Detailed Studies of Learning

- Data Mining to study sources of Learning
- +/- paper
- Retest

What Should They Learn?

ONLINE: Integrated Two Way Learning

- Digital Age?!
- Various New Ideas
What Correlates with Learning in Remedial Course?


~2 Std Dev Learning Effect

Average Extrapolated Gain

p-values

Mastering Physics 0.00002
Written Homework 0.26
Group Problems 0.013*
Class Participation 0.076

Habits have 2 sigma effects on learning changing them is duty of teacher
Copying Analytic HW degrades analytic score

Students didn’t copy tutoring on these

Students copied tutoring on analytic

Standard Dev’s Learning ➔

Fraction of electronic homework copied

Final (analytic)
N = 428
β = -2.42

MBT Post - MBT Pre
N = 368
β = -0.17
Usual Partial Credit Grading: 2 Sigma?

• What A students learned that C students didn’t
• A- students (1 Sigma +): a reasonable expectation of what students should learn
• C students: those we pass without many reservations
Quality of Analytic Answer

i  ii  iii  iv  v

A  C

0  12  25  37  50
Quality of Written Plan  A          C

Verbal Plans of Both Incomplete > 50% of time!
Conclusions on What’s Learned

• Note: Score of C’s is 60% that of A’s
• A’s Good analytic or verbal 4x C’s
• C’s significantly wrong 4x A’s

• Partial Credit Grading
• Rewards Partial Understanding
What Do Seniors Remember From Freshman Physics?

• Give them the same test and see!
RETENTION from Pre- & PostTest

Forbidden Region:
More than 100% on posttest!

Forbidden Region:
Less than 0 on posttest!

Pure gain curve – intercept at 100%

Pure loss curve – intercept at 0%
**Increased Gain on Subtest Math**

Subtest S: Pure Gain = 0.69  
$R^2 = 0.74$

* Freshman responses unavailable for 8 students (4 Group 1, 3 Group 2 and 1 Group 3).
Subtest Physics Concepts: 50% Loss of Knowledge Gained in Freshman Course

Use It or Forget It

teach what’s useful??

Fit Parameters:
Intercept pegged to zero.
Slope = $-0.52 \pm 0.12$.
$R^2 = 0.35$
What To Teach in Introductory Physics
David E. Pritchard, Analia Barrantes, Brian Belland

CONCERN: Before working more on education reform, I wanted to be sure of what teachers wanted to teach besides the syllabus.

PROCEDURE: Asked people, especially AAPT/PERC Distilled Free Responses down to ~12 responses in 4 categories

MY QUESTION: Due to a change in the academic calendar, you have 20% more time to teach the calculus-based introductory physics course to non-physics majors, and the syllabus has not been expanded. What learning will you seek to add or emphasize with this extra time?
Wider Content

Labs

Physics from few Ideas

Epistemology

Concepts - Newtonian Thinking

Plan - Set Up

Sense Making

Scientific Argument

Science in News/Society

Relation to everyday life

Ed Researchers

Atomic Resch

Educators

Course Content

Philosophy

Problem Solving

Relation to the Outside world
Experts don’t want to teach what students want to learn
Rethinking Education in the Age of Technology

A. Collins and R. Halverson

<table>
<thead>
<tr>
<th></th>
<th>School World Now</th>
<th>Digital World/Life</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Goal</strong></td>
<td>Just in Case Knowledge</td>
<td>Just in Time Knowledge</td>
</tr>
<tr>
<td><strong>When</strong></td>
<td>To Age 21, Sep-June 8AM-3PM</td>
<td>Lifelong Learner, Anytime, anywhere</td>
</tr>
<tr>
<td><strong>Group By</strong></td>
<td>Age</td>
<td>Interest, Level, Profession</td>
</tr>
<tr>
<td><strong>Method</strong></td>
<td>On paper</td>
<td>Online</td>
</tr>
<tr>
<td><strong>Teacher Role</strong></td>
<td>Subject Expert, Source of Information</td>
<td>Coach &amp; Guide</td>
</tr>
</tbody>
</table>

The contemporary school is inappropriate!

