CLASSEROOM DEMONSTRATIONS:
LEARNING TOOLS OR ENTERTAINMENT?

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Swarthmore College

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Harvard University

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Goals of demonstrations

- Educate
- Motivate

Are these goals met?
Background

Study: vary mode of presentation

Results: impact on student understanding

Conclusions
Psychology research: people remember what they expect to see

Education research: students may not learn much from demonstrations
Research on learning from demonstrations:

- Ability to predict outcome improves somewhat by seeing demonstration
- Understanding of concepts does not!

Research on learning from demonstrations:

- Sequences of interactive demonstration-based activities produce learning gains
- Replaces one hour of lecture per week

Can demonstrations be more educational?

How else can demonstrations be improved?
Can demonstrations be more educational?

- Peer Instruction: increase engagement by interspersing lectures with questions
Peer Instruction

1. Question
2. Thinking
3. Individual answer
4. Peer discussion
5. Group answer
6. Explanation
Can demonstrations be more educational?

- Peer Instruction: increase engagement by interspersing lectures with questions
- Demonstrated improvement in student understanding of lecture material

Can demonstrations be more educational?

Get students thinking:
Can demonstrations be more educational?

- Get students thinking: ask for predictions
Can demonstrations be more educational?

- Get students thinking: ask for predictions
- Create opportunities to explain and ask: students record and discuss predictions
Can demonstrations be more educational?

- Get students thinking: ask for predictions
- Create opportunities to explain and ask: students record and discuss predictions
- Confront and resolve: students rethink prediction after observation
7 demonstrations presented to 7 sections \((N \approx 15)\) of introductory physics class in one of 4 ‘modes’: 
7 demonstrations presented to 7 sections \((N \approx 15)\) of introductory physics class in one of 4 ‘modes’: 

- demonstration not shown
- traditional presentation
- students predict before demonstration
- students predict, compare, and discuss
Sample demonstration
A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading \( x \). If the metal block is now placed over the right-hand scale, the two scale readings are:

1. right scale = \( x \), left scale = \( x \)
2. right scale = \( x \), left scale = 0
3. right scale = 0, left scale = \( x \)
4. right scale = 2 \( x \), left scale = 0
5. right scale = 0, left scale = 2 \( x \)
6. right scale = 1.5 \( x \), left scale = 0.5 \( x \)
7. right scale = 0.5 \( x \), left scale = 1.5 \( x \)
8. none of the above
A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is placed at the center of the plank, halfway between the scales, the scales have the same reading $x$. The metal block is now placed over the right-hand scale.

1. What are the two scale readings now? Why?

2. Record your observation of the demonstration.

3. Compare your prediction (1) to your observation (2). Do they agree?

   __ Completely   __ Mostly   __ Somewhat   __ Not at all

4. After discussing your prediction and the demonstration with your neighbors, record why your prediction and the reasoning behind it were correct or incorrect (use the back of this sheet if you need more room).
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PREDICTION

2. Record your observation of the demonstration.

OBSERVATION

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<table>
<thead>
<tr>
<th>1. What are the two scale readings now? Why?</th>
</tr>
</thead>
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<tr>
<td><strong>PREDICTION</strong></td>
</tr>
<tr>
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<td><strong>OBSERVATION</strong></td>
</tr>
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<tr>
<td>___ Completely  ___ Mostly  ___ Somewhat  ___ Not at all</td>
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<tr>
<td><strong>DISCUSSION</strong></td>
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</table>
7 demonstrations presented to 7 sections \((N \approx 15)\) of introductory physics class in one of 4 ‘modes’

Demonstration mode rotates from section to section
Web-based test

- questions identical to worksheets
- graded solely on effort
Testing

- Web-based test
  - questions identical to worksheets
  - graded solely on effort
- Analyze responses for ($N = 122$, 7 questions):
  - demonstration outcome
  - physical understanding
1. A plank of negligible mass is supported at its two ends by platform scales. When a block of metal is located at the center of the plank, halfway between the scales, the scales have the same reading of 10 N as shown in (a).

\[ a \]
\[ \begin{array}{c}
\text{10 N} \\
\text{10 N}
\end{array} \]

\[ b \]
\[ \begin{array}{c}
? \\
?
\end{array} \]

If the metal block is now placed over the left-hand scale, as in (b), what are the readings on the scales? Explain your answer briefly.

\[ c \]
\[ \begin{array}{c}
? \\
?
\end{array} \]

What are the readings when the block is placed halfway between the left-hand end and the center of the plank, as in part (c) of the diagram? Explain your answer briefly.
## Results: Outcome of demonstrations

<table>
<thead>
<tr>
<th></th>
<th>correct outcome</th>
<th>$P$-value</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>61%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>observe</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>predict</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>discuss</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>observe</td>
<td>70%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>predict</td>
<td></td>
<td></td>
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<td>61%</td>
<td>–</td>
<td>297</td>
</tr>
<tr>
<td>observe</td>
<td>70%</td>
<td>0.03</td>
<td>220</td>
</tr>
<tr>
<td>predict</td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>220</td>
</tr>
<tr>
<td>predict</td>
<td>77%</td>
<td>&lt; 0.001</td>
<td>179</td>
</tr>
<tr>
<td>discuss</td>
<td></td>
<td></td>
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<td>77%</td>
<td>&lt; 0.001</td>
<td>179</td>
</tr>
<tr>
<td>discuss</td>
<td>82%</td>
<td>&lt; 0.0001</td>
<td>158</td>
</tr>
</tbody>
</table>
“As demonstrated in lecture, both scales will read 10N, regardless of where the center of mass is located. The platform and the metal block form one unit that is being measured, so the scales show two evenly distributed readings, no matter where the metal block is placed along the platform.”
Memory is a reconstruction at instant of recall, not like a video replay.

