Die zwei Welten von Learning Analytics

Gerd Kortemeyer
Michigan State University

CampusSource Tagung Hagen
März 2017
First Law

- The first law of Learning Analytics and Educational Data Mining
First Law

- The first law of Learning Analytics and Educational Data Mining

You cannot analyze data that you don’t have
It is thus important to understand the data sources:

- **Institutional Data**
  - **Student Information Systems (SIS)**
    - Demographics
    - Final Grades
    - Enrollments

- **Transactional Data**
  - **Learning Systems (e.g., LMS)**
    - Access Logs
    - Performance Data
  - **Clicker Systems**
# Data Sources

<table>
<thead>
<tr>
<th></th>
<th>Institutional Data</th>
<th>Transaction Data</th>
</tr>
</thead>
</table>
| **Good**     | • Clean  
               • Longitudinal  
               • Comprehensive                                      | • Cheap  
                                                                                       • Insight into learning behavior |
| **Neutral**  | • Condensed                                                                        | • Orders of magnitude more data                                                   |
| **Bad**      | • Expensive  
               • A whole semester of learning in one number | • Noisy  
                                                                                       • Incomplete, only some aspects of a course  
                                                                                       • Often limited to course container  
                                                                                       • Limited to subset of students who used the system |
Administration: Institutional Data
Institutional Data

- Aim is increased graduation rate
- Important quality measure of university
- **Universities are in competition!**
- Recruitment
- Protection of student investment
  - Tuition of $30-$50k per year
Institutional Data

MICHIGAN STATE UNIVERSITY
GENERAL FUND
2015-2016 BUDGETED REVENUES

OTHER UNIVERSITY FUNDS $95.6M (7.6%)
Includes indirect cost recovery, investment income, and other revenues

STATE APPROPRIATIONS $268.3M (21.2%)

TUITION AND FEES $899.9M (71.2%)
The 2015-16 academic year costs $13,560 for entering Michigan resident lower division undergraduates and $36,360 for entering nonresident lower division undergraduates.

TOTAL BUDGETED REVENUES: $1,263,800,000
Graduation Rates at Michigan State University - College Factual
www.collegefactual.com › All Colleges › Michigan State University › Outcomes
Graduation Rates at Michigan State University. 79.1% of students graduate within a reasonable time (three or six years depending on the degree). Much higher than the expected graduation rate of 66.5%. Among the best overall graduation rates with 79.1% of students graduating in a reasonable time.
Institutional Data

When we look at the six-year graduation rates of all MSU students, we can trace back their average cumulative GPAs back from the point at which they left the university (either by graduating or by no longer taking classes). Doing so creates a chart that looks like this (yellow lines represent the average cumulative GPAs of students who graduated, and gray lines represent the average GPAs of the students who left without graduating):
Institutional Data

- Changes of majors – STEM/non-STEM
Institutional Data

- Statistics often by race
- Example: number of credits completed per semester
Institutional Data

- Background: liberal arts in US
- Students do not just take classes in their major and related subjects
- E.g., even if you major in physics you take history, English, sports, ...
Institutional Data

- Case-Matching: find impact of different courses/interventions by matching everything else

Matched Students on 6 Attributes

1. Gender
2. Race/Ethnicity
3. Residency
4. ACT Score (or SAT Converted to ACT)
5. High School GPA (rounded to the tenth of a point)
6. Pell Eligibility
Institutional Data

- Example: evaluate impact of undergraduate research experiences on GPA
Institutional Data

- Analyzing course sequences
  - “Students with certain demographics pass particular courses after passing certain other ones”
  - “Students with certain demographics do not pass …”
- Goal: **rule sets for timely graduation**
- **Guides for academic advisors**
- Purely analyzing course success, not learning!
Institutional Data

