



STUDENT LEARNING AND ANALYTICS AT MICHIGAN

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Next-Generation Analytics with the Learning Dashboard

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Carnegie Mellon University



Cognitively Informed Analytics to Improve Teaching and Learning

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Teaching Professor, Department of Psychology



“How’s your course going?”

Question

How do you know how your course is going?

- A. Based on latest quiz/exam scores
- B. Comparing to previous students/classes
- C. By the “feel” of discussions, participation
- D. Other
- E. It's often rather hard to tell

Students spend 100+ hours
across the term, and yet show
learning gains of only 3%.

(Lovett, Meyer, & Thille, 2008)





3%

We can improve that.

Is learning analytics enough?

Is learning analytics enough?

Prediction



Action

Is learning analytics enough?

Prediction + Understanding  Targeted Action

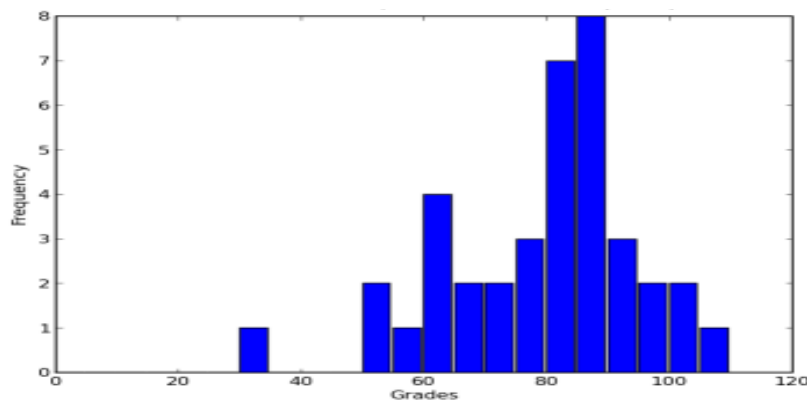
Instructors need up-to-date, *actionable* information

- Quick snapshot of how class is doing
- Access to details on areas of strength & difficulty
- Alerts to noteworthy patterns in student learning
- Pointers to opportunities for adapting their teaching

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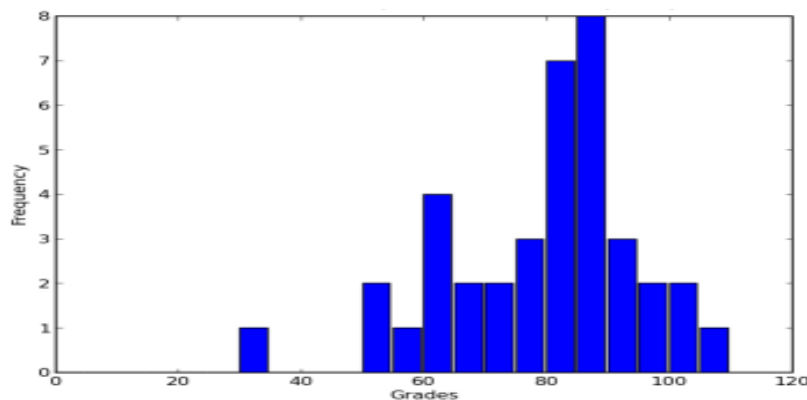
But instructors typically only have access to averages or distributions of student scores on graded activities



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Implications are rather coarse
Results come late, after unit is completed

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Emotional response

No reason/incentive to remediate

Don't know what to do next

We want:

Understanding of students' *learning states*

We need:

Learning analytics *informed by cognitive theory*

The *Learning Dashboard*

Cognitively informed learning analytics system that estimates students' learning skill by skill

Instructors
Students
Designers
Administrators



Deep insights into student learning

When students interact with online learning systems, they produce a rich data stream

Most learning analytic systems barely tap this potential:

Track what students do

Record which questions students get right or wrong

Summarize student progress and performance

Predict some future behavior

The *Learning Dashboard* gets more out of the data:

