

Carnegie Mellon University



Learning Science for Better Learning

Marsha C. Lovett, Ph.D.

Director, Eberly Center for Teaching Excellence & Educational Innovation
Teaching Professor, Department of Psychology

16, 000



Like tying shoelaces

Change is hard

Relevant research can inform and guide effective innovations in teaching

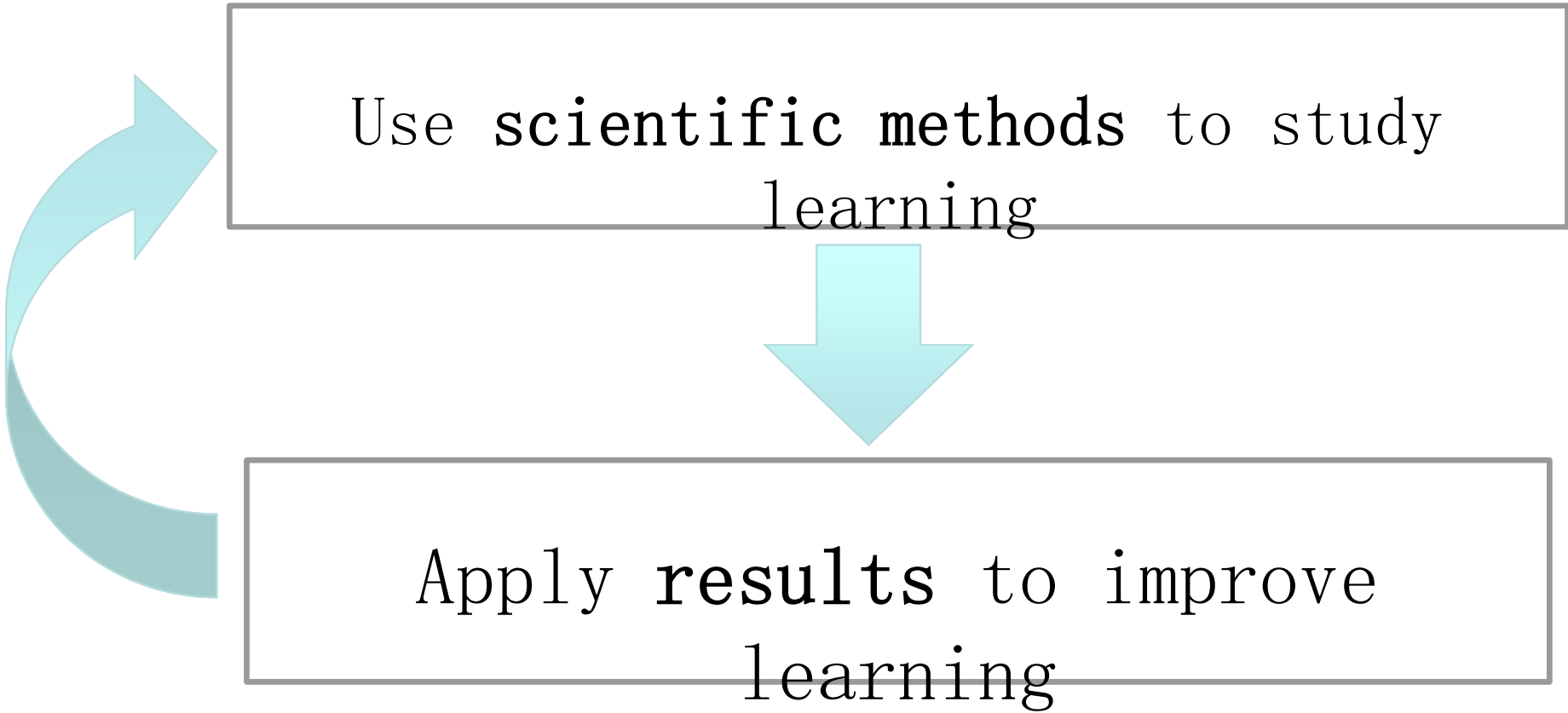
- Acquainted with learning science research
- Examples that have immediate relevance
- Critical consumer of educational



Expert Blind Spot

Occurs when expert instructors are blind to the learning needs of students

- Presume students do things the way we do
- Mis-predict what students find difficult
- Fail to see the steps students must learn
- Over-estimate what students know & can do



Use scientific methods to study
learning

Apply results to improve
learning



High-Impact Educational Practices



WHAT THEY ARE,
WHO HAS ACCESS TO THEM,
AND WHY THEY MATTER

BY GEORGE D. KUH

WITH AN INTRODUCTION BY CAROL GEARY SCHNE
AND FINDINGS ON STUDENT SUCCESS FROM AAC&I
LEAP INITIATIVE

Organizing Instruction to Improve Student Learning A Practice Guide

HOW LEARNING WORKS

7 Research-Based Principles
for Smart Teaching

Susan A. Ambrose
Michael W. Bridges | Michele DiPietro
Marsha C. Lovett | Marie K. Norman

U.S. DEPARTMENT OF EDUCATION



Evaluation of Evidence-Based Practices in
Online Learning
A Meta-Analysis and Review of Online Learning Studies



VISIBLE LEARNING A SYNTHESIS OF OVER 800 META-ANALYSES RELATING TO ACHIEVEMENT

"Reveals teaching's Holy Grail"
The Times Educational Supplement



E-LEARNING *and the* Science of Instruction

Proven Guidelines for Consumers and
Designers of Multimedia Learning

RUTH COLVIN CLARK | RICHARD E. MAYER



NCER 2007-2004
U.S. DEPARTMENT OF EDUCATION

ies NATIONAL CENTER FOR
EDUCATION RESEARCH
Institute of Education Sciences

Robust Results on Learning

Spaced practice > cramming

Active learning > lecture

IES Practice Guide (2007)

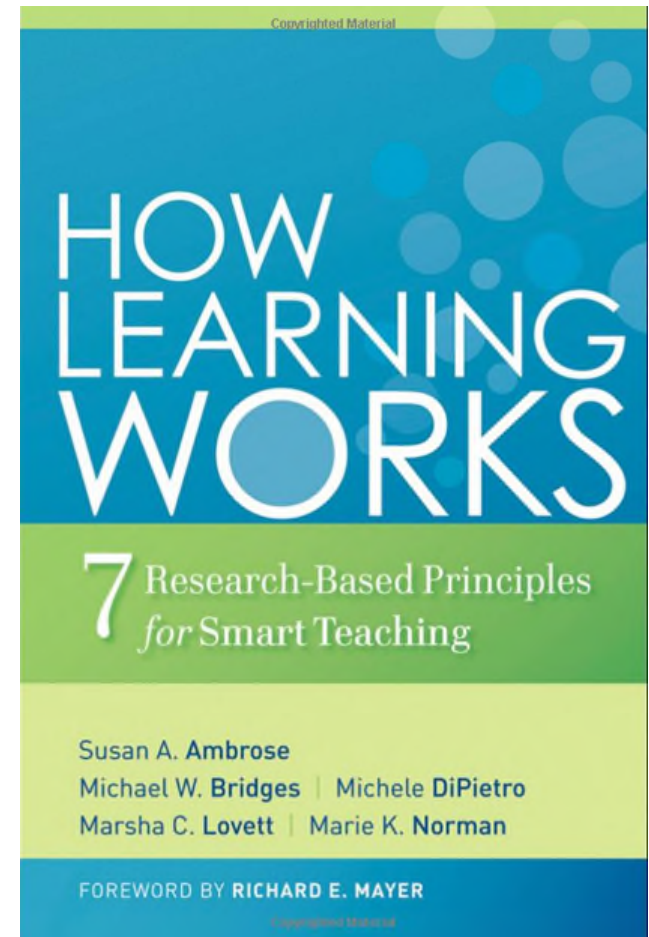
- Evidence
- Instructional strategies
- Roadblocks
- Solutions

