Analytics

What’s inside LON-CAPA data?

Gerd Kortemeyer
Michigan State University
... or

- all the questions you wish you had not asked
Apologies

- Presenting a garden variety of results from several years
- Not a coherent story, instead just giving an overview of what might be in the data
- There are many, many null-results, but not presented here
  - There is a lot of noise in the data that does not go away with bigger numbers.
    - Big Data does not suddenly make everything clear-cut
  - This noise is not measurement “error,” it’s weird behavior of students.
    - Big Data sometimes just more weirdness.
    - Students are not particles.
Analyzing online course components

We are analyzing online course components in a variety of scenarios:

- MOOCs
- Virtual University Courses
- Blended Courses
- Flipped Courses
- Online Textbooks
- …
Quite a lot of data, actually ...

Data in LON-CAPA

- 160 partner institutions
- 48% postsecondary institutions
- 440,000 shared learning objects
- 198,000 shared homework problems
- 7,700 courses hosted since 1999
- 965,000 student-course enrollments served since 1999
- 94% postsecondary student-course enrollments
- 150,000 student-course enrollments per year
- 73,520,000 problems served since 1999
- 138,320,000 problem transactions since 1999
- 72,560,000 problems solved since 1999
Unproductive Behaviors

- Unproductive behaviors
  - Selective reading – only studying a subset of the materials
  - Cramming – studying “last minute”
  - Guessing – entering random solutions, not thinking
  - Copying – copying solutions from other students

- Cannot be observed with traditional textbooks and courses, but can be measured in online course components
As an aside …

- How can anybody actually read these huge, expensive chunks of paper?
Finding signatures of unproductive behavior

Common to all online scenarios: data!
Data Mining Access Logs

Typical online course materials

Data on materials and homework
Course Structure

- Looking at different course structures:
  - Traditional course: few high-stake exams
  - Reformed course: frequent, short quizzes, peer-instruction, frequent conceptual homework
- Same online textbook materials for both
Online Course Materials

- Online course material access – cramming
- Average page views per day per student
- Guess when exams took place

Daniel T. Seaton, Gerd Kortemeyer, Yoav Bergner, Saif Rayyan, and David E. Pritchard,
Analyzing the Impact of Course Structure on eText Use in Blended Introductory Physics Courses,
American Journal of Physics 82, 1186-1197 (2014)
Online Course Materials

- 100% students access at least 40% of pages
- 50% students access at least 80% of pages
- 50% students access at least 50% of pages

Completely Online versus Blended

- Class reform of blended courses help
- What about completely online?
- Other course:
  - One section: completely online
  - Other section: only difference that there are traditional lectures
- Everything else the same
- Students self-select
Completely Online versus Blended

- Students in blended class read less pages than in online class
- Everybody does online homework

<table>
<thead>
<tr>
<th></th>
<th>Any</th>
<th>Pages only</th>
<th>Problems only</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traditional</td>
<td>2364</td>
<td>87</td>
<td>2276</td>
</tr>
<tr>
<td>Online</td>
<td>2500</td>
<td>265</td>
<td>2235</td>
</tr>
</tbody>
</table>

![Graph showing average page accesses/student for Traditional and Online classes.](image)
Completely Online versus Blended

- Students in online class work more irregularly
- Typical week
Completely Online versus Blended

- Auto-Correlation Function of Accesses versus exam scores
Completely Online versus Blended

- Auto-Correlation Function of Accesses versus exam scores
Completely Online versus Blended

- Interestingly, most significant for the students in the **blended** sections
- Problems more important than text

<table>
<thead>
<tr>
<th>Type</th>
<th>Sections</th>
<th>Intercept $\epsilon$</th>
<th>Hourly $\beta_{\text{hourly}}$</th>
<th>Daily $\beta_{\text{daily}}$</th>
<th>Weekly $\beta_{\text{weekly}}$</th>
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<td>−0.560***</td>
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<td>62.977***</td>
<td>−0.371</td>
<td>3.128*</td>
<td>−0.369</td>
</tr>
</tbody>
</table>

* indicates $p < 0.05$; while *** indicates $p < 0.001$
Online Course Materials

Conclusion:

- Students don’t really “read the book”
  - Unless you run a reformed course with more formative assessment
  - Nothing new …

- BUT: students do homework!
  - Let’s look at online homework
Online Homework

Superman Stops a Train

An out-of-control train is racing toward the main terminal train station - only Superman can help. The train has a mass of 45000 kg, and Superman has a mass of 103 kg. If the train has a velocity of 35 m/s, how fast does Superman have to fly in the opposite direction to stop it in a totally inelastic steel-Man-of-Steel collision?

