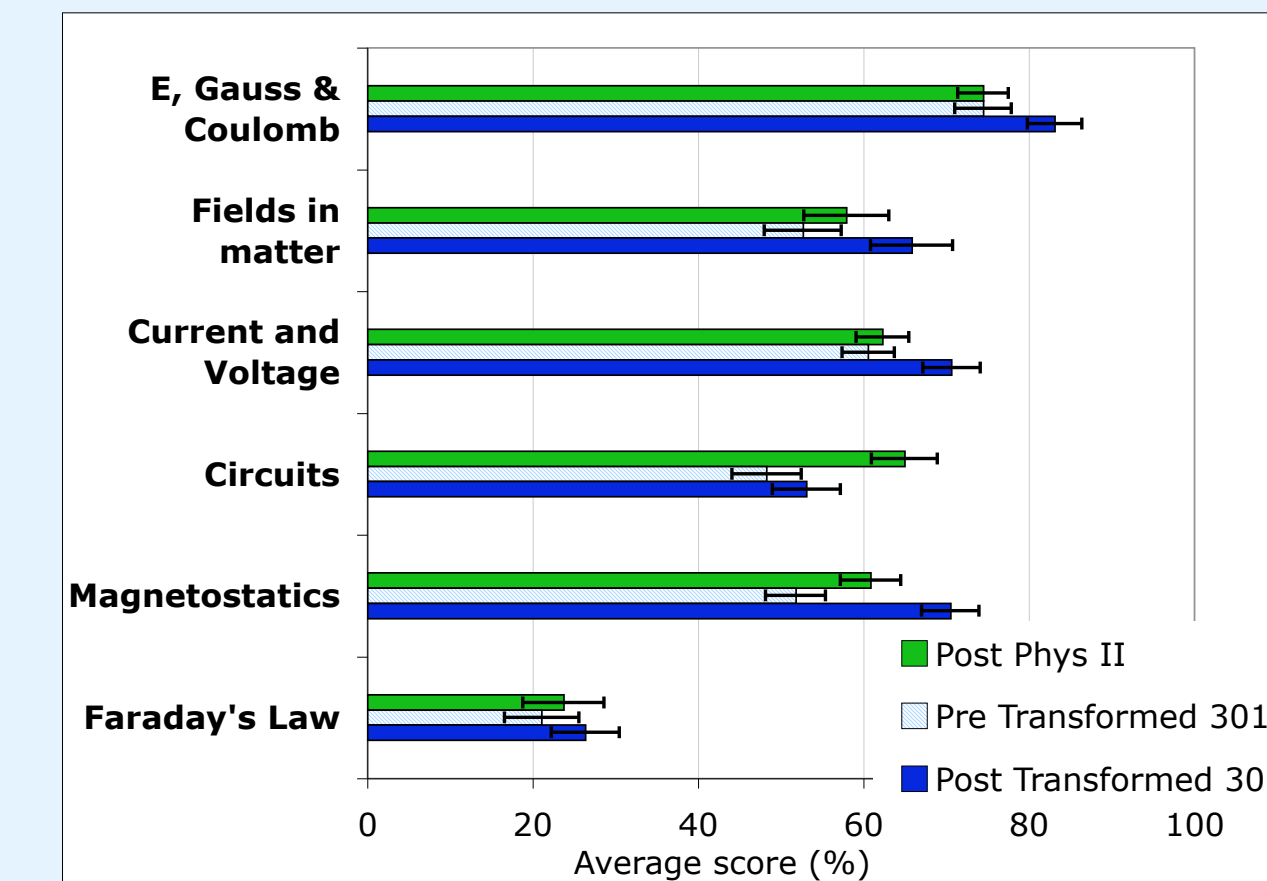


Transformed upper-division E&M yields marginal improvements in BEMA; lower-division courses have long-lasting impact.

N=38 students tracked through transformed 301, + N=19 (transformed 301, but no freshman Tutorials)

Comparison [9]: At peer institutions, typical freshman BEMA post ~35%-45%.