PNAS (2014) meta-analysis

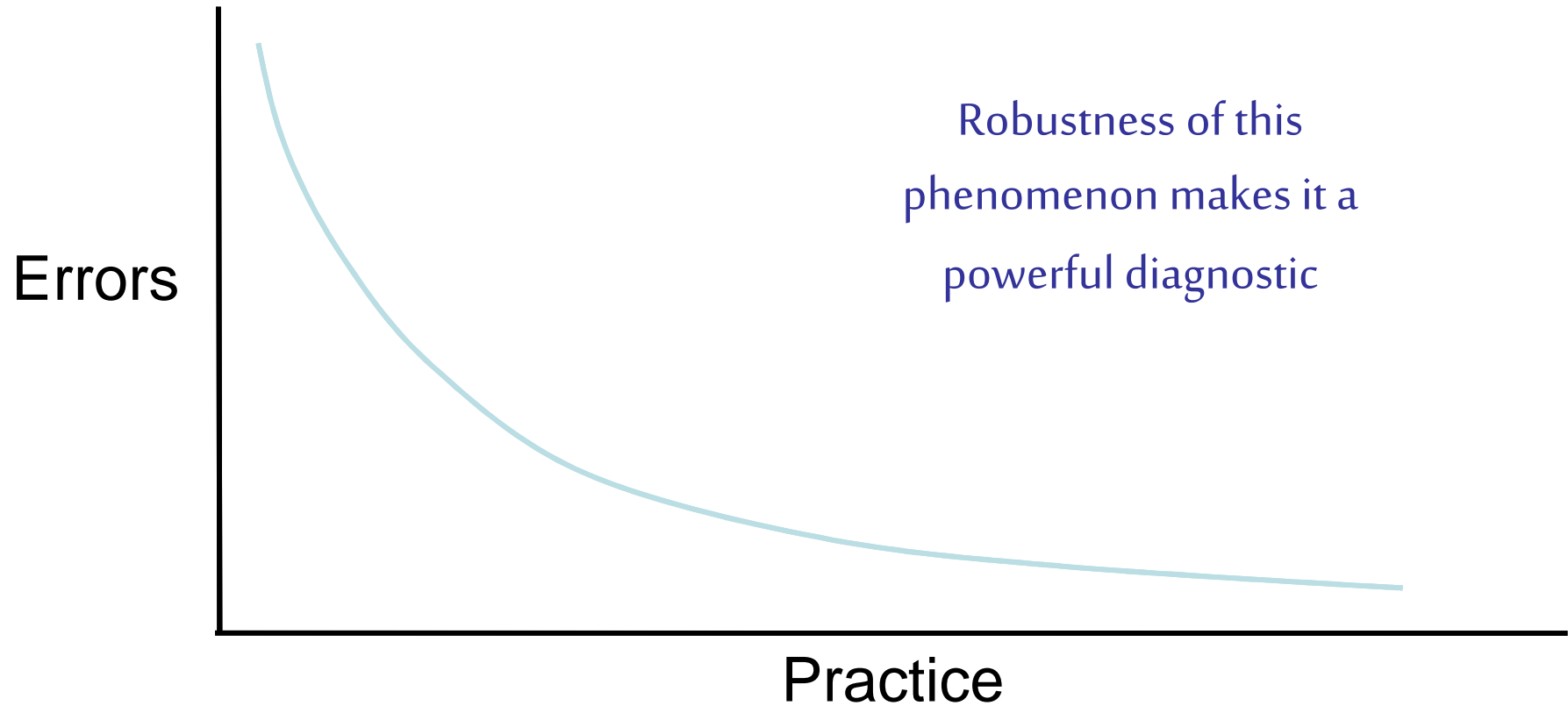
- 225 studies of active learning vs. lecture
- With active learning, **exam scores up** and **failure rates down**

Principles of Learning

1. Prior knowledge
2. Organization of knowledge
- ➔ 3. Motivation
4. Practice and feedback
5. Development of mastery
6. The “whole” student
7. Self-directed learning

