Innovating education to educate innovators:
Lessons from Physics Education Research

Using Existing Evidence to Improve STEM Education
2017 AAAS Annual Meeting
Boston, MA
CLASS

1st exposure

ROOM

deeper understanding

ROOM

1st exposure

CLASS

deeper understanding
question
question

think
question

think

poll
question
→
think
→
poll
→
discuss
question
→
think
→
poll
→
discuss
→
repoll
Higher learning gains
Higher learning gains

<table>
<thead>
<tr>
<th></th>
<th>Normalized Gain (%)</th>
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<tr>
<td>Lecture</td>
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Higher learning gains

<table>
<thead>
<tr>
<th>Exam Score (%)</th>
<th>Count</th>
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<tr>
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1985 exam scores
Higher learning gains

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1991 exam scores
Higher learning gains

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<td>60</td>
<td>40</td>
<td>20</td>
<td>10</td>
<td>0</td>
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</tbody>
</table>

1985/91 exam scores

- Exam scores range from 0% to 100%
- The count of students in each score range is shown.
Higher learning gains

Similar gains at 2yr colleges!
Higher learning gains
Better retention
Higher learning gains
Better retention

Higher learning gains
Better retention

Higher learning gains
Better retention

Higher learning gains
Better retention
Freshmen
Upperclass
SAT math scores

Probability of switching

Higher learning gains
Better retention

since 1991:

over 10,000 articles on Peer Instruction
Active learning increases student performance in science, engineering, and mathematics

Scott Freemana,1, Sarah L. Eddy, Miles McDonough, Michelle K. Smithb, Nnadozie Okoroafora, Hannah Jordta, and Mary Pat Wenderotha

aDepartment of Biology, University of Washington, Seattle, WA 98195; and bSchool of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results indicate that average examination rates were 21.8% under active learning but 33.8% under traditional lecturing (Fig. 1 and SI Methods). The analysis, then, focused on two related questions. Does active learning increase scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (ii) failure rates, usually measured as the percentage of students receiving a D or F grade or withdrawing from the course in question (DFW rate).

The analysis, then, focused on two related questions. Does active learning boost examination scores? Does it lower failure rates?

Results

The overall mean effect size for performance on identical or formally equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 (95% CI: 0.30, 0.64, Z = 9.781, P << 0.001)—meaning that on average, student performance increased by just under half a SD with active learning compared with lecturing. The overall mean effect size for failure rates was an odds ratio of 1.95 (Z = 10.4, P << 0.001). This ratio is equivalent to a risk ratio of 1.5, meaning that on average, students in traditional lecture courses are 1.5 times more likely to fail than students in courses with active learning. Average failure rates were 21.8% under active learning but 33.8% under traditional lecturing—a difference that represents a 55% decrease in the odds of failing.
Active learning increases student performance in science, engineering, and mathematics

Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt,
Mark Pat Wenderoth

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Results

The overall mean effect size for performance on identical equivalent examinations, concept inventories, and other assessments was a weighted standardized mean difference of 0.47 (9.781, P << 0.001)—meaning that on average, student performance increased by just under half a SD with active learning as compared with lecturing. The overall mean effect size for a failure rate was an odds ratio of 1.95 (Z = 10.4, P << 0.001). The failure rate was 28% under traditional lecturing—equal to a risk ratio of 1.5, meaning that on average, students in classes with traditional lecturing were 1.5 times more likely to fail than students in classes with active learning. Average failure rates were 21.8% under active learning—a difference that represents a 55% reduction in the risk of failure.
self-efficacy
ownership
team- and project-based learning
self-efficacy (a.u.)

- pre
- post

P11b
self-efficacy (a.u.)

- **P11b**
  - pre: 80
  - post: 70

- **AP50b**
  - pre: 60
  - post: 70
CLASS
1st exposure

ROOM
deeper understanding

ROOM
1st exposure

CLASS
deeper understanding
1st exposure deeper understanding

ROOM

deeper understanding

CLASS

1st exposure

ROOM
how to effectively transfer information outside classroom?
want:
every student prepared for every class
want:

every student prepared for every class

(without additional instructor effort)
Solution

turn out-of-class component also into a social interaction!
In the preceding two chapters, we developed a mathematical framework for describing motion along a straight line. In this chapter, we continue our study of motion by investigating inertia, a property of objects that affects their motion. The experiments we carry out in studying inertia lead us to discover one of the most fundamental laws in physics—conservation of momentum.

4.1 Friction

Picture a block of wood placed on a smooth wooden surface. If you give the block a shove, it slides some distance but eventually comes to rest. Depending on the smoothness of the block and the smoothness of the wooden surface, this stopping may happen sooner or it may happen later. If the two surfaces in contact are very smooth and slippery, the block slides for a longer time interval than if the surfaces are rough or sticky. This you know from everyday experience: A hockey puck slides easily on ice but not on a rough road.

Figure 4.1 shows how the velocity of a wooden block decreases on three different surfaces. The slowing down is due to friction—the resistance to motion that one surface or object encounters when moving over another. Notice how the velocity decreases as the block slides on each surface. The block slides easily over the low-friction surfaces that have friction at all, such that an object, once given a shove, continues to glide forever. There is no totally frictionless surface over which objects slide forever, but there are ways to minimize friction. You can, for instance, float an object on a cushion of air. This is most easily accomplished with a low-friction track—a track whose surface is dotted with little holes through which pressurized air blows. The air serves as a cushion on which a conveniently shaped object can float, with friction between the object and the track all but eliminated. Alternatively, one can use wheeled carts with low-friction bearings on an ordinary track. Figure 4.2 shows low-friction carts you may have encountered in your own experiences. Although there is still some friction for the track to move along its length with, for example, if the track is not perfectly smooth or perfectly round. The less friction there is, the less the cart has to move to come to rest.

Figure 4.1 Velocity-versus-time graph for a wooden block sliding on three different surfaces. The rougher the surface, the more quickly the velocity decreases.

Another advantage of using such carts is that the track constrains the motion to being along a straight line. We can then use a high-speed camera to record the cart’s position at various instants, and from that information determine its speed and acceleration.

4.1 (a) Are the accelerations of the motions shown in Figure 4.1 constant? (b) For which surface is the acceleration largest in magnitude?
thoughtful reading and interpretation
thoughtful reading and interpretation

close to 95%!
social engagement in & out of classroom a must
• overwhelming evidence
• research data is essential