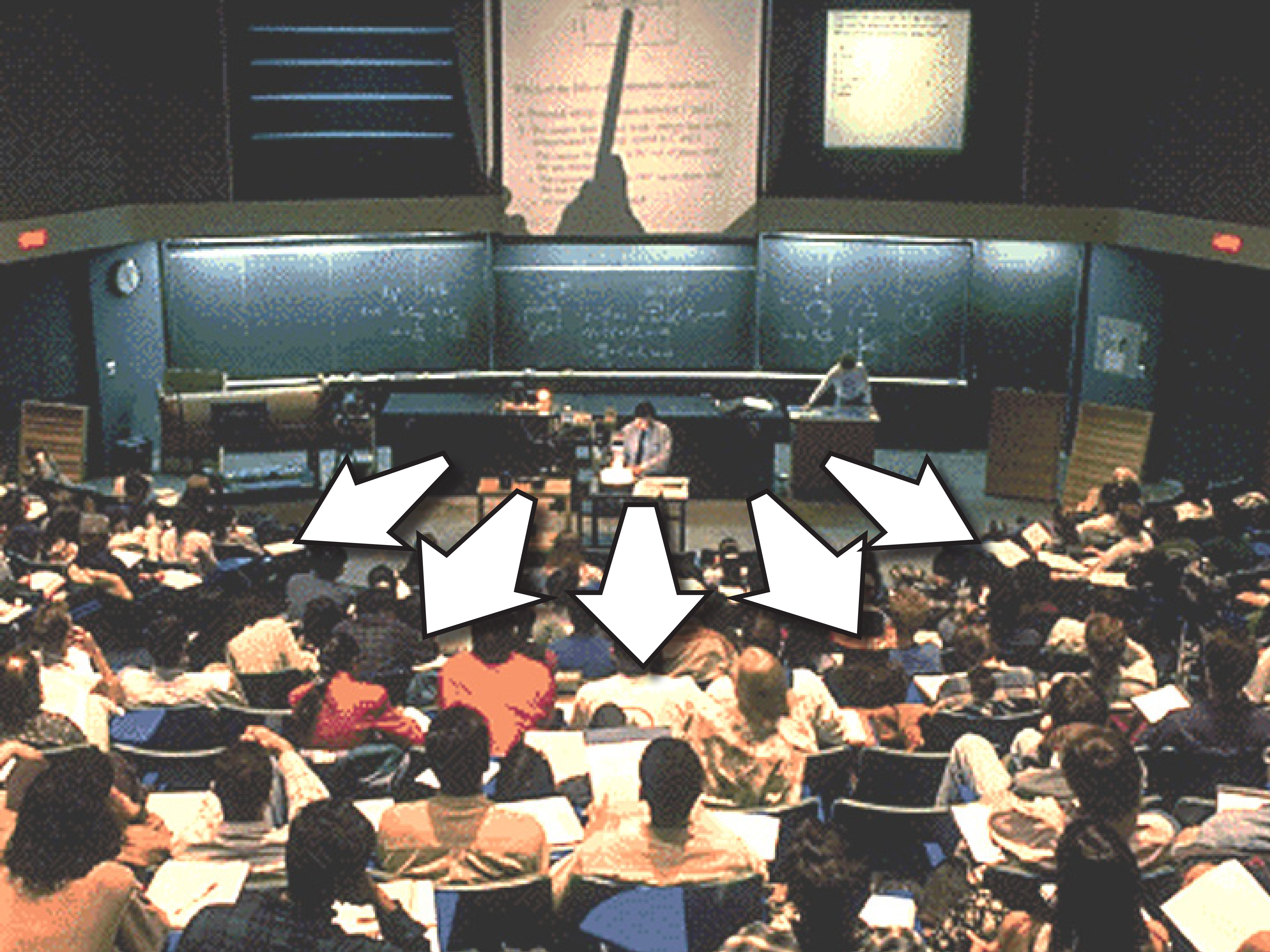
Innovating education to educate innovators: Lessons from Physics Education Research