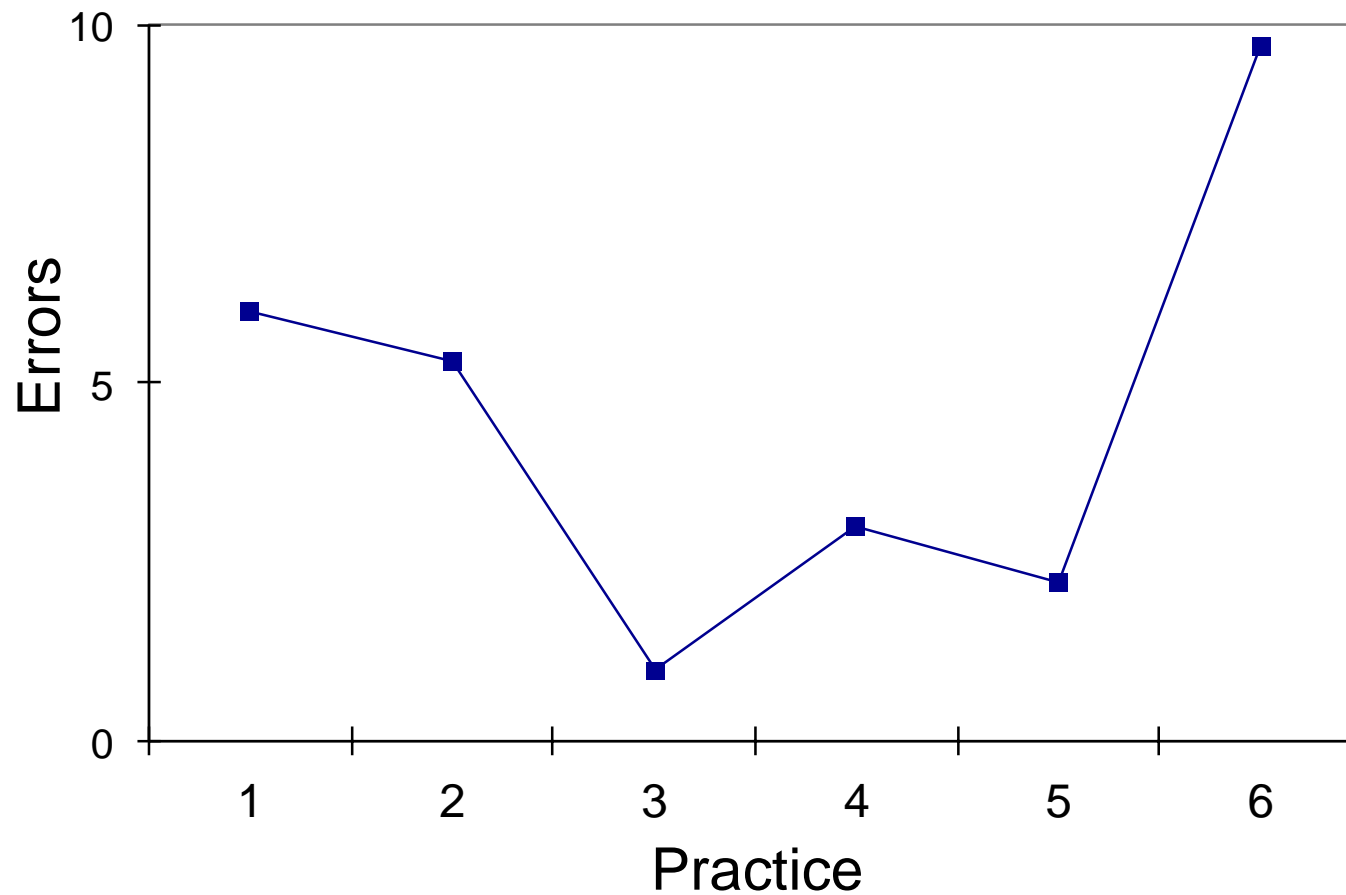


The Power Law of Learning

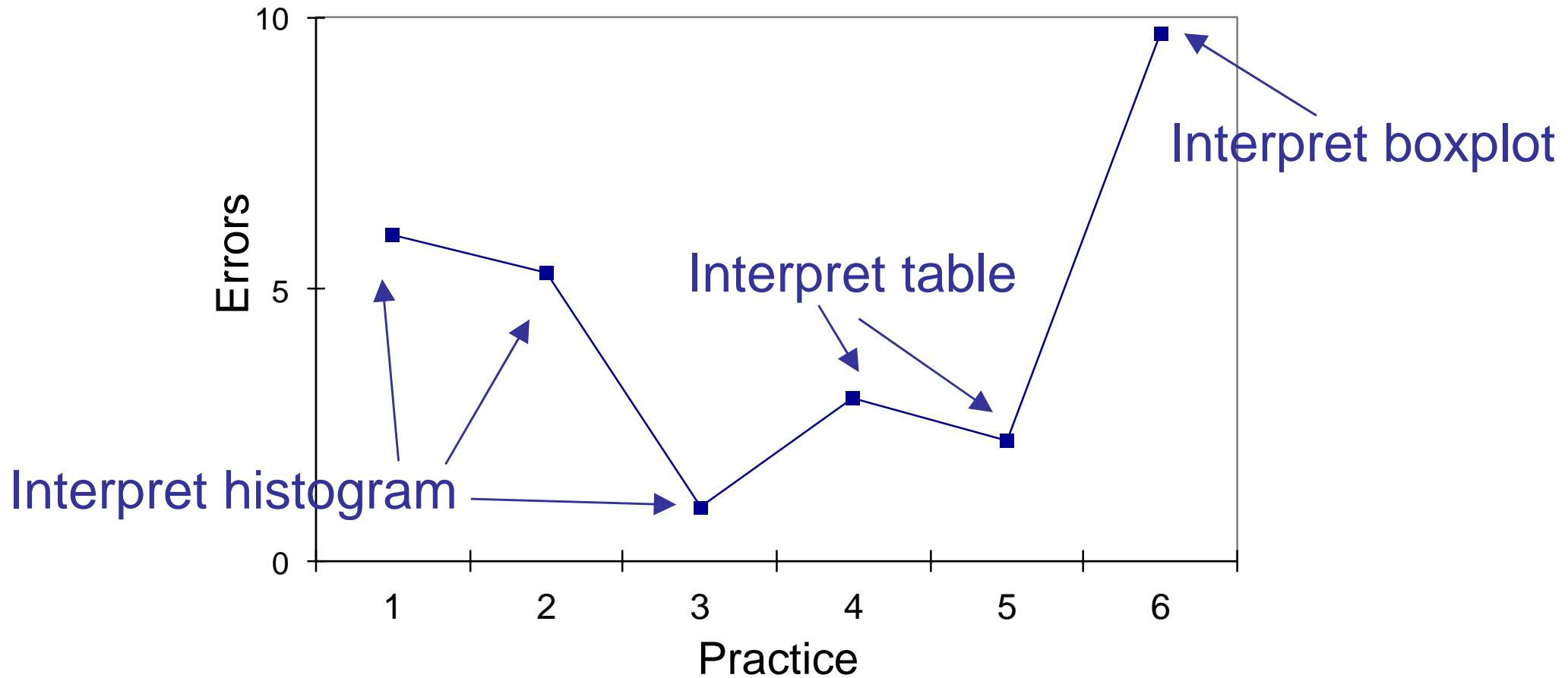


As students practice, performance improves with marginally decreasing returns

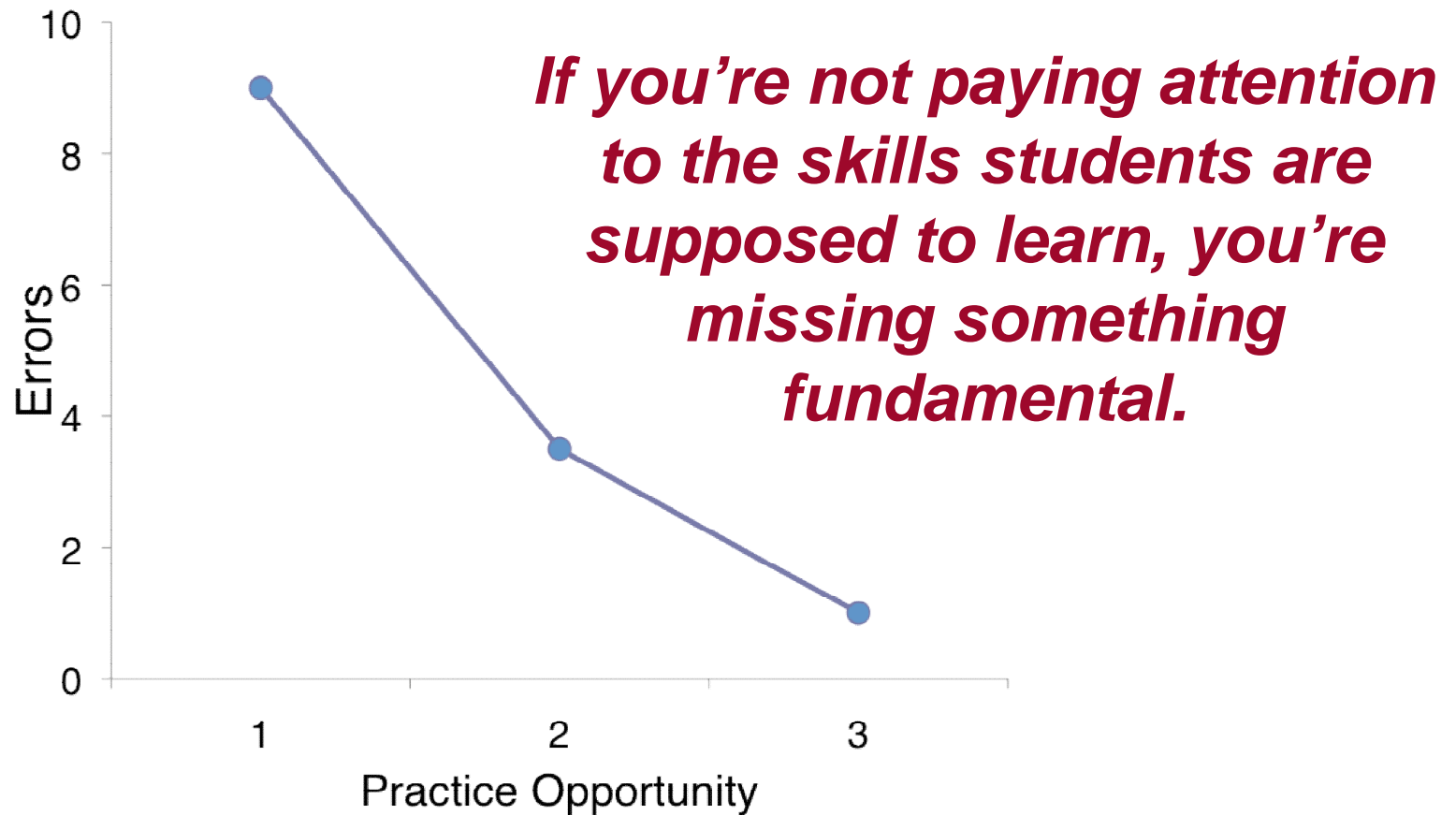
The Performance We Observe



The Underlying Skills



Performance Re-indexed



The Power Law of Learning revealed

A few key results regarding practice

Practicing a given skill
improves performance *on that skill*

Practice activities are effective to the degree that they

1. **Align with the skills** students need to learn
2. Offer opportunities for **repeated practice**
3. Provide **targeted and timely feedback**