Reveals what students did/not learn

Quantifies how well students have learned each skill

Identifies consequential patterns in students' learning behaviors

Measures effectiveness of instructional and design choices

Learning Dashboard's Key Ingredients

Cognitive & Learning Theory

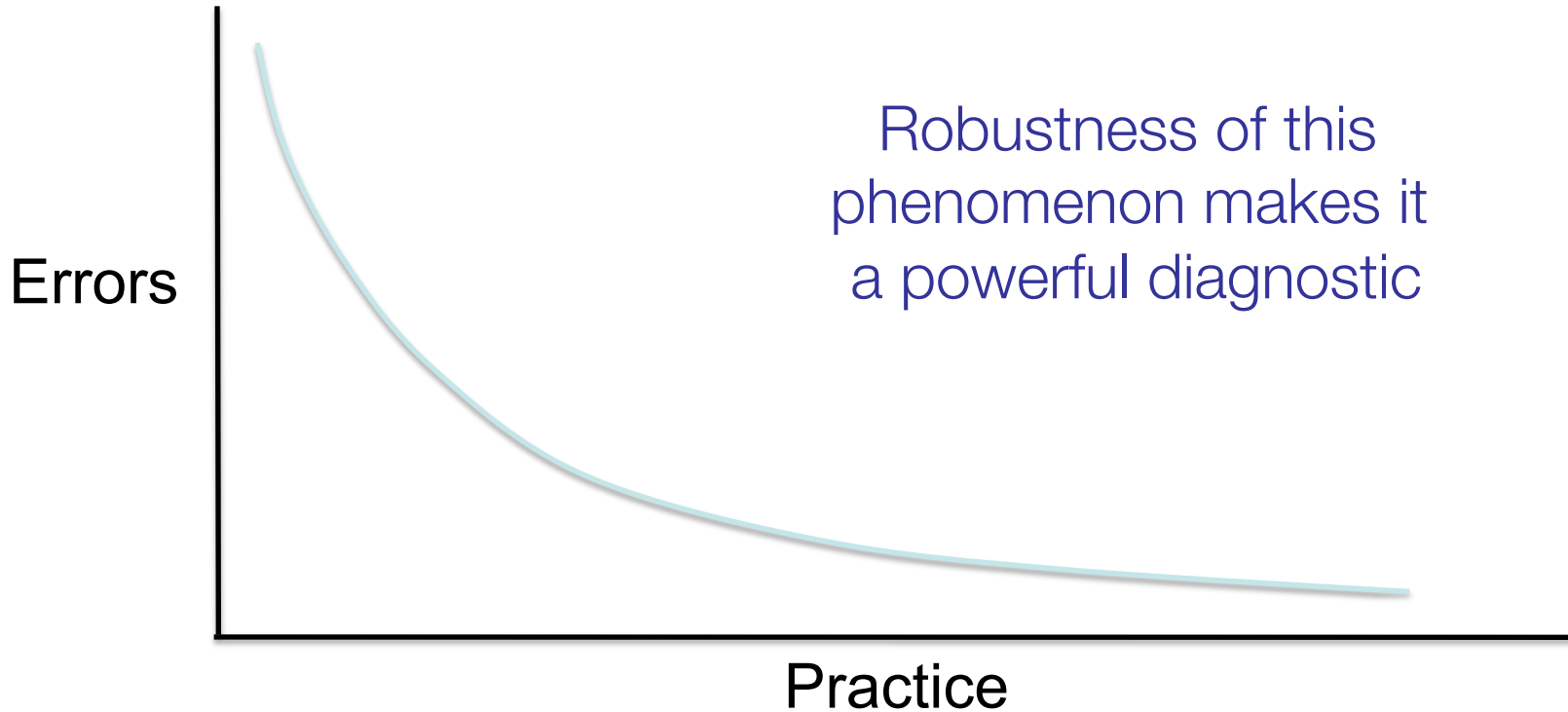
State-of-the-Art Statistical Models

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Cognitive & Learning Theory

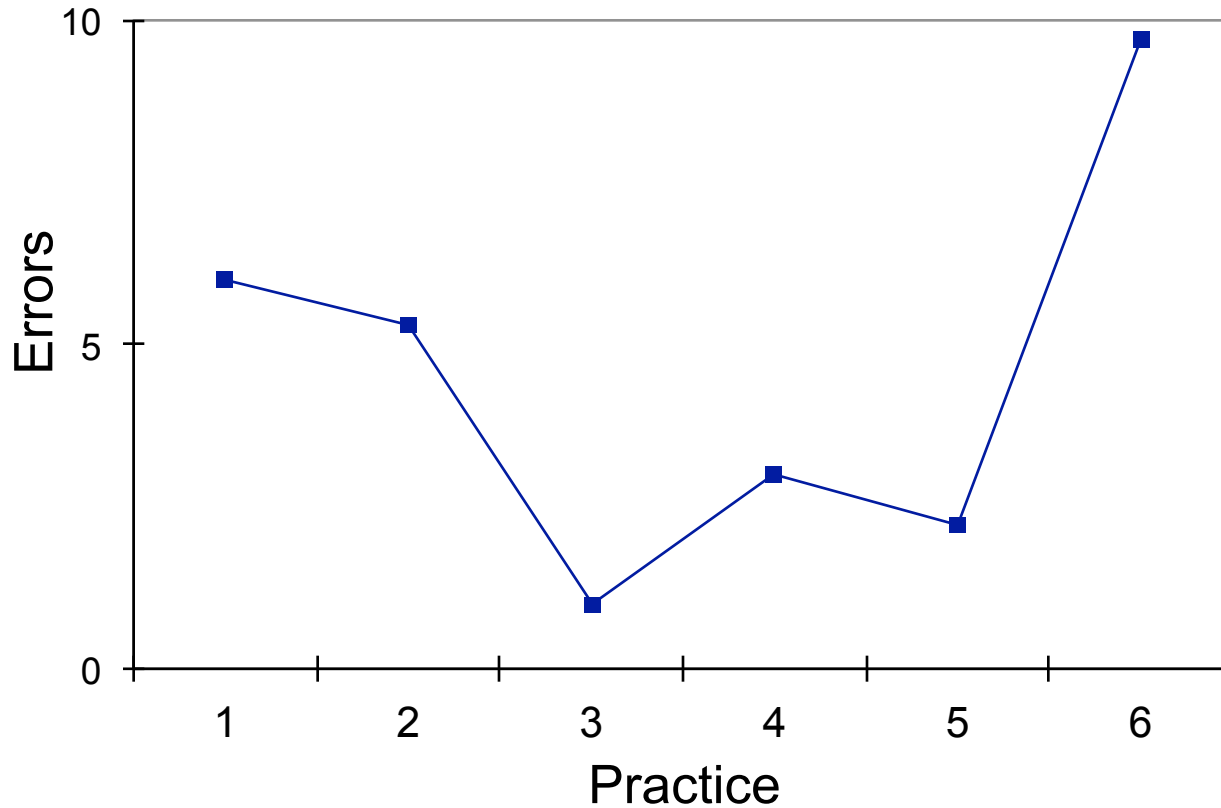
- Decades of research about how people learn
- Starting from a core architecture of cognition, we build a quantitative cognitive model of skill learning
- This exposes deeper features of students' learning than you can get at by looking at just raw performance
- A key idea is that learning is *skill specific*:

The Power Law of Learning

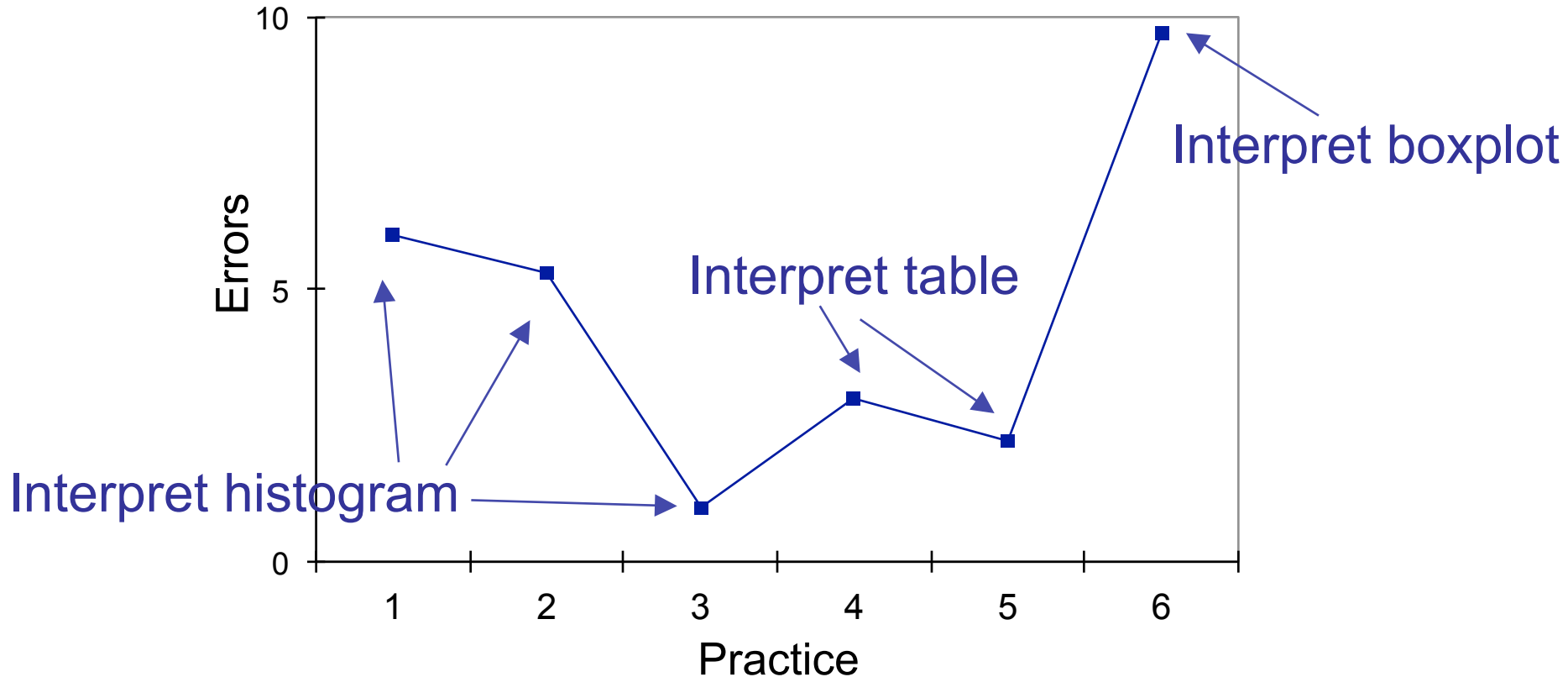


As students practice, performance improves with marginally decreasing returns

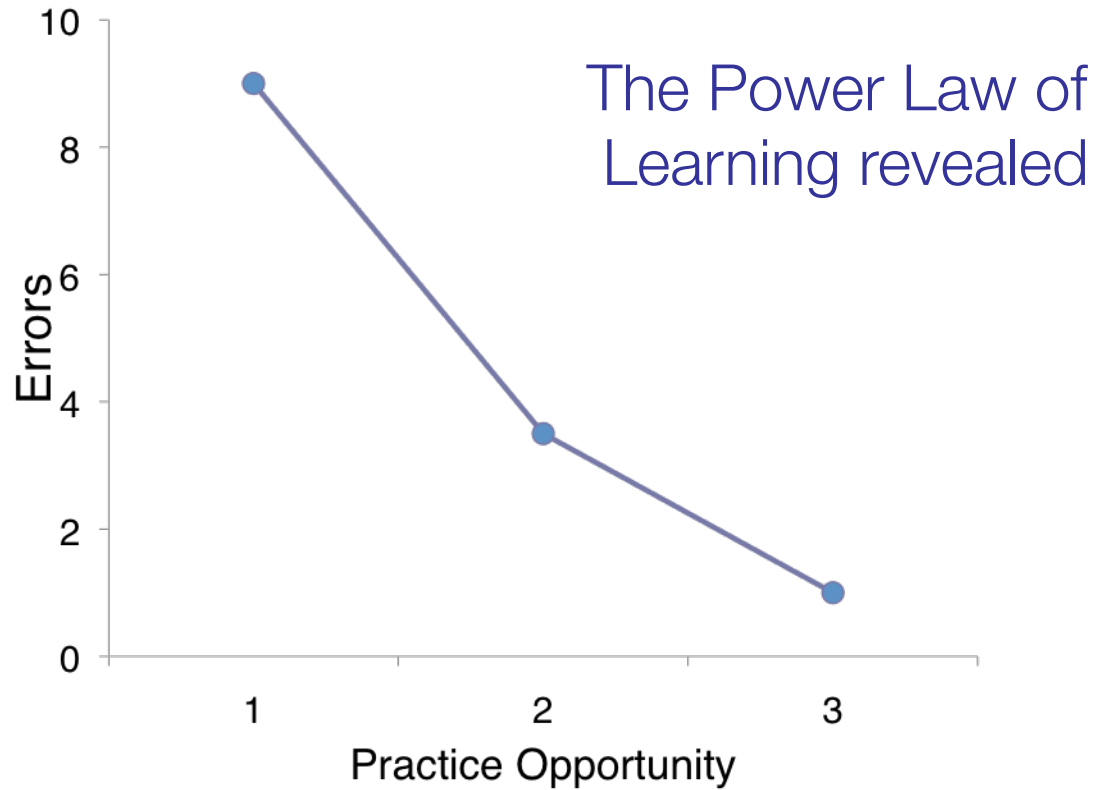
The Performance We Observe



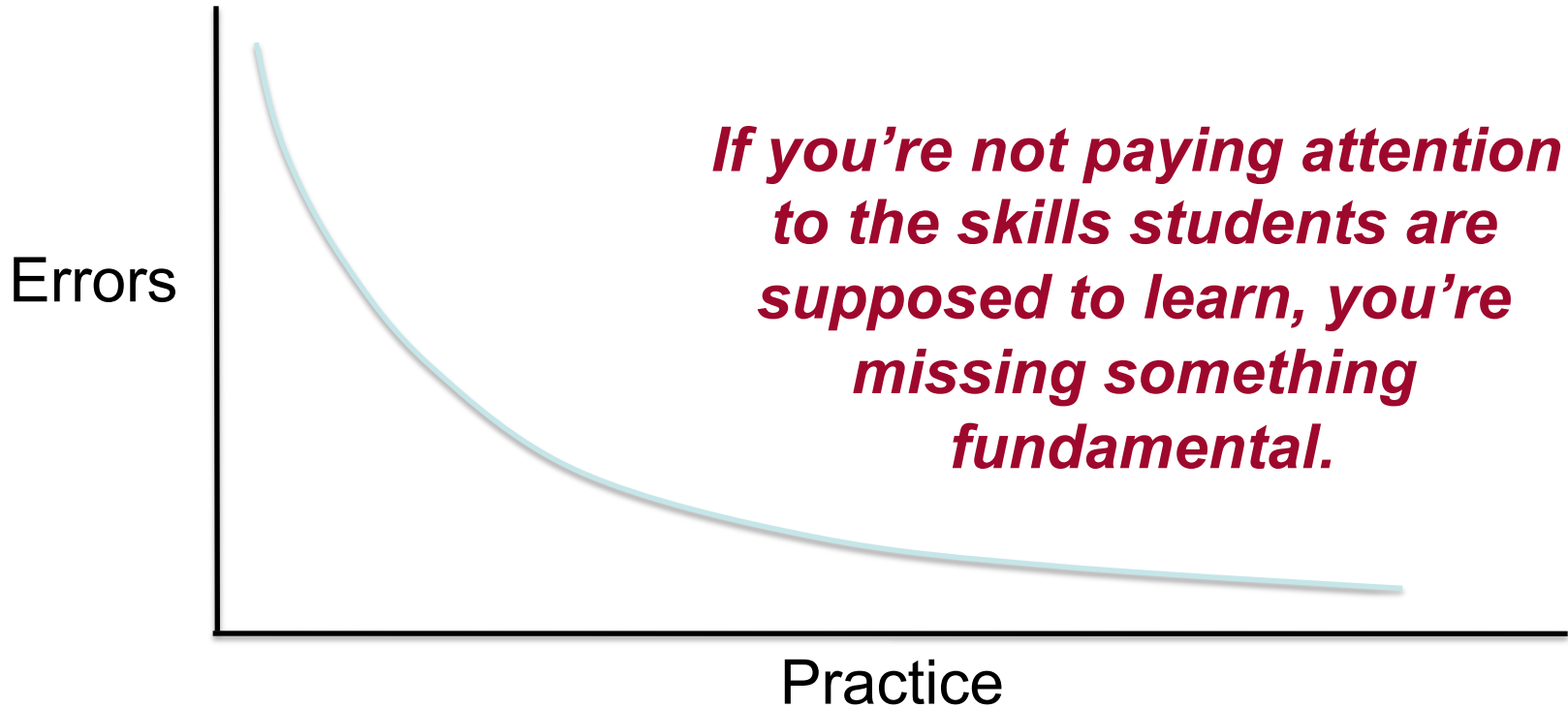
The Underlying Skills



Performance Re-indexed



The Power Law of Learning



As students practice *a given skill*, their performance *at that skill* improves; Other skills are not affected.