Submit Answer  Tries 0/5

Randomized problem

Multiple tries

Open-ended numerical
Online Homework

- Online behavioral features:
  - Number of tries before correct answer
  - Correct on first try
  - Total time spent on problem
  - Discussion participation
  - Working close to deadline
  - Giving up versus working up to deadline
  - First access of problem set after becoming available
  - ..., etc, etc, etc, ... you can define as many as you want
**Online Homework**

- See how well you can predict course grade from this online behavior

<table>
<thead>
<tr>
<th>Classifier</th>
<th>2-Classes</th>
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<tr>
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<td>59.9</td>
<td>33.1</td>
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<td><strong>Tree Classifier</strong></td>
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<tr>
<td>Bayes</td>
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<td>Parzen</td>
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<td><strong>Non-tree Classifier</strong></td>
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</tr>
<tr>
<td>CMC</td>
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<td><strong>70.9</strong></td>
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## Online Homework

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### Online Homework

- Most important features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Importance %</th>
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<tr>
<td>Total_Correct_Answers</td>
<td>100.00</td>
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<tr>
<td>Total_Number_of_Tries</td>
<td>58.61</td>
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<tr>
<td>First_Got_Correct</td>
<td>27.70</td>
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<td>Time_Spent_to_Solve</td>
<td>24.60</td>
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<td>Total_Time_Spent</td>
<td>24.47</td>
</tr>
<tr>
<td>Communication</td>
<td>9.21</td>
</tr>
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</table>
Online Homework

- What does that mean?
  - Most important: did the student solve homework problems eventually?
  - Second: not too many tries
  - Third (factor four lower!): did they get it right on the first attempt?

- Tenacity more important than immediate genius!

Online Homework

- What does that mean?
  - Most important: did the student solve homework problems eventually?
  - Second: not too many tries
  - Third (factor four lower!): did they get it right on the first attempt?

Tenacity more important than immediate genius!

B. Minaei-Bidgoli, D. A. Kashy, G. Kortemeyer, and W. Punch,
*Predicting Student Performance: an Application of Data Mining Methods with an Educational Web-Based System (LON-CAPA)*,
Frontiers in Education Conference 2003
Typical Online Physics Problem

Superman Stop Train

An out-of-control train is racing toward Superman - only Superman can help. The train has a mass of 103 kg. How fast does Superman have to fly into the train to stop it? The train and Superman are totally inelastic steel-Man-of-Steel! How many?

Multiple tries

Tries 0/5

How many?
How Many Tries to Grant?

- Quick survey among 74 PER faculty and LON-CAPA users
- Self-identified as instructors-of-record
How Many Tries to Grant?

- Quick survey among 74 PER faculty and LON-CAPA users
- Self-identified as instructors-of-record

Not exactly consensus ...
# How Many Tries to Grant?

- Why is there no consensus?
- Balancing act

<table>
<thead>
<tr>
<th></th>
<th>Low Number of Allowed Tries</th>
<th>High Number of Allowed Tries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Possibly Good</td>
<td>• Better exam preparation</td>
<td>• Better mastery-based formative assessment</td>
</tr>
<tr>
<td></td>
<td>• Less grade-inflation</td>
<td>• Encouragement</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Less whining</td>
</tr>
<tr>
<td>Possibly Bad</td>
<td>• Discouragement</td>
<td>• Random guessing</td>
</tr>
<tr>
<td></td>
<td>• Copying</td>
<td>• False sense of security</td>
</tr>
<tr>
<td></td>
<td>• More whining</td>
<td></td>
</tr>
</tbody>
</table>

- Possibly Good
- Possibly Bad
Random Guessing

Gerd Kortemeyer and Peter Riegler, Large-Scale E-Assessments, Prüfungsvorbereitung und -nachbereitung: Erfahrungen aus den USA und aus Deutschland, Zeitschrift für E-Learning, Volume 5, Issue 1, (2010)
Tries versus Success

- How many tries does it take (20 allowed)?

\[ y = 38808e^{-0.414x} \]

\[ R^2 = 0.98166 \]
Tries versus Giving Up

- After how many tries do students give up (20 allowed)?

![Graph showing the relationship between tries and giving up. The line is given by the equation $y = 962.49e^{-0.274x}$ with $R^2 = 0.94869$.](image)
Tries Follow Decay Laws!