Align practice with desired skills

Skill – Select and apply appropriate statistical tests



Apply statistical tests from the current chapter



Analyze data, drawing on variety of statistical tests

Skill – Compare and critique authors' arguments

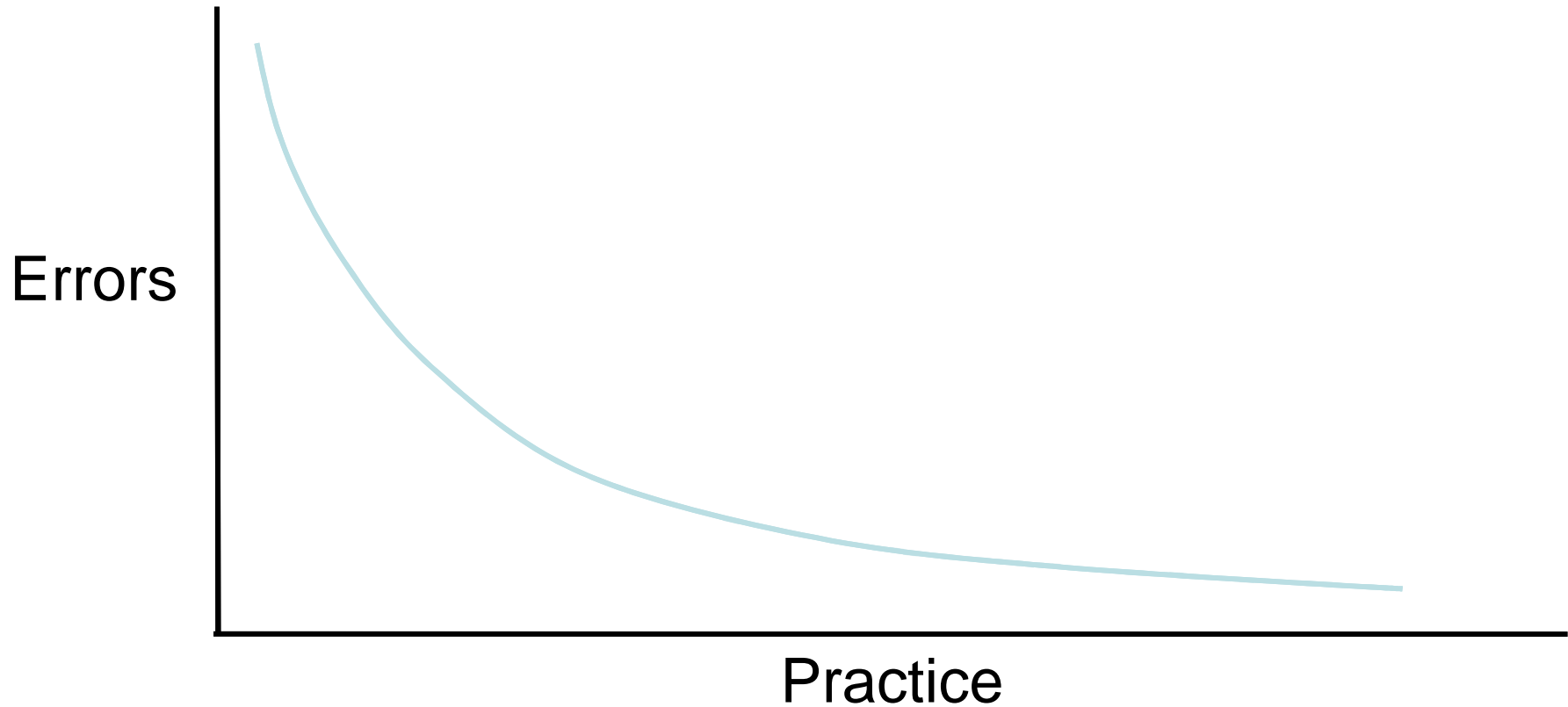


Class discussion evaluating relative merits of different arguments



Paper summarizing individual authors' arguments

Repeated Practice Opportunities



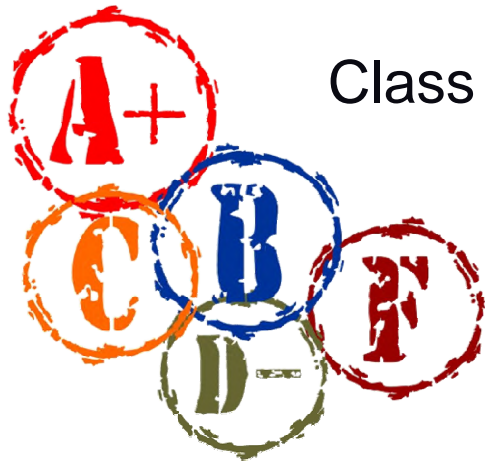
As students practice, performance improves with marginally decreasing returns

Targeted and timely feedback

Current situation:

Students do their homework and turn it in

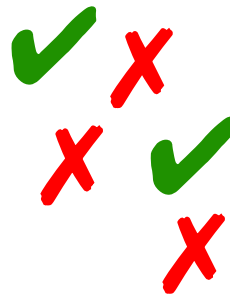
Days later, they receive graded papers



Class has moved on to next topic

No incentive to remediate

What we want:



Give students feedback in a timely manner so they can learn from it

Can technology help?

Review of Online Learning Studies

Current state of the
art:

1000+ studies

What do they tell us
about the
effectiveness of
online learning?

U.S. DEPARTMENT OF EDUCATION



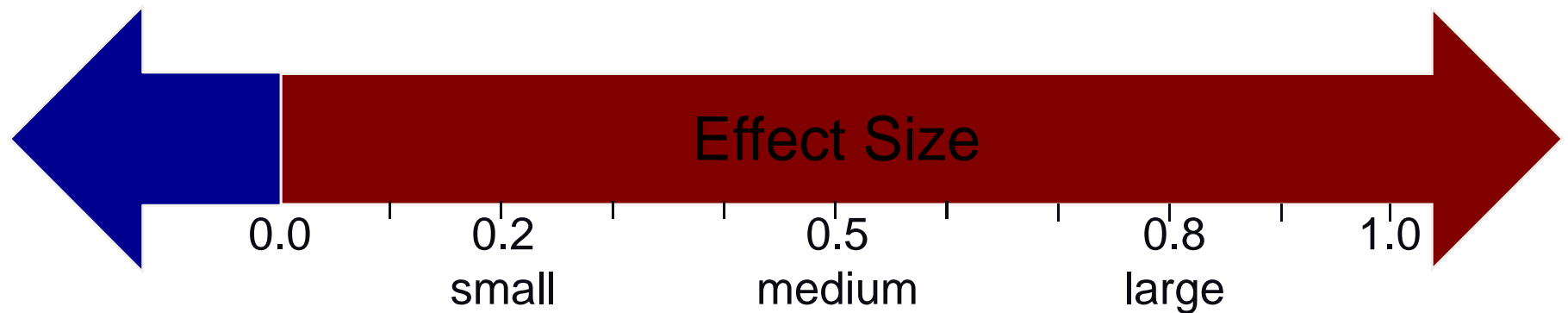
Evaluation of Evidence-Based Practices in
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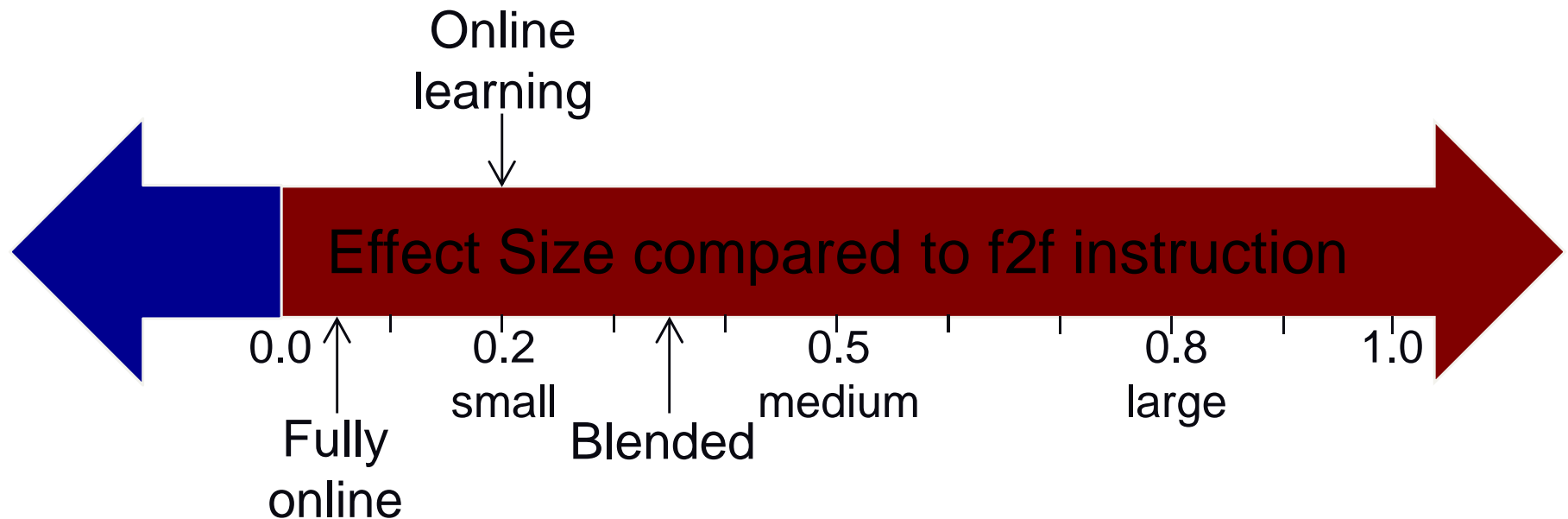
U.S. Department of Education (2010).

Meta-analysis combines across results

Draw on multiple studies to quantitatively estimate the overall effect of treatment vs. control



Results look favorable, but...

