How Mastery Learning Works at Scale

Steve Ritter
Michael Yudelson
Stephen Fancsali
Susan Berman

Carnegie Mellon University
Carnegie Learning

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Adaptive learning in the education factory

• What happens when adaptive learning meets
  – Instructor expectations and practices
  – Student expectations and practices
  – Institutional structure and requirements
About Carnegie Learning

• Started at CMU in 1998
  – Acquired by Apollo Group (U Phoenix) in Sept. 2011
  – Acquired by private investors in Nov. 2015

• Publisher of US 6-16 Math Curricula
  – Core curriculum
    • Cognitive Tutor Software
    • Textbooks
    • Professional Development
  – K-12
    • 400,000 students/year in 2000 schools
  – Higher Ed
    • Developmental mathematics

• Continuing research
Effective at Scale

- RAND Corporation, with funding from US Dept. of Education (IES)
- Algebra 1, blended implementation
- Random assignment of 147 schools, 19,000 students
  - 7 regions across US
  - 2 cohorts
- Intent-to-treat analysis
- Results from year 2 HS
  - No diff in year 1
Model implementation

• Blended
  – Software used 2 days/week
  – Text, collaborative activities 3 days/week
  – Parallel tracks
    • Teacher-paced classroom
    • Student-paced software
MATHia Software

Sequenced topics, unlocked upon completion

Multi-step problem-solving

Mastery via Bayesian Knowledge Tracing
Mastery Learning

• Educational theory (Bloom, 1968)  
  – But used much earlier
• Every student can learn
• Make sure students master one topic before teaching the next  
  – What a topic?  
  • For CT, knowledge component level
• Strong evidence of effectiveness  
  – E.g. Kulik, Kulik & Bangert-Drowns (1990)
Mastery learning goal
Consistent level of challenge

Percent Correct (all students, all actions)

Ritter, et al. (2007)

Data from 88 Geometry students in 1 school
MASTERY LEARNING IN PRACTICE
Mastery in practice

Some classes implement mastery learning

Some don’t
Study

• 1 large urban district
  – Southeastern United States
• 49 middle schools
• 280 classes
• ~11,000 students

• Selected because of size, regular usage, varied implementations
Mastery learning violations are common!

Median = 21%
WHY VIOLATE MASTERY LEARNING?
Theoretical arguments against using MATHia’s mastery

• Pedagogy
  – Don’t believe mastery learning works

• Measurement
  – Teachers might know what students know better than Cognitive Tutor

• Optimization
  – To maximize outcomes, sometimes exposure beats mastery
Structural barriers to mastery

• Teaching can be more difficult
  – Students may need instruction on a wide range of topics

• School systems may assume group pacing
  – Benchmark exams, pacing guides, scheduling

• Expanding instructional time may be impractical
  – Plus worries about “completing” early
Mastery violators make more errors and they increase over time
Mastery Violations affect lower-performing students most

![Graph showing error rate comparison between high and low performing students following mastery and violating mastery.](image_url)
Causation

• Vicious cycle
  – Lower-performing students (on initial tests) violate mastery more often
    • Teacher wants to stay on pace
  – Mastery learning violations differentially hurt these students

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Scaling adaptive learning in traditional schools

• Mastery learning is in all adaptive systems
  – Or some other measure of student knowledge
• Mastery learning is effective
  – Even in traditional environments
• Teachers don’t always recognize this
  – Reporting systems, data like this can help
  – Need to find balance, not binary choice
  – Fundamental problem: do we prescribe or suggest?
• Adaptive learning systems may be more effective in alternative school models.
Next steps

• Relate mastery following to external performance measures
• Model whether prerequisite relationships predict mastery violation effect
• Experimental interventions to improve mastery following