Carnegie Mellon University

Learning Engineering: Applying Research & Data to Improve Outcomes

Marsha C. Lovett, Ph.D.
Director, Eberly Center for Teaching Excellence & Educational Innovation
Teaching Professor, Department of Psychology

16,000

Like teaching

Change is hard

Relevant research and rich data can inform and guide *effective* innovations in teaching

Creating 21st Century Instruction

Research-based instruction significantly outperforms intuition in improving learning outcomes.

Intuition suggests:	But research shows:
Instruction is best when it matches the learner's style.	There is no effect (or negative effect) of matching learner's style.
Adding images will enhance engagement and hence learning.	Extraneous images distract and reduce learning outcomes.

LEAP

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
LEAP INITIATIVE

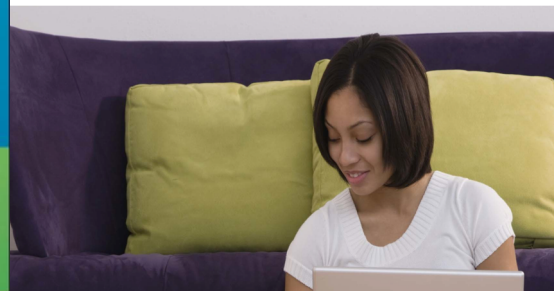
HOW LEARNING WORKS

7 Research-Based Principles *for* Smart Teaching

Susan A. Ambrose
Michael W. Bridges | Michele DiPiet
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

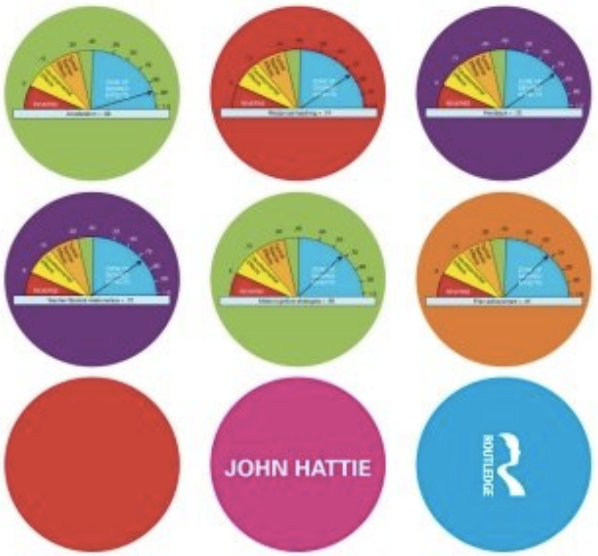


Organizing Instru
to Improve Stude
A Practice Guide

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

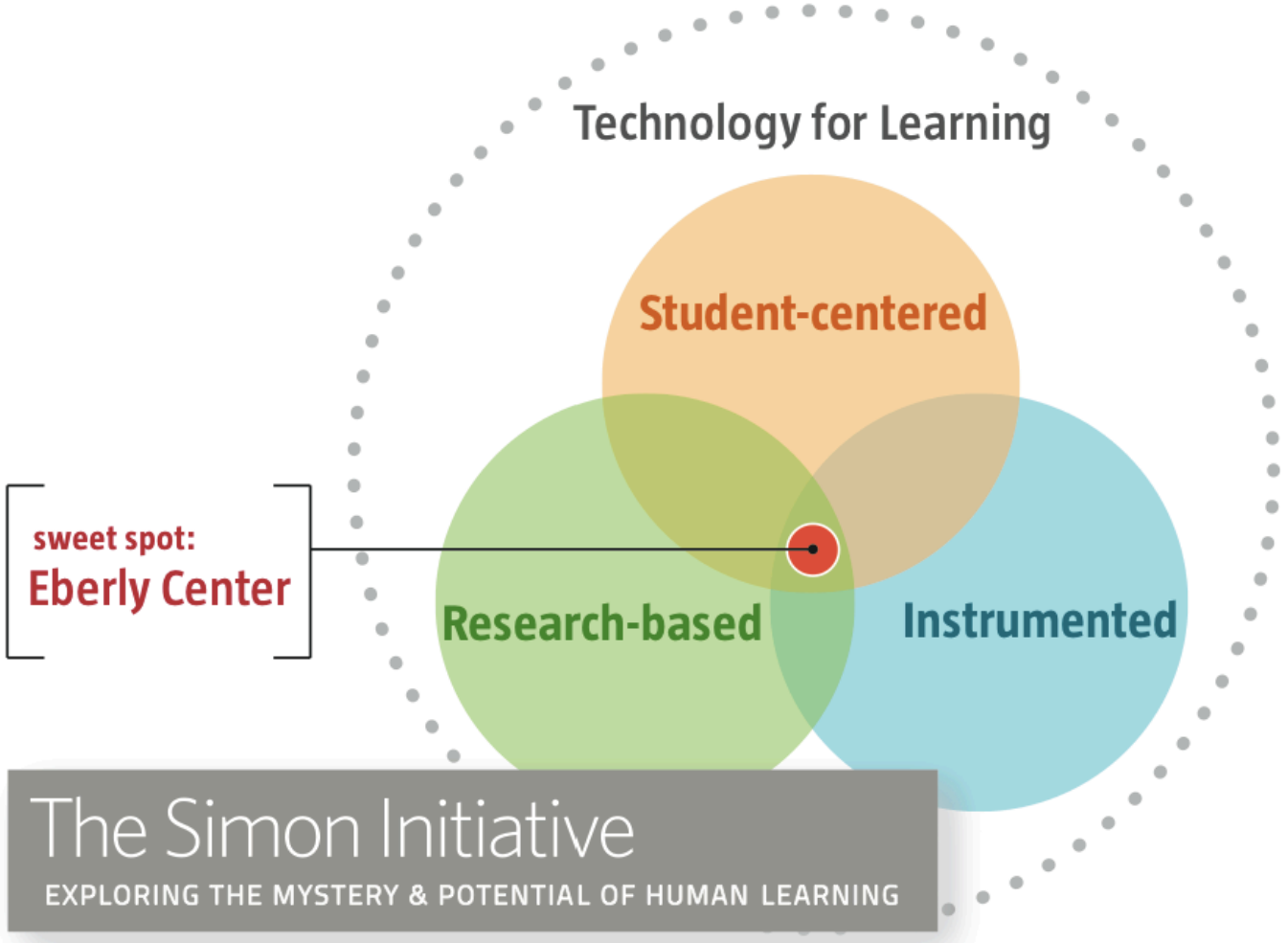
RUTH COLVIN CLARK | RICHARD E. MAYER

NCER 2007-2004
U.S. DEPARTMENT OF EDUCATION

ies NATIONAL CENTER FOR EDUCATION RESEARCH
Institute of Education Sciences

Eberly Center

Teaching Excellence & Educational Innovation



Learning Science → Instructional Design

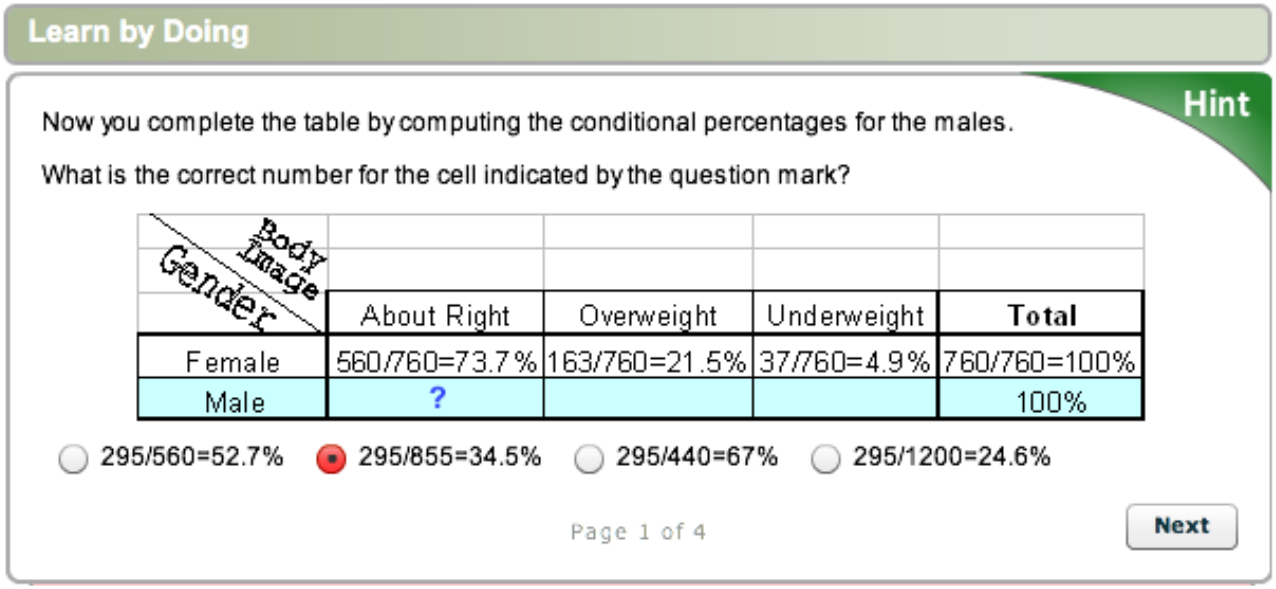
Practicing a given skill
improves performance ***on that skill***

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

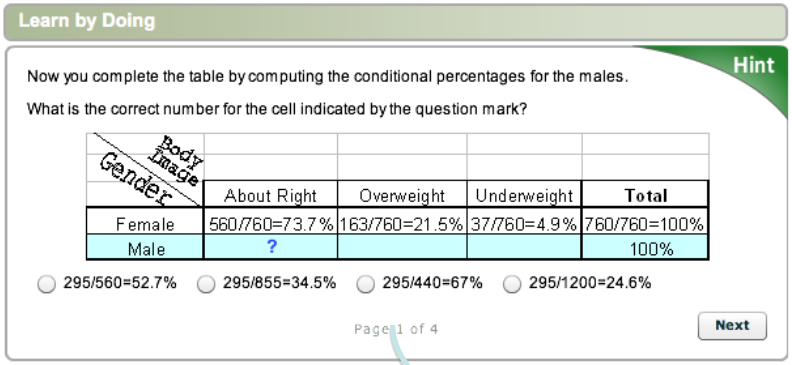
Research-based online instruction

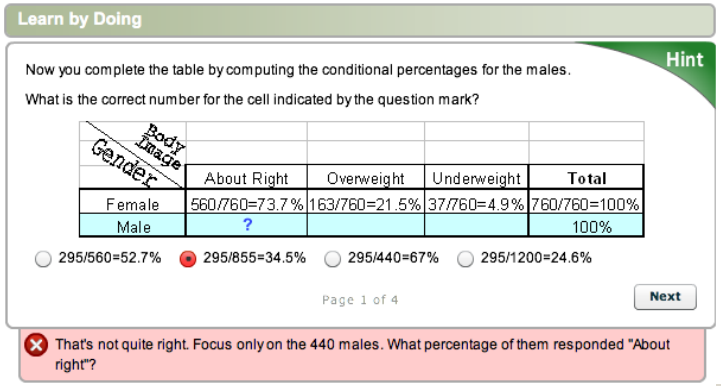
Online courses and modules built within the Open Learning Initiative platform



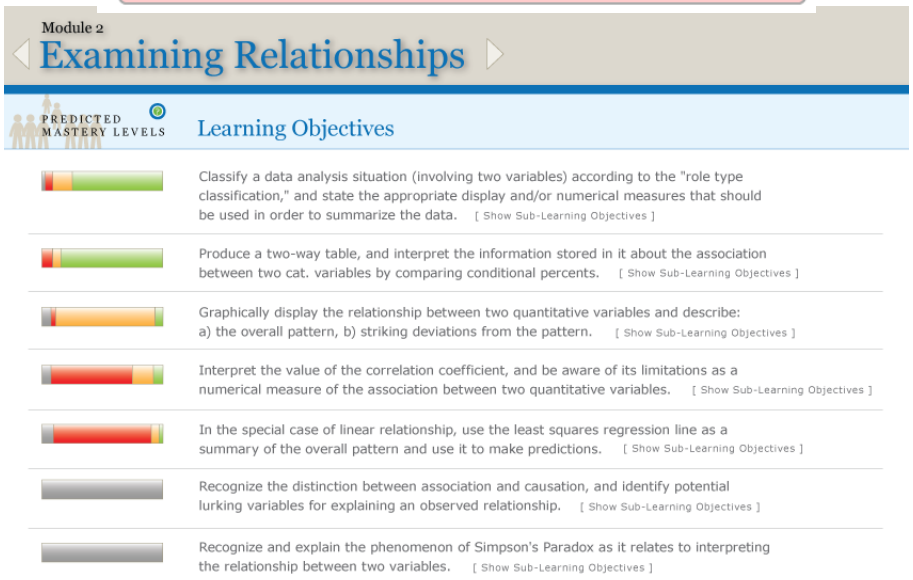
Learning activities are instrumented to *continuously* assess student learning