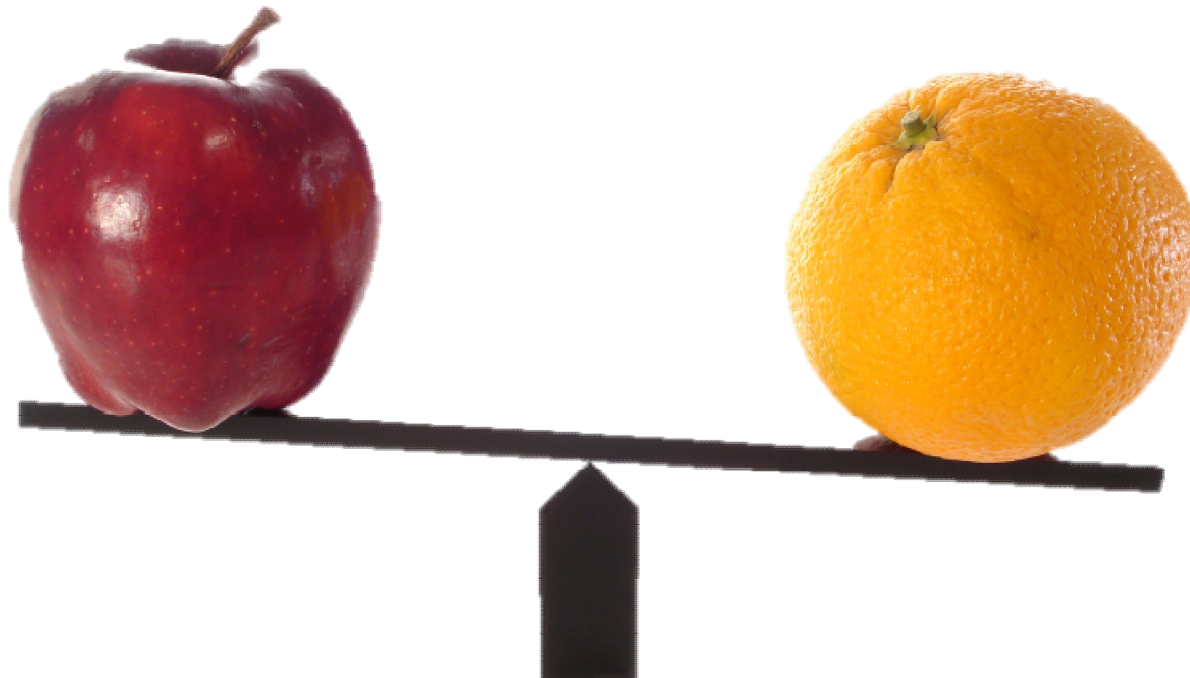


Online (fully/blended) conditions often had more time

Online (fully/blended) vs. face-to-face often differed in content and pedagogy

So, it's not about the technology...

"The observed advantage for blended learning conditions is not necessarily rooted in the media used per se and may reflect differences in content, pedagogy and learning time."



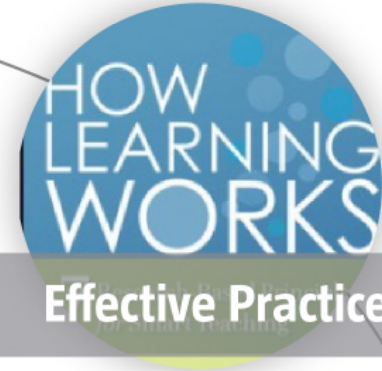
Positive results for online learning
stem from how you design it



Empowered Faculty

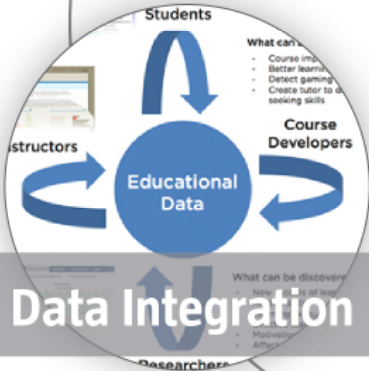


Global Learning Council



Effective Practice

Carnegie Mellon University The Simon Initiative



Data Integration



Engaged Learners



Innovative Research



Spin Outs & Spin Ins

Carnegie Mellon University

Crossing Boundaries

Impact

Teaching

Climate

Energy

Challenges

CROSSING BOUNDARIES
TRANSFORMING LIVES

2013

Brain

Regional

Economic

Leveraging

Sciences

Opportunities

Data

Mind

Learning

Development

Transforming Lives

A few key results regarding practice

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improves performance *on that skill*

Practice activities are effective to the degree that they

1. Align with the skills students need to learn
2. Offer opportunities for repeated practice
3. Provide targeted and timely feedback

Research-based online instruction

Online course in introductory statistics
built within the Open Learning Initiative
platform

Learn by Doing

Hint

Now you complete the table by computing the conditional percentages for the males.

What is the correct number for the cell indicated by the question mark?

| Body Image Gender | About Right | Overweight | Underweight | Total |
|------------------------------|---------------|---------------|-------------|--------------|
| Female | 560/760=73.7% | 163/760=21.5% | 37/760=4.9% | 760/760=100% |
| Male | ? | | | 100% |

☐ 295/560=52.7% ☒ 295/855=34.5% ☐ 295/440=67% ☐ 295/1200=24.6%

Page 1 of 4

Next

✗ That's not quite right. Focus only on the 440 males. What percentage of them responded "About right"?

Learning activities are instrumented to *continuously* assess student learning

Feedback to
Student

Learn by Doing

Hint

Now you complete the table by computing the conditional percentages for the males.
What is the correct number for the cell indicated by the question mark?

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Page 1 of 4

Next

Feedback to
Instructor

Learn by Doing

Hint

Now you complete the table by computing the conditional percentages for the males.
What is the correct number for the cell indicated by the question mark?

| Body Image Gender | About Right | Overweight | Underweight | Total |
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Module 2

Examining Relationships

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. [Show Sub-Learning Objectives]
- 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 summary of the overall pattern and use it to make predictions. [Show Sub-Learning Objectives]
- Recognize the distinction between association and causation, and identify potential lurking variables for explaining an observed relationship. [Show Sub-Learning Objectives]
- Recognize and explain the phenomenon of Simpson's Paradox as it relates to interpreting the relationship between two variables. [Show Sub-Learning Objectives]

The *Learning Dashboard* provides an accurate and evolving picture of how well students have learned particular skills

by analyzing rich interaction data *in terms of* established cognitive theory & computational models of learning