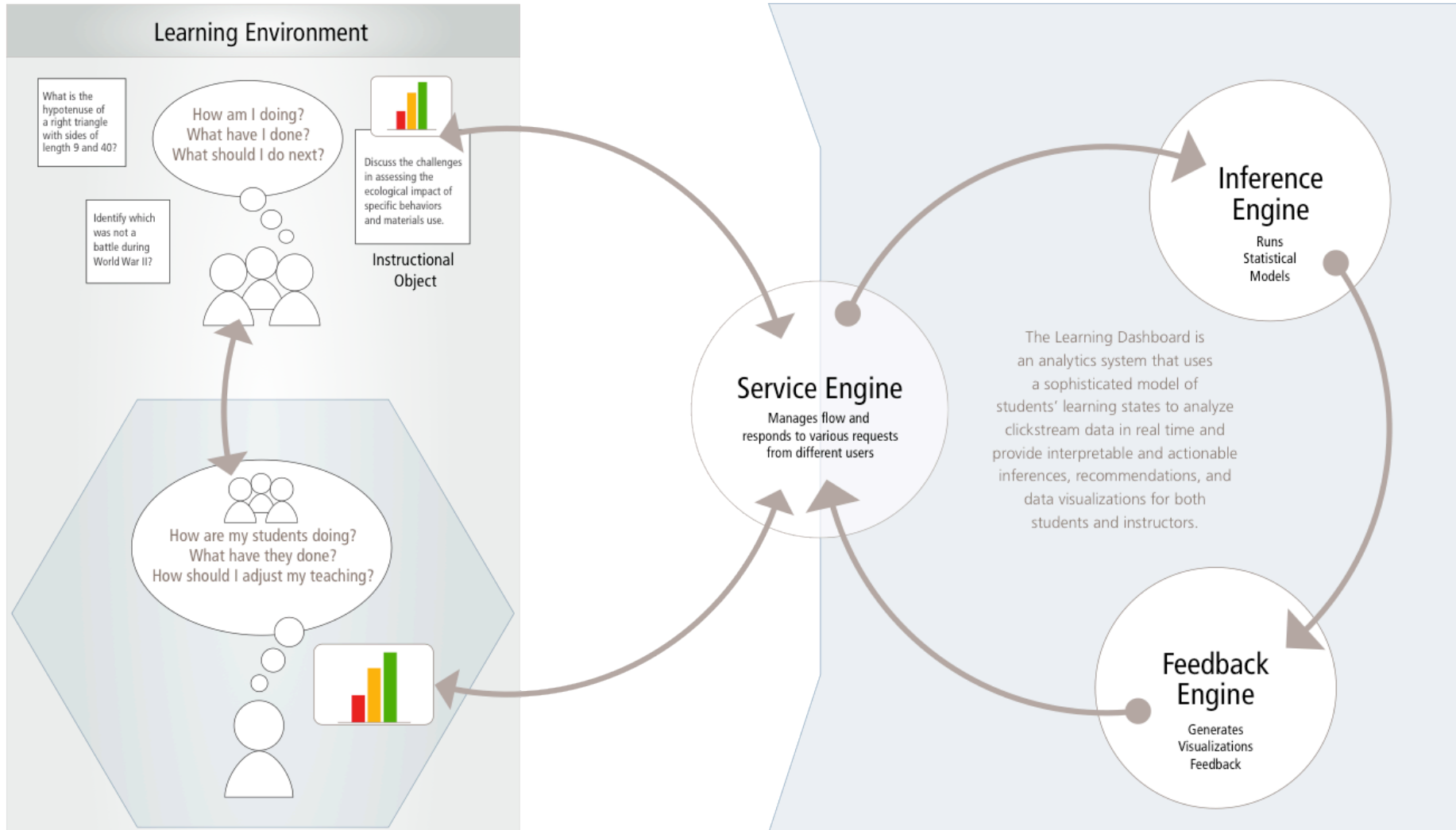
Learning Dashboard's Key Ingredients

State-of-the-Art Statistical Models

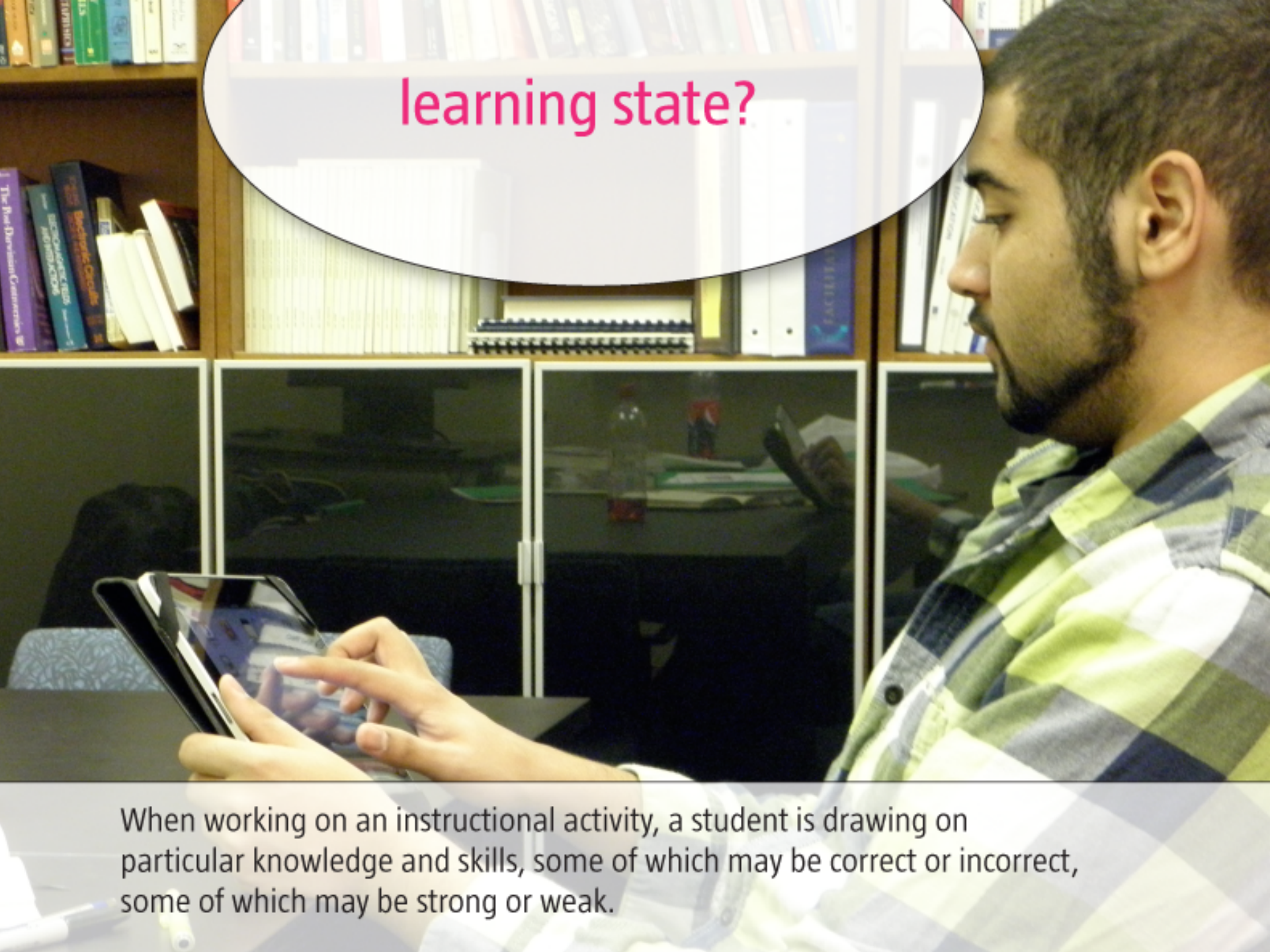
- Bayesian hierarchical models capture multiple components of variation in the data to make sharp inferences
 - The latent variables of interest – *students' learning states* - become more accurate as data accrues
 - “Borrowing strength” across students, classes, and populations improves precision and generalizability
- Sophisticated algorithms enable efficient computation

LEARNING DASHBOARD

Instrumenting for the Learning Dashboard is simple and easily automated



Learning Dashboard, Copyright 2012, All Rights Reserved

A young man with a beard, wearing a plaid shirt, is sitting at a desk in a library or study area. He is looking at a tablet computer he is holding in his hands. The background shows bookshelves filled with books and a desk with a water bottle and papers. A thought bubble is superimposed over the top part of the image, containing the text 'learning state?'.

learning state?

When working on an instructional activity, a student is drawing on particular knowledge and skills, some of which may be correct or incorrect, some of which may be strong or weak.



estimated learning state



student learning state



The student's interactions are transmitted to the *Learning Dashboard* where state-of-the-art statistical and cognitive models make inferences about the student's current learning state.

estimated learning state



Module 8 :: Random Variables

You will be working to achieve these learning objectives

LEARNING OBJECTIVES

Distinguish between discrete and continuous random variables.

Find the probability distribution of discrete random variables, and use it to find the probability of events of interest.

Find the probability density function of continuous random variables, and apply it to find probabilities.

TO CONTENT

TO CONTENT

TO CONTENT

TAKE PRE-TEST

Apply the rules of mean and variance to find the mean and variance of a linear transformation of a random variable and the sum of two independent random variables.

TO CONTENT

TAKE PRE-TEST

TO CONTENT

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TO CONTENT

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Find probabilities associated with the normal distribution.