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



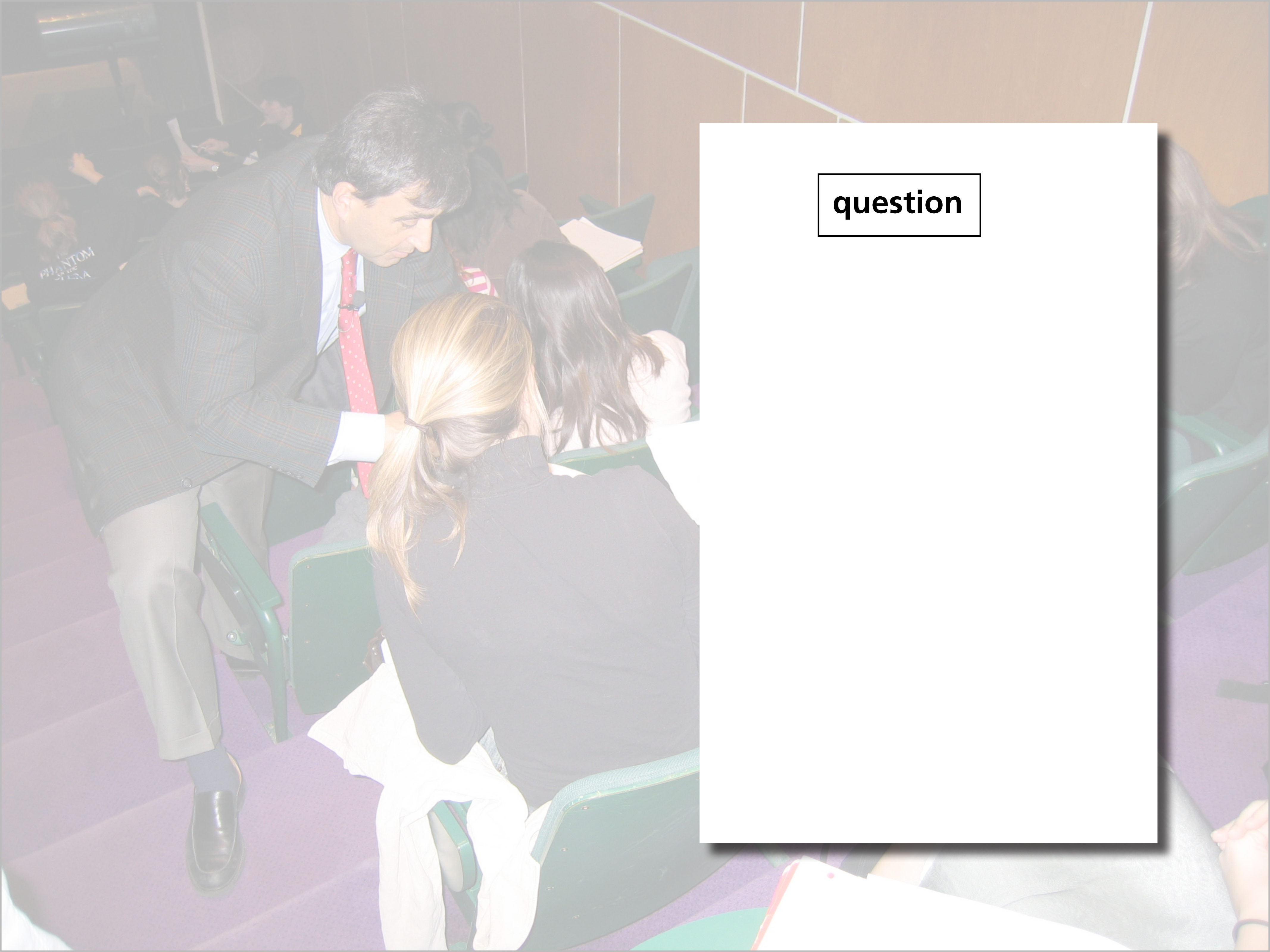
CLASS

1st exposure

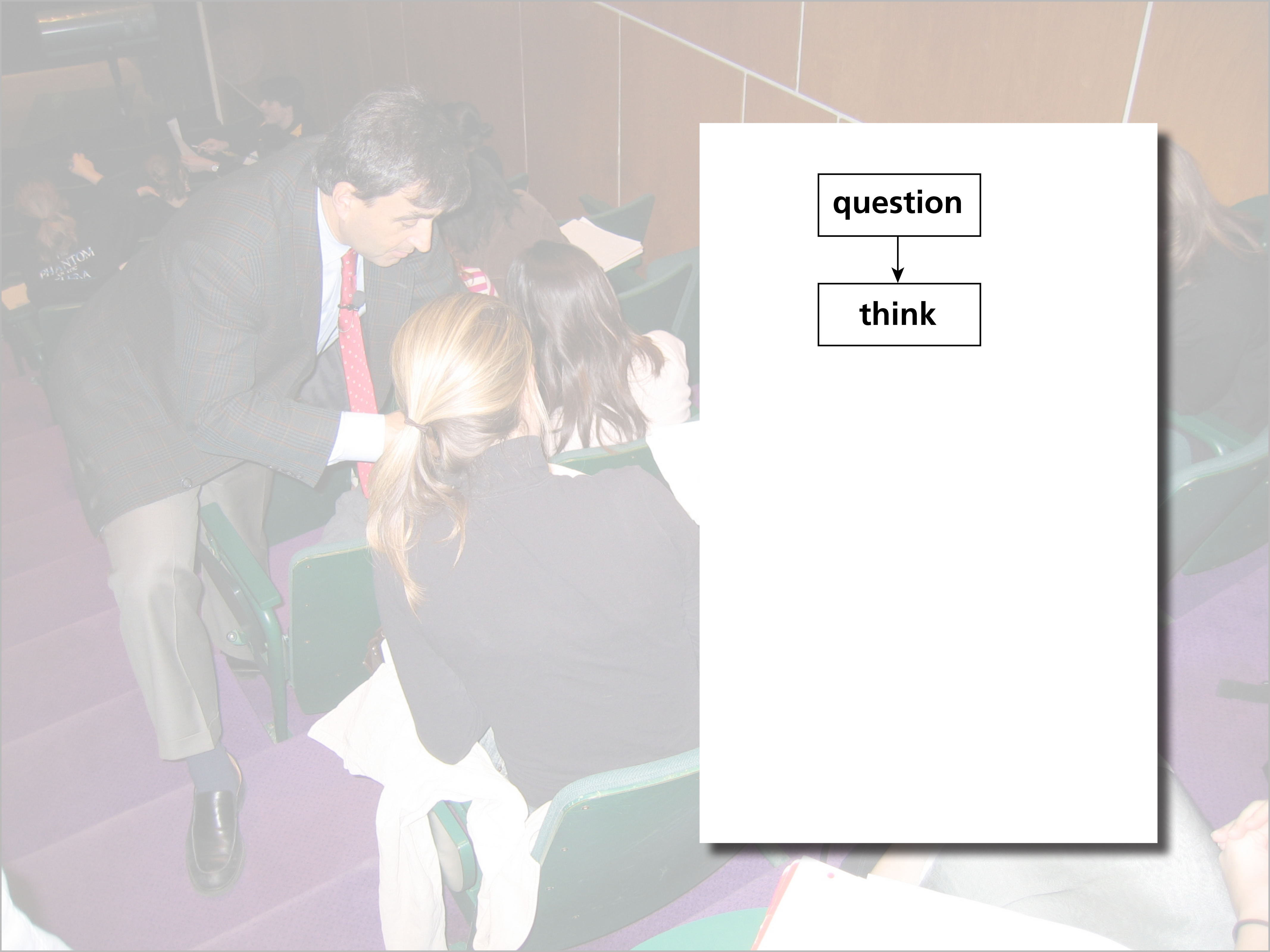
ROOM

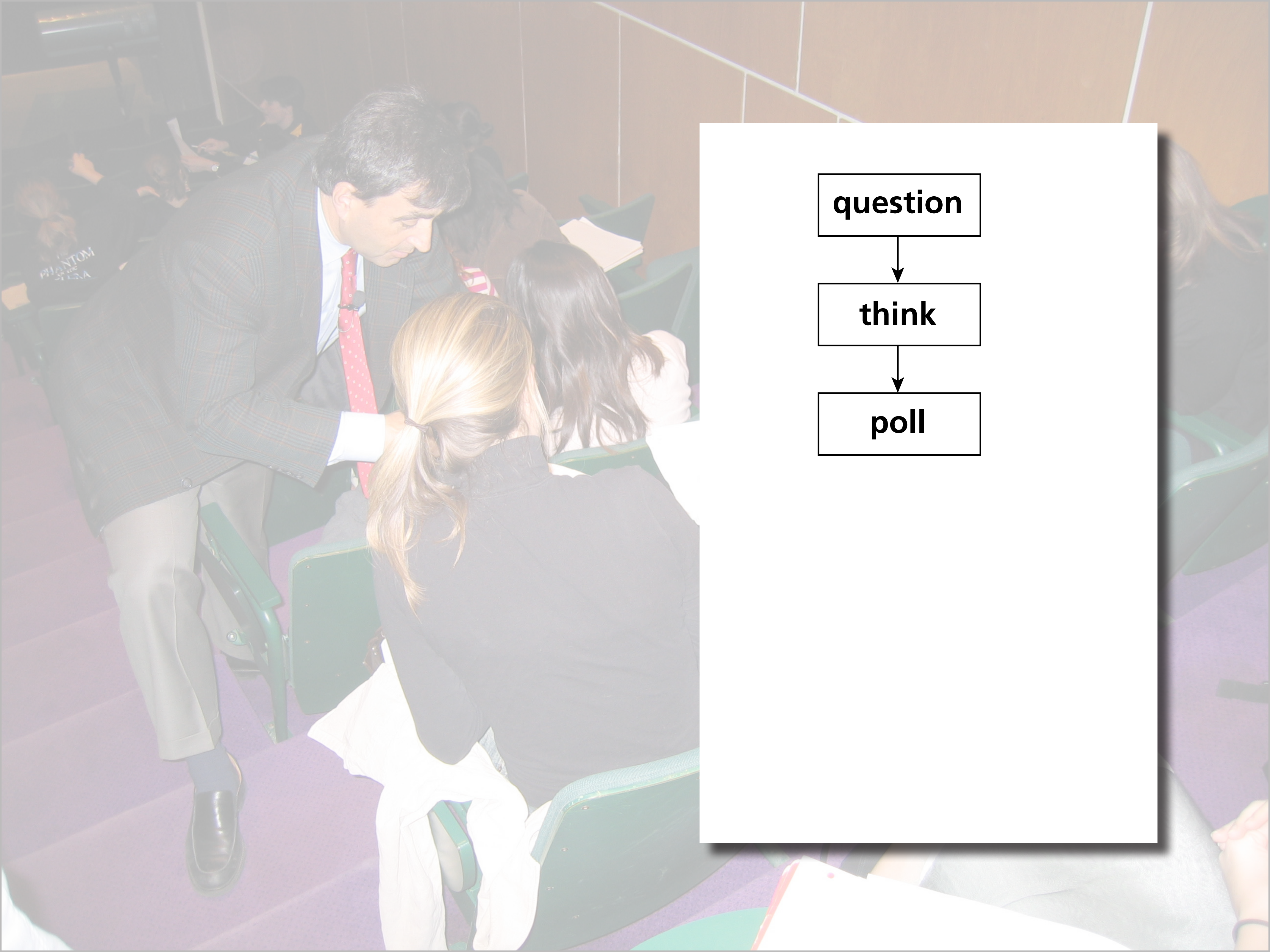
deeper understanding

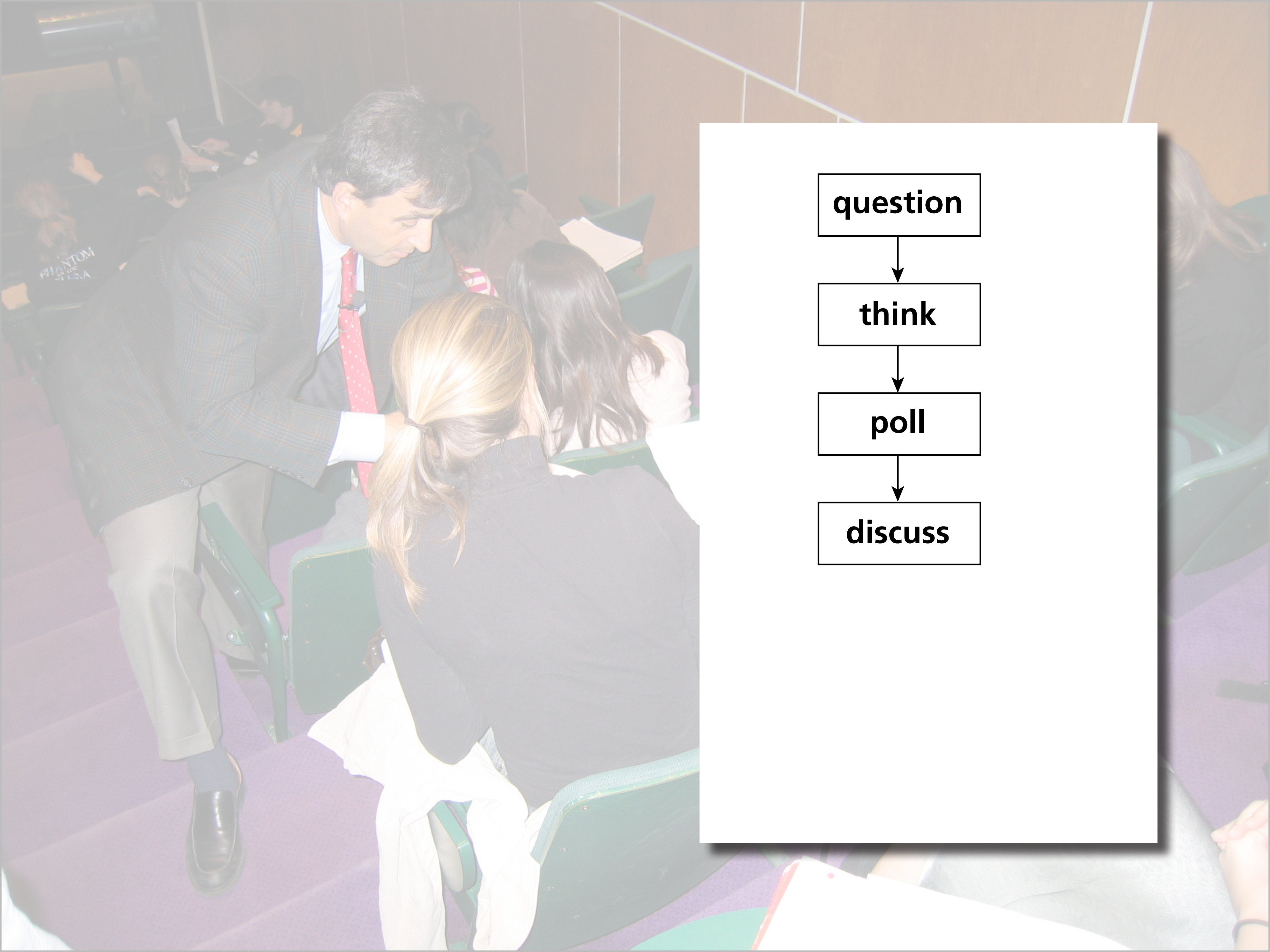

CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding

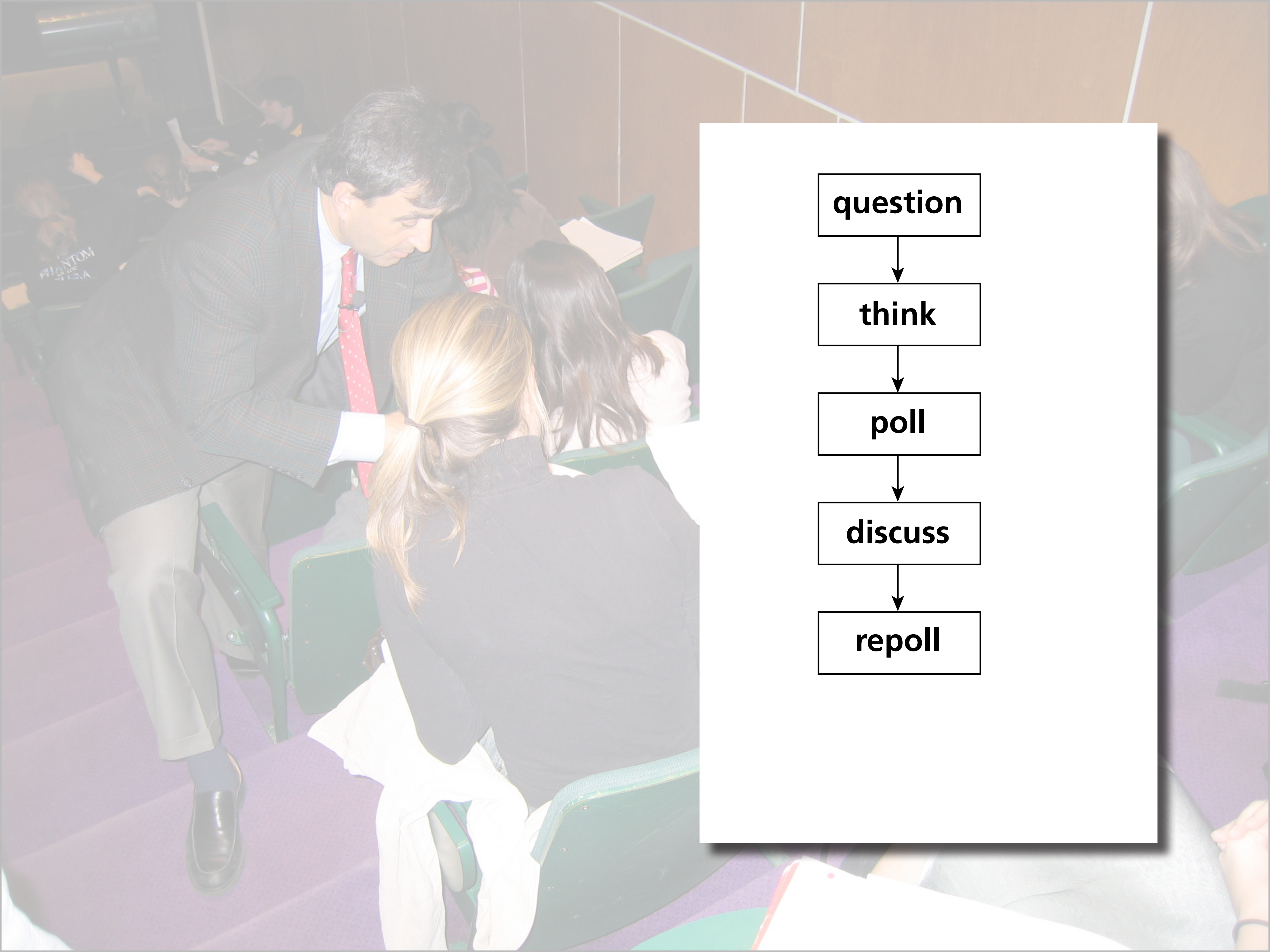


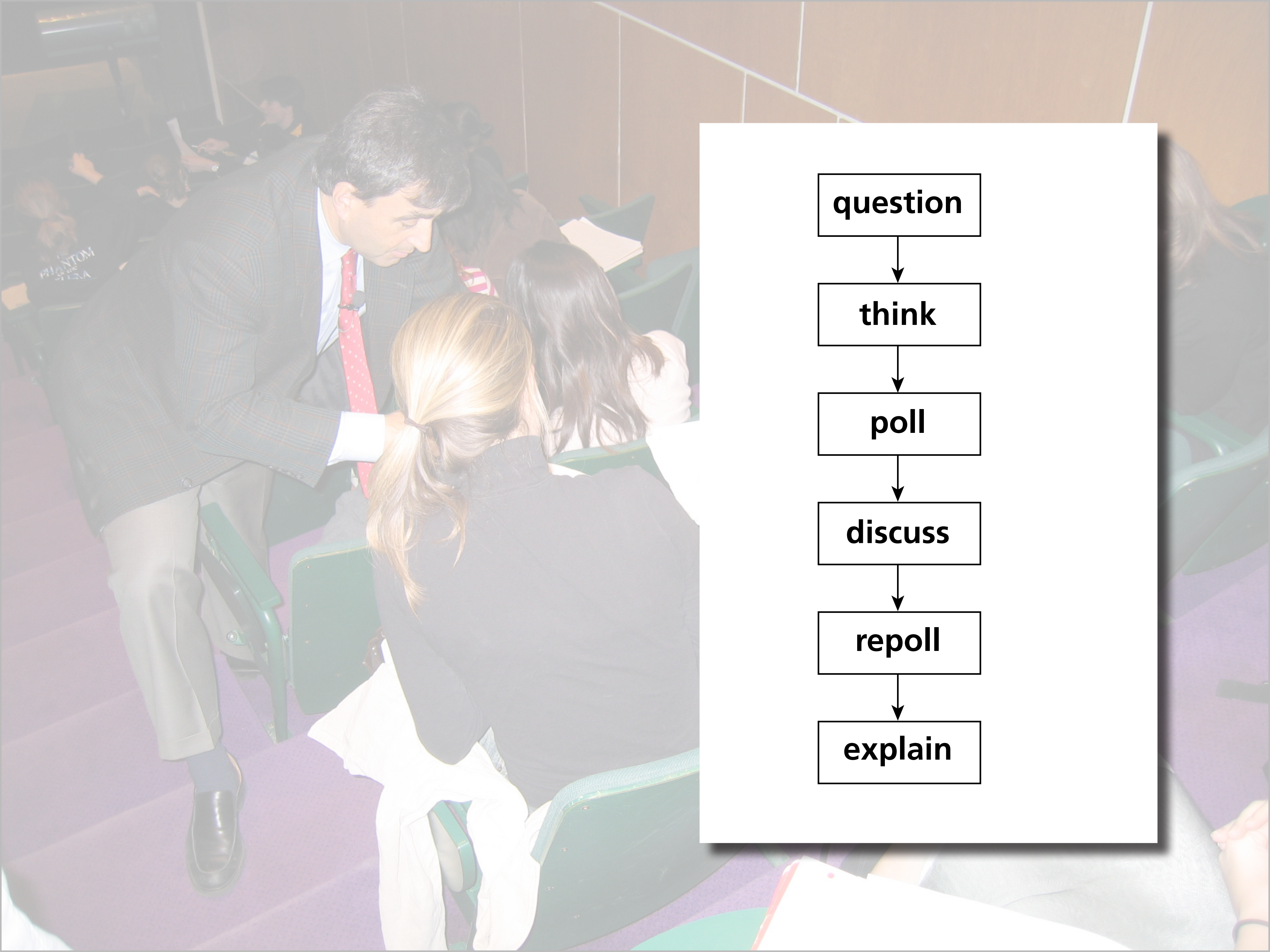