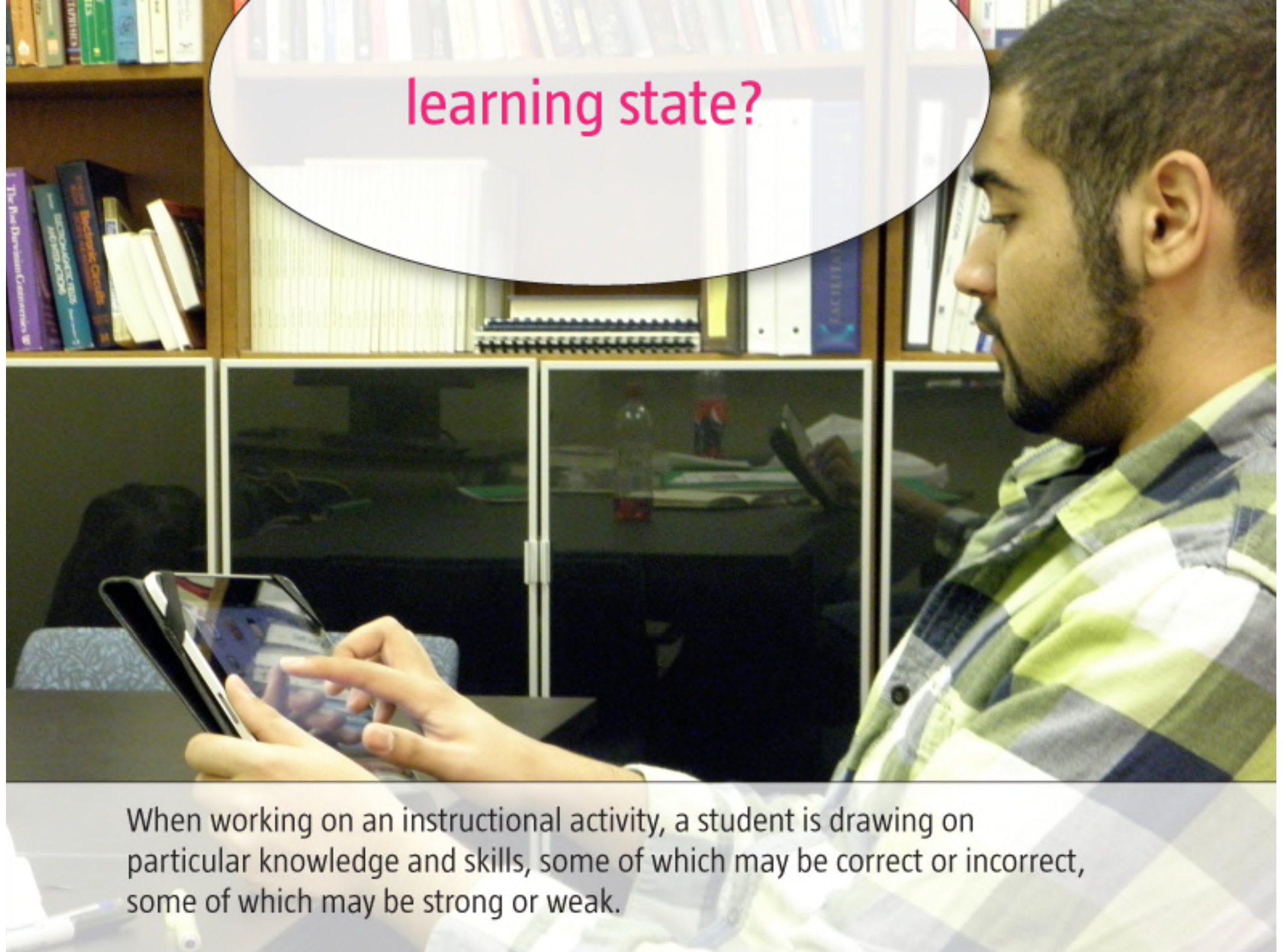
Cognitively informed learning analytics

Most learning analytics 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

A photograph of a young man with a beard, wearing a green and blue plaid shirt, sitting at a desk in a library or study area. He is looking down at a tablet computer he is holding with both hands. The background shows bookshelves filled with books and a glass display case containing various items. A semi-transparent purple oval is overlaid on the upper 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

LEARNING OBJECTIVES



You will be working to achieve these learning objectives

Distinguish between discrete and continuous random variables.

TO CONTENT

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

TO CONTENT

Apply the rules of means and variances 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

Fit the binomial model when appropriate, and use it to perform sample calculations.

TO CONTENT TAKE PRE-TEST

Explain how a density function is used to find probabilities involving continuous random variables.

TO CONTENT TAKE PRE-TEST

Find probabilities associated with the normal distribution.

TO CONTENT TAKE PRE-TEST

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

TO CONTENT TAKE PRE-TEST

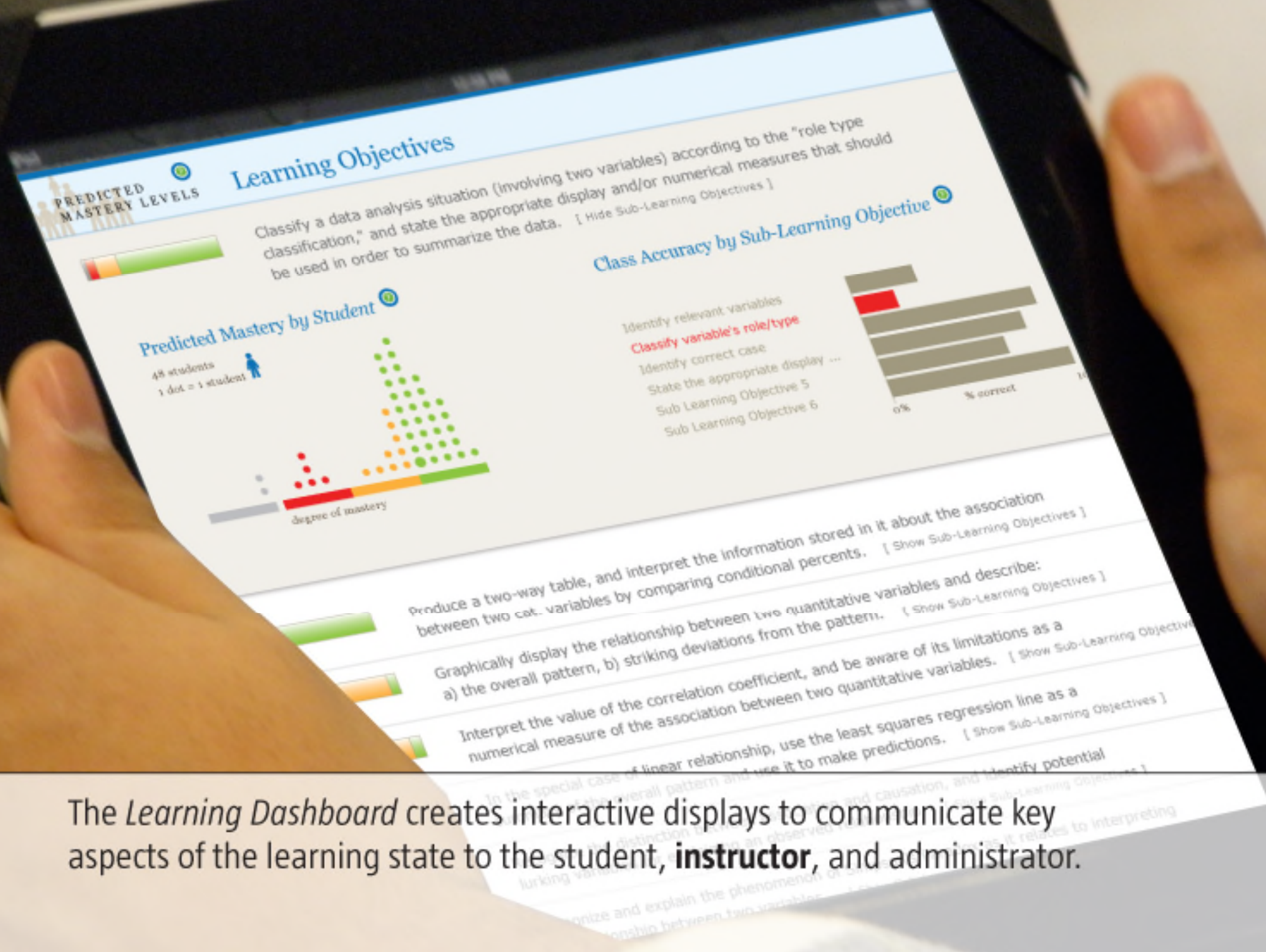
LEARNING PLAN

Calendar view showing dates 1 through 31. A blue star is placed on the 16th. Below the calendar, there is a section for "Important dates" with links: "June 15 :: link to assignment" and "June 27 :: link to test". At the bottom, there is a section for "Instructors" listing "Marka Loren" and "Christopher Genovesi".

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.



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**.