- Comparing three classes: 10 tries, 12 tries, and 20 tries max.
- Surprisingly, for all these classes, both success and giving up follow:
  \[
  \Delta N_s(n) = N_{s,0} \exp(-\lambda_s n)
  \]
  \[
  \Delta N_a(n) = N_{a,0} \exp(-\lambda_a n)
  \]
- Tries are independent of each other!
- Lambdas are like probabilities
- Students do not learn from their previous mistakes!
Tries versus Success

- Is it just the low-achieving students who do not learn from previous failures?

No.
Tries versus Success

- “Probabilities” of succeeding or giving up on a particular attempt

![Graph showing the relationship between maximum allowed tries and decay constant. The line equation is y = -0.0137x + 0.6877.]

- Points represent success and giving up attempts.
Tries versus Success

- Using this model of "decay constants"

![Graph showing cumulative success rate against maximum allowed tries. The graph peaks at a cumulative success rate of approximately 0.55 around 5 tries, then decreases, and finally increases again. The x-axis represents the maximum allowed tries, ranging from 0 to 40, and the y-axis represents the model cumulative success rate, ranging from 0.3 to 0.6.]

Ran out of tries

Solved by accident

5
Hmm ...  

- A lot depends on homework
- How meaningful is online homework?
Item Response Theory

- IRT was developed for summative assessments
  - Trying with online homework
Item Response Theory

- You can see the “noise”
- This is guessing and copying
Item Response Theory

- Having finished homework eventually is more meaningful than on the first try
  - We already knew that …
Item Response Theory

- IRT can be used for online homework
- Final result ability better predictor of exam ability
- However, best predictor: first try during the first quarter of the semester!
  - Unproductive behavior increases over the course of the semester!

Why?

- Why do students not learn from their previous failed attempts?
- By being able to try again, they should have a chance to verify their solutions and think through the physics.
- Why is this opportunity apparently wasted?
Why?

- Prime suspect: plug-and-chug
- Just plugging numbers from one equation into the next
- No chance to backtrack
- No chance to do dimensional analysis, etc., etc.
Why?

- Plug-and-chug is typical for numerical problems
- As soon as numbers appear in the problem, they apparently have to be used asap.

\[
\begin{align*}
\text{a) } T &= (m+M) \left( g + a \right) \\
&= \frac{T}{g+a} = \frac{m+M}{m+M} \\
&= \frac{a}{m+M} - g \\
\text{b) } F &= 60.0 \left( \frac{9410}{60+915} \right) \\
&= 645 \, N \\
\text{c) } T &= (m+M) \left( \frac{1}{2} g + a \right) \\
&= \frac{T}{\frac{1}{2} g + a} = \frac{m+M}{m+M} \\
&= \frac{a}{m+M} - \frac{1}{2} g \\
\text{d) } F &= m \left( \frac{T}{m+M} \right) \\
&= 12.0 \left( \frac{9410}{12+915} \right) \\
&= 136.5 \, N
\end{align*}
\]
Why?

Really, these problems are not very good. Take a bunch of numbers, plug them into equations, get another number. Who really cares about these numbers? What do the students really learn?

Superman Stops a Train

An out-of-control train is racing toward the Metropolis terminal train station - only Superman can help. The train has a mass of 45000 kg, and Superman has a mass of 103 kg. If the train has a velocity of 35 m/s, how fast does Superman have to fly in the opposite direction to stop it in a totally inelastic steel-Man-of-Steel collision?
Another Approach

- Curb plug-and-chug
- Have students turn in some derivations and graphs simply by photographing them with their cell phones and uploading them to the CMS
… or maybe …

- Give better homework
- Multiple-part, non-numeric (symbolic/conceptual), dynamic, randomizing scenarios
  - Less success by random guessing
    - Random guessing leads students down a garden path
  - Less chances of success by blind copying
    - Every scenario and path different
    - Students can and should discuss the physics, not just the result
A plate capacitor has been charged. Its plates are then pushed closer together after they had been disconnected from the voltage source.

- The capacitance increases.
- The capacitance stays the same.
- The capacitance decreases.

Submit Answer  Tries 0

- The voltage increases.
- The voltage stays the same.
- The voltage decreases.

Submit Answer  Tries 0

- The charge increases.
- The charge stays the same.
- The charge decreases.

Submit Answer  Tries 0
A plate capacitor has been charged. Its plates are then pulled further apart while still connected to the voltage source.

- The capacitance increases.
- The capacitance stays the same.
- The capacitance decreases.