question

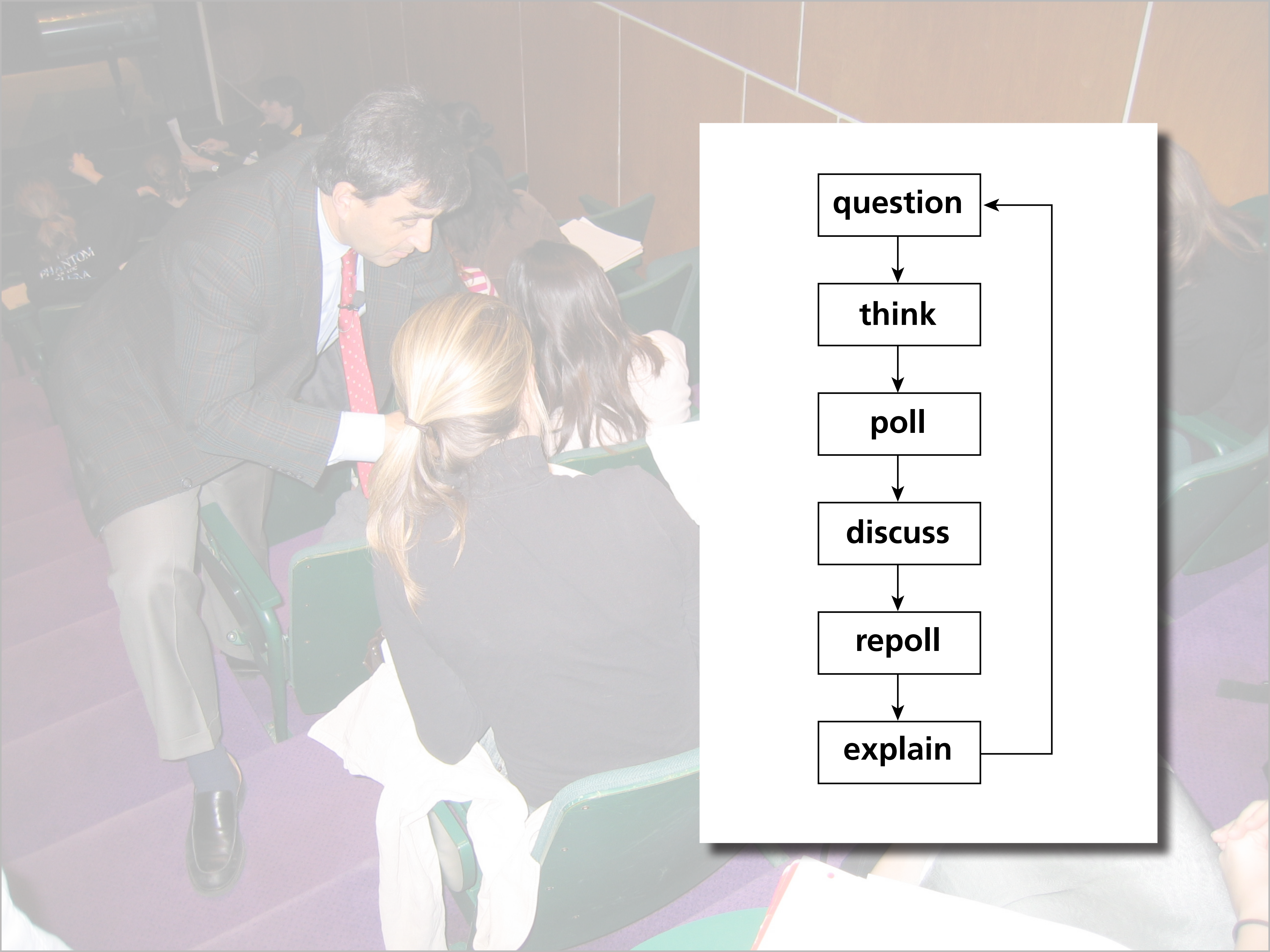

question
think


question
think
poll


question
think
poll
discuss


question
think
poll
discuss
repoll

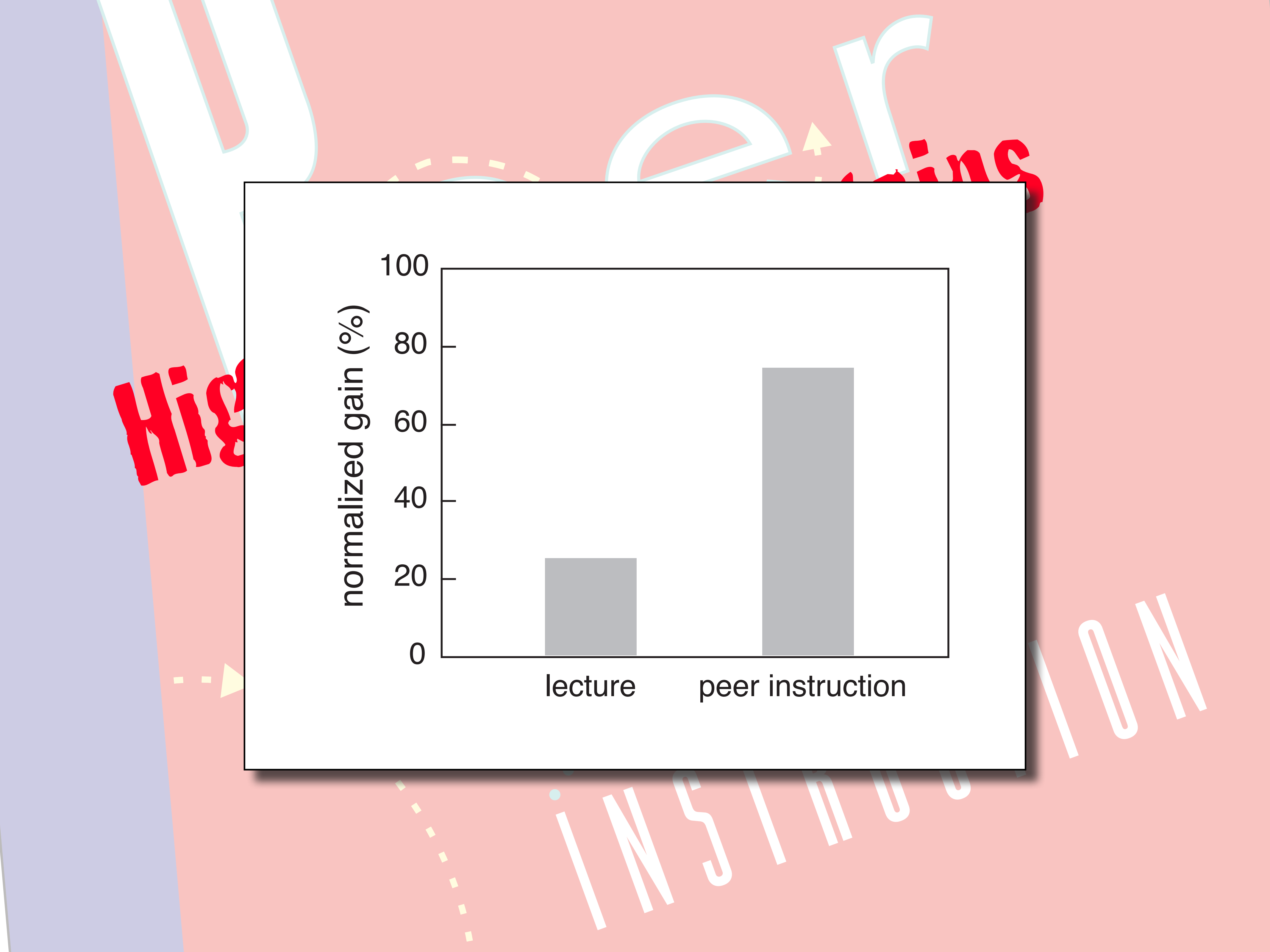

question
think
poll
discuss
repoll
explain

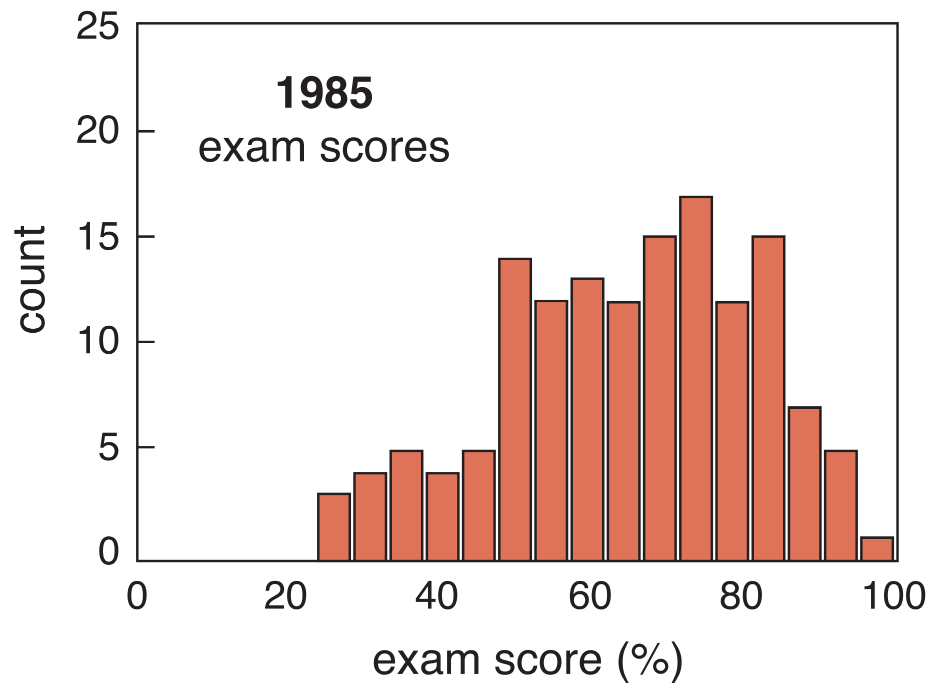

question
think
poll
discuss
repoll
explain

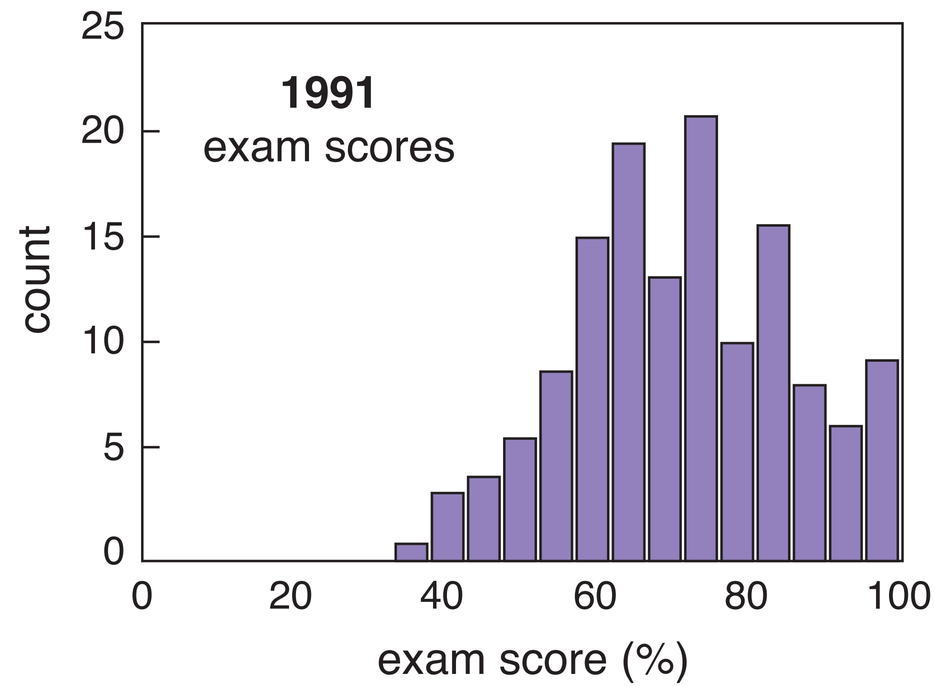
Peer

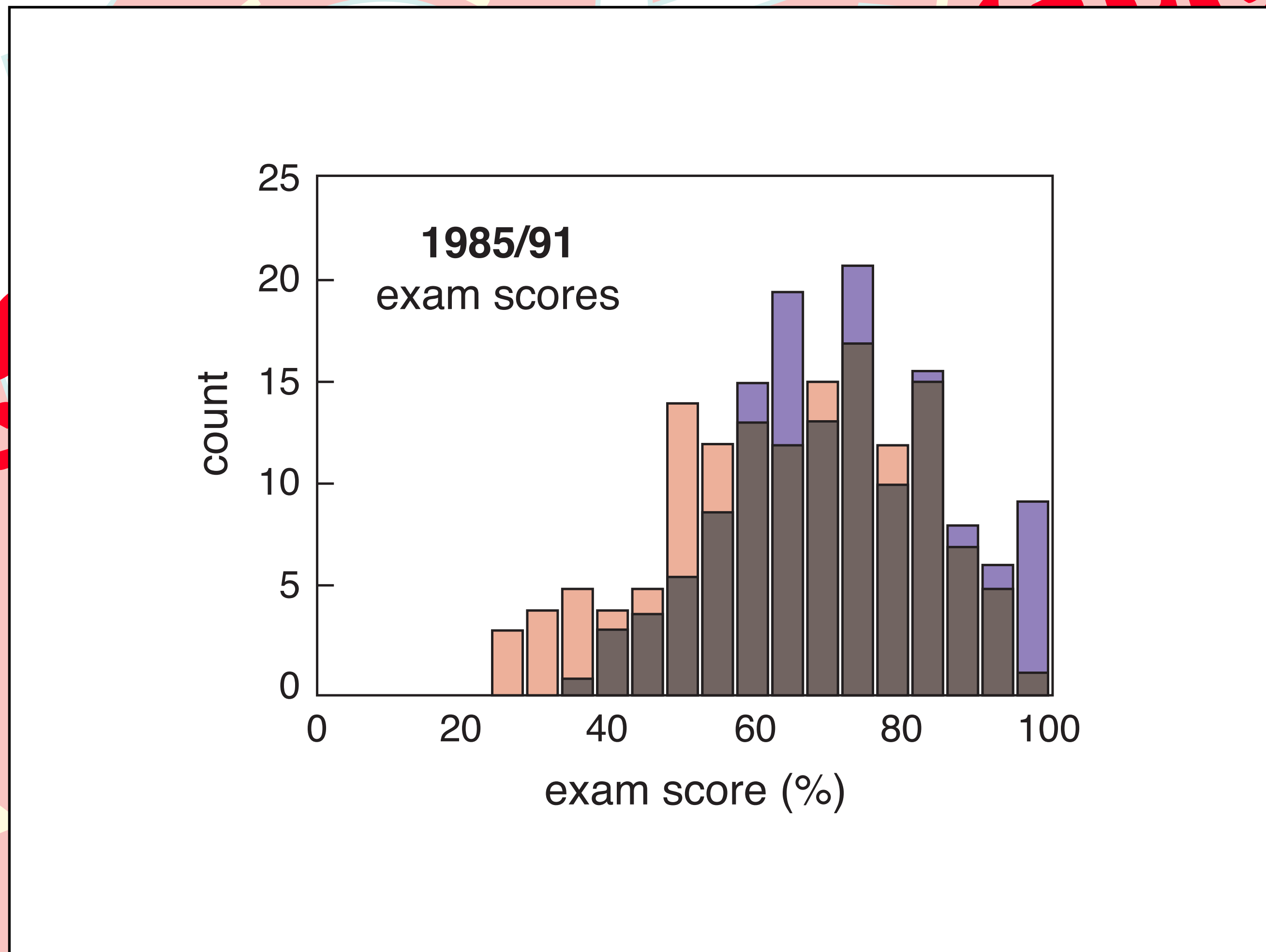