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

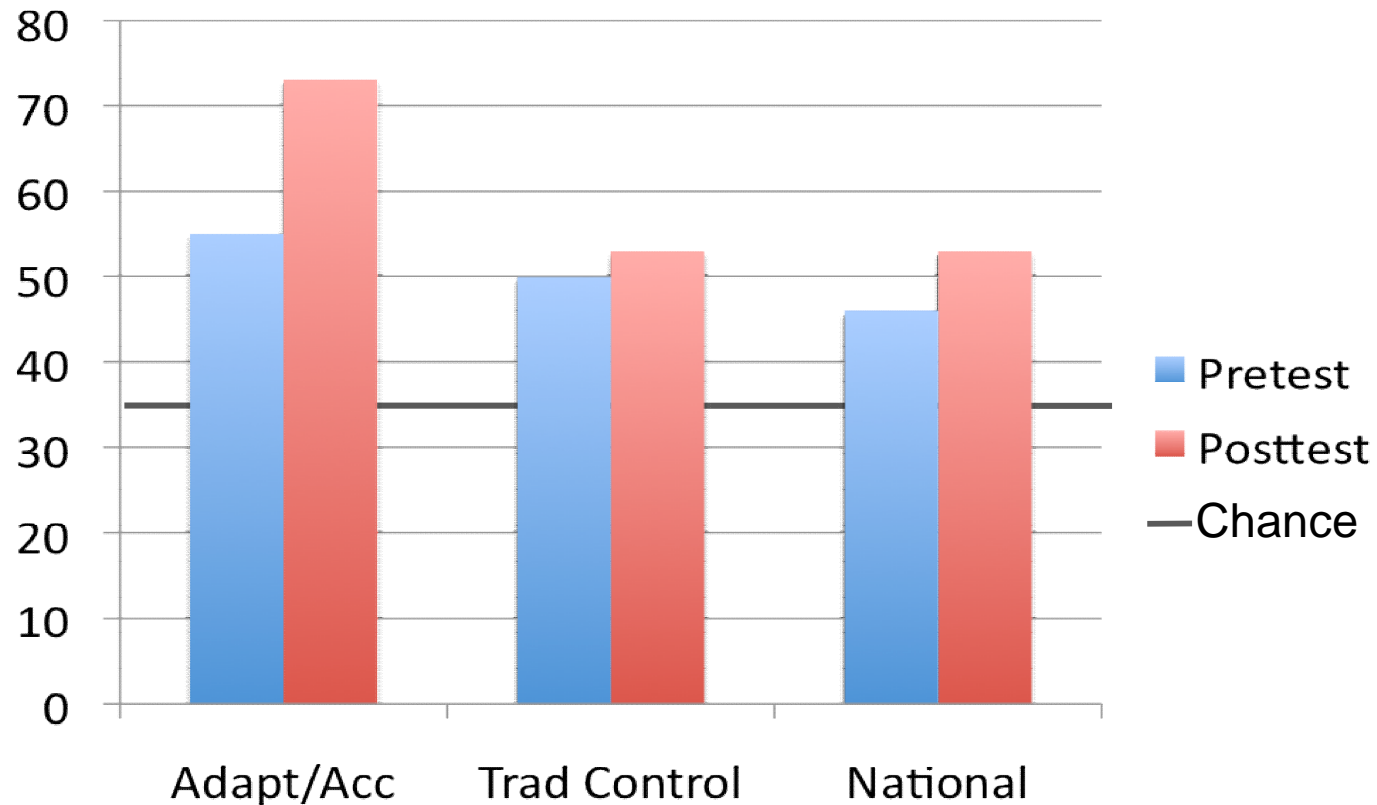
< Homework: read textbook & complete problem sets

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

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

Same content but different *kind* of instruction

Standardized Test Results

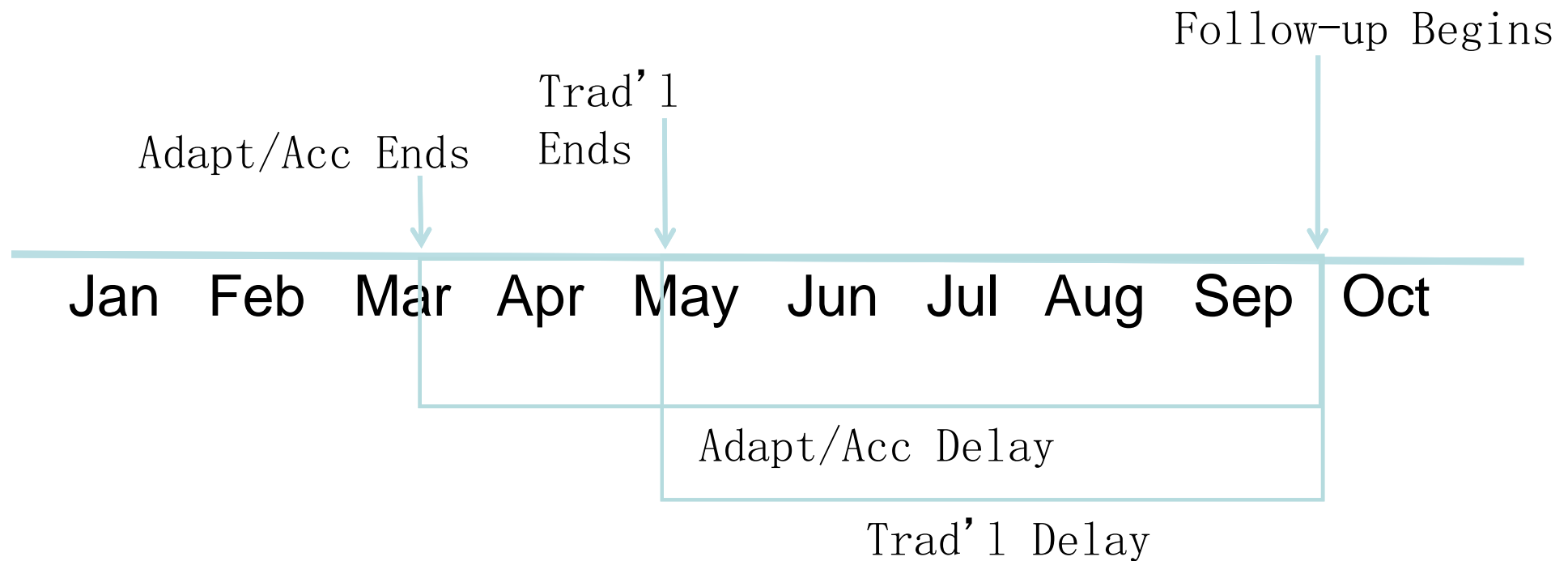


Adaptive/Accelerated group gained significantly more pre/post than the Traditional Control group, 18% vs. 3%