Rethink: Role of Teacher, Centrality of Online
My Zero Based Thinking

• Make Online Education Interactive & Integrated
  – Personal Tutors, Games, Class, Social Software

• Universal Assessment of Every Key-Stroke
  – To guide student & tutor toward their goals
  – To certify the student’s progress

• Improve Content Interactively/w Data Mining
  – Have students suggest/rank utility of resources
  – Solicit student feedback, measure effect, for content
  – Example with Video

• Help Students Educate Each other
  – Discussion Groups with Ranked Peers
  – Student groups produce content, system judges it
The IRT graph has less error and shows the trend better: Students selected by SAT scores have an advantage until the fifth week of the course at MIT (vs. second semester in most colleges as claimed by ETS).
Zero Based Thinking

• Make Online Education Interactive & Integrated
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  – Student groups produce content, system judges it
Content Revision from Feedback Reduces Percentages of Students Not Finishing and Requesting Solution, and Reduces Number of Wrong Answers.
Streaming text of lecture with audio. This is a transcription of the lecture that allows indexing, search, etc. A keyword search starts the system in the appropriate place.

Student can highlight any part of window and Add To My Notes

Course ROADMAP
This might be the Table of Contents with highlight of where this Video fits in.

VIDEO Window
The video should be a combination of equations, power-points, demonstrations and professor. Videos should be a maximum of 10 minute segments, ideally with integrated peer instruction (clicker) questions.

Contains standard start and stop buttons.

User-Ranked FAQ’s relevant to lecture,
FAQ’s are rearranged with the most popular at the top of the list. Prof. of TA gives some video responses

Suggest URL’s that helped you!
Find more via Data Mining or Targeted Google Window
Zero Based Thinking

• Make Online Education Interactive & Integrated
  – Personal Tutors, Games, Class, Social Software
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• Help Students Educate Each other
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  – Student groups produce content, system judges it
How and What Are Students Learning, and Why?

To Improve Education Scientifically
We must know:
  What Students Learn
  How they learned it
  How long it took them

Then we can optimize their learning

Online Learning Systems Give Enough Data

But NO GOOD if we don’t teach right stuff
Learning Effect > 2 for Different Paths Within Tutor

(29% of all) Fail First Attempt

(11% of all) First Go to Hint and Subtask

(60% of all): Correct on First Try

25% No Feedback Or Hint
7% Useful Feedback Only

δS_t
-0.8 SD
0.3 SD
0.6 SD
1.5 SD

Second Attempt
Second Attempt

Second Attempt Correct

Y-J Lee, D. Pallazo and DEP

Second Attempt

Fail Second Attempt
~21% of all students

δS_t

SD
-0.8 SD
0.3 SD
0.6 SD
1.5 SD

SD

SD
How and What are Students Learning
And Why?

http://RELATE.MIT.edu

Dave Pritchard
Andrew Pawl
Analia Barrantes
Saif Rayyan
Raluca Teodorescu

Saif    Dave    Raluca    Andy

Analia
Neither Pure Gain nor Loss

Forbidden Region:
More than 100% on posttest!

Forbidden Region:
Less than 0 on posttest!

Score Shift from Pre to Post

Pretest Score

100%
0
−100%
100%
Perceived Utility of Topics by Group (from MIT Survey)
## 12 Distilled Questions, 4 Categories

<table>
<thead>
<tr>
<th>Course Content</th>
<th>More Content: Gyroscopes, QM, Nuclear Discovery-based or Traditional lab</th>
</tr>
</thead>
</table>
| Scientific Ideas | Scientific Method  
Physics from a few ideas  
Epistemology, how do I know, derivations |
| Problem Solving | Vocabulary of Subject Domain  
Concepts - should be Newtonian Thinkers  
Problem Solving - concepts, plan, set up  
Sense - making of solution, estimation |
| Physics & World Understanding | Communication of Solution/Science in News  
Relation to everyday life/things |
60% Lost on Analytic Final Exam Problems
Among Group 1 Students