Use the normal distribution as an approximation of the binomial distribution, when appropriate.

TO CONTENT

TAKE PRE-TEST

TO CONTENT

TAKE PRE-TEST

LEARNING PLAN

1 2 3 4
5 6 7 8 9 10 11
12 13 14 15 16 17 18
19 20 21 22 23 24 25
26 27 28 29 30

Important notes

- [June 15](#) :: [link to assignment](#)
- [June 20](#) :: [link to test](#)

Show all deadlines

Instructors

- Marika Lorenz
- Christopher Genova

The *Learning Dashboard* creates interactive displays to communicate key aspects of the learning state to the **student**, instructor, and administrator.



Student clicks on a recommendation from the *Learning Dashboard* and goes back into content.

PREDICTED MASTERY LEVELS



Learning Objectives

Classify a data analysis situation (involving two variables) according to the "role type classification," and state the appropriate display and/or numerical measures that should be used in order to summarize the data. [Hide Sub-Learning Objectives]

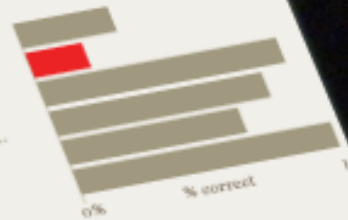
Predicted Mastery by Student

48 students
1 dot = 1 student



Class Accuracy by Sub-Learning Objective

Identify relevant variables
Classify variable's role/type
Identify correct case
State the appropriate display ...
Sub Learning Objective 5
Sub Learning Objective 6



Produce a two-way table, and interpret the information stored in it about the association between two cat. variables by comparing conditional percents. [Show Sub-Learning Objectives]

Graphically display the relationship between two quantitative variables and describe: a) the overall pattern, b) striking deviations from the pattern. [Show Sub-Learning Objectives]

Interpret the value of the correlation coefficient, and be aware of its limitations as a numerical measure of the association between two quantitative variables. [Show Sub-Learning Objectives]

In the special case of linear relationship, use the least squares regression line as a numerical measure of the association between two quantitative variables. [Show Sub-Learning Objectives]

The *Learning Dashboard* creates interactive displays to communicate key aspects of the learning state to the student, **instructor**, and administrator.

Accelerated Learning Hypothesis

Hypothesis: With this kind of adaptive teaching and learning, students can learn the **same material** as they would in a traditional course in **shorter time** and still show **equal or better learning**.