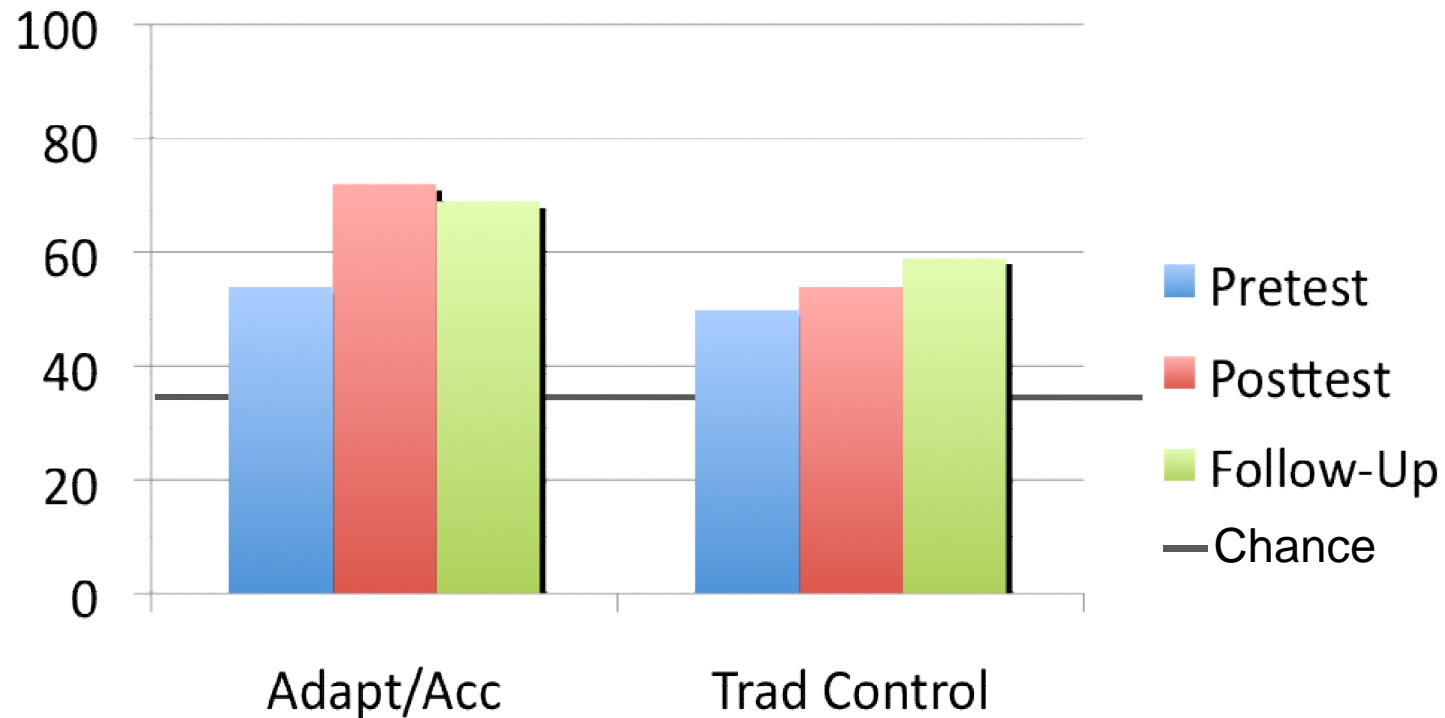
Follow-up: Retention & Transfer

Goal: Study students' retention and transfer in both groups

Students were recruited at the beginning of the following semester

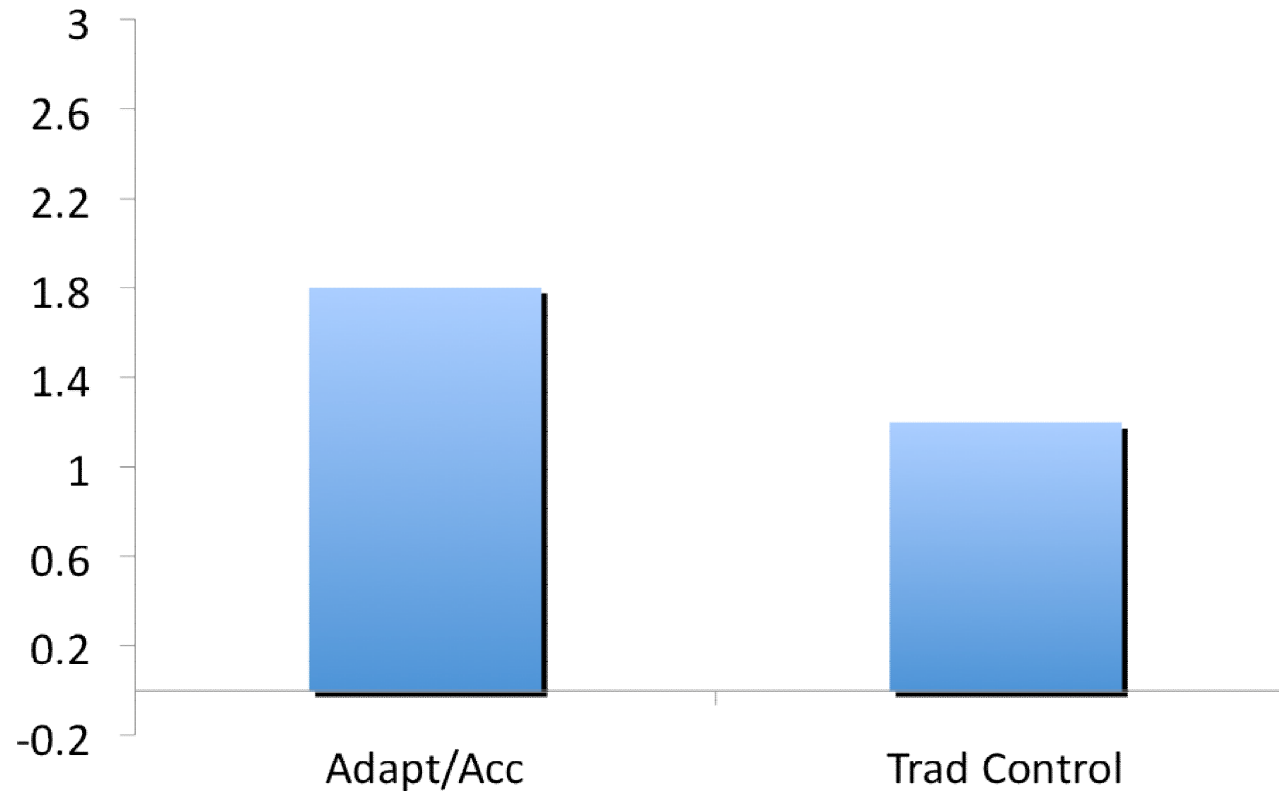


Retention: Standardized test



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.

CMU Statistics Study

Traditional
College Course

> 100 hours

~3% learning gain



Learning
Science

Adaptive, Data-
Driven OLI
Course

< 50 hours

~18% learning gain

Replicated 3 times at CMU
External report by ITHAKA

Lovett, Meyer, & Thille (2008, 2010).
See jime.open.ac.uk/jime/article/view/2008-14

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

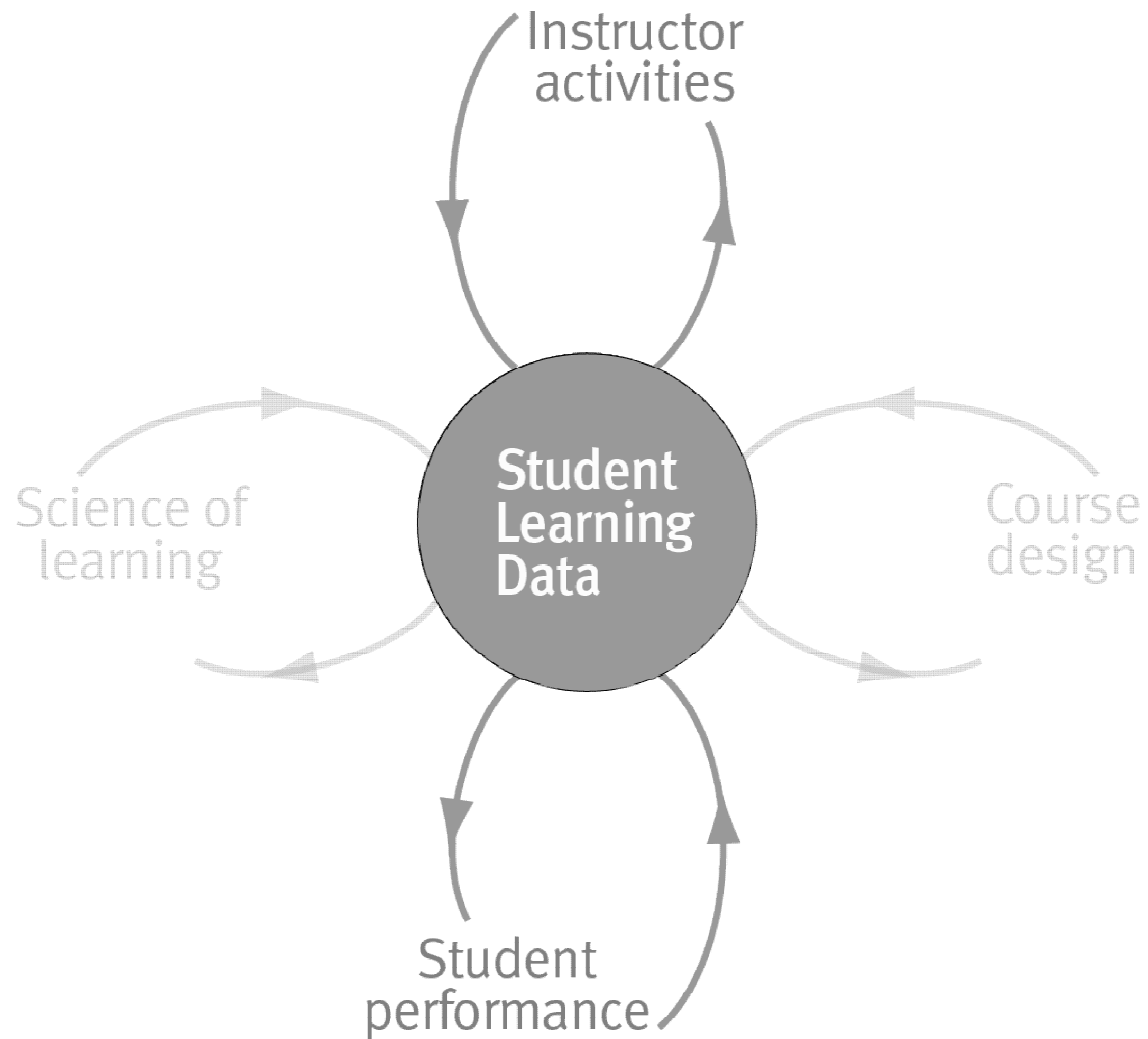
Take-Home Messages

Learning science research provides rich theory and results on how students learn

Designing instruction based on learning science principles produces positive results

Key role for technology is to automate and augment putting them into practice

Interaction data drive feedback loops



CMU Accelerated Learning Studies

#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



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