Feedback to Student

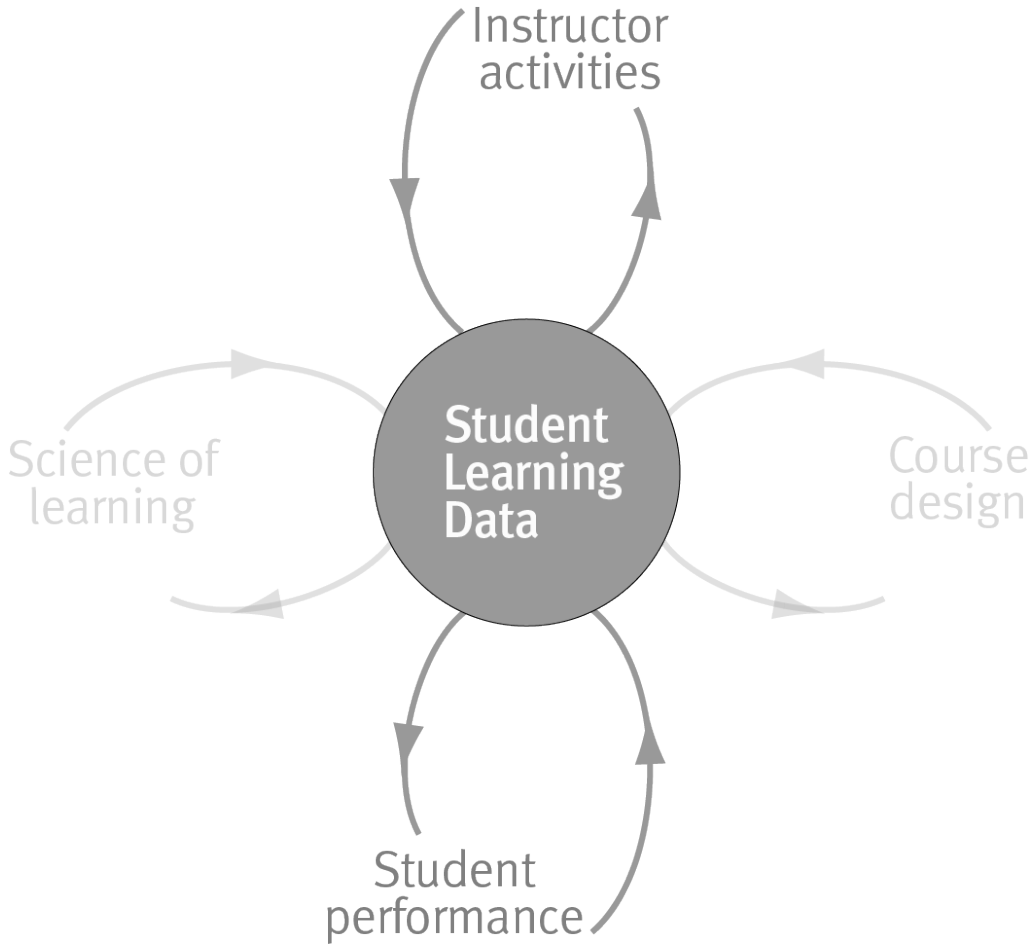




Feedback to Instructor



Interaction data drive feedback loops



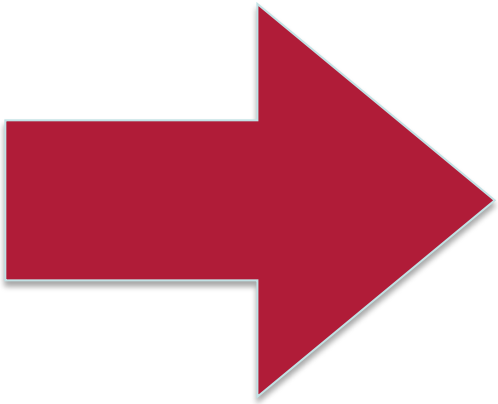
A Few Sample Projects

Statistics Course	Accelerated Learning + Retention
DNA Replication Module	Learning Gain for Common “Crunch point”
Prose Style Modules	Scaffolding + Transfer to Authentic Task

CMU Statistics Study

Traditional College Course

> 100 hours
~3% learning gain



Adaptive, Data-Driven OLI Course

< 50 hours
~18% learning gain

Replicated 3 times at CMU
External report by ITHAKA

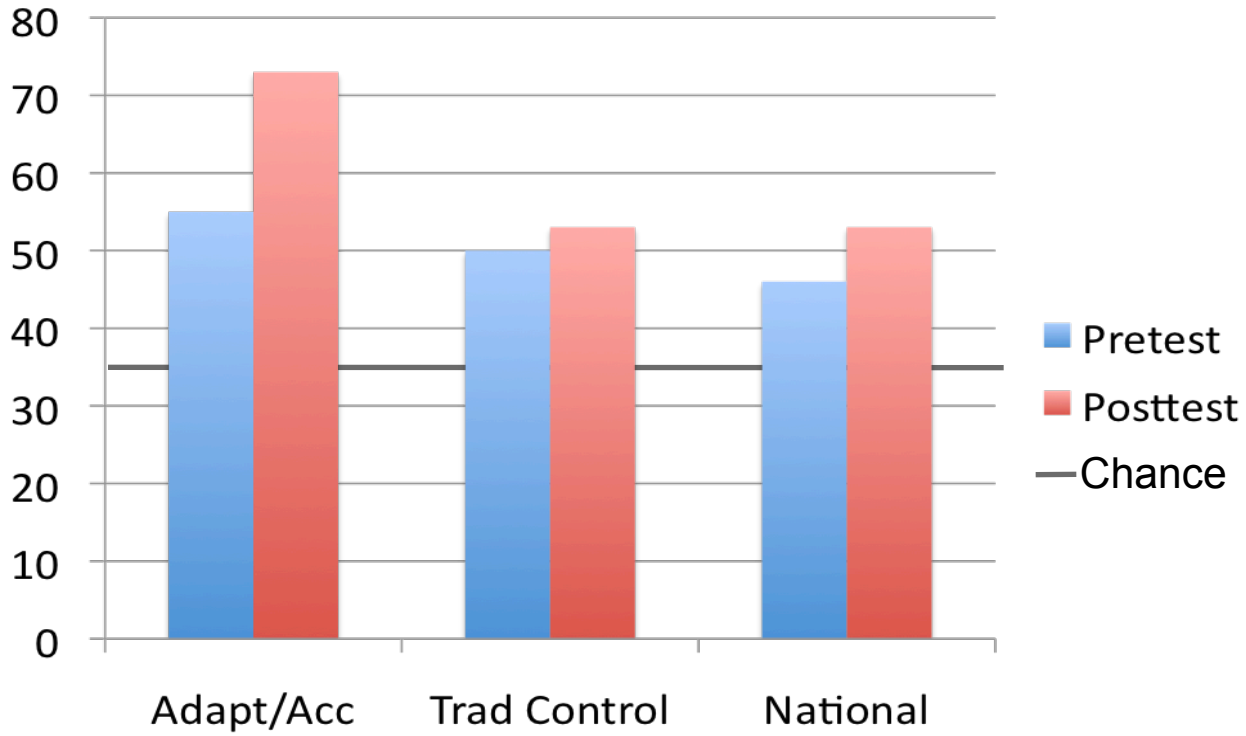
Lovett, Meyer, & Thille (2008, 2010).
See jime.open.ac.uk/jime/article/view/2008-14

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

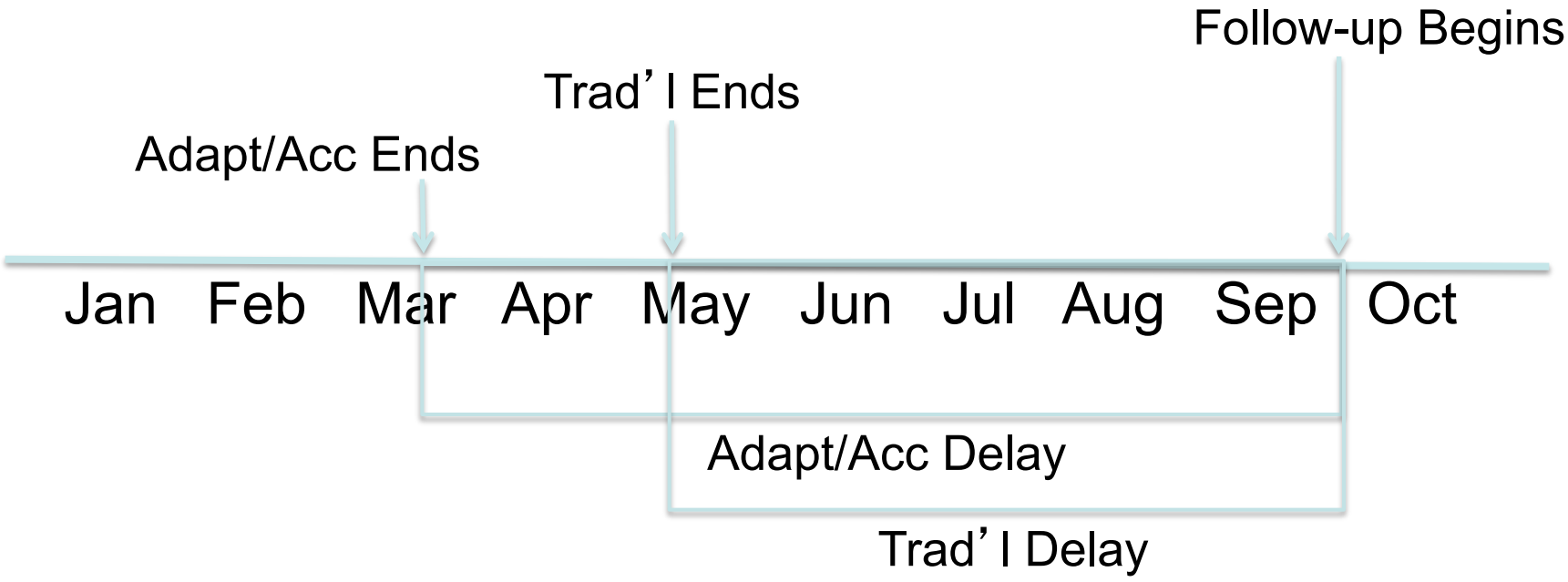


Adaptive/Accelerated group gained significantly more pre/post than the Traditional Control group, 18% vs. 3%