Fill in gaps in memory with information from schemas and scripts (mental models).

Incorrect model can lead to inaccurate memory of scenario.
### Results: Understanding

<table>
<thead>
<tr>
<th></th>
<th>fully correct</th>
<th>p-value</th>
<th>h-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>22%</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>observe</td>
<td>24%</td>
<td>0.64</td>
<td>0.05</td>
</tr>
<tr>
<td>predict</td>
<td>30%</td>
<td>0.04</td>
<td>0.18</td>
</tr>
<tr>
<td>discuss</td>
<td>32%</td>
<td>0.02</td>
<td>0.23</td>
</tr>
</tbody>
</table>
## Results: Understanding

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</tr>
</thead>
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<td>–</td>
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<tr>
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<td>24%</td>
<td>0.64</td>
<td>0.05</td>
</tr>
<tr>
<td>predict</td>
<td>30%</td>
<td>0.04</td>
<td>0.18</td>
</tr>
<tr>
<td>discuss</td>
<td>32%</td>
<td>0.01</td>
<td>0.23</td>
</tr>
</tbody>
</table>
### Results: Understanding

<table>
<thead>
<tr>
<th>Activity</th>
<th>Fully Correct (%)</th>
<th>p-value</th>
<th>h-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>22%</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>observe</td>
<td>24%</td>
<td>0.64</td>
<td>0.05</td>
</tr>
<tr>
<td>predict</td>
<td>30%</td>
<td>0.04</td>
<td>0.18</td>
</tr>
<tr>
<td>discuss</td>
<td>32%</td>
<td>0.01</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Results: Cost vs. benefit

- **observe**: 11 min
- **predict**: 13 min
- **discuss**: 21 min

The graph shows the ratio of $(R - R_{\text{no demo}}) / R_{\text{no demo}}$ for different activities:

- **outcome**: Light gray bars
- **explanation**: Dark gray bars
**Half-lens demonstration**

A giant light bulb is placed to the left of a converging lens at a distance greater than the focal length of the lens. The image of the bulb is formed on a screen to the right of the lens. What will happen to the image if you block the top half of the lens with a card?

1. The top half of the image disappears.
2. The bottom half of the image disappears.
3. The entire image disappears.
4. The image becomes blurred.
5. The image becomes fainter.
## Results: 3 ILD demos

<table>
<thead>
<tr>
<th></th>
<th>correct outcome</th>
<th>P-value</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>46%</td>
<td>−</td>
<td>162</td>
</tr>
<tr>
<td>observe</td>
<td>61%</td>
<td>0.040</td>
<td>41</td>
</tr>
<tr>
<td>predict</td>
<td>74%</td>
<td>0.002</td>
<td>31</td>
</tr>
<tr>
<td>reinforce</td>
<td>87%</td>
<td>&lt; 0.001</td>
<td>30</td>
</tr>
</tbody>
</table>
## Results: 3 ILD demos

<table>
<thead>
<tr>
<th>correct explanation</th>
<th>$P$-value</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>no demo</td>
<td>36%</td>
<td>–</td>
</tr>
<tr>
<td>observe</td>
<td>42%</td>
<td>0.258</td>
</tr>
<tr>
<td>predict</td>
<td>58%</td>
<td>0.011</td>
</tr>
<tr>
<td>reinforce</td>
<td>67%</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>
Conclusions

- Demonstrations without active engagement produce little gain in understanding.
- Predicting outcome gives significant learning gains without costing time.
- Reflection and discussion produce further improvement.
Collaborators: J. Paul Callan, Adam P. Fagen, Eric Mazur

Funding: National Science Foundation

Research: Students and staff of Physics 1
Demonstrations: Wolfgang Rueckner, Nils Sorensen
Discussion: Gay Stewart, Pamela Kraus, David Sokoloff

For a copy of this talk and additional information:

http://mazur-www.harvard.edu
Students don’t necessarily know what the point is!

Traditional demonstrations rarely engage students actively

Demonstrations are unrelated to exams

Roth et al., J. Res. Sci. Teach. 34, 509 (1997)
24% of students

Correct (mentions torque)
Answers

24% of students

20 0 20 0

Correct (mentions torque)

38% of students

15 5 15 5

Proportional reasoning
Answers

20% of students

6% do not balance forces
2% give other incorrect answers

10% of students

independent of position

qualitative reasoning