(Lovett, Meyer, & Thille, 2008)

Three Accelerated Learning Studies

Within the Open Learning Initiative's Statistics course:

#1 Small class, expert instructor

Collect baseline data on standard measures

Test new dependent measures

#2 Replication with larger class

With retention & transfer follow-up 4+ months later

#3 Replication and extension to a new instructor

Adaptive/Accelerated vs. Traditional

Two 50-minute classes/wk

Four 50-minute classes/wk

Eight weeks of instruction

Fifteen weeks of instruction

Homework: complete OLI activities on a schedule

Homework: read textbook & complete problem sets

Tests: Three in-class exams, final exam, and CAOS test

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Same content but different *kind* of instruction

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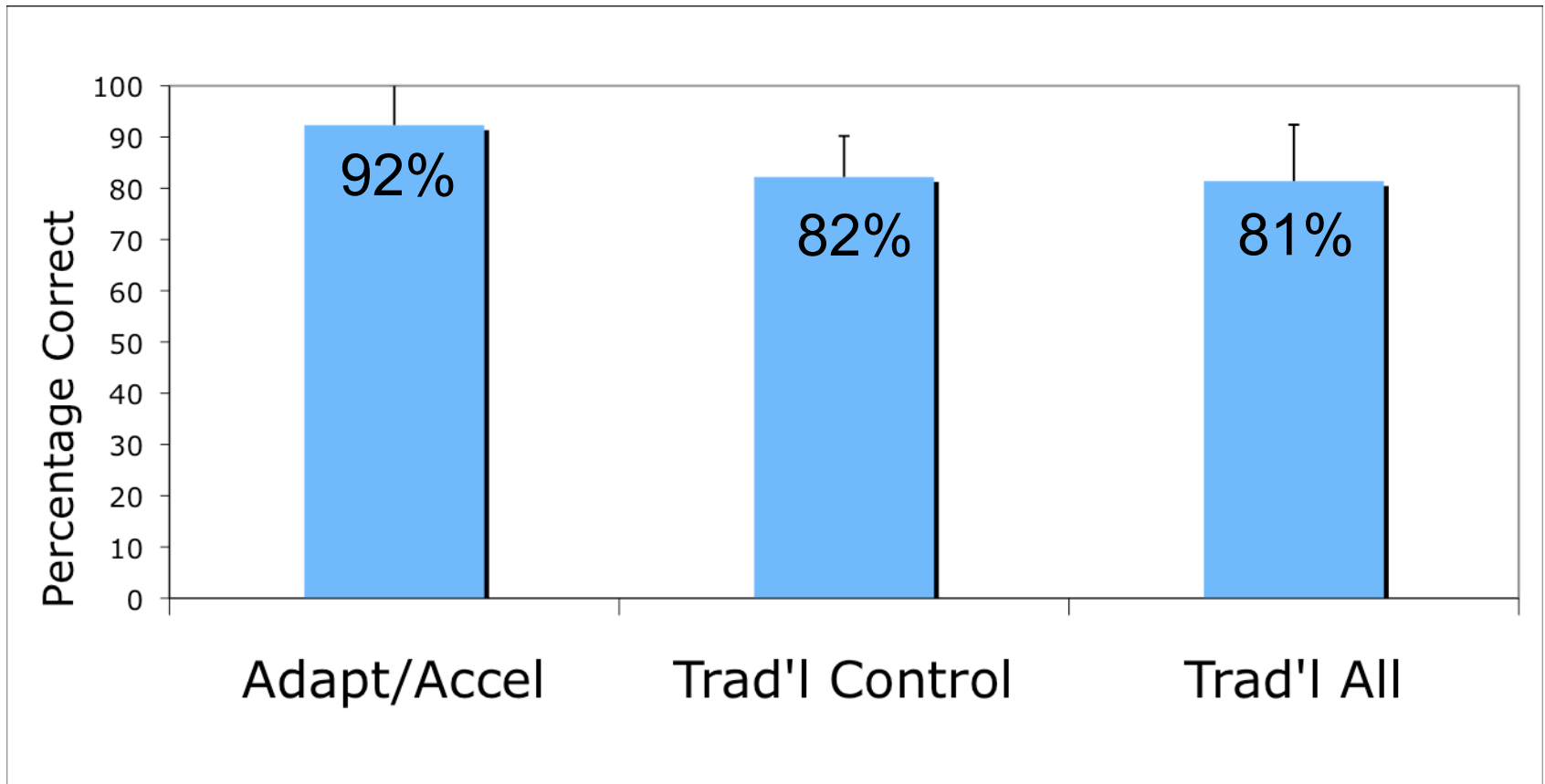
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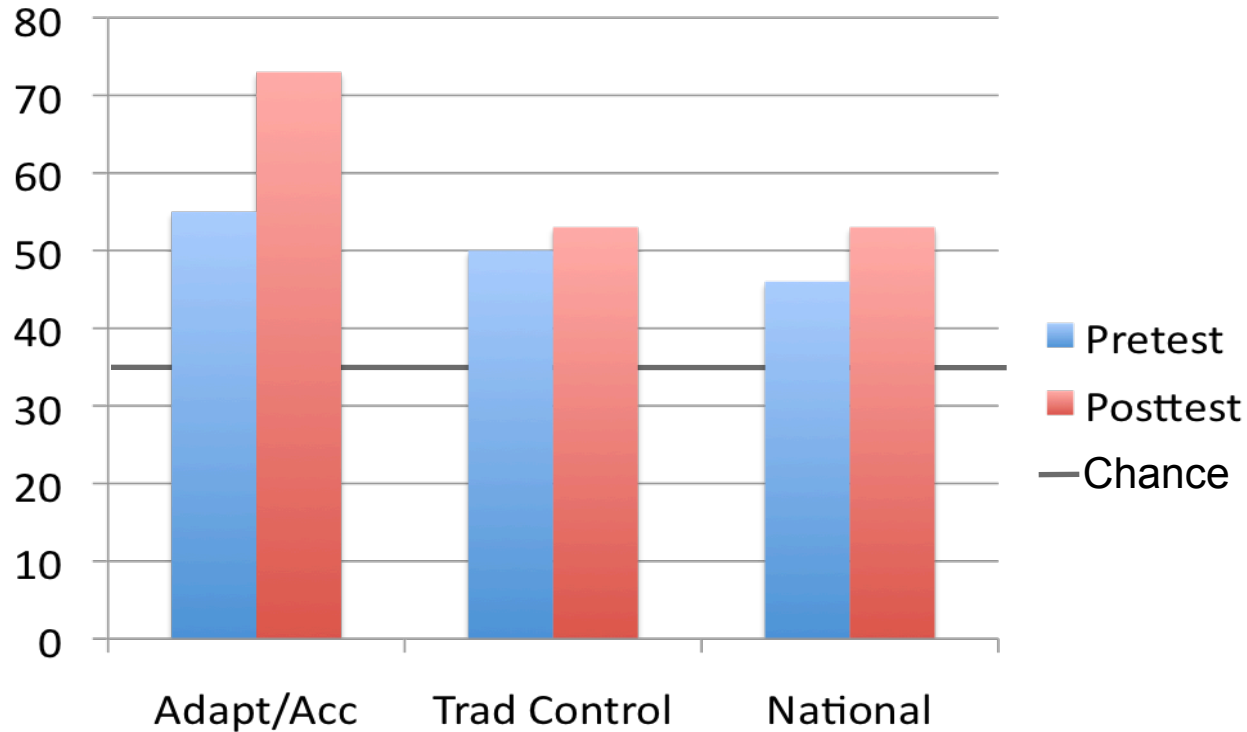
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Final Exam Performance



Adaptive/Accelerated had highest exam scores, but they were not statistically different from Traditional.