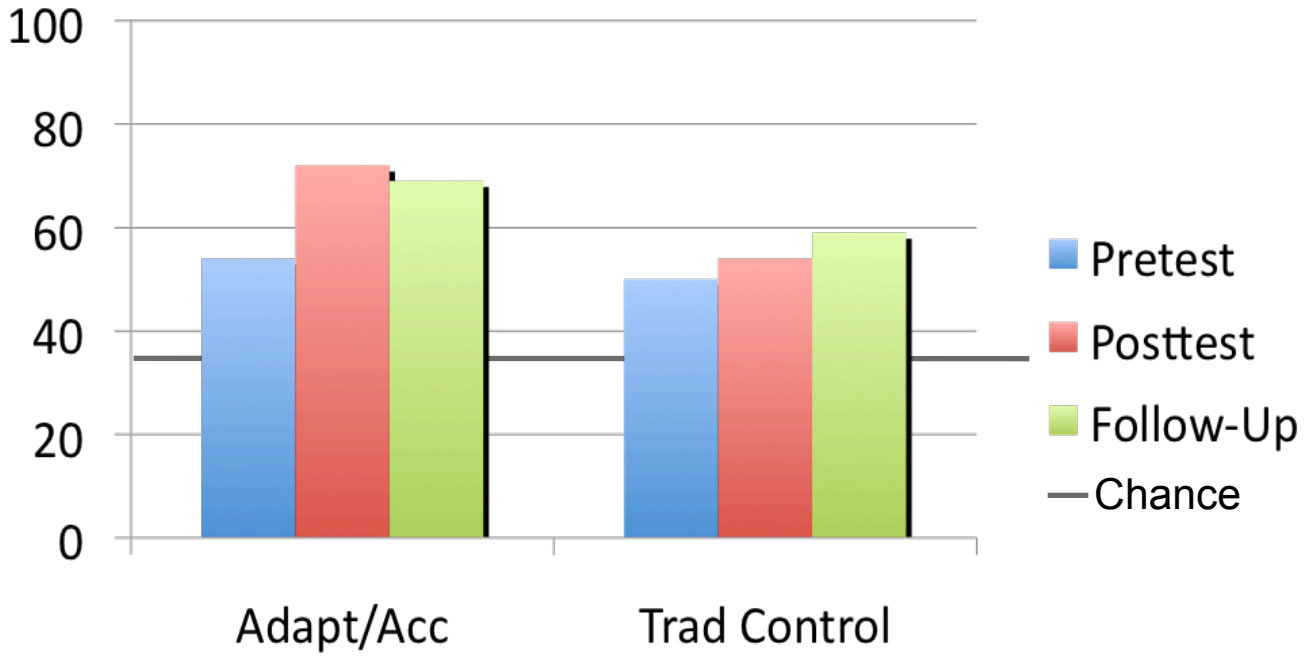
Follow-up: Retention & Transfer

Goal: Study students' retention and transfer in both groups

Students were recruited at the beginning of the following semester

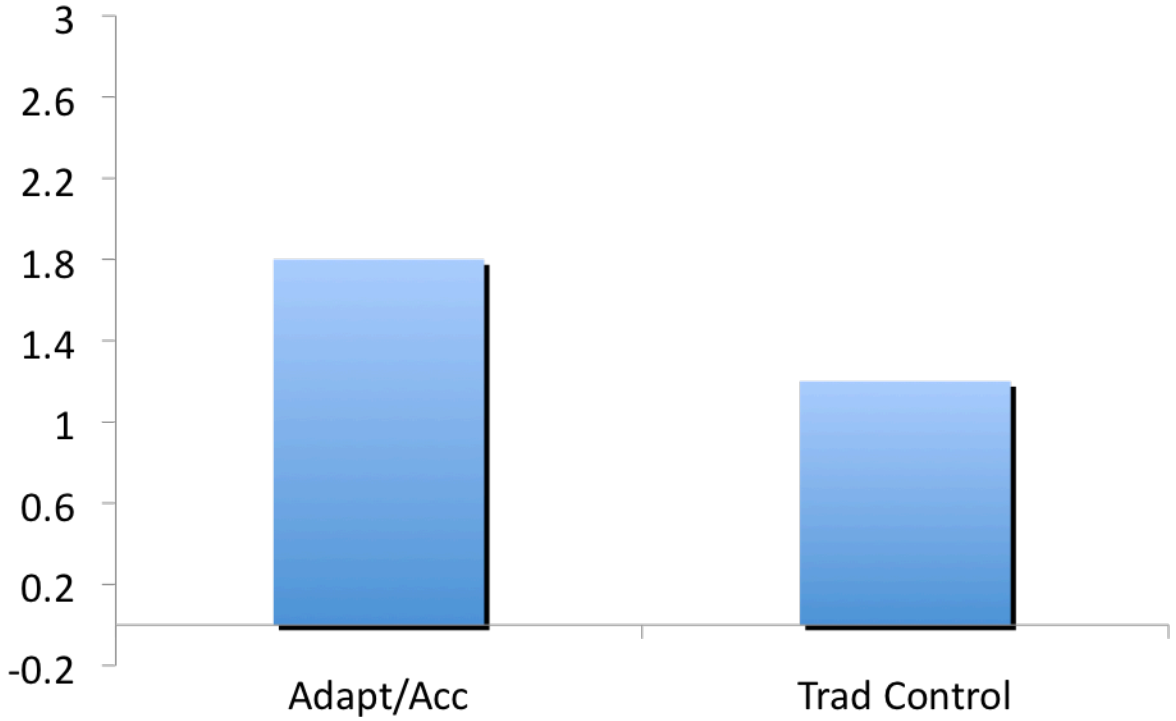


Retention: Standardized test



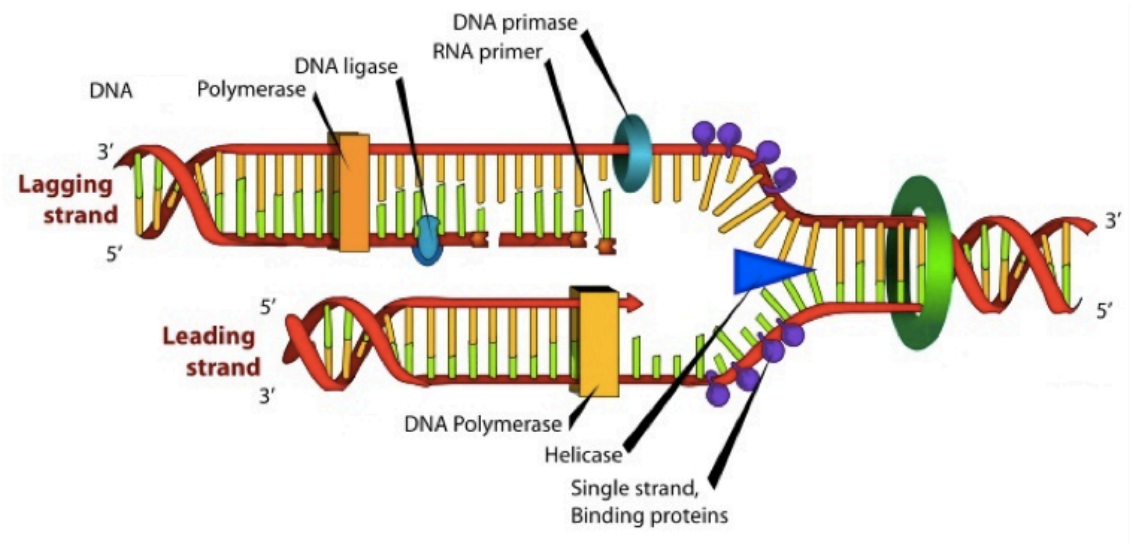
At 6-month delay, Adaptive/Accelerated group scored higher on CAOS than Traditional Control, $p < .01$.

Transfer: Open-Ended Data Analysis



Adaptive/Accelerated group scored significantly higher than Traditional Control.

DNA Replication Module



By Mariana Ruiz (DNA replication) Public Domain

did I get this

Which of these separates the two complementary strands of DNA?

○ single-strand binding protein ○ helicase ○ DNA polymerase ○ RNA primer

Which of these attaches complementary bases to the template strand?

○ helicase ○ single-strand binding protein ○ RNA primer ○ DNA polymerase

Which of these is later replaced with DNA bases?

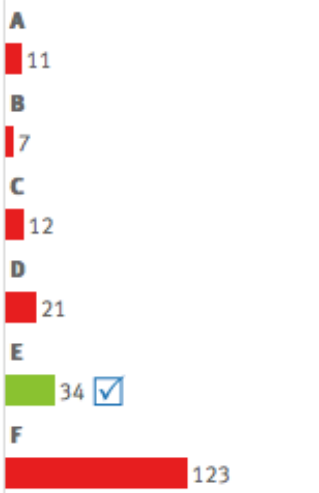
○ DNA polymerase ○ RNA primer ○ single-strand binding protein ○ helicase

Where did students make the most mistakes?

Question	Students	% Correct
Question 1	208	16%
Question 2	203	63%
Question 5	192	76%
Question 3	202	86%
Question 4	192	89%

Question 1

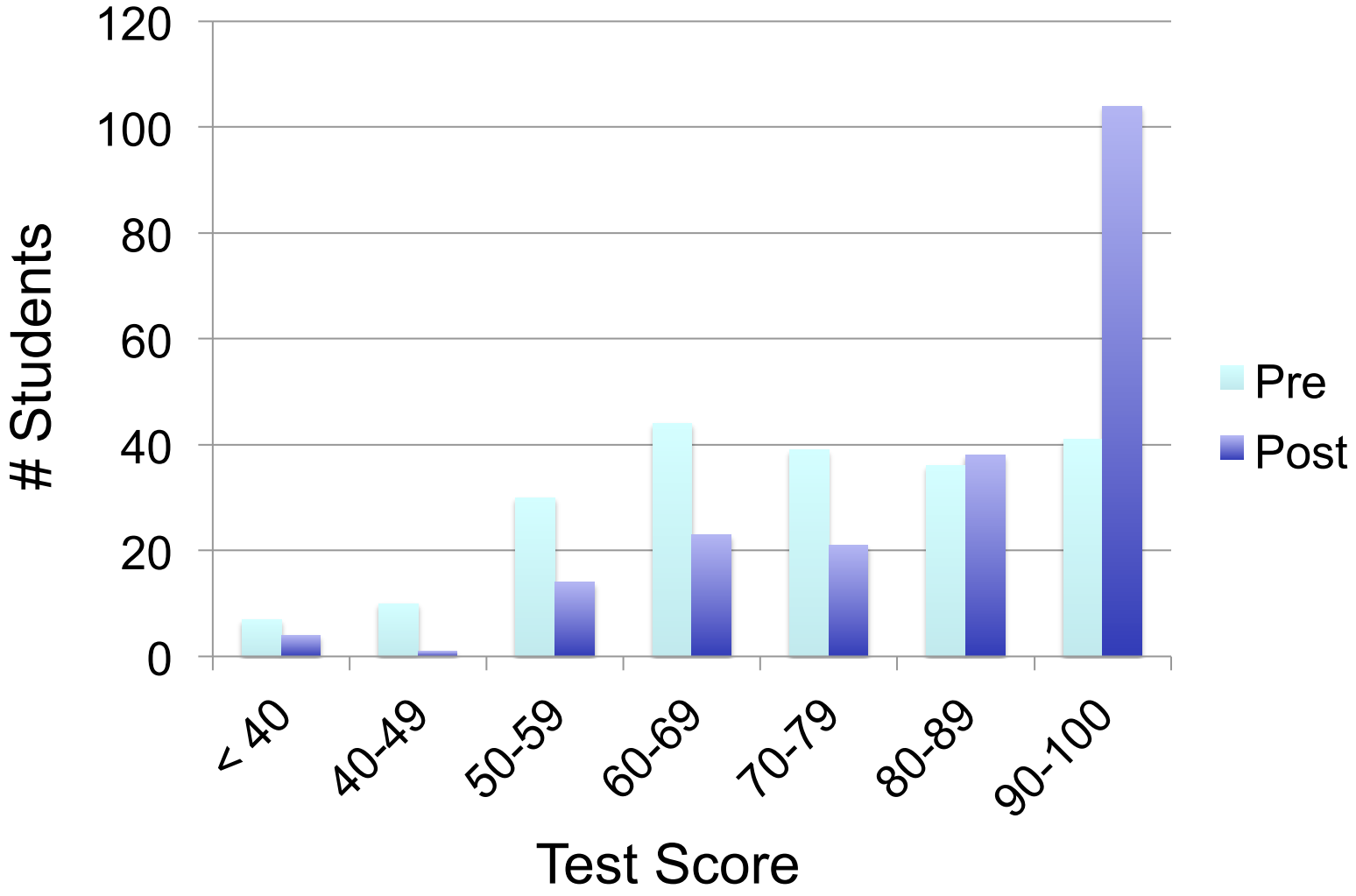
208 responses, 16% correct



A closed circular prokaryotic chromosomes replicates from a single origin of replication. If the rate of DNA synthesis by DNA polymerase is 500 bp/sec and the chromosome contains a million bp, how long will it take to replicate the chromosome?

A. 10 sec
B. 20 sec
C. 100 sec
D. 200 sec
E. 1000 sec
F. 2000 sec

Distribution of Scores Pre/Post DNA Module



Module 5 / Identifying Nominalizations Derived from Verbs

LEARNING OBJECTIVE

Identify and transform nominalizations.

Prose Style Modules

The key to identifying nominalizations derived or converted from verbs is to look for nouns that refer to actions. In looking for them, however, it might be helpful to know that many nominalizations have common endings. Table 1 lists the common endings for nominalizations derived from verbs, along with an example nominalization with that ending and its corresponding verb.

Table 1. Common Endings for Nominalizations Derived from Verbs

Ending	**Example Nominalization**	*Verb*
-age	stor*age*	store
-ance/ence	contriv*ance*	contrive
-ant	adulter*ant*	adulterate

learn by doing

Identify all the nominalizations that refer to an action in the following sentence: hint

Adolf Loo's famous essay, 'Ornament and Crime,' decisively linked unornamented architecture with the culture of modernity and, in doing so, became one of the key formulations of modern architecture.

NEXT »

Reset this Activity

Learning Dashboard

NOTE: Click on the word(s) in the sentence to select/identify nominalization(s).

