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Next-Generation Analytics with the Learning Dashboard

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Cognitively Informed Analytics to Improve Teaching and Learning

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“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
Learning Dashboard’s Key Ingredients
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:*
As students practice, performance improves with marginally decreasing returns.
The Performance We Observe

![Graph showing performance over practice with errors on the y-axis and practice on the x-axis. The graph shows a decrease in errors from practice 1 to practice 3, followed by an increase from practice 3 to practice 6.](Carnegie Mellon University)
The Underlying Skills

- Interpret histogram
- Interpret table
- Interpret boxplot
Performance Re-indexed

The Power Law of Learning revealed

- Graph showing the relationship between practice opportunity and errors, with a downward trend indicating improvement with more practice opportunities.
As students practice a given skill, their performance at that skill improves; Other skills are not affected.

The Power Law of Learning

If you’re not paying attention to the skills students are supposed to learn, you’re missing something fundamental.
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 Environment
- How am I doing? What have I done? What should I do next?
- Discuss the challenges in assessing the ecological impact of specific behaviors and materials use.
- Identify which was not a battle during World War II?
- How are my students doing? What have they done? How should I adjust my teaching?

Inference Engine
- Runs Statistical Models

Service Engine
- Manages flow and responds to various requests from different users

Feedback Engine
- Generates Visualizations Feedback

The Learning Dashboard is an analytics system that uses a sophisticated model of students’ learning states to analyze clickstream data in real time and provide interpretable and actionable inferences, recommendations, and data visualizations for both students and instructors.
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.
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.
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.

(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

Eight weeks of instruction

Homework: complete OLI activities on a schedule

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

Same content but different kind of instruction

Four 50-minute classes/wk

Fifteen weeks of instruction

Homework: read textbook & complete problem sets

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

Same content but different kind of instruction
Final Exam Performance

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

Adapt/Accel: 92%
Trad'I Control: 82%
Trad'I All: 81%
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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Adapt/Acc Ends

Trad’l Ends

Adapt/Acc Delay

Jan   Feb   Mar   Apr   May   Jun   Jul   Aug   Sep   Oct

Follow-up Begins
Follow-up: Retention & Transfer

Goal: Study students’ retention and transfer in both groups

Students were recruited at the beginning of the following semester

Adapt/Acc Ends

Trad’l Ends

Adapt/Acc Delay

Trad’l Delay

Follow-up Begins
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%!