Submit Answer) Tries 0

- The voltage increases.
- The voltage stays the same.
- The voltage decreases.

Submit Answer) Tries 0

- The charge increases.
- The charge stays the same.
- The charge decreases.

Submit Answer) Tries 0
At $t=0$ s, a car cruises at a constant positive velocity. Suddenly, a light switches to red. At $t=10$ s, the driver is maximum on the brake. The car then stops in front of the red light for over 2 seconds. Eventually, it drives off, and then again cruises at a constant velocity. The car cannot accelerate with more than $3 \text{ m/s}^2$. Provide a graph of its acceleration as a function of time.

### Different stories

- Graphical input
- Open-ended
- Infinitely many correct answers
As promised: classroom data

- Now some data generated inside the classroom
- Some classical statistics
- Again use IRT to see:
  - How much “random” noise is there?
  - Can problem quality be determined?
Clicker Data and Exams

- Is clicker data correlated with exam performance?
  - Initial and final responses equally correlated
Clicker Data IRT

- One lecture (momentum conservation)
  - Initial and final response
Clicker Data IRT

- One lecture (momentum conservation)
  - Initial and final response

Clicker data is meaningful.
About as meaningful as online homework
Clicker Data IRT

- “Good” items: much discrimination

Which cart exerts a stronger magnitude force during the collision?

a) Cart 1  
b) Cart 2  
c) No magnitude forces, both zero  
d) Same magnitude forces

Which cart exerts a stronger magnitude force during the collision?

a) Cart 1  
b) Cart 2  
c) No magnitude forces, both zero  
d) Same magnitude forces
Clicker IRT

• “Bad” problems

Strange Point Mass Billiard

\[
\begin{align*}
\vec{v}_{1,f} &= \left( \begin{array}{c} 10 \\ -6 \end{array} \right) \text{ m/s} \\
\vec{v}_{1,f} &= \left( \begin{array}{c} 5 \\ 1 \end{array} \right) \text{ m/s}
\end{align*}
\]

Initial

Arthur
\( m_A = 70 \text{ kg} \)

Violet
\( m_v = 55 \text{ kg} \)

Cart
\( m_c = 20 \text{ kg} \)

At rest with respect to ground

Speeds with respect to ground, no friction

\( |v_A| = 2 \text{ m/s} \)

\( |v_v| = 4 \text{ m/s} \)

\( |v_c| = ? \)

Final

\[ A) 0 \text{ m/s} \]
\[ B) 2 \text{ m/s} \]
\[ C) 4 \text{ m/s} \]
\[ D) 8 \text{ m/s} \]
\[ E) 16 \text{ m/s} \]
Clicker IRT

- **So: what's the difference?**

**Good**

Which cart exerts a stronger magnitude force during the collision?

a) Cart 1  
b) Cart 2  
c) No magnitude forces, both zero  
d) Same magnitude forces

**Bad**

\[ \begin{align*}  
\vec{v}_{x,i} &= \left( \frac{10}{-6} \right) \text{ m/s} \\
\vec{v}_{x,f} &= \left( \frac{5}{1} \right) \text{ m/s} \\
\end{align*} \]

A) \( \vec{v}_{x,f} = \left( \frac{10}{-14} \right) \text{ m/s} \)  
B) \( \vec{v}_{x,f} = \left( \frac{-6}{7} \right) \text{ m/s} \)  
C) \( \vec{v}_{x,f} = \left( \frac{-12}{-5} \right) \text{ m/s} \)

**Diagram:**

- **Strange Point Mass Billiard**
  - Initial: Arthur (m_a=70kg), Violet (m_v=55kg), Cart (m_c=20kg)
  - Final: Speeds with respect to ground, no friction
  - \( |v_{x}|=2 \text{ m/s} \)  
  - \( |v_{y}|=4 \text{ m/s} \)  

- **RadioCrasher**
  - Initial: Arthur (m_a=70kg), Violet (m_v=55kg), Cart (m_c=20kg)
  - Final: Speeds with respect to ground, no friction
  - \( |v_{x}|=2 \text{ m/s} \)  
  - \( |v_{y}|=4 \text{ m/s} \)  
  - \( |v_{c}|=? \)
Outlook

• More research needed how problem characteristics influence unproductive behavior

• Looking at the events (and there are millions of them)
  1. Fail on a problem
  2. Do something
  3. Succeed on that problem
     ◦ Look at the something
Thank you!

- Gerd Kortemeyer
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