The following *did I get this?* exercise tests your understanding of the material covered in this unit.

did I get this

Revise the following sentence:

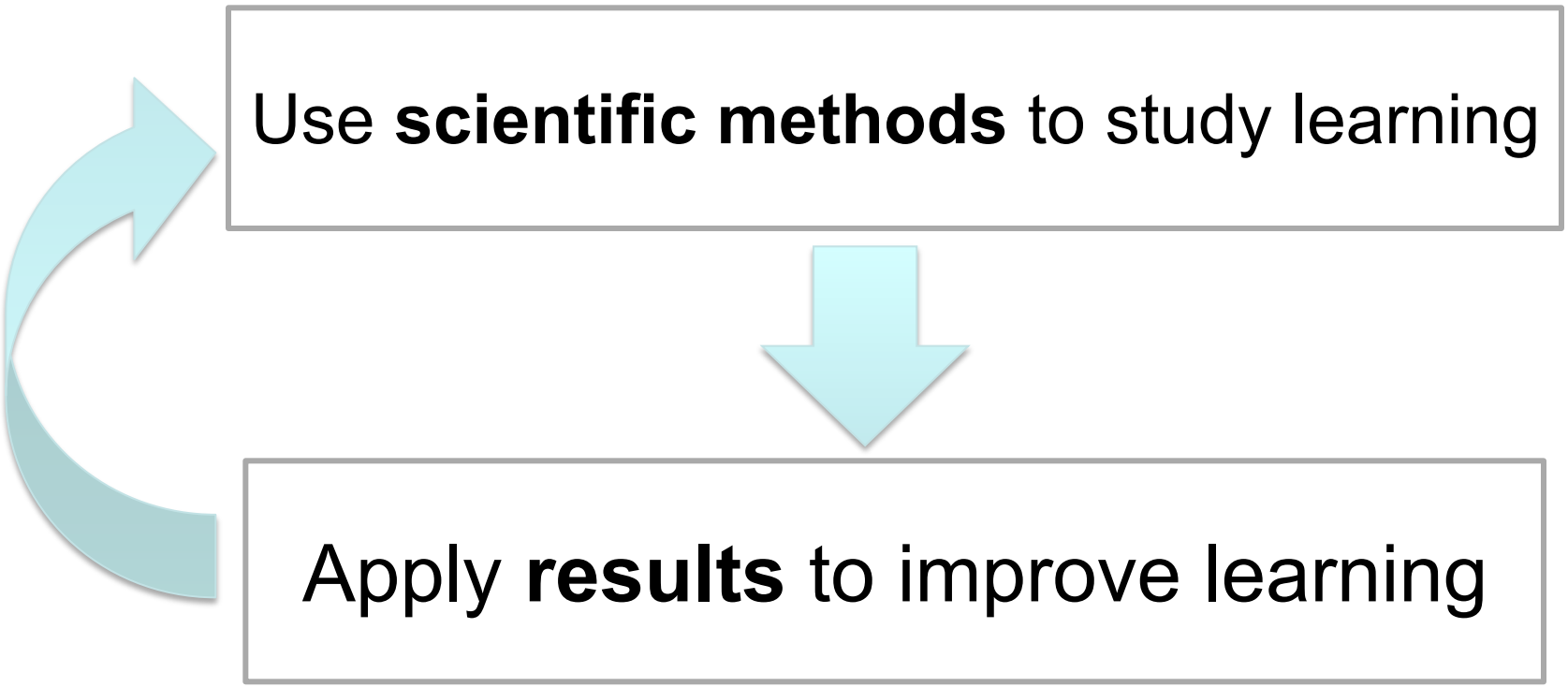
By contrast, Lubell wants to highlight the inevitable incompleteness of one's knowledge of one's past.

Submit and Compare

Revise the following sentence:

Under this standard, the event of death is determined as the time at which there is irreversible loss of whole brain function.

Submit and Compare


Use **scientific methods** to study learning
Apply **results** to improve learning

Themes Underlying Our Approach

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

Learning Engineering: Applying Research & Data to Improve Outcomes

Norman Bier

@normanbier

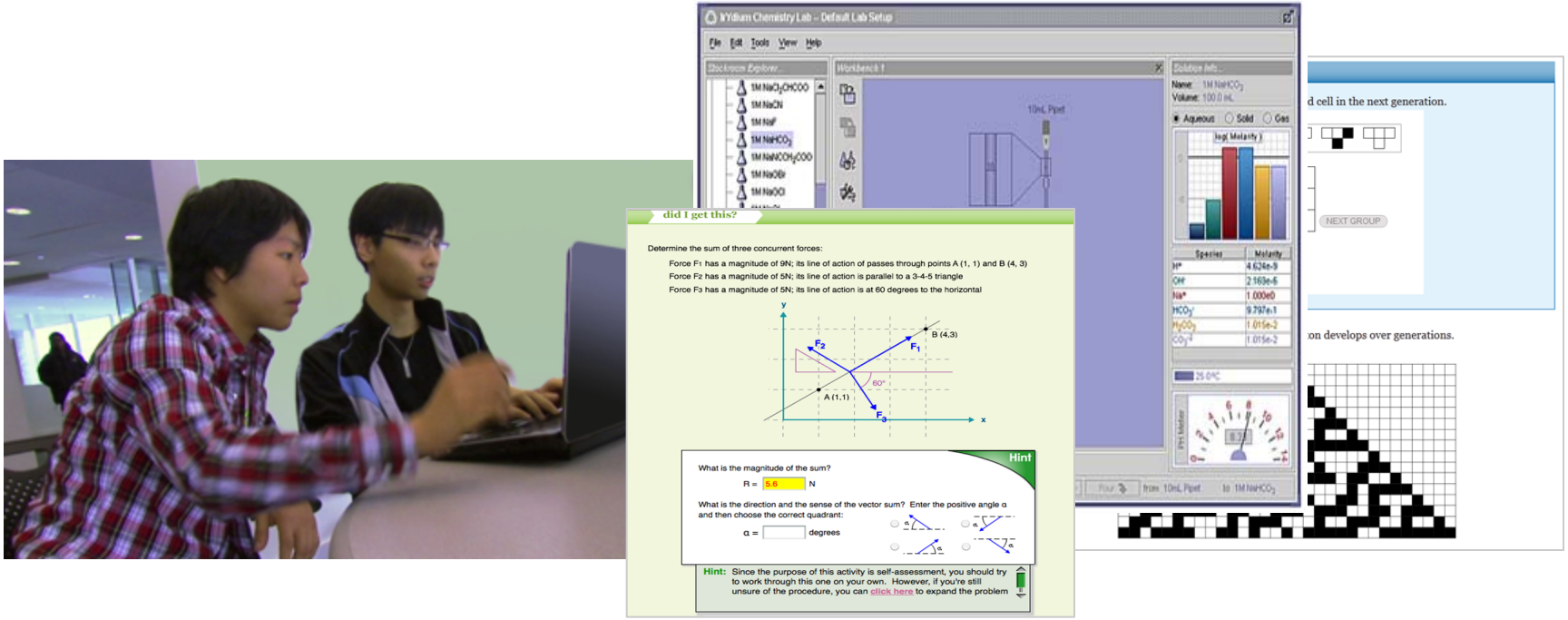
Open Learning Initiative

Carnegie Mellon University

April 27, 2015

What is the Open Learning Initiative?

Scientifically-based online learning environments based on the of technology and the science of learning with instruction. OLI is **designed** to simultaneously improve learning and facilitate learning research.



The Open Learning Initiative

Established in 2002 to produce and improve exemplars of scientifically-based online courses that enact instruction and support instructors. Current goals:

- Support better learning and instruction with high-quality, scientifically-based, classroom-tested online courses and materials.
- Share our courses and materials openly and freely so that anyone can learn.
- Develop a community of use, research, and development.

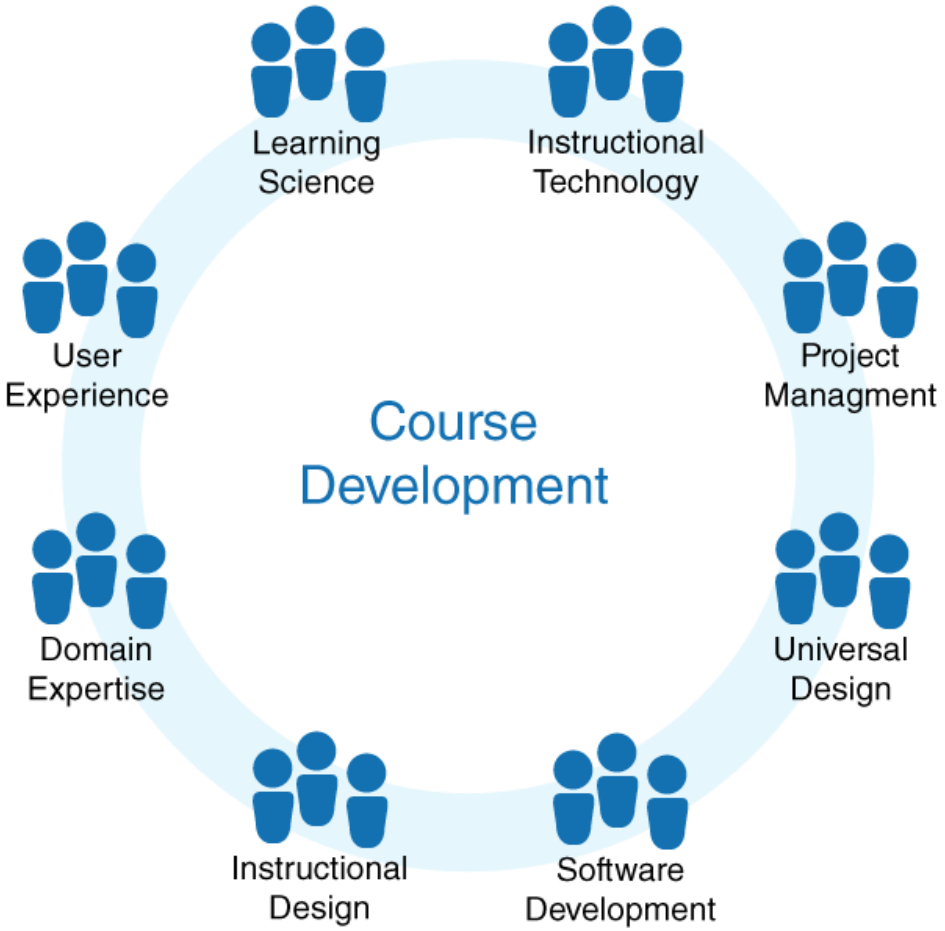
Open Learning Initiative

Transforming higher education through the science of learning.

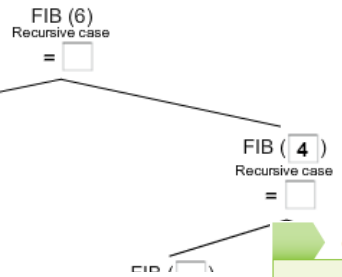
An approach to designing, developing, delivering and improving learning experiences

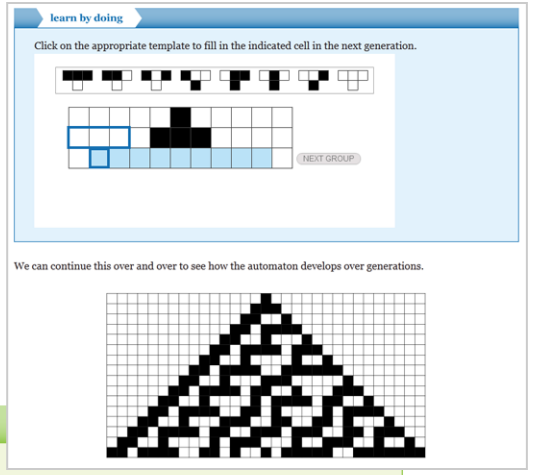
Science	• Science of Learning • Evaluation • Improvement
Technology	• Platform • In-course Affordances
Teams	• Team-based Development • Communities of Research and Use
Data	• Capture • In-course Use • Iterative Improvement • Research

Team-based design and development



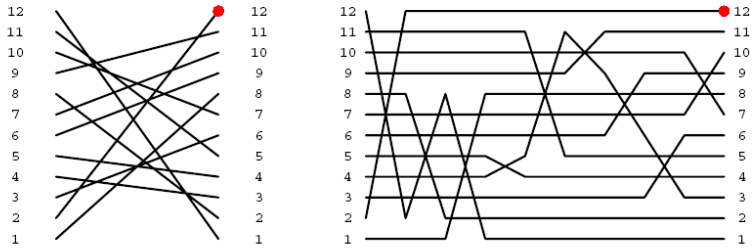
Embed lessons in technology **and** in process





So $(1, 2)(2, 3)(3, 4)(4, 5) = (5, 4, 3, 2, 1)$.

Here is a more complicated permutation on $n = 12$, and its decomposition into transpositions.



There are many other identities relating to transpositions. For the next proposition, we abuse notation and use exponents for permutations given in cycle notation.

Proposition

$$(a, b) \circ (b, c) \circ (a, b) = (a, c)$$

$$(1,\ldots,n)^i \circ (1, 2) \circ (n,\ldots,1)^i = (i + 1, i + 2)$$

where $0 \leq i \leq n - 2$

As already mentioned, the decomposition into transpositions is not unique. In fact, not even the number of transpositions used is unique. However, there is still an invariant.