Group 1 Fit Parameters:
Intercept pegged to zero.
Slope = $-0.61 \pm 0.10^*$
$R^2 = 0.66^*$

*If civil and environmental engineers are excluded from Group 1, the resulting slope is -0.64 and the $R^2$ is 0.71.
Surprise: All Groups IMPROVED on "standard" mathematical material

<table>
<thead>
<tr>
<th>Subtest $S$ of the MBT</th>
<th>Included Questions</th>
<th>Topic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1, 2, 3, 23, 24, 25</td>
<td>Graphical Kinematics</td>
</tr>
<tr>
<td></td>
<td>13, 14</td>
<td>1-D Equilibrium</td>
</tr>
<tr>
<td></td>
<td>19</td>
<td>2-D Vector Addition</td>
</tr>
</tbody>
</table>
Test Scores of Copying Groups

Net of 1.0 std dev for about 60% copying implies ~ 1.8 std. dev. effect size for no copying vs. all copying
Analytic Final Exam vs. Copying

Students’ initial grades not very dependent on fraction copied

Phys. Rev. Special Topics
prst-per.aps.org/toc/
PRSTPER/v6/i1

N = 428
β = -2.42
r = -0.46
p < 2.2 × 10^{-16}
Teach→Learn: Assess Learning

What: Are Students Learning?
Requires TWO ASSESSMENTS:

How: Which activities cause learning?
Book, tutorial, lecture, homework, laboratories, part ii of problem 7
- Much Harder to Determine

What: Habits are Bad or Good?
Must Stop Bad, and Encourage Good

Why: Are We Teaching the Right Stuff?
What activity(s) are they learning from? Can’t Improve Learning w.o. Knowing This!

Pre and Post Testing Gives Gain
-then study

What Students with High Gain Did

Elements: recitations, written & online HW, group problems
Correlate - amount of each element with improvement

- Just a correlation: causation by inference
Gain on Final Exam

December 2000,1 to May 2001,2
-Alex and Dave P. cybertutor.MIT

Elsa-Sofia Morote and D. E. Pritchard

~2 Std Dev Learning Effect

Average Extrapolated Gain

Mastering Physics 0.00002
Written Homework 0.26
Group Problems 0.013*
Class Participation 0.076

p-values
Two Sigma Effect Size

- About what expert personal tutor gives
- Two grade levels in elementary school

Encouraging: Students Learn What we Tutor!
Orientation

1. What they learned from (online homework)
2. What A- students learned that C didn’t (4x)

Now: Online Socratic Tutor used for Data Mining

Next: HABITS
   – Copying (bad)
   – Requesting help before guessing (good)
Socratic Pedagogy of Online Tutor

Demand Appropriate Response

Problem Statement & Figures

Requestable List of Hints (plan of attack)
Declarative Hint

Hints open on request in any order.
This is a Declarative Hint.
It Informs, Suggests, Reminds, etc.
This hint is a SubTask

It Requests a Response that helps answer the main question.

Responding is optional, although informative.
Wrong Answer Feedback

Feedback Addresses Particular Error(s) in Student’s Response with advice or challenge

Hint 1. What’s happening here?
In this situation, which of the following statements is true?
A component of the tension causes acceleration of the bob.
Correct

Hint 2. Find the vertical acceleration of the bob

Hint 3. Find the tension in the string

Find the magnitude, $T$, of the tension force in the string.

Express your answer in terms of some or all of the variables $m$, $L$, and $\theta$, as well as the acceleration due to gravity $g$.

$$T = \frac{m \cdot g}{\sin(\theta)}$$

Again; 3 attempts remaining

Hint 4.

Hint 5.