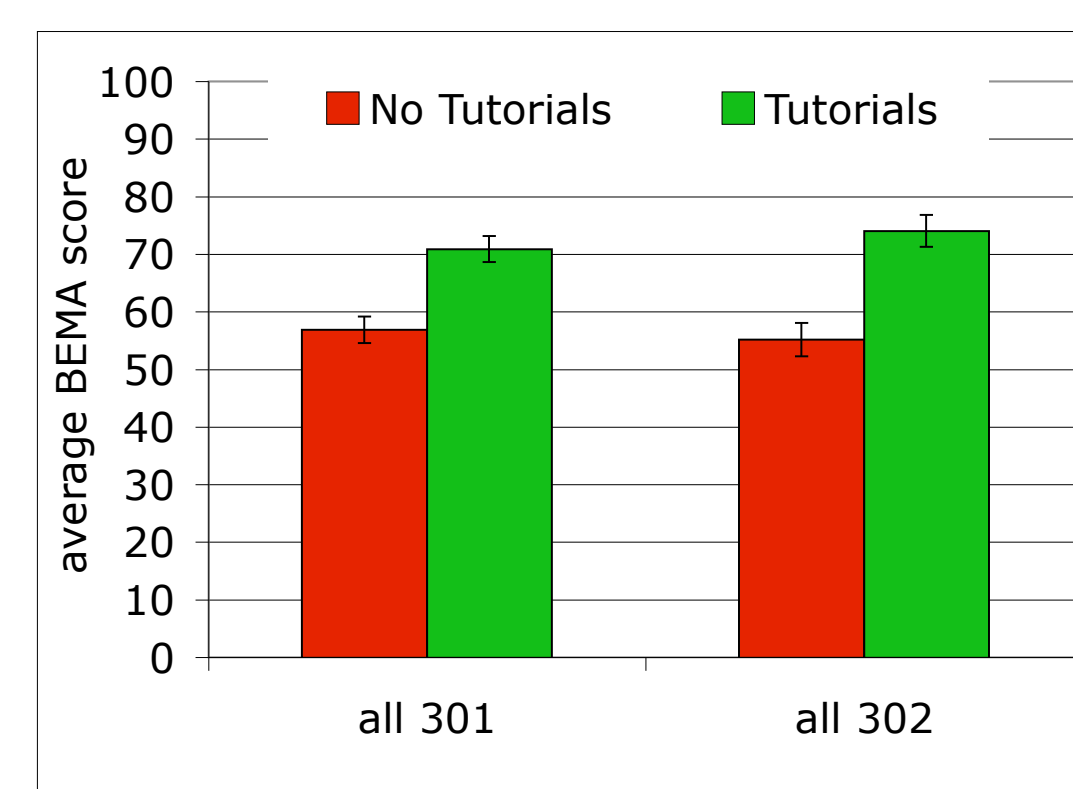
#### Shifts in sub-topics of BEMA (Transformed upper-division 301)



Across topics, we see little shift over ~1.5 years. Students show small positive rebounds after taking transformed 301. (Circuits are not covered in 301, Faraday's law only lightly at the end. Data tracks N=38 students through transformed 301 only)

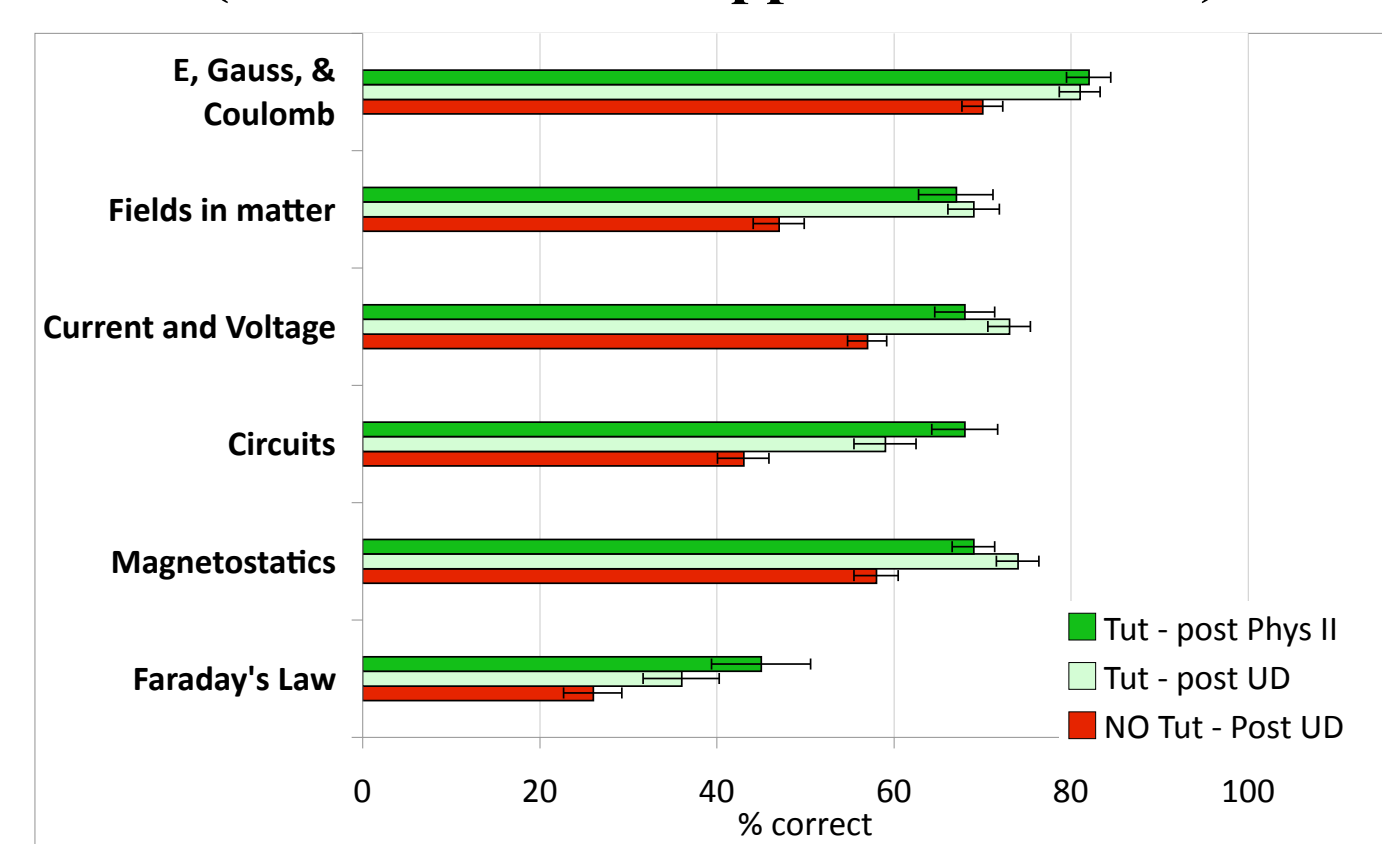
### Longitudinal impacts of freshman E&M experience