INSTRUCTION

Higher learning gains

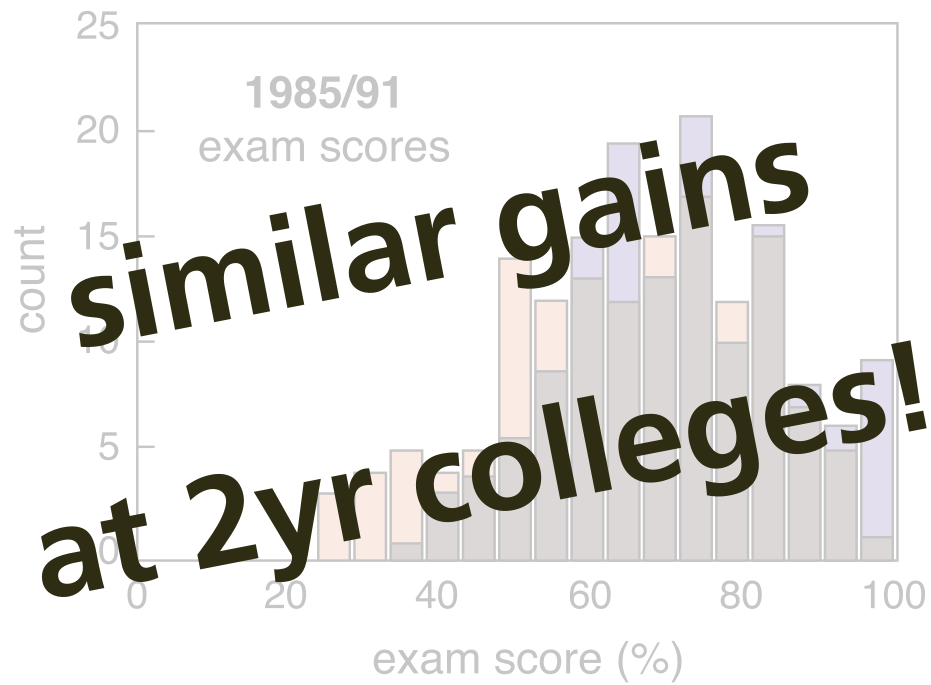

normalized gain (%)
100
80
60
40
20
0
lecture
peer instruction


1985
exam scores
count
exam score (%)
0
5
10
15
20
25
0
20
40
60
80
100


1991
exam scores
count
exam score (%)
0
5
10
15
20
25
0
20
40
60
80
100


1985/91
exam scores
count
exam score (%)
0
5
10
15
20
25
0
20
40
60
80
100

similar gains at 2yr colleges!

