What Students Learn from What and How?

And Is this OK with you?

http://RELATE.MIT.edu

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Teach → Learn: Assess Learning

What Are Students Learning?
COMPARE TWO ASSESSMENTS: compare A- and C

What Activities cause learning?
Book, tutorial, class, homework, laboratories, part ii of problem 7
- Much Harder to Determine

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

Are We Teaching the Right Stuff?
According to Whom?
Themes: Problem Solving and Data

I want my students to learn to solve problems that involve combining known principles in new ways, i.e. multi-concept problems whose givens and unknowns are not connected in any single formula in the book.

Data >>>>Opinion
Allows scientific improvement
What does observed 2 sigma learning Mean?

- A- group (1 Sigma +): a reasonable expectation of what students should/could learn
- C group (1 Sigma -): pass with no reservations
- What A- students learned that C students didn’t
Quality of Analytic Answer

A’s completely correct >50% vs 10%
C’s significantly wrong ~50% vs ~12%
Quality of Written Plan

- **A**
  - Wrong: 50
  - Incomplete: 37
  - Good: 25

- **C**
  - Wrong: 50
  - Incomplete: 37
  - Good: 25

Verbal Plans of Both Incomplete > 50% of time!
Summary of Performance

- C score 79% of average, 62% that of A’s, but:
- A’s: Very Good analytic or verbal 4x C’s
- C’s: wrong 4x A’s

CONCLUSION:

- Partial Credit Grading Rewards Partial Understanding
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

Course Activities: recitations, written HW, 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

Elsa-Sofia Morote and D. E. Pritchard

~2 Std Dev Learning Effect
Plan of This Talk

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

Now: Online Socratic Tutor
   – Great Data for Data Mining

Next: HABITS, good and bad
In a ballistic pendulum an object of mass $m$ is fired with an initial speed $v_0$ at the bob of a pendulum. The bob has a mass $M$ (usually $M \gg m$), which is suspended by a rod of length $L$ and negligible mass. After the collision, the pendulum and object stick together and swing to a maximum angular displacement $\theta$ as shown.

Problem Statement & Figures

Demand Appropriate Response

Requestable List of Hints (plan of attack)

Part A

Find an expression for $v_0$, the initial speed of the fired object. Express your answer in terms of some or all of the variables: $m$, $M$, $L$, $\theta$, and the acceleration due to gravity $g$.

$$v_0 = \boxed{\text{[Expression]}}$$

Ballistic Pendulum

Find an expression for $v_0$, the initial speed of the fired object.

Hint 1. How to approach the problem

Hint 2. Determine which physical laws and principles apply

Hint 3. Describe the collision

Hint 4. Describe the swing
Wrong Answer Feedback

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

Hints open on request in any order.

This is a Declarative Hint.

It Informs, Suggests, Reminds, etc.

Ballistic Pendulum

Find an expression for \( v_0 \), the initial speed of the fired objet.

**Hint 1. How to approach the problem**

There are two distinct physical processes at work in the ballistic pendulum. You must treat the collision and the following swing as two separate events. Identify which physical law or principle applies to each event, write an expression to describe the collision, write an expression to describe the swing, and then relate the two expressions to find \( v_0 \).

**Hint 2. Determine which physical laws and principles apply**

**Hint 3. Describe the collision**

**Hint 4. Describe the swing**

**Hint 5**

This hint will be visible after you complete previous item(s).
This hint is a SubTask

It Requests a Response that helps answer the main question.

Responding is optional, although informative.
Eductional Data Mining: Tutors give DATA!

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??
- 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
Net of 1.3 std dev for about 60% copying implies ~ 2.1 std. dev. effect size for no copying vs. all copying
Analytic Final Exam vs. Copying

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}
Students’ initial grades not very dependent on fraction copied

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

\[ N = 428 \]
\[ \beta = -2.42 \]
\[ r = -0.46 \]
\[ p < 2.2 \times 10^{-16} \]
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 \(-0.5 \pm 0.3\)

\(N = 428\)
\(\beta = -0.61\)
\(p = 0.03\)
\(r = -0.12\)
Students didn’t copy tutoring on these
copying analytic HW degrades analytic score
Implications of Differential in Correlation

- Amazing correlation with single activity
- MBT learning (concepts & numerical)
  - Independent of copying!
  - Shows copiers can learn physics
  - Strongly implies could learn analytic problems if they did Mastering

- Also implies Mastering teaches NO concepts or numerical skills
- Students Don’t Think Like Experts!
A good habit: using hints first

MasteringPhysics.com (or any tutor) offers many possible paths for the student. Do some paths result in more learning?
Learning Effect of Various Paths

Y-J Lee, D. Pallazo and DEP

(29% of all) Fail First Attempt

(11% of all) Go to Hint and Subtask

(60% of all): Correct on First Try

~21% of all students

Second Attempt Fail

Second Attempt Correct

Second Attempt

Correct on First Try

(60% of all) Correct on First Try

(57% of all): Useful Feedback Only

(13% of all): Go to Hint and Subtask

(25% of all): No Feedback Or Hint
Learning Effect of Various Paths

- 25% No Feedback Or Hint
- 57% Useful Feedback Only
- 4% Hint Only
- 12% Hint and Subtask-OK
- 2% Hint and Subtask-not OK

(29% of all) Fail First Attempt

(11% of all) Go to Hint and Subtask

(60% of all): Correct on First Try

Second Attempt

Second Attempt Correct

Fail Second Attempt ~21% of all students
Learning Effect of Various Paths

- 25% No Feedback Or Hint
  - 2% Hint and Subtask-not OK
  - 4% Hint Only
  - 12% Hint and Subtask-OK
- 57% Useful Feedback Only
  - 0.3 SD
- 2% Hint and Subtask-not OK
  - 0.6 SD
- (60% of all): Correct on First Try
- (11% of all) Go to Hint and Subtask
- (29% of all) Fail First Attempt
- Fail Second Attempt
  ~21% of all students
- Second Attempt
- Second Attempt Correct

\[ \delta s_t \]
-0.8 SD
0.3 SD
0.6 SD
1.5 SD
Why is Hints-First so Beneficial?