Standardized Test Results

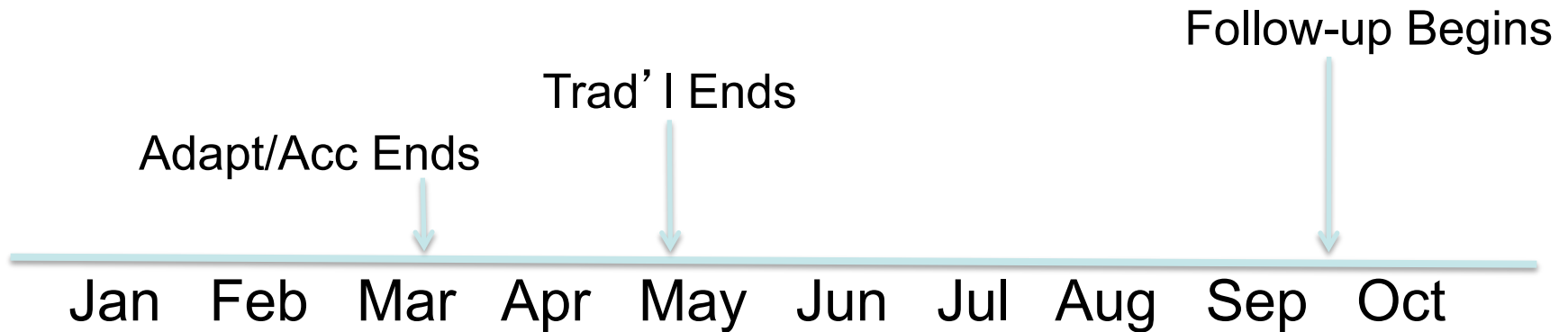


Adaptive/Accelerated group gained significantly more pre/post than the Traditional Control group, 18% vs. 3%

Follow-up: Retention & Transfer

Goal: Study students' retention and transfer in both groups

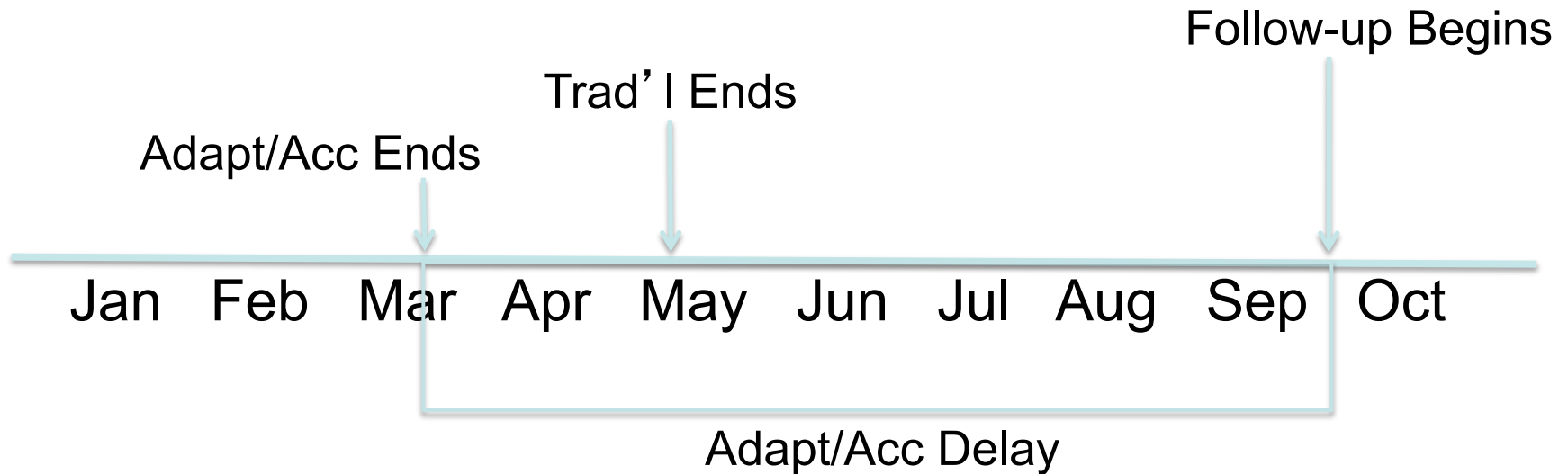
Students were recruited at the beginning of the following semester