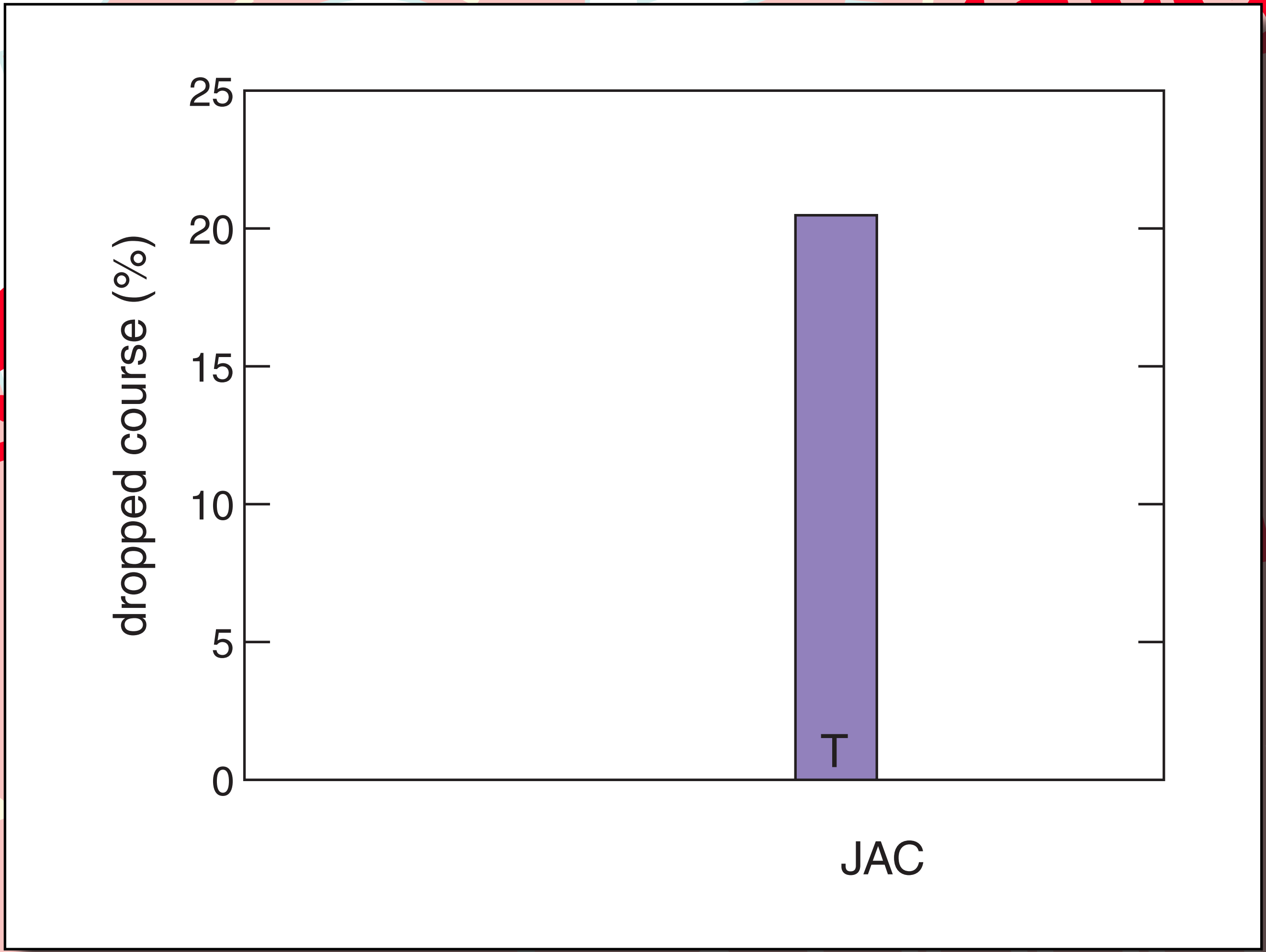


Peer

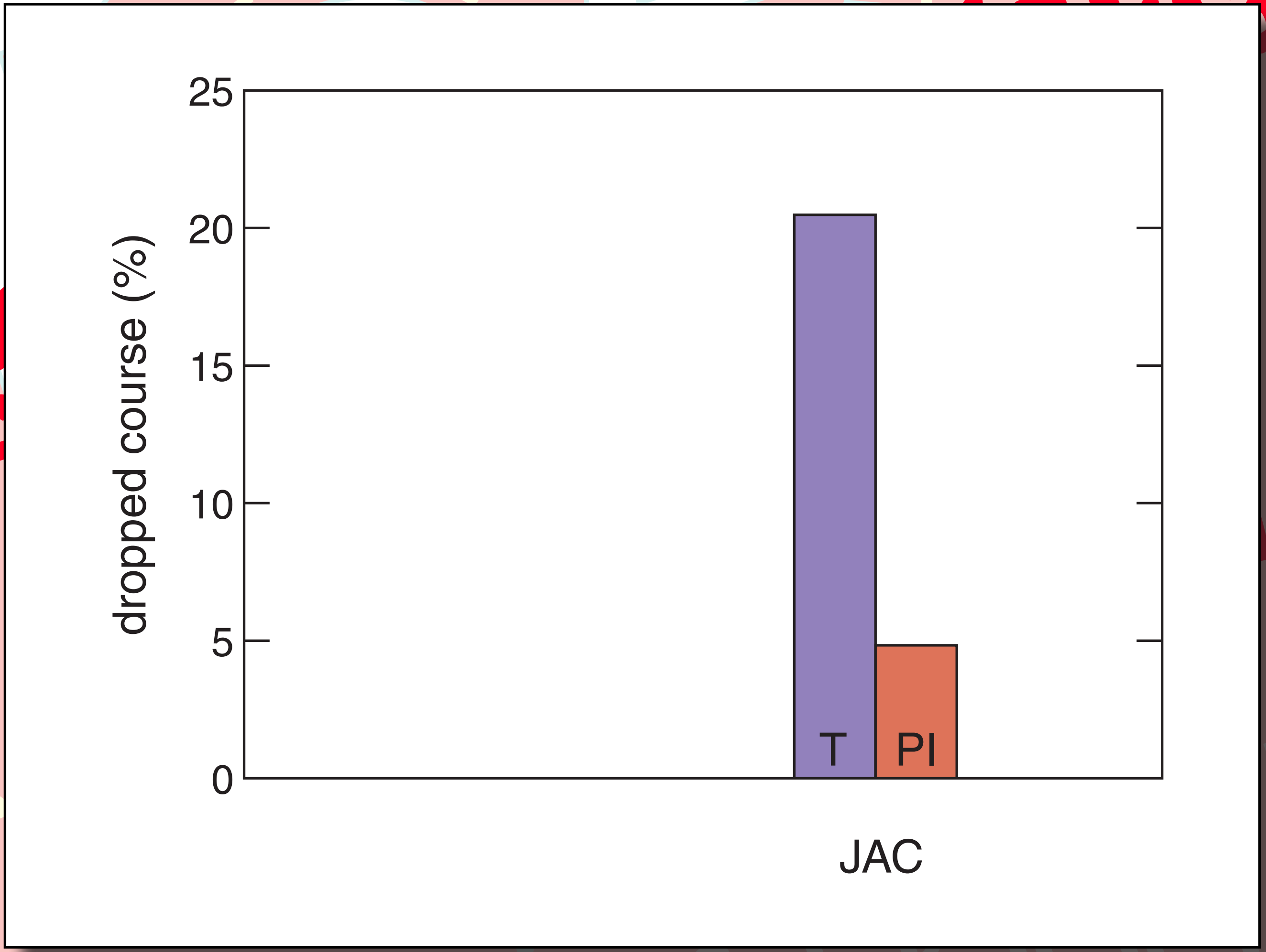
INSTRUCTION

Higher learning gains

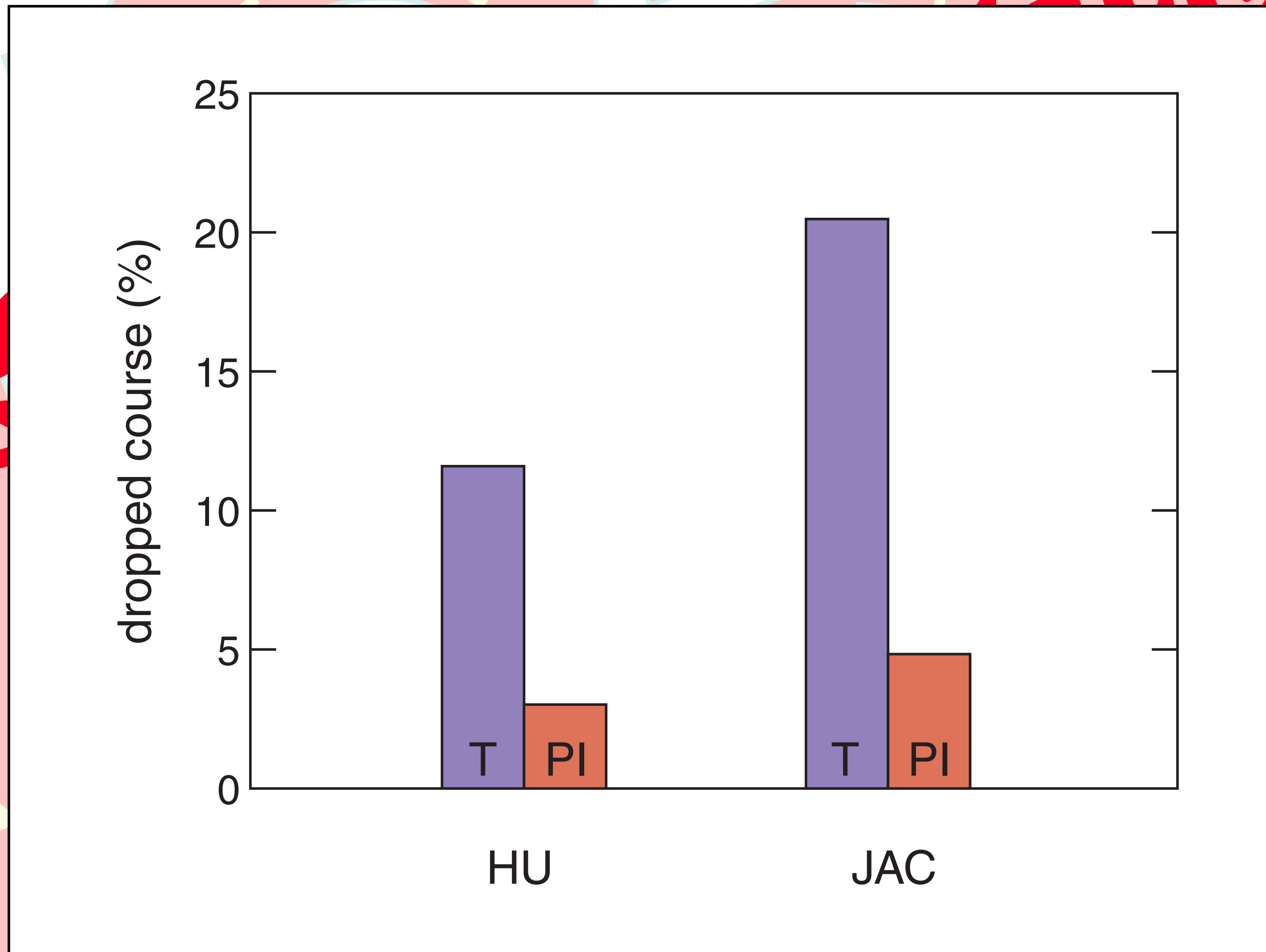
Better retention



N. Lasry *et al*., *Am. J. Phys.*, 76 (2008)



N. Lasry *et al.*, *Am. J. Phys.*, 76 (2008)



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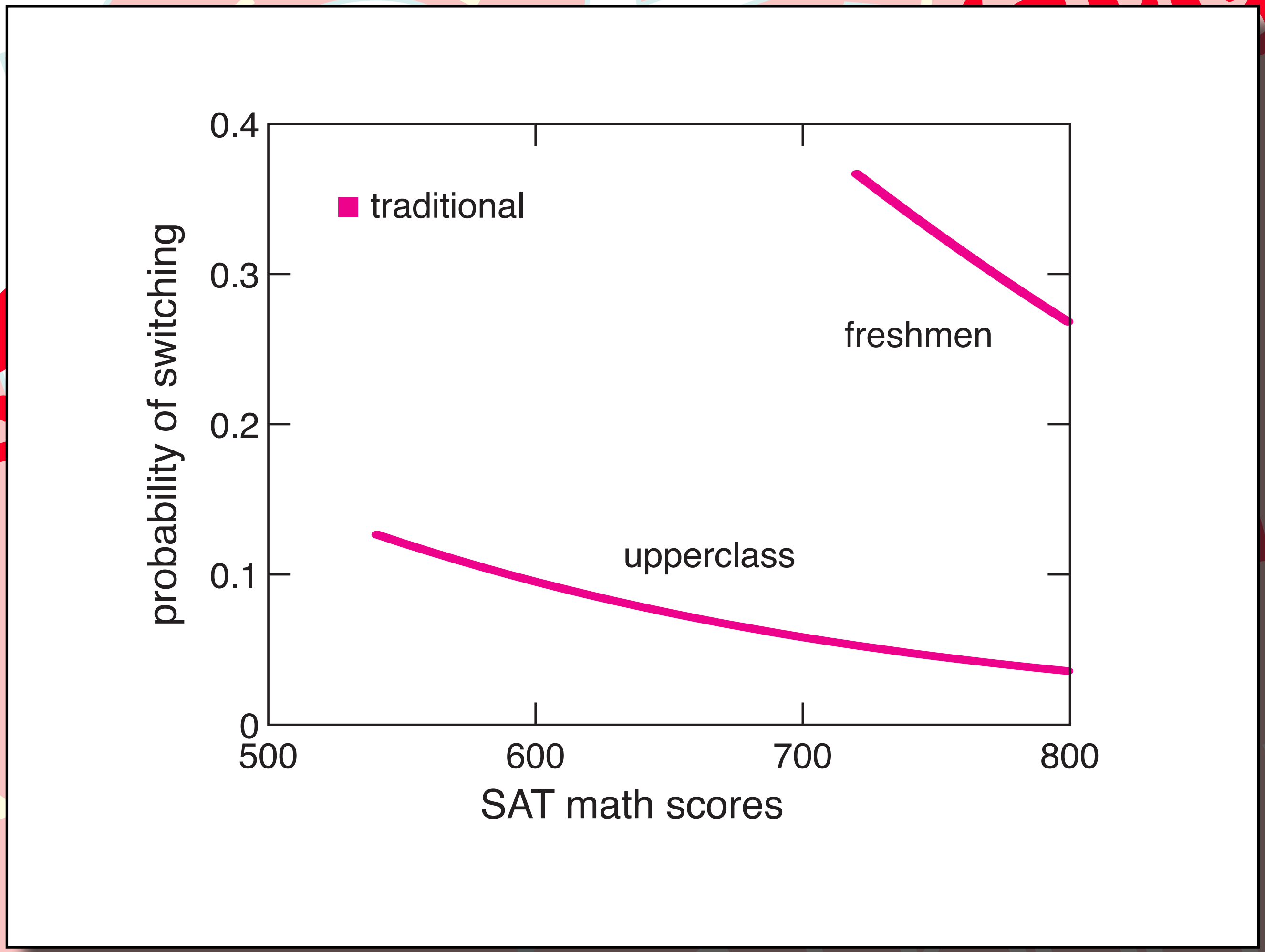
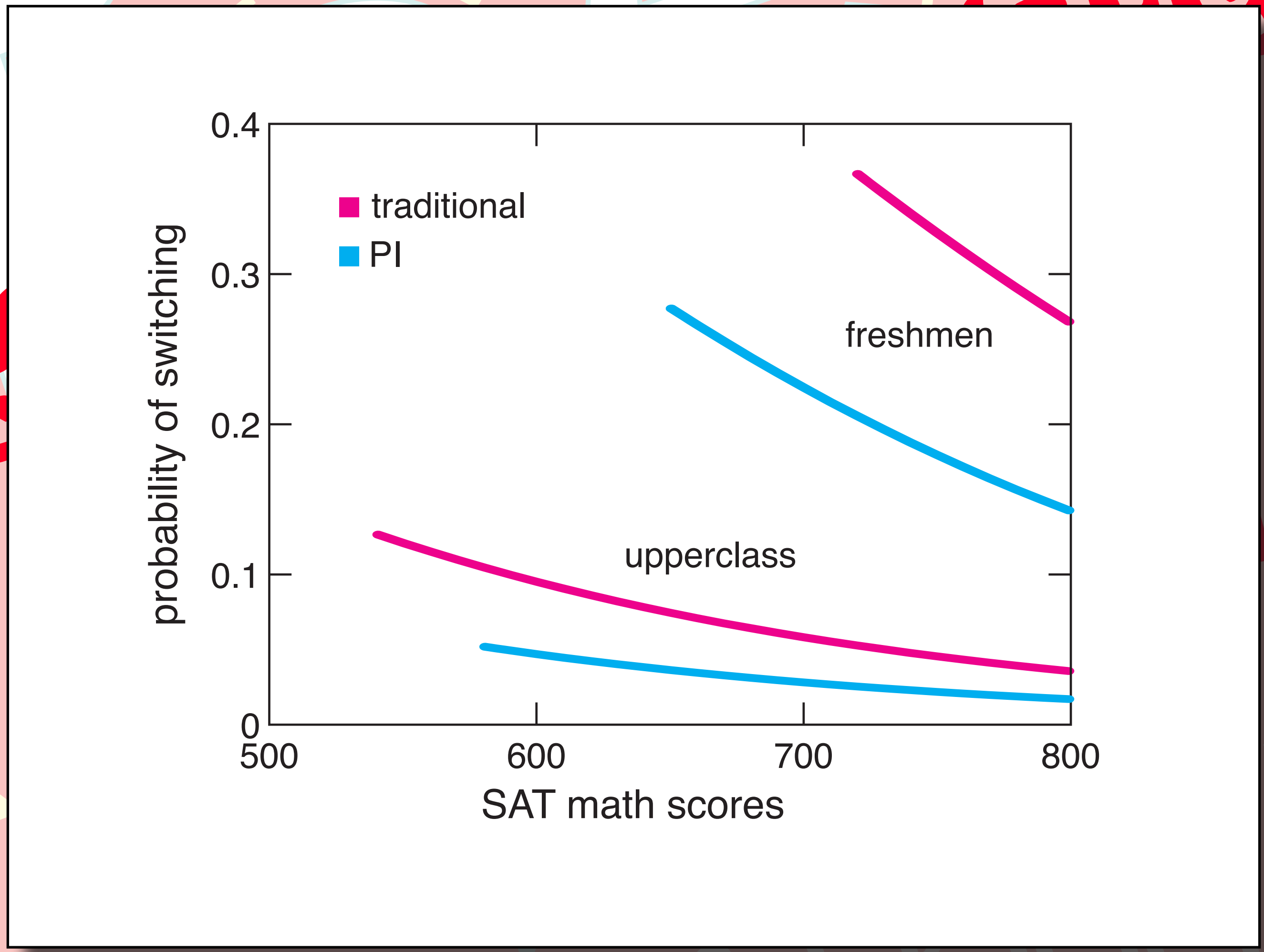


J. Watkins *et al.*, *J. Coll. Sci. Teach.*, 42 (2013)



J. Watkins *et al.*, *J. Coll. Sci. Teach.*, 42 (2013)

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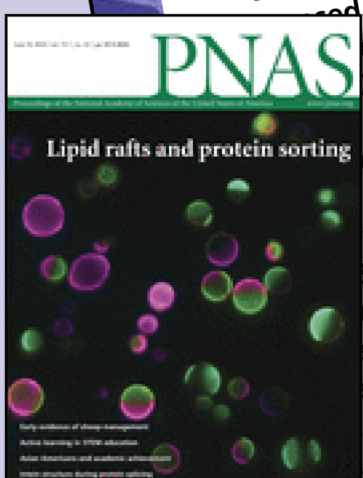
PNAS

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School 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 course 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 in-
...ased by 0.47 SDs under active learning (n = 158 studies), and
...e odds ratio for failing was 1.95 under traditional lecturing
...7 studies). These results indicate that average examination
... improved by about 6% in active learning sections, and that
...nts in classes with traditional lecturing were 1.5 times more
... to fail than were students in classes with active learning.
...rogeneity analyses indicated that both results hold across
...STEM disciplines, that active learning increases scores on con-
... inventories more than on course examinations, and that ac-
... learning appears effective across all class sizes—although the
...eatest effects are in small ($n \leq 50$) classes. Trim and fill analyses
...d fail-safe n calculations suggest that the results are not due to