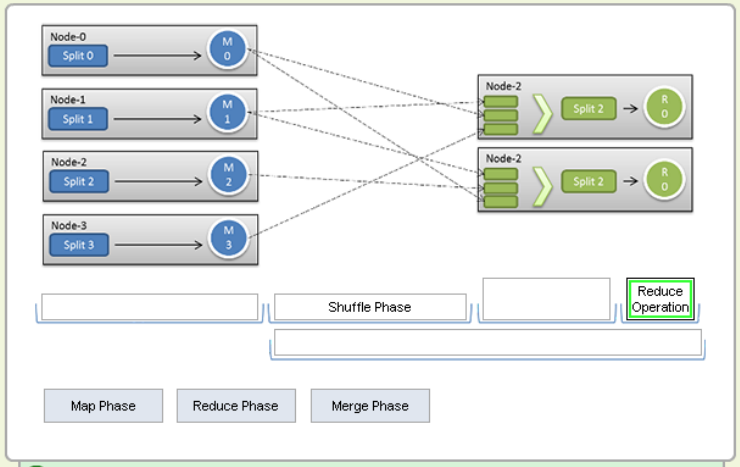
Even permutation

(definition) A permutation is even if it can be written as the product of on **even** number of transpositions, and **odd** if it can be written as the product of on odd number of transpositions.

did I get this

MapReduce Phases

The following image illustrates the various phases of MapReduce. Match the letters (A,B,C,D and E) with their corresponding phase names below:

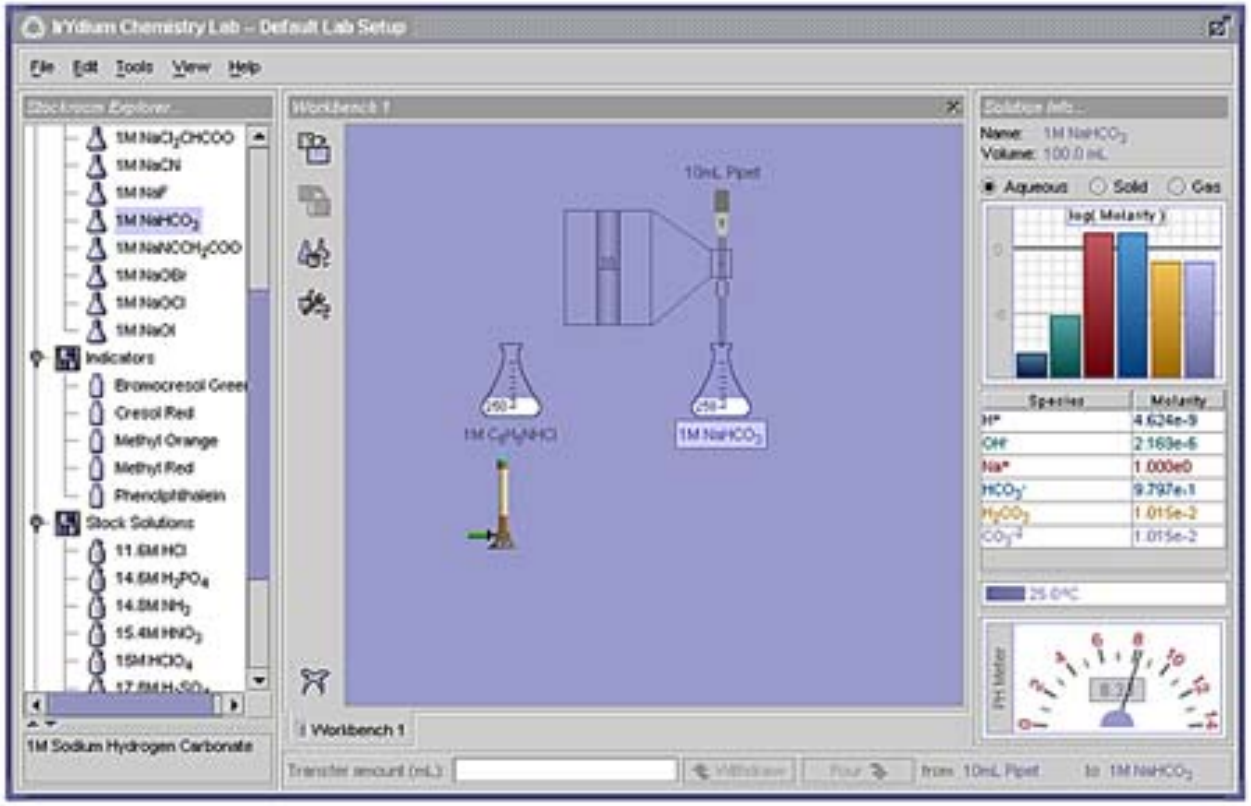


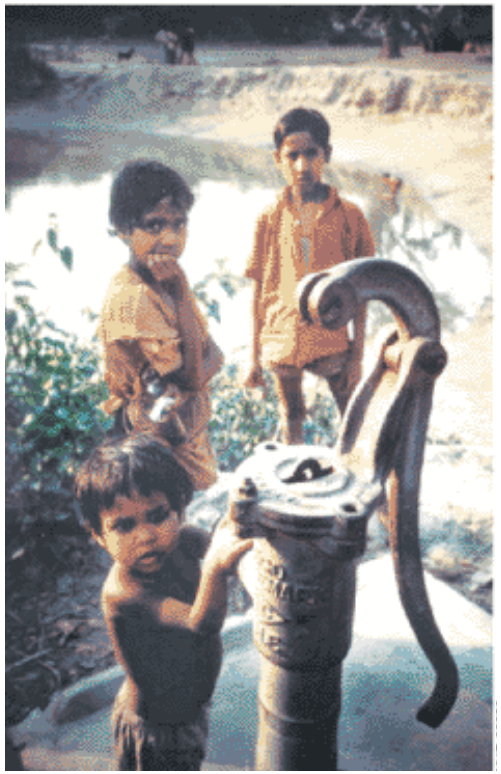
Correct. The Reduce Operation refers to the reduce function (or reducers) being applied to the merged intermediate outputs.

Learning Dashboard

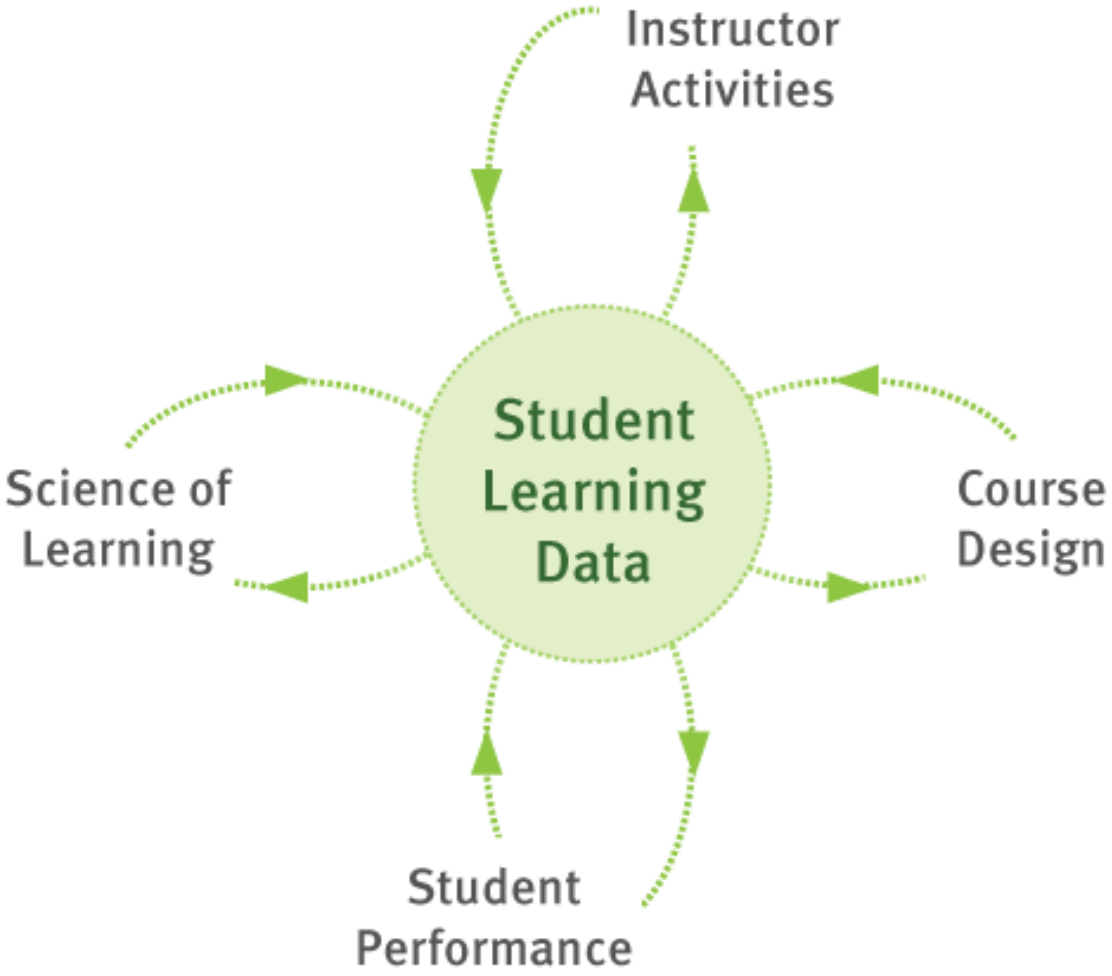
Identifying Specific Learning Challenges:

Practice Synthesizing and Applying Skills & Knowledge

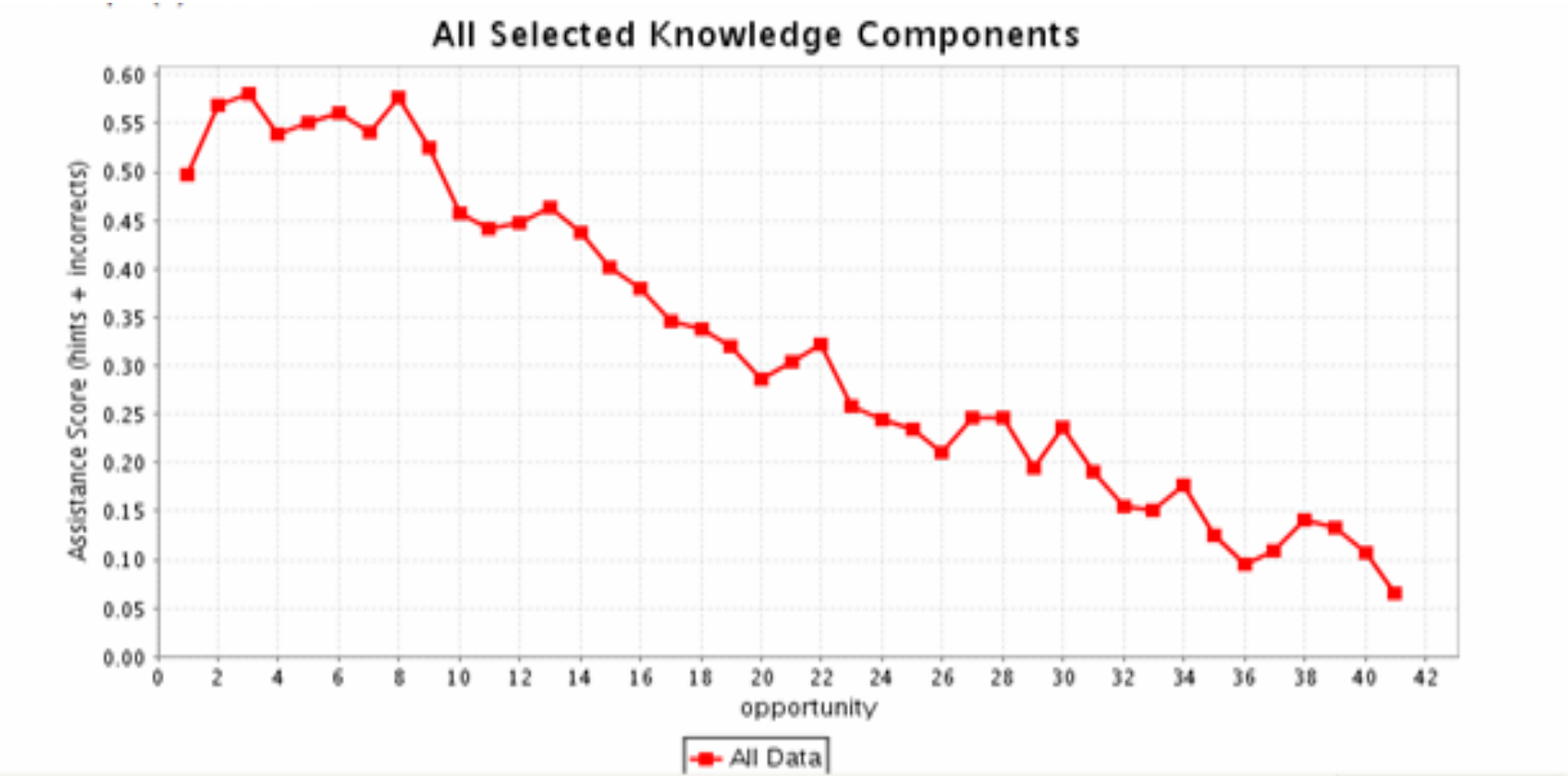




Feedback loops for **continuous improvement**

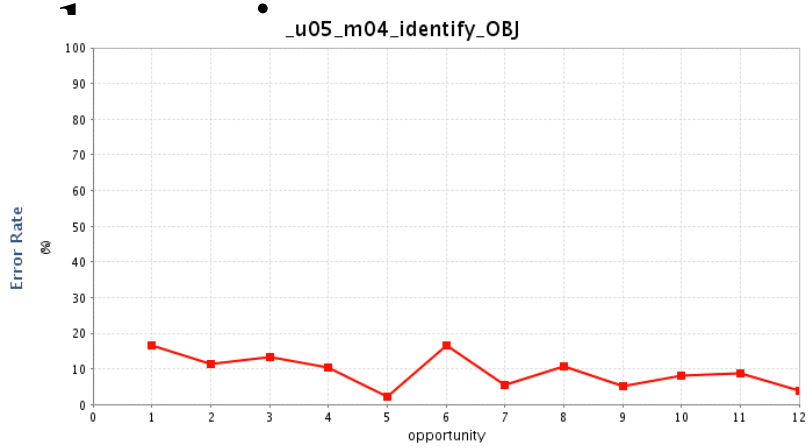


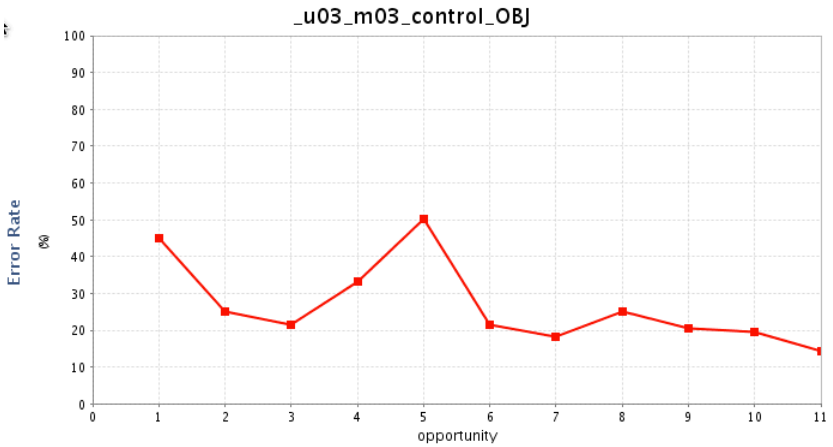
Learning Curve Analysis

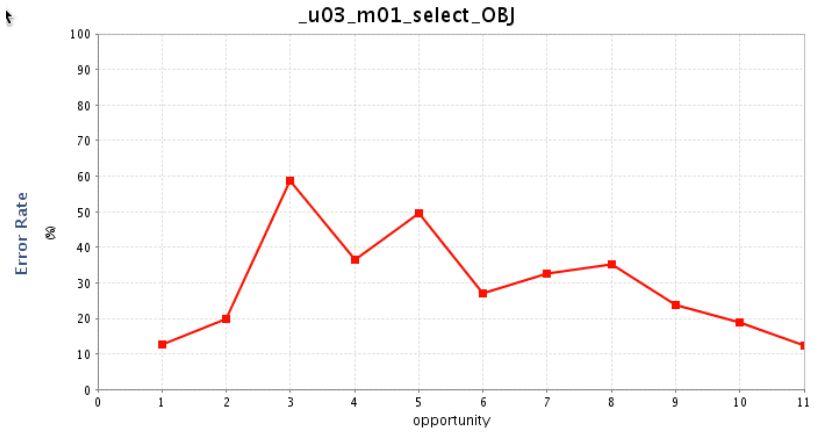


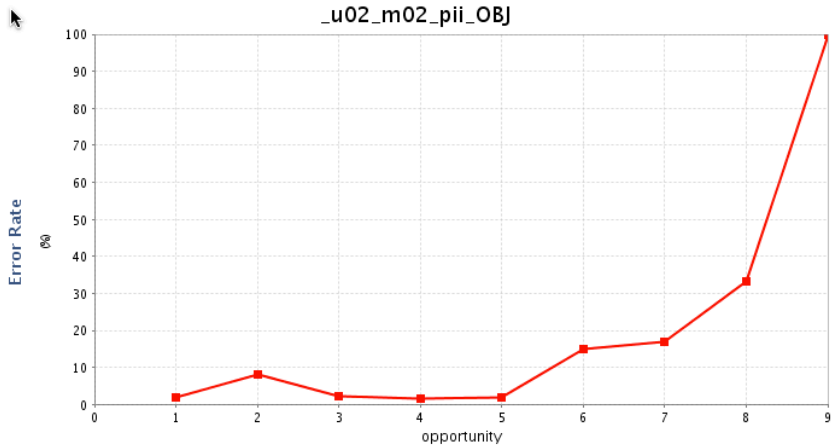
DataShop: Pittsburgh Science of Learning Center

Other Learning Curves



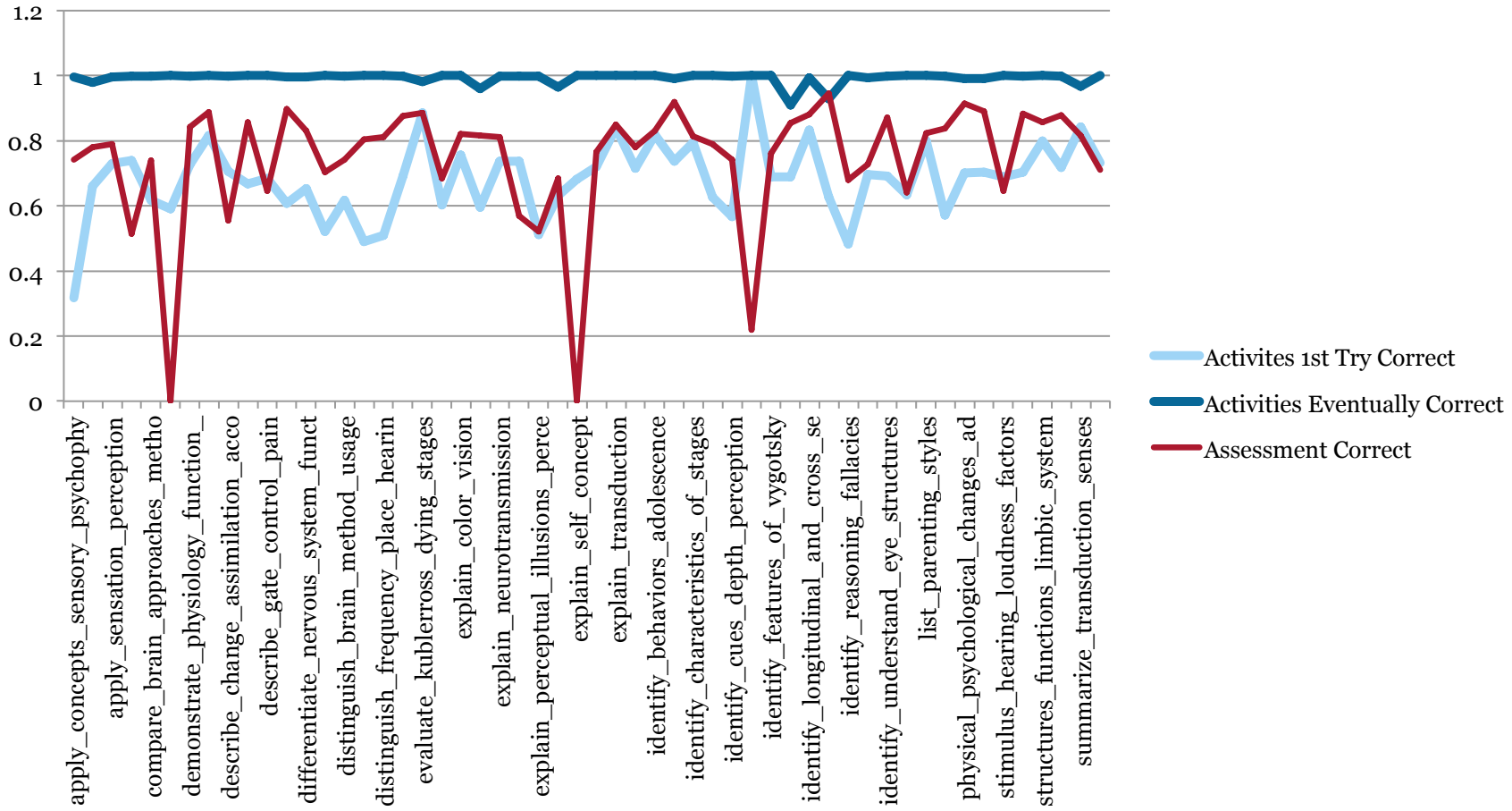






DataShop: Pittsburgh Science of Learning Center

Practice and Assessments



Is the hypothesis I built holding up?

Reports

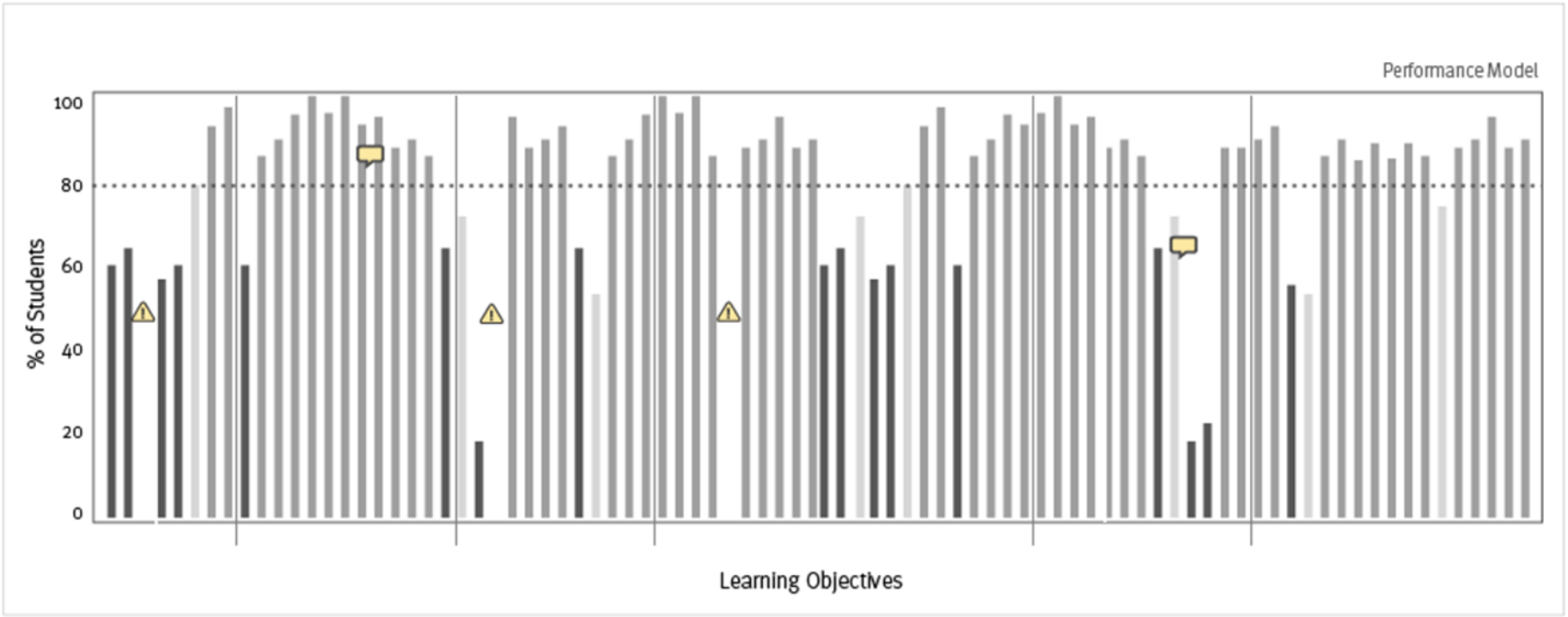
Performance | Usage | Feedback (3) | Model Checker

Modern Biology v. 1.4 [EDIT]

SUMMARY

Enrollment	Courses	Institutions	LOs	Student Input Opportunities
900: 700 academic 200 open	220	50	18	50

Learning Objectives ▼ | All Learning Objectives ▼ | All Modules ▼ | ◉ Objectives Chart ○ PSLC Help Curve



LEARNING OBJECTIVES Module 4 ▼

1. List atoms (elements) found in biological systems that are most important to life, including the most common atoms and trace elements.
2. Identify the more electronegative atom when comparing two atoms.