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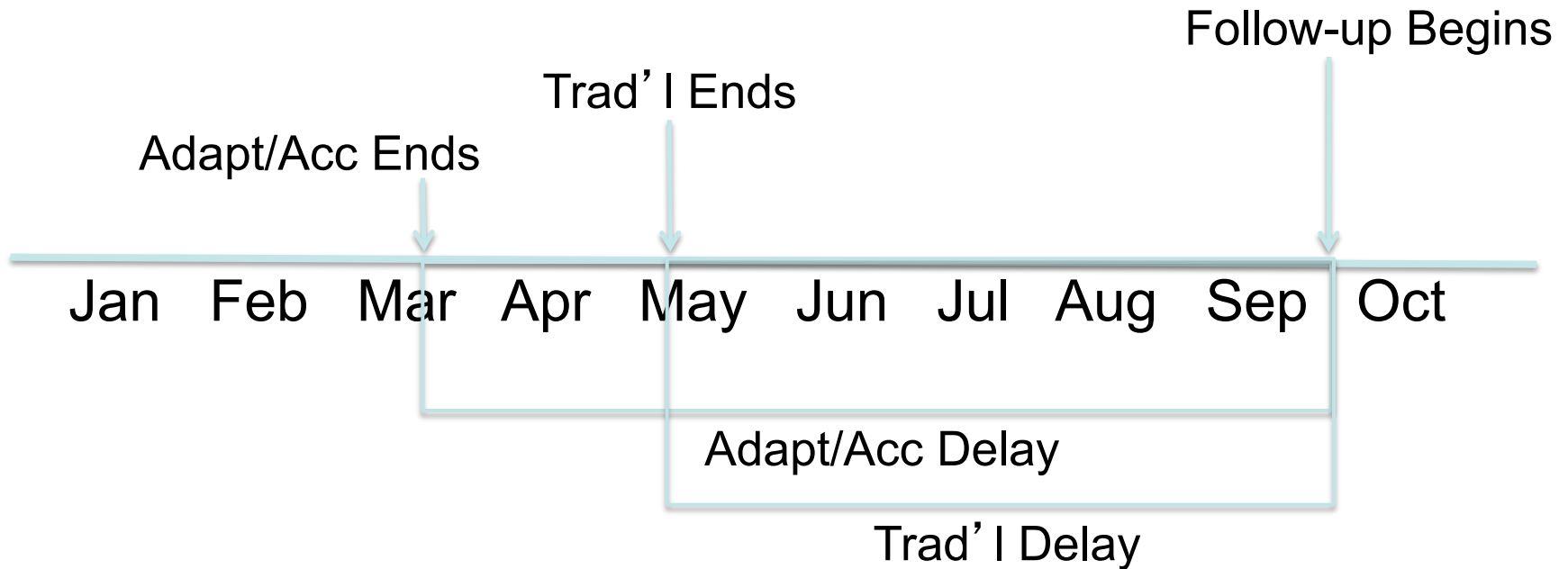
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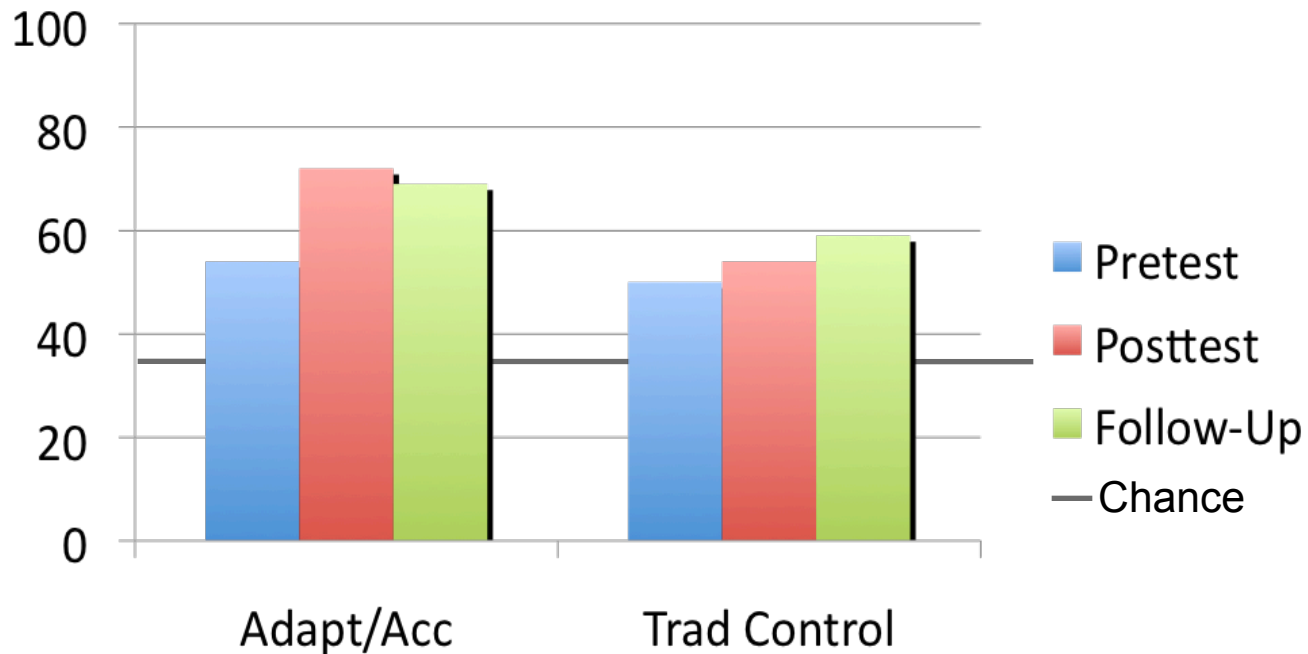
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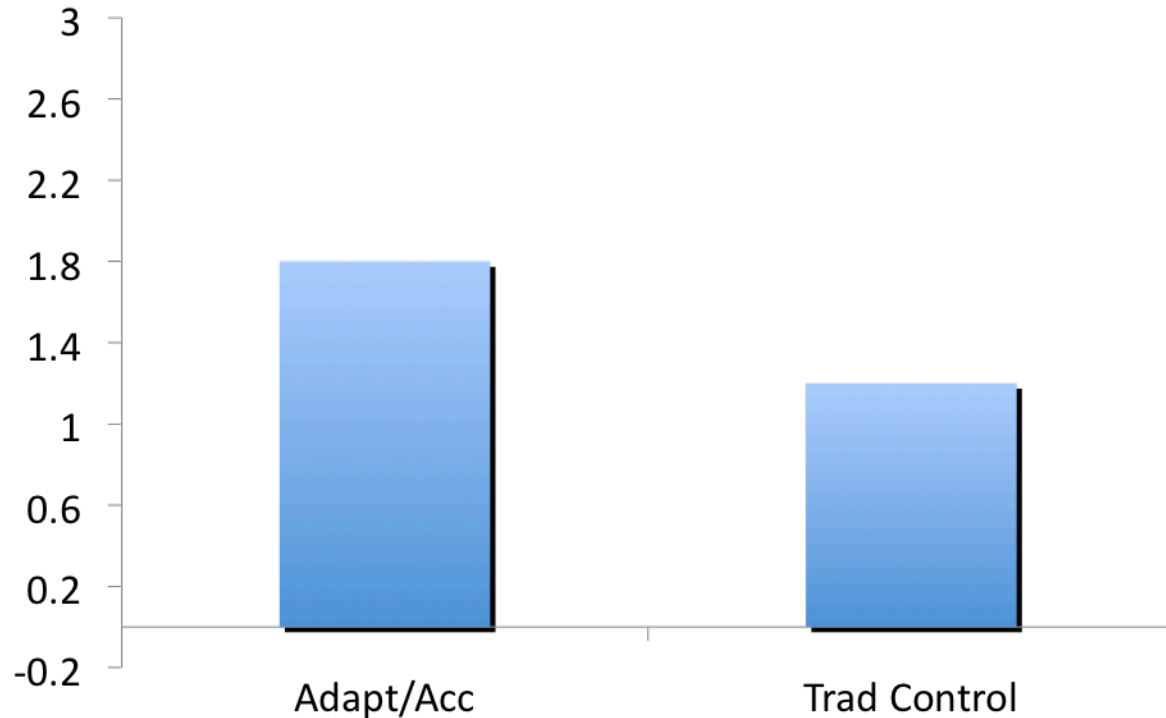


Retention: Standardized test



At 6-month delay, Adaptive/Accelerated group scored higher on CAOS than Traditional Control, $p < .01$.

Transfer: Open-Ended Data Analysis



Adaptive/Accelerated group scored significantly higher than Traditional Control.

Quotes

This is so much better than reading a textbook or listening to a lecture! My mind didn't wander, and I was not bored while doing the lessons. I actually learned something. – *Student in study*

The format [of the adaptive/accelerate course] was among the best teaching experiences I've had in my 15 years of teaching statistics. – *Professor from Study 1*

At the University of Maryland, Baltimore County, teacher Bonnie Kegan found one big advantage was the timely feedback the software gave by tracking students' answers to questions posed as they worked through each lesson. "You can drill down and see what questions they're missing," she says.

– from "Tapping Technology to Keep Lid on Tuition"
by David Wessel, *Wall Street Journal*, July 19, 2012

Take-Home Points

- Currently, the rich data available from students' learning interactions are only barely being tapped.
- Cognitively informed models and sophisticated statistics add value to learning analytics.
- The *Learning Dashboard* contributes to significant improvements in teaching and learning: students' gains jump from 3% to 18%!