• Metacognitive Monitoring of Own Knowledge?
  – Know they don’t know how to solve
  – Use hints until they know they do know how to solve

• Observation: Not same students each time

• We’ll have to do more research!
Outline

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
Do we engender the learning faculty or students want?
A Course that teaches Problem Solving Skills
What Do Graduating Seniors Recall?  
Do they remember our wisdom??

Expect users of mechanics (Gp 3)

<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>
Increased Gain on Subtest Math

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

100% Learning on This Line

Normalized gain at graduation = 0.69

Freshman course normalized gain = 0.35

* Freshman responses unavailable for 8 students (4 Group 1, 3 Group 2 and 1 Group 3).
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.
<table>
<thead>
<tr>
<th>Type of Problem</th>
<th>English Biology</th>
<th>Chem EE Mat. Sci</th>
<th>Physics M.E. Aero</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytic Problems</td>
<td>Mostly two concepts, some requested Plan</td>
<td>-59(4)</td>
<td>-41(7)</td>
</tr>
<tr>
<td>Advanced Physics Concepts</td>
<td>Rotation, Oscillation, Orbits</td>
<td>-55(13)</td>
<td>-58(10)</td>
</tr>
<tr>
<td>Basic Physics Concepts (MBT)</td>
<td>Force, Motion, Energy, Momentum</td>
<td>-48(9)</td>
<td>-95(25)</td>
</tr>
<tr>
<td>Graphs &amp; Vectors (MBT)</td>
<td>Reviewed in Math &amp; Physics</td>
<td>+68(5)</td>
<td>+74(14)</td>
</tr>
</tbody>
</table>
Perceived Utility of Topics by Group (from MIT Survey)

% Responding Useful

Topic

forces    motion    energy    momentum    rotation    gyro    orbits    oscillations    probl solving

All Students  Group1  Group 2  Group 3
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?
~700 Instructor Votes
Wider Content

Labs

Physics from few Ideas

Epistemology

Concepts - Newtonian Thinking

Plan - Set Up

Sense Making

Sense Making

Scientific Argument

Science in News/Society

Relation to everyday life

Students

Average Instructors

Course Content

Philosophy

Problem Solving

Relation to the Outside world
Professors vs Students (r=-0.4)

- 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!”
- \( \rightarrow \) RECOMMENDATION: more attention to why intro physics is relevant to their futures.
Modeling Applied to Problem Solving

Frequent Problem (e.g. CLASS question)
After I study a topic in physics and feel that I understand it, I have difficulty solving problems on the same topic.

MAPS: Students Learn to Solve Problems
1. Measurably better
2. In a more concept-based manner
3. With better organization of knowledge
4. With improved learning attitudes
5. With Transfer to future E&M course
Improved Performance

Performance on Fall Final Exam and on IAP Retest

Standard Deviations from Mean of Large Fall Course

Number of Students vs. Standard Deviations from Course
Improved Attitudes

CLASS Shifts

Shift in % Favorable (Expertlike) Responses

Category #

Typical Course
ReView Course
Transfer: Benefit in E&M from Mechanics z-score

- All students above -1.2 stdev (N=1298)
- ReView Group 1 (N=34)
- ReView Group 2 (N=15)
- Control Group (N=18)
- F students from 07 (N=11)
Students worked in groups of 2:
- Individual and On-Board Problem Solving.
- Table activities (4 students per table).

2.5 week ReView for D’s in Fall Phys 1
Take Home Lessons

• Partial Credit Grading Rewards Partial Understanding

• MasteringPhysics gives 2 sigma gain on analytic problems

• Homework Copying is Largest Anti-Learning Factor: you MUST and Can Reduce It!

• Seniors Used It or Lost It (~50% or more)

• What to Teach YOUR Students?
Digital Education Future?!

To age 16 in class
Teacher
Teach a Class
Broadcast Radio
Passive
Author
High Stakes Tests
Next Edition

Lifelong Anytime/where
Coach & Electronic Tutor
Help Student Learn
Two-way Radio
Inter-Active
Authors/Researchers
Integrated Assessment
Next Day
Education Improvement

Identify the problem or needed improvement
Plan (with committee?) approach
Modify instructional procedure/material
Survey Student and Staff Approval
Scientific Education Reform

Identify the problem or needed improvement
Plan (with committee?) approach
Modify instructional procedure/material
Survey Student and Staff Approval
Scientific Education Reform

Read the literature
Identify the problem or needed improvement
Plan (with committee?) approach
Modify instructional procedure/material
Survey Student and Staff Approval
Assess the Outcome
Rethink and Recycle
Publish the New Results