Post-upper division BEMA scores.



Students with freshman Tutorials score ~15 pts higher on the BEMA (at the upper-division level.) Difference is statistically and pedagogically significant ( $p < .01$ )

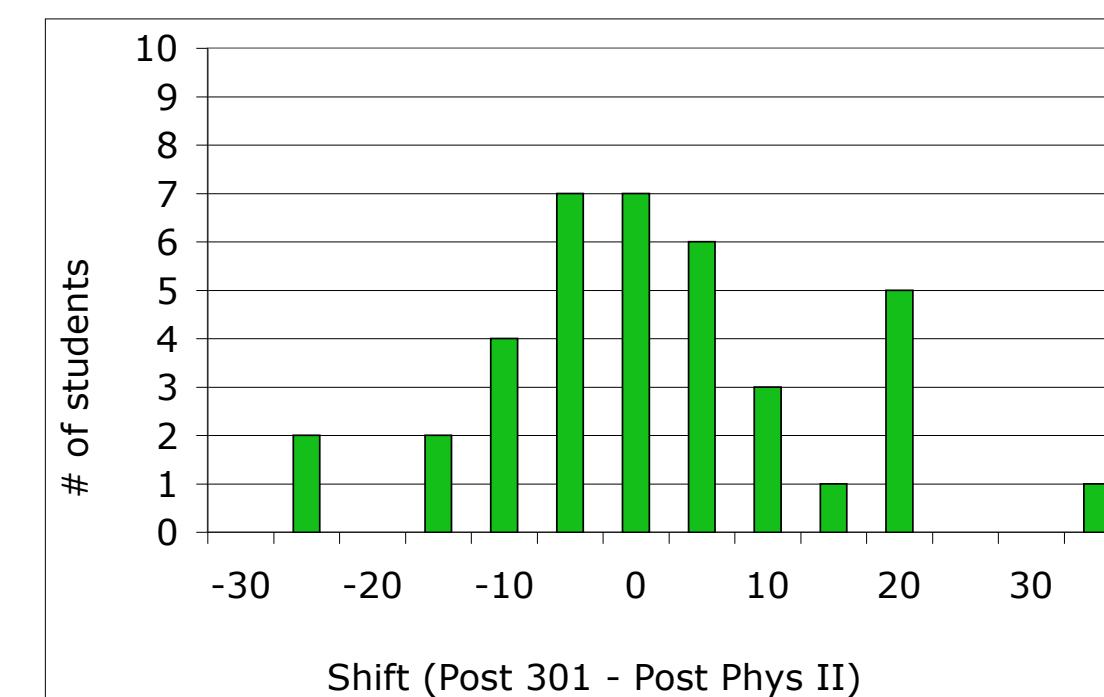
#### Results in sub-topics of BEMA (After traditional upper-division 301)



Clusters (3-8 questions each) of questions from BEMA Across topics, we see little shift over ~1.5 years. Upper-division students with freshman Tutorial experience consistently score higher.