- Main target: academic advising
- Each college
- 6 advisors for 1800 students

Faculty & Staff Directory > Advisors

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<tr>
<th>Last Name</th>
<th>First Name</th>
<th>Title</th>
<th>Unit</th>
<th>Email</th>
<th>Bio</th>
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<td>Horrocks</td>
<td>Kylie</td>
<td>Recruitment Coordinator</td>
<td>Advisors</td>
<td><a href="mailto:kylie@msu.edu">kylie@msu.edu</a></td>
<td>Bio</td>
<td>(517) 353-6480</td>
<td>E-31 Holmes</td>
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<tr>
<td>Mills</td>
<td>Karen</td>
<td>Director of Academic Affairs and Advising</td>
<td>Advisors</td>
<td><a href="mailto:tkaczyk@msu.edu">tkaczyk@msu.edu</a></td>
<td>Bio</td>
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<tr>
<td>Slavin</td>
<td>Anne (Schrock)</td>
<td>Academic Advisor/Interim Assistant Director</td>
<td>Advisors</td>
<td><a href="mailto:schrock7@msu.edu">schrock7@msu.edu</a></td>
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<td>(517) 353-6480</td>
<td>E-30C Holmes</td>
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<tr>
<td>Tillett</td>
<td>Ed</td>
<td>Field Career Services Coordinator</td>
<td>Advisors</td>
<td><a href="mailto:tillett@csp.msu.edu">tillett@csp.msu.edu</a></td>
<td>Bio</td>
<td>(517) 353-4607</td>
<td>E-36A Holmes</td>
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<tr>
<td>Williamson</td>
<td>Sharita</td>
<td>Academic Advisor</td>
<td>Advisors</td>
<td><a href="mailto:will1809@msu.edu">will1809@msu.edu</a></td>
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<td>Bio</td>
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<td>E-33 Holmes</td>
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Institutional Data

- Goal: predictive advising

![Major Matcher]

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</table>
Institutional Data

Degree Navigator is a flexible, undergraduate advising and degree-audit tool. It helps you and your adviser work together to manage your degree progress.

LOGIN

Enter your MSU ID and password

MSU ID
(MSU NetID or MSU Community ID)

Password

Authenticator

Login

Guest users: Please enter GUEST for MSU NetID and skip the password field.

INFORMATION

- Welcome
- Getting Started
- Technical Advice
- Frequently Asked Questions

If you experience accessibility issues using a page on this site, please contact the MSU IT Service Desk by email at ithelp@msu.edu or by calling 517-432-6200.
Institutional Data

- This can kill innovation in teaching and learning, no room for “experiments” – no risks
- “take the other course, you will likely get a better grade”

Just completely changed my physics course – risk!
Institutional Data

Unpopular personal opinion:

- Learning Analytics of Institutional Data is Not Analyzing Learning
  - Current trend toward more institutional “learning” analytics copied from industry
  - Feels like it turns students into data points and faculty into interchangeable commodities
  - Better progress toward degree as a “product”

- Still very helpful for students, given our framework!
Academic Computing
Transactional Data
Transactional Data

- Transactional data can be found in a variety of scenarios:
  - MOOCs
  - Virtual University Courses
  - Blended Courses
  - Flipped Courses
  - Online Textbooks
  - Clicker Logs
  - ...
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
Transactional Data

- Research on transactional data still basically a collection of separate studies
- No well-formulated goal like: “Admitted students graduate as quickly as possible”
- “Learning” is a much more ambiguous animal
- Will present some examples of studies
Predictors of Success

A lot of student success comes down to productive and unproductive study behavior.
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
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?
- Look at another 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
- But: everybody does online homework

<table>
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<th>Problems only</th>
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<tbody>
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<tr>
<td>Online</td>
<td>2500</td>
<td>265</td>
<td>2235</td>
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</table>

How often particular online course pages are viewed
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

- Negative effect of mostly weekly access most significant for the students in the blended sections

<table>
<thead>
<tr>
<th>Type</th>
<th>Sections</th>
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<td>3.128*</td>
<td>−0.369</td>
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* 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 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

Due this Friday, Feb 27 at 11:00 pm (EST)
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

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Online Homework

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

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Online Homework

- Most important features

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<th>Feature</th>
<th>Importance %</th>
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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!

Typical Online Physics Problem

Superman Stop

An out-of-control train is racing toward Metropolis - only Superman can help. The train has a mass of 103 kg. If Superman has to fly in front of the train to bring it to a stop, how fast does Superman have to fly in to bring the train to a stop? Assume the collision is totally inelastic steel-Man-of-Steel.

Multiple tries

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>
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</thead>
</table>
| **Possibly Good** | • Better exam preparation  
• Less grade-inflation                                      | • Better mastery-based formative assessment  
• Encouragement  
• Less whining                                      |
| **Possibly Bad**  | • Discouragement  
• Copying  
• More whining                                             | • Random guessing  
• False sense of security                                  |
Random Guessing

Tries versus Success

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

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

\[ R^2 = 0.98166 \]

Student-problem data points:
number of students times
number of problems
Tries versus Giving Up

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

\[ y = 962.49e^{-0.274x} \]

\[ R^2 = 0.94869 \]
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

\[ y = -0.0137x + 0.6877 \]
Tries versus Success

- Using this model of “decay constants”

![Graph showing model cumulative success rate vs. maximum allowed tries. The graph peaks at 5 tries, indicating the best success rate.}]
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!