...ublication bias. The results also appear robust to variation in the
methodological rigor of the included studies, based on the quality
of controls over student quality and instructor identity. This is the
...argest and most comprehensive metaanalysis of undergraduate
...published to date. The results raise questions about
...lecturing as a control in research
...eferred, empirically

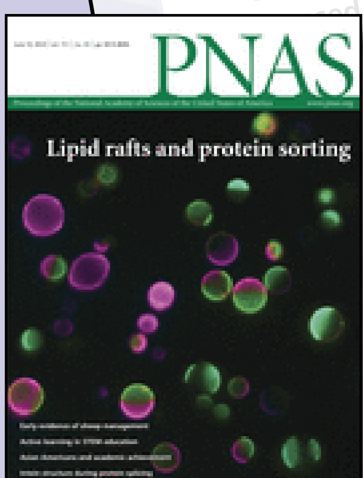
225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*) and evaluated student performance using two outcome variable...
(*i*) scores on identical or formally equivalent examinations, conce...
inventories, or other assessments; or (*ii*) failure rates, usual...
measured as the percentage of students receiving a D or F gra...
or withdrawing from the course in question (DFW rate).

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

Results

The overall mean effect size for performance on identic...
equivalent examinations, concept inventories, and other a...
ments was a weighted standardized mean difference of 0.4...
9.781, $P << 0.001$)—meaning that on average, student ...
mance increased by just under half a SD with active l...
compared with lecturing. The overall mean effect size fo...
rate was an odds ratio of 1.95 ($Z = 10.4$, $P << 0.001$). T...
ratio is equivalent to a risk ratio of 1.5, meaning that on...
students in traditional lecture courses are 1.5 times more...
fail than students in courses with active learning. Avera...
rates were 21.8% under active learning but 33.8% un...
...lecturing—a difference that represents a 55%...