Feedback
Check over your trigonometry.
Eductional Data Mining: Tutors >> Tests

Fine Grain Assessment – Holy Grail
• Assessment of Detailed Mental State
• Guide for the Teacher
• Ultimately will guide individual tutoring

Habits of Mind and Behavior
• What Habits help/hinder learning??
• Shih: working through all hints gives learning
• Palazzo/me: homework copying reduces learning
• Better to open hints prior to responding?
1. Respond in <1 min – insufficient to read and answer
2. Correct on first try vs. 90% of remaining students

Warnakulasooriya, Pallazo and DEP
*J. Exptl Anal Behavior* 88 103-113 2007
Dependence of Concept on Copying

Copying has insignificant correlation with Gain on ConceptTest. Copiers and Non-copiers both have learning effect \( \sim 1.2 \).

Posttest Slope: \(-0.6 \pm 0.3\)

Pretest Slope: \(-0.5 \pm 0.3\)

Graph showing the relationship between the fraction of electronic homework copied and learning effect.
Copying correlates with Course Failure

About $\frac{1}{2}$ of the Failures to Finish both semesters on schedule occur among the 19% repeated copiers.
Copying at MIT Has Been Reduced!

HOW?
Change to Studio Physics
Smaller, Shorter Assignments
Pass/no record → Grades
Homework Copying  
--a Serious Academic Concern

Homework Copying $\rightarrow$ Dramatic Academic Decline

The Decline is Specific to Type of HomeWork Copied

Demographic and Personal Factors Important

Course Format Changes Reduced Copying $\times 4$

Copying homework is serious learning problem that you can do something about!
Learning Effect of Various Paths

(29% of all) Fail First Attempt

(11% of all) Go to Hint and Subtask

(60% of all): Correct on First Try

Y-J Lee, D. Pallazo and DEP

*Phys Rev Sp. Topics*

Why is Hints-First so Beneficial?

• Metacognitive Monitoring of Own Knowledge?
  – Know they don’t know
  – Then know when they do
• Observation: Not same students each time
• We’ll have to do more research!
Orientation

1. What they learned from (online homework)
2. What A- students learned that C didn’t (4x)
3. Online Socratic Tutor used for Data Mining
4. HABITS
   - Copying (bad)
   - Requesting help before guessing (good)

Now: what do graduating students retain of Physics 1

WHY should we teach what we teach?
What Do Graduating Seniors Recall?  
Do they remember our wisdom??

Expect users of mechanics (Gp 3) will recall more than humanities (Gp 1)

<table>
<thead>
<tr>
<th>Group</th>
<th>Included Majors</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Group 3</strong></td>
<td>Aeronautics and Astronautics, Mechanical Engineering, Physics</td>
<td>9</td>
</tr>
<tr>
<td>(Majors likely to use mechanics.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Group 2</strong></td>
<td>Chemical Engineering, Economics, Electrical Engineering and Computer Science, Materials Science and Engineering</td>
<td>21</td>
</tr>
<tr>
<td><strong>Group 1</strong></td>
<td>Biological Engineering, Biology, Brain and Cognitive Sciences, Civil and Environmental Engineering, Literature, Management, Mathematics, Political Science.</td>
<td>26</td>
</tr>
<tr>
<td>(Majors unlikely to use mechanics.)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Professors & Students?

- Catalog says College will turn students into Lifelong Problem Solvers
- Professors “Welcome to college where we’re going to turn you into expert professionals and problem solvers”
- Catalog says freshman year is for exploration after which students are able to pick any major
- Students “I’m looking for a major, show me why physics is relevant to my interests and life. Then I might invest 10+ years to become an expert!”
- → RECOMMENDATION: more attention to why intro physics is relevant to their futures.
Digital Education Future?!

Teacher → Coach & Electronic Tutor
Teach a Class → Help Student Learn
Broadcast Radio → Two-way Radio
Passive → Inter-Active
To age 16 in class → Lifelong Anytime/where
Author → Authors/Researchers
High Stakes Tests → Integrated Assessment
Next Edition → Next Day