Item Response Theory

- Can one explicitly model individual unproductive behavior in IRT?

\[ p_{ij,2P3TL} = \chi_j (1 - p_{ij}) + (1 - \gamma_j) p_{ij} \]

\[ = \chi_j + \frac{1 - \gamma_j - \chi_j}{1 + \exp(a_i(b_i - \theta_j))} \]

- Latent copying and guessing traits:
  - Copying: getting problem correct even though they shouldn’t based on ability
  - Guessing: getting problem incorrect even though they should get it correct
Item Response Theory

- Modeling guessing did not bring about significant improvements
- Modeling copying increased exam score prediction from $R^2=0.35$ to $R^2=0.45$. 
Item Response Theory

- Distribution of copying trait for first attempt homework data
Clicker 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

![Item Characteristic Curves, Initial Choice](image)

![Item Characteristic Curves, Final Choice](image)
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

\[ \vec{v}_{1,f} = \begin{pmatrix} 10 \\ -6 \end{pmatrix} \text{ m/s} \]

\[ \vec{v}_{1,f} = \begin{pmatrix} 5 \\ 1 \end{pmatrix} \text{ m/s} \]

\(2 \text{ m at rest}\)

A) \(\vec{v}_{2,f} = \begin{pmatrix} 10 \\ -14 \end{pmatrix} \text{ m/s}\)

B) \(\vec{v}_{2,f} = \begin{pmatrix} -6 \\ 7 \end{pmatrix} \text{ m/s}\)

C) \(\vec{v}_{2,f} = \begin{pmatrix} 12 \\ -5 \end{pmatrix} \text{ m/s}\)

RadioCrasher

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

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

At rest with respect to ground

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

Speeds with respect to ground, no friction

\(|\vec{v}_A| = 2 \text{ m/s}\)

\(|\vec{v}_V| = 4 \text{ m/s}\)

Final

\(|\vec{v}_C| = ?\)

A) 0 m/s
B) 2 m/s
C) 4 m/s
D) 8 m/s
E) 16 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

Strange Point Mass Billiard

\[
\begin{align*}
A) \quad \vec{v}_{x,f} &= \left( \frac{10}{14} \right) \text{ m/s} \\
B) \quad \vec{v}_{y,f} &= \left( \frac{-6}{7} \right) \text{ m/s} \\
C) \quad \vec{v}_{z,f} &= \left( \frac{-12}{5} \right) \text{ m/s}
\end{align*}
\]

RadioCrasher

<table>
<thead>
<tr>
<th>Speeds with respect to ground, no friction</th>
</tr>
</thead>
<tbody>
<tr>
<td>A) 0 m/s</td>
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</tr>
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</tr>
</tbody>
</table>
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
The Best of Both Worlds?

- Should institutional and transactional learning analytics be joined?

- Argument: no
  - Faculty should not know how a student is doing overall, as that may taint grading
  - Administrators should not directly influence how faculty teach

- Exception: Academic Advisors
  - Warning signs – call in student
  - Need transactional analytics so they can advise the student during the semester
US versus Germany

MICHIGAN STATE UNIVERSITY
2015-2016 BUDGETED REVENUES

- TOTAL BUDGETED REVENUES: $1,263,800,000
- STATE APPROPRIATIONS $268.3M (21.2%)
- OTHER UNIVERSITY FUNDS $95.6M (7.6%)
  Includes indirect cost recovery, investment income, and other revenues
- TUITION AND FEES $899.9M (71.2%)
The 2015-16 academic year costs $13,560 for entering Michigan resident lower division undergraduates and $36,360 for entering nonresident lower division undergraduates

900 million dollars per year
None without IT
US versus Germany

- When it comes to digitization of higher education, the USA is now in a post-innovation phase
- **No** courses that do not rely heavily on IT systems
- Mission-critical systems at MSU need to scale 50,000 students who generate 200,000 student-course enrollments every semester
- 450 million dollars in tuition at stake every semester
- Our IT systems currently hold credit information worth 36 billion dollars
US versus Germany

- Administration expects commercial turnkey systems with million-dollar contracts
- Contractual guarantees and penalties for up-time, disaster recovery, liability, security, support guarantees (being on-site within hours)
- No “hobby systems”
- Innovation is dead!
US versus Germany

- Germany about 20 years behind
  - Sorry, it’s true

- Don’t repeat the same mistakes:
  - Don’t invest in hobby systems
    - don’t try to write software solely at universities
    - get strong industry partners from the start who can eventually take over the high-stakes responsibilities
  - Don’t kill innovation either
US versus Germany

- **Strong industry partner and open-source is not in contradiction**
- **But software that**
  - does not scale several orders of magnitude
  - won’t work on enterprise-level in mission-critical functions
  - has an unfavorable “bus factor”
  - isn’t likely going to come with full contractual backing and guarantees
- is not worth investing into: dead end.
Thank you!

- Gerd Kortemeyer
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