“students in classes with traditional lecturing 1.5 times more likely to fail than students in classes with active learning”

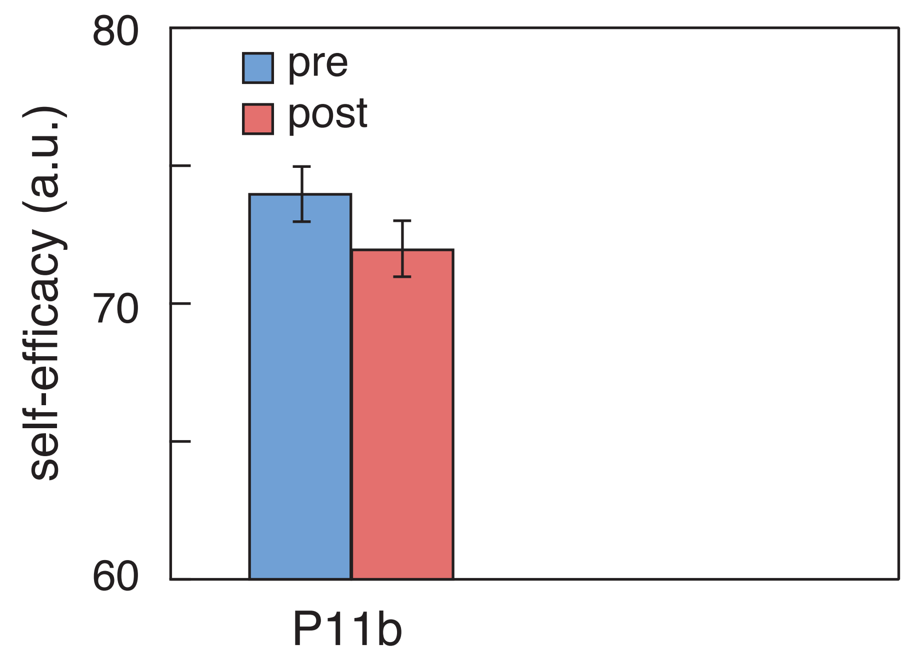


S. Freeman *et al.*, *PNAS* 111, 23 (2014)

Peer

self-efficacy

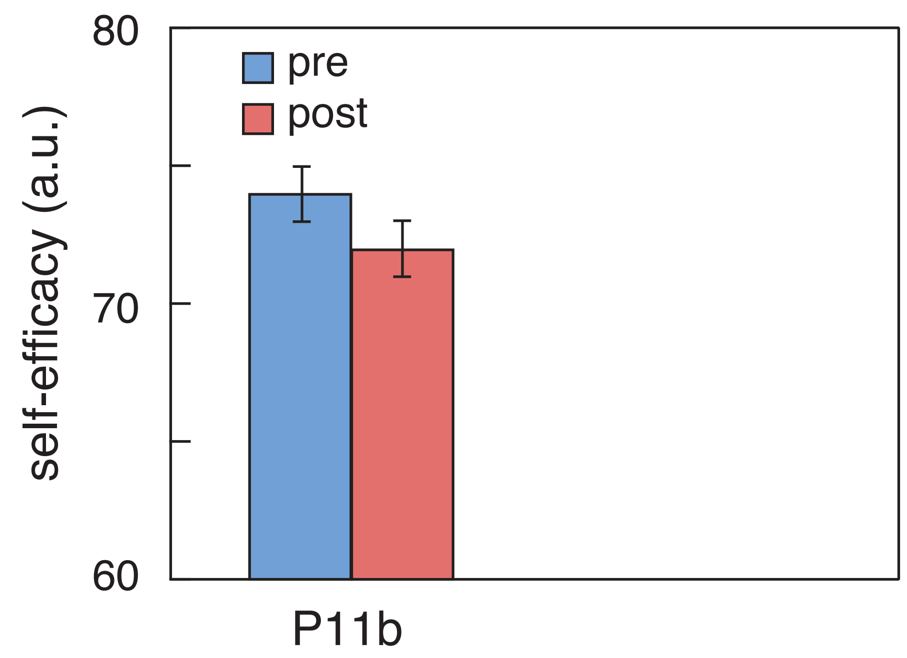
INSTRUCTION



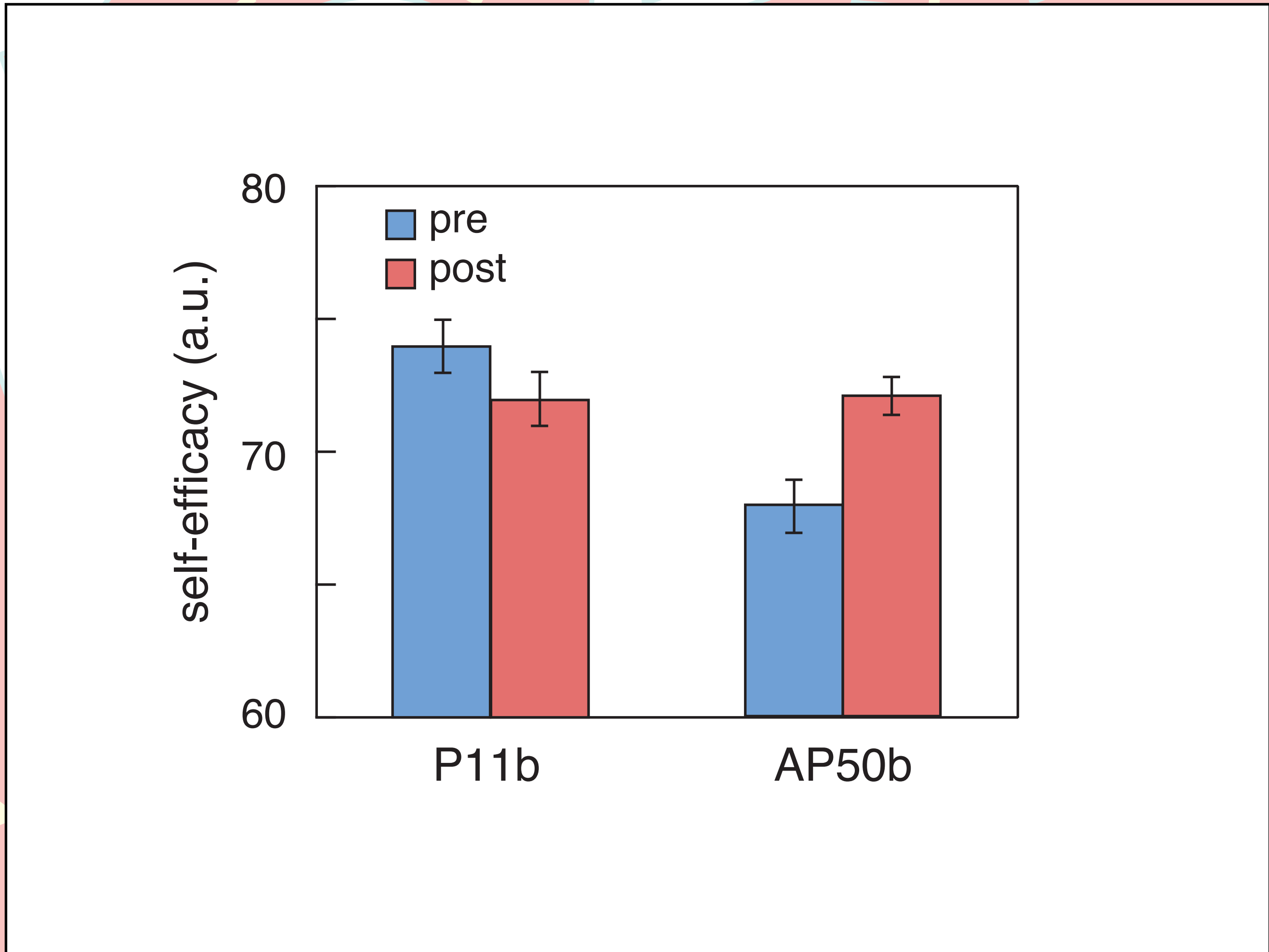
80
70
60
self-efficacy (a.u.)
pre
post
P11b