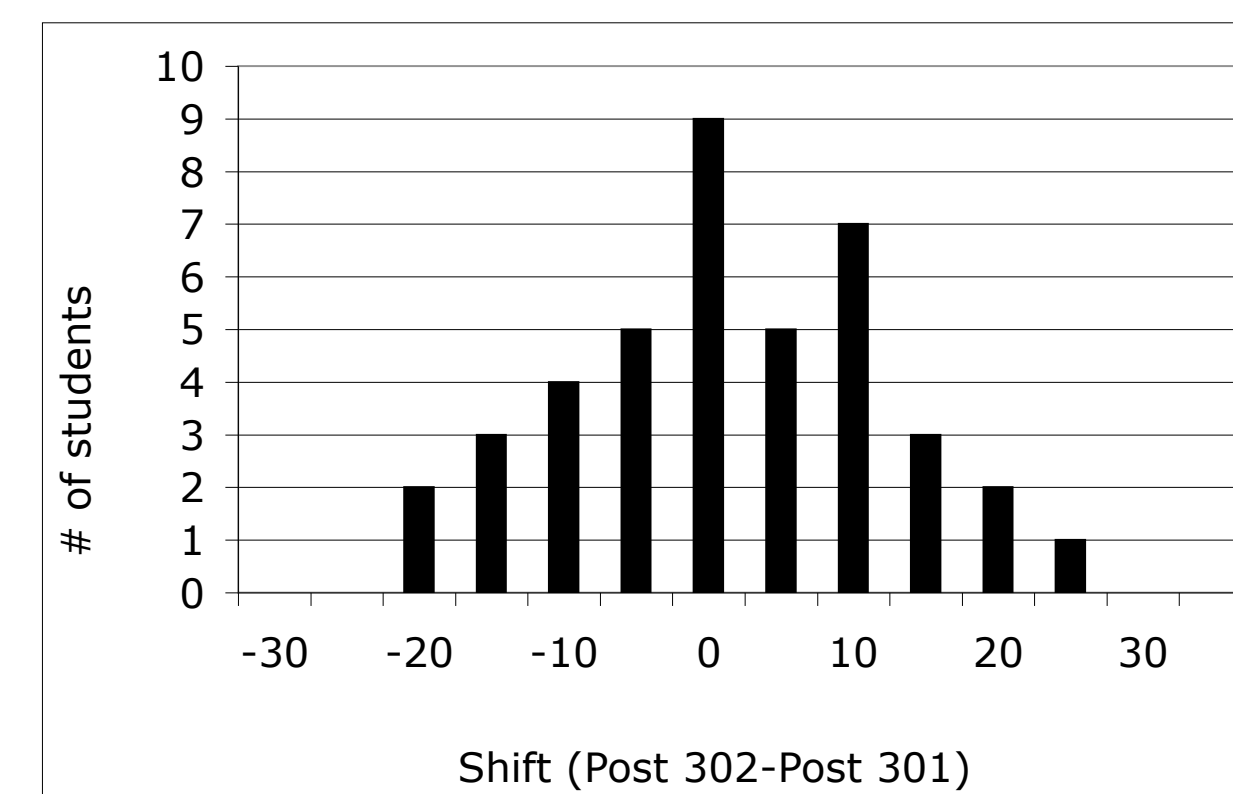
### Impacts of Traditional upper division E&M

Shift in BEMA for tracked students from post Physics II (freshman) to post 301 (upper-division)



Average students' BEMA scores not affected by traditional junior-level Physics 301 (shift is  $0 \pm 2$ , post-freshman to post-upper-div) (In Phys II, ave gain of these N=38 students was  $+39 \pm 2$ )

Shift in BEMA for tracked students from post-301 (upper-division E&M I) to post-302.



Students' BEMA scores are not incrementally impacted by Physics 302 (average shift is  $0 \pm 2$  from post-301 to post-302) (N=41 students tracked from 301 to 302.)

### Conclusions

- CU students with freshman Tutorial experience have higher long-term BEMA scores[7] ... but, negligible improvement on BEMA from traditionally taught upper-division E&M.
- Students show surprisingly small "fade" on BEMA after ~1.5 year (with a small rebound after traditional Phys 301, but no additional rebound after Phys 302.) ... with consistently small differences across subsets of BEMA topics questions
- Students' CUE scores significantly improve after transformed Physics 301 course, but still only modest impacts on BEMA scores.

### References

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