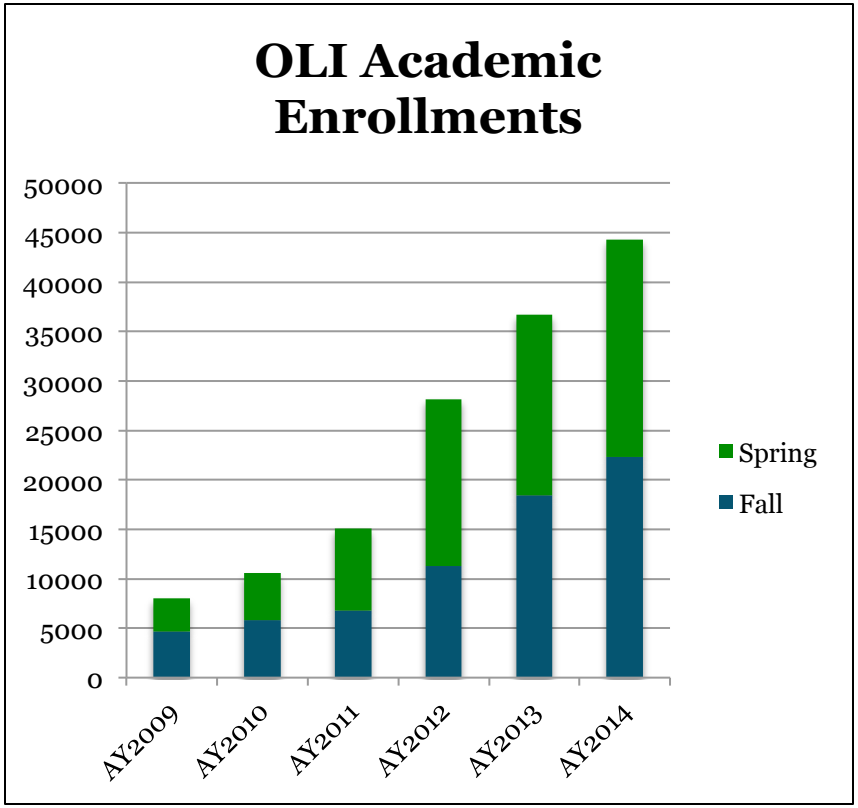
Since 2006

Course Use

- Used by 1809 Instructors in 1050 Institutions
- 1,245,807 Independent Learner Enrollments (Registered and Anonymous)

Development

- 44 Academic and 9 CMU service courses have been created.
- By 104 contributing Faculty from 55 Institutions

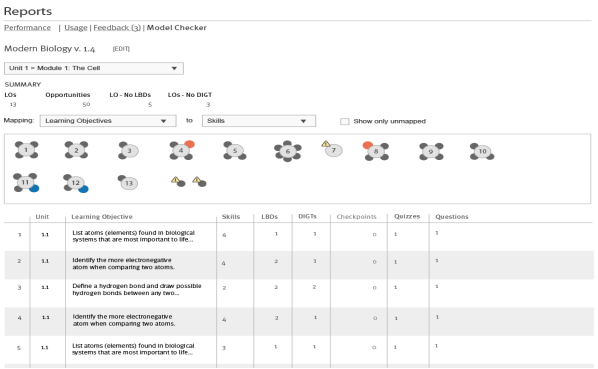


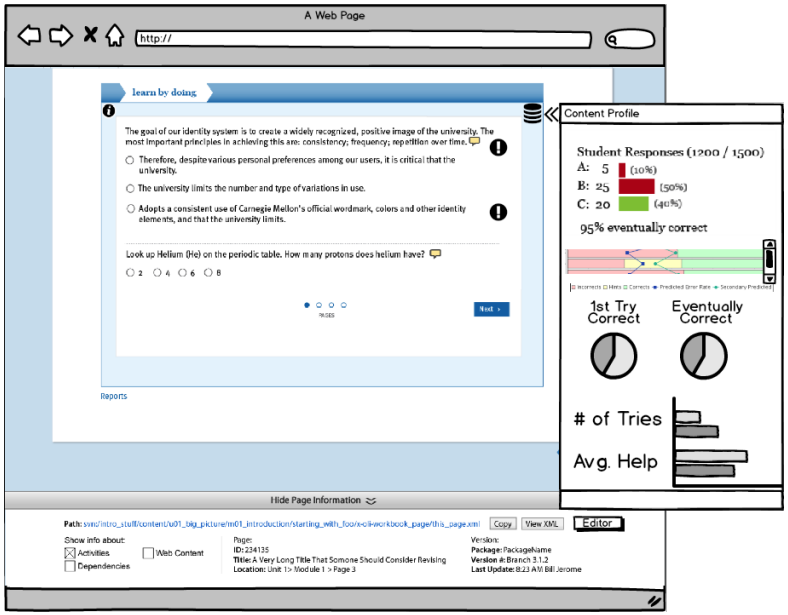
Current Work

Embedding data into design & improvement

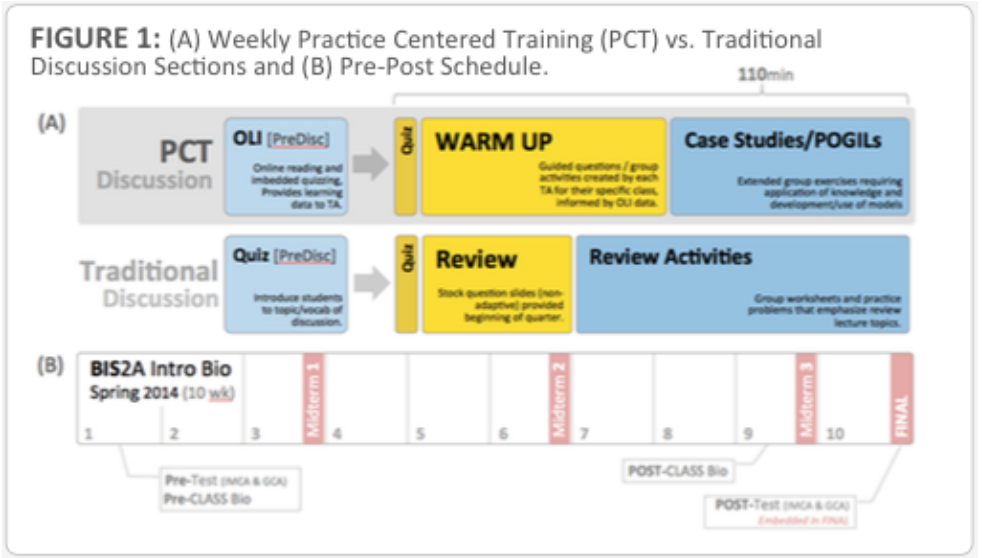
IDEA Project

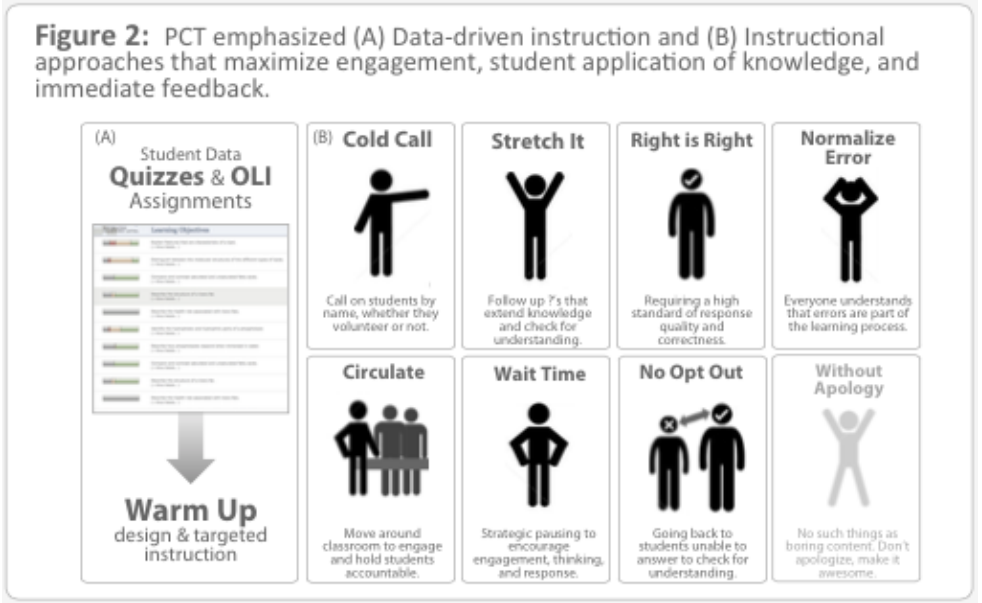
- NSF DIR Project
- Tools for supporting learning engineering
- Integration into workflow
- Existing and new analytic methods
- 3 Core components:
  - Model Checker
  - Performance Profiler





New Approaches: ALMAP at UC Davis

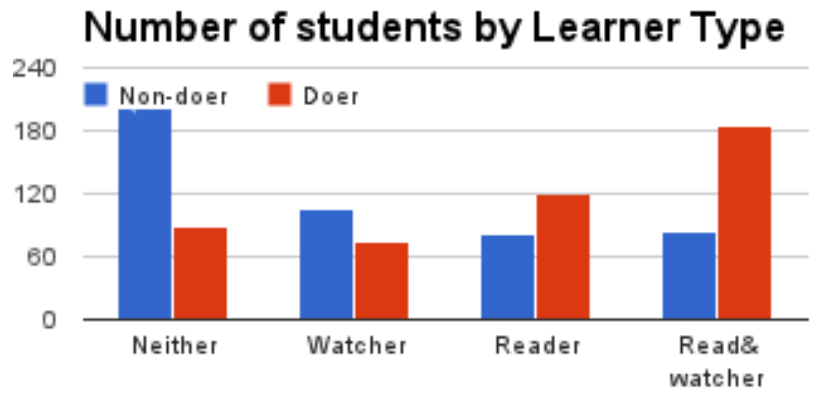


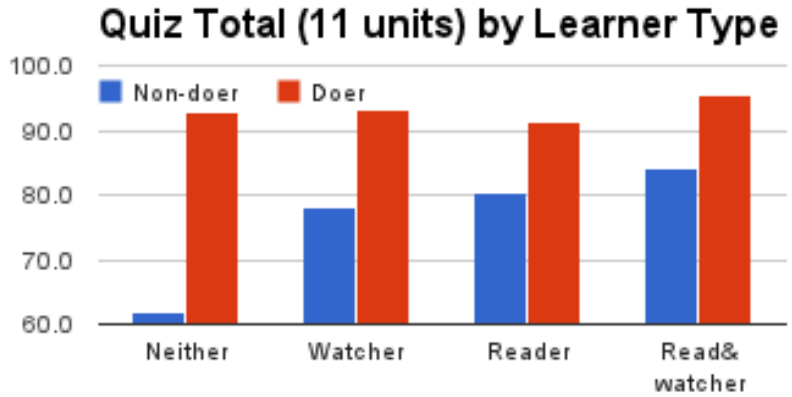


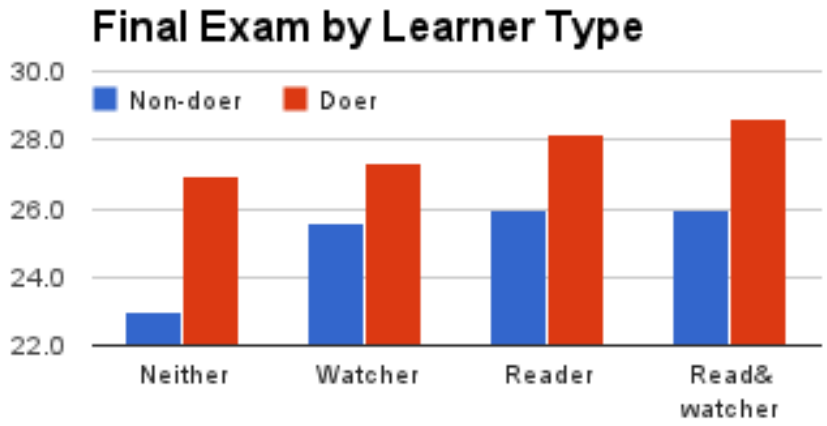
Learning is Not a Spectator Sport

Presented at L@S 2015

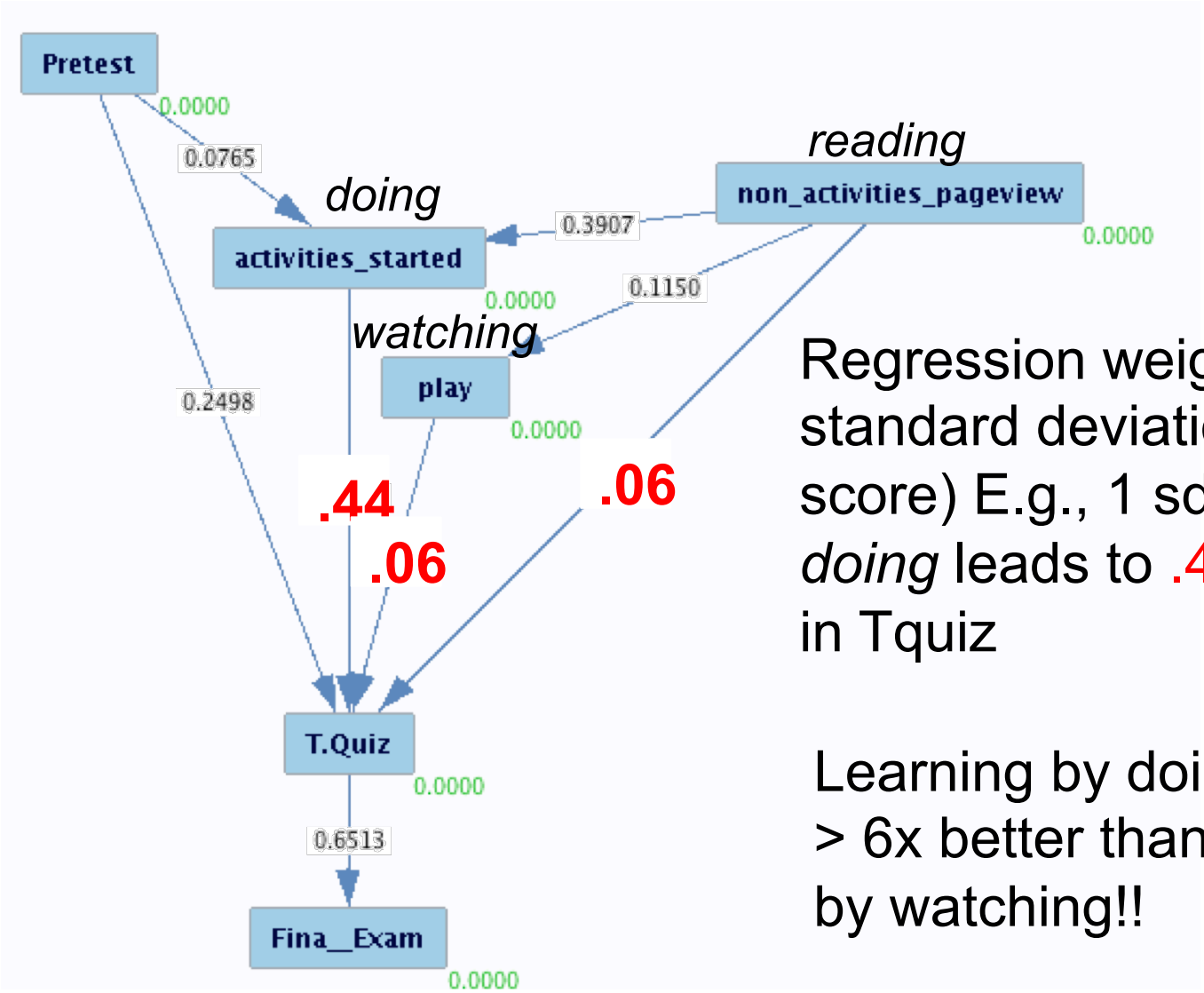
- Collaboration between GA Tech and Carnegie Mellon
- Psychology MOOC using OLI course
- Where does learning occur?
- Watching vs Reading vs Doing







Tetrad inference of causal relationships



Regression weights in standard deviation units (z-score) E.g., 1 sd increase of *doing* leads to .44 increase in Tquiz

Learning by doing
> 6x better than learning by watching!!

Looking ahead

CMU as a hub

CTAT Cognitive Tutor Authoring Tools

LearnLab
Pittsburgh Science of Learning Center

DANCE
Discourse Affordances for Natural Collaborative Exchange

ETC global
Carnegie Mellon
PITTSBURGH

ChemCollective

HCII
Human-Computer Interaction Institute

SimStudent
A Computational Model of Learning

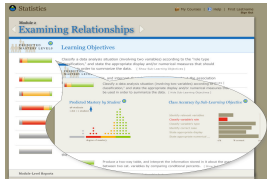
Integrative Design, Arts and Technology Network

Pittsburgh Science of Learning Center
DATASHOP

Open Learning Initiative
Carnegie Mellon University
Transforming higher education through the science of learning.

Autolab

Eberly Center
Teaching Excellence & Educational Innovation

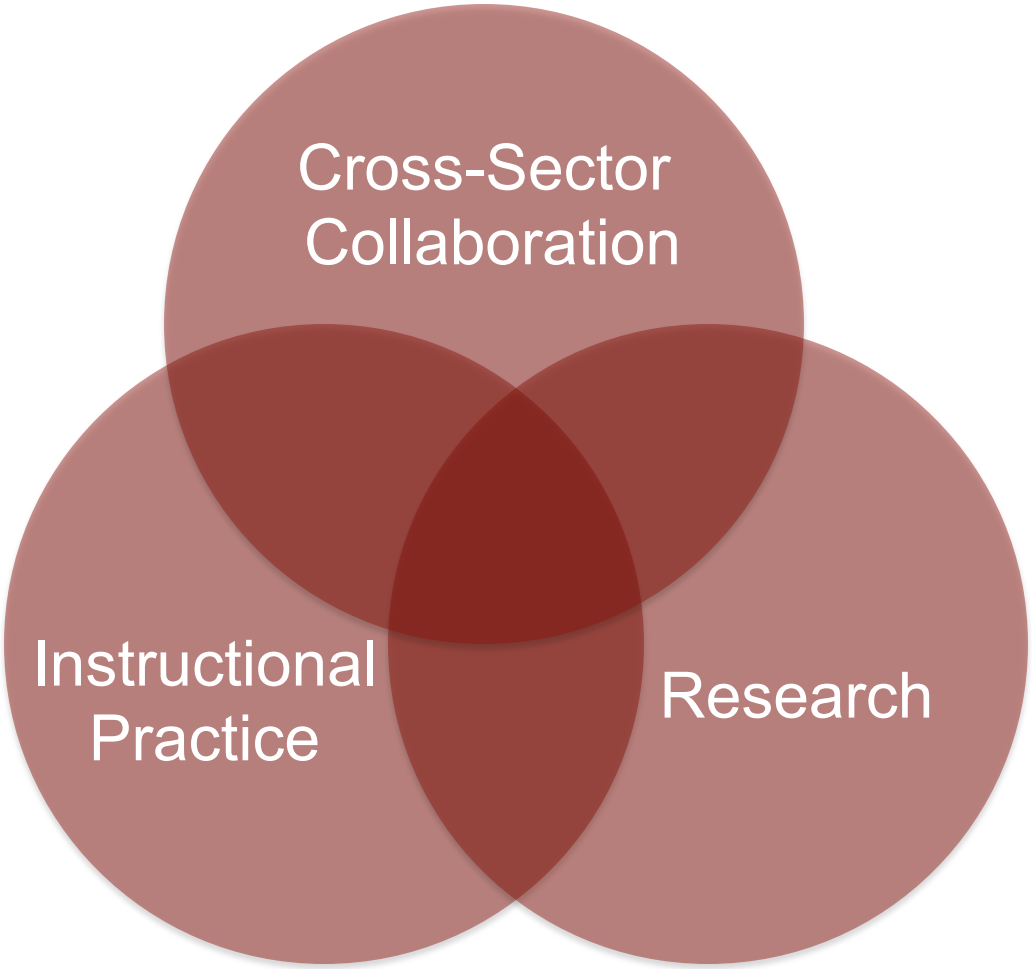


PIER @ Carnegie Mellon
PROGRAM IN INTERDISCIPLINARY EDUCATION RESEARCH

The Carnegie Mellon Genetics Cognitive Tutor

The Simon Initiative

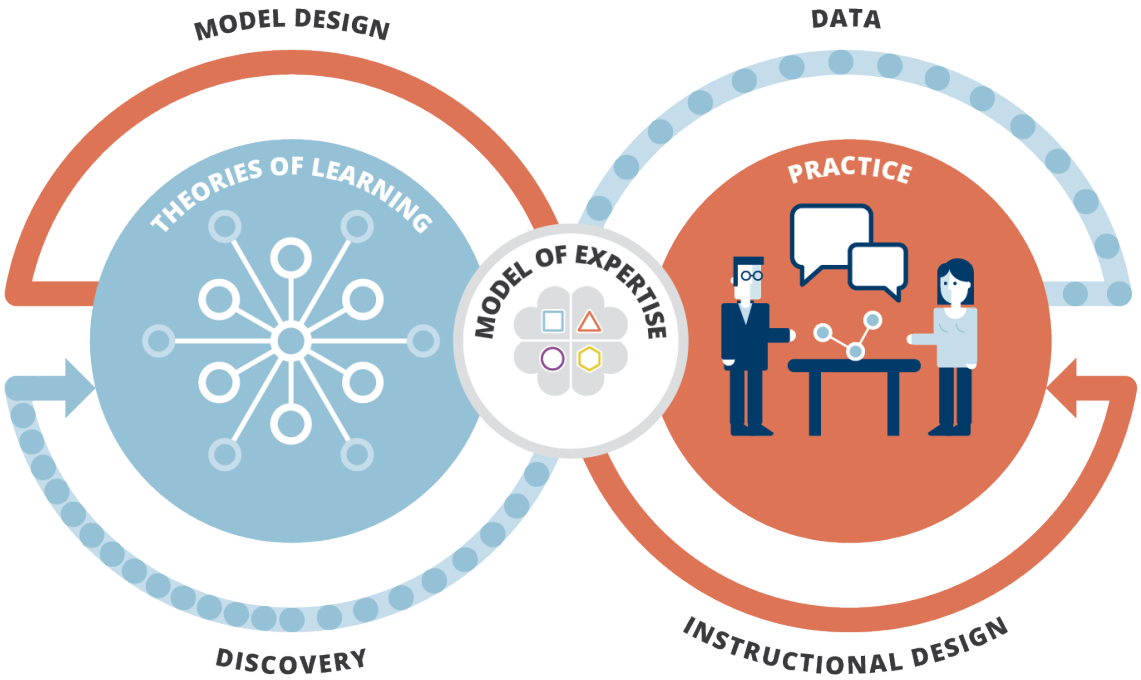
GLOBAL LEARNING COUNCIL



Eberly Center
Teaching Excellence & Educational Innovation

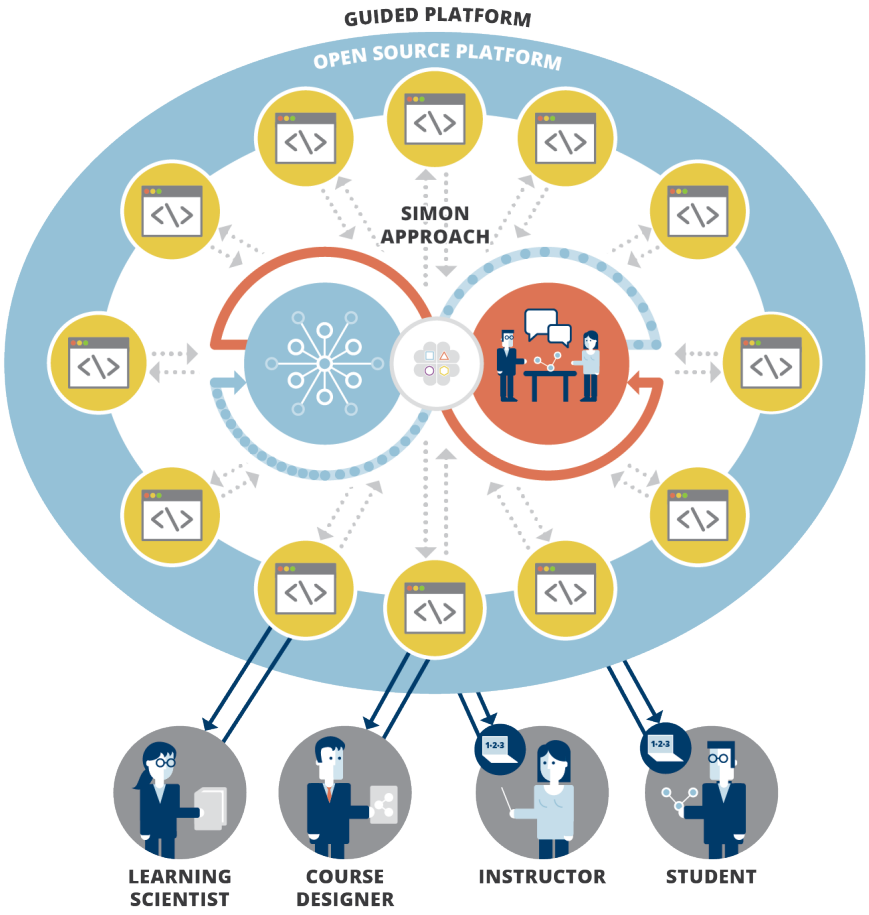
DataLab
A project of the Simon Initiative

The Simon Initiative



A data-driven virtuous cycle of learning science research and innovative educational practice causes demonstrably better learning outcomes for students from any background or place

The Simon Initiative



At CMU: To build a *learning engineering ecosystem* in which learning science research can feasibly and frequently be leveraged to demonstrably improve CMU education, and in which CMU education can provide data which can be leveraged to improve theories of learning

Globally: To provide accessible tools and methods with which any person or institution can adopt and improve upon CMU's approach to learning engineering

Questions?

nbier@cmu.edu