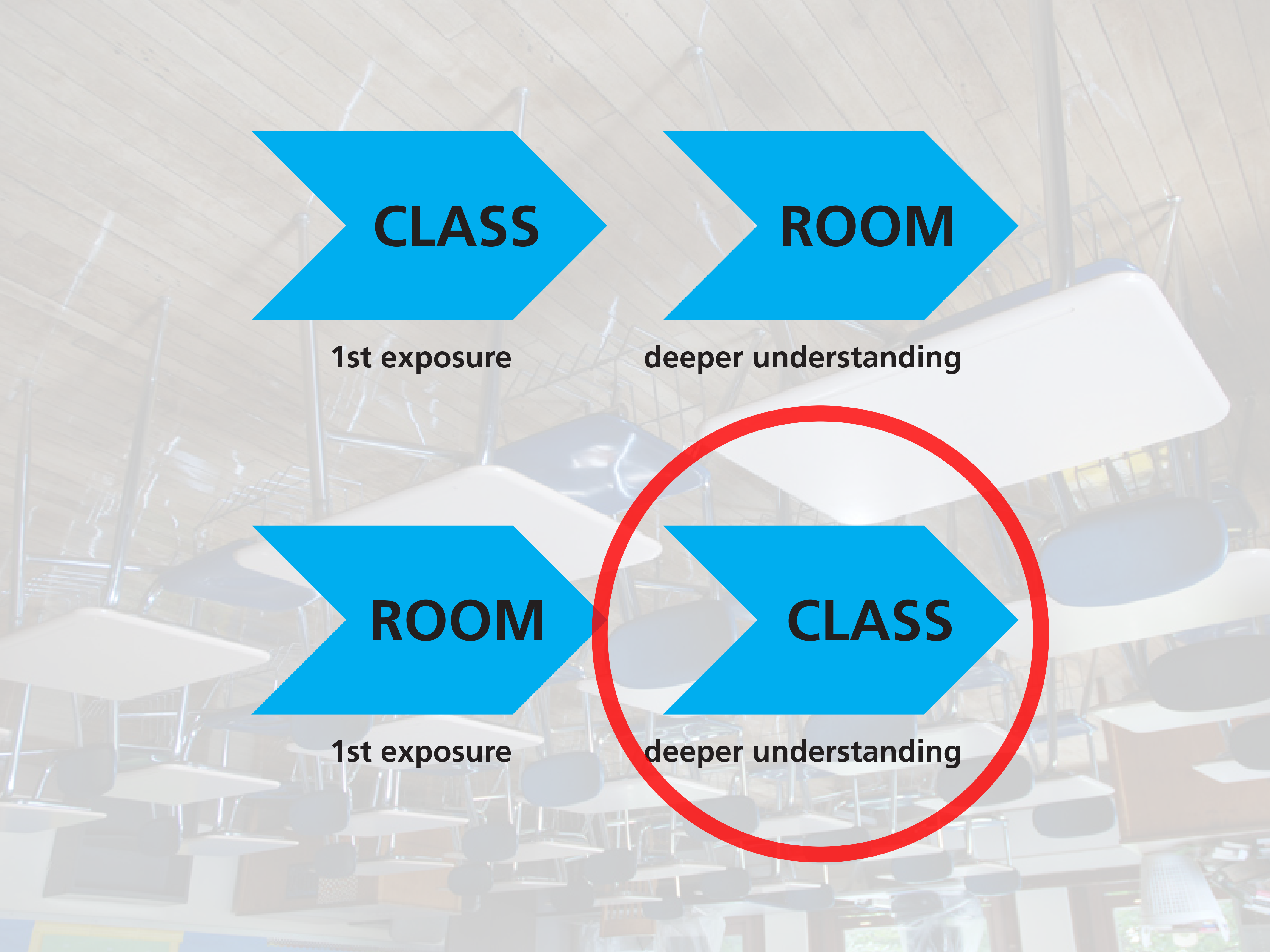

ownership

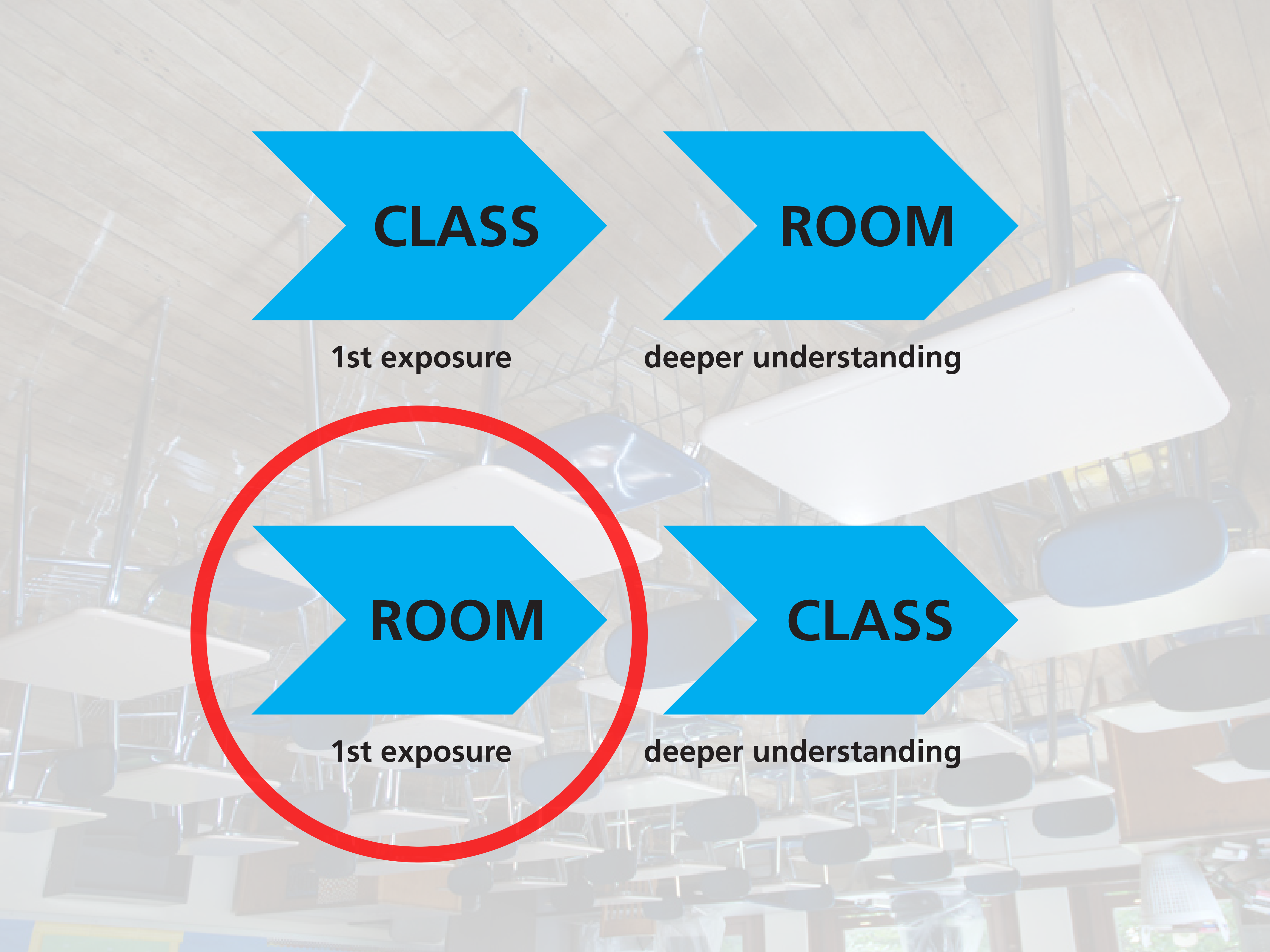
team- and project-based learning



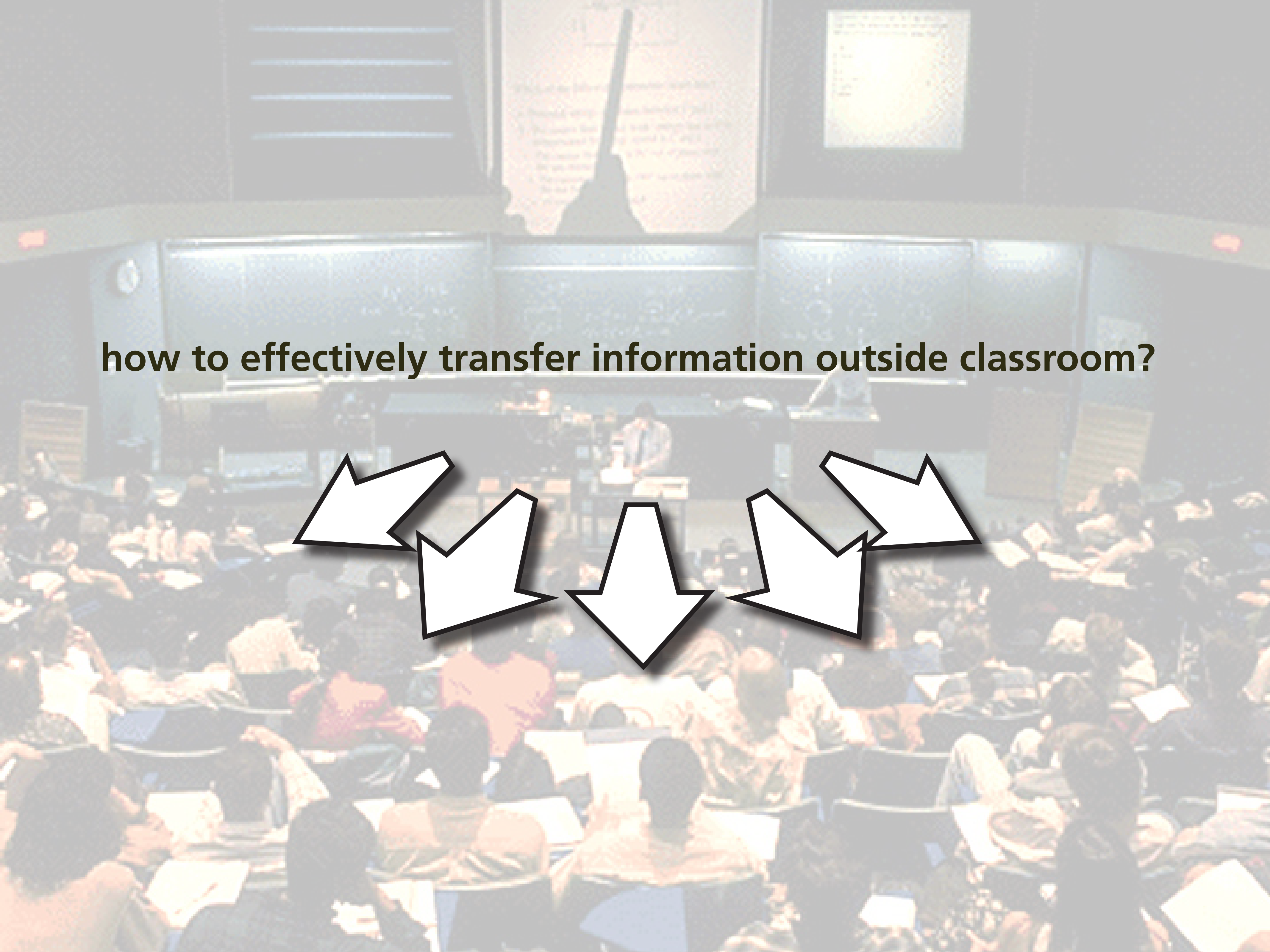
80
70
60
self-efficacy (a.u.)
pre
post
P11b

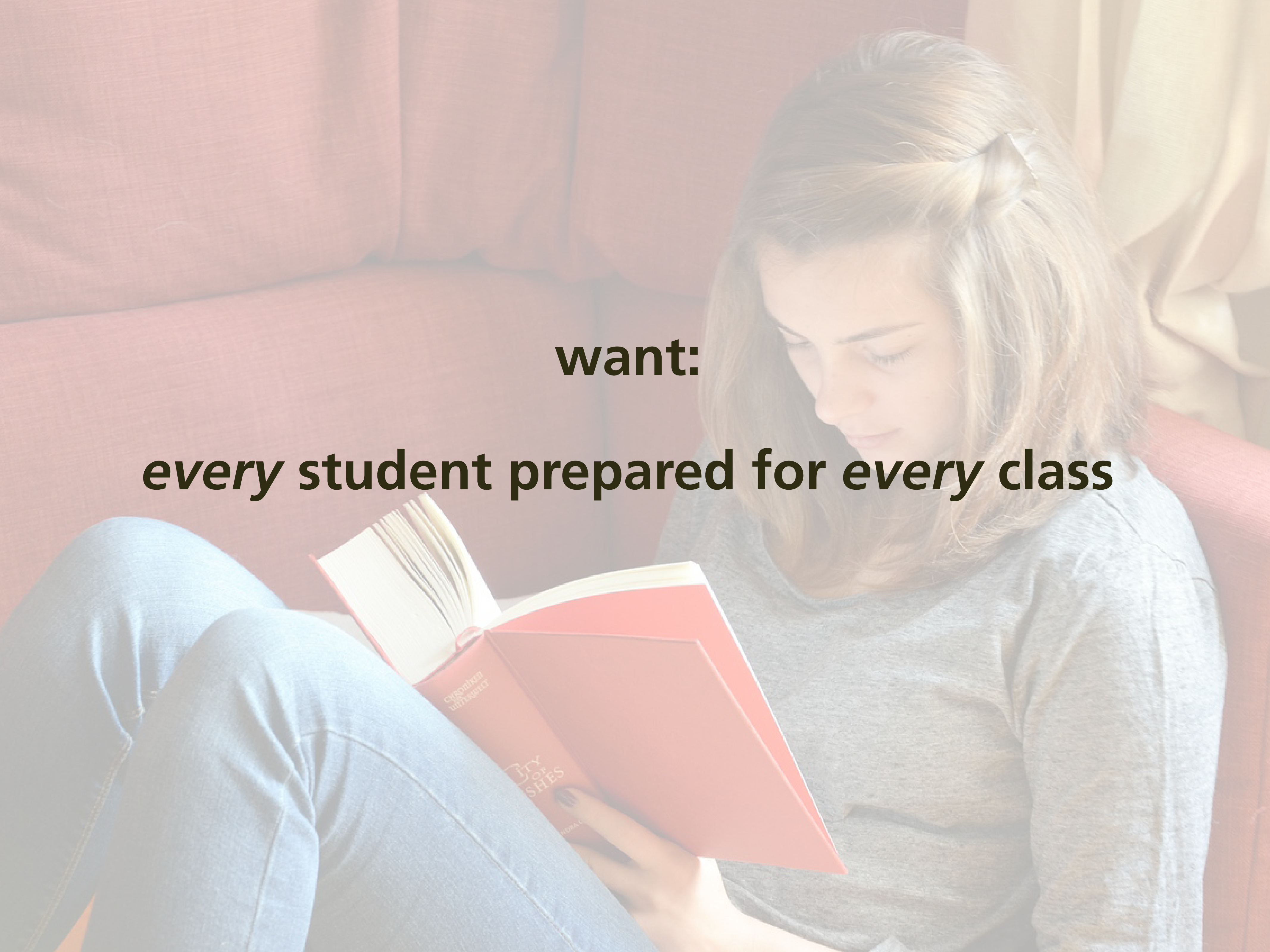

80
70
60
self-efficacy (a.u.)
pre
post
P11b
AP50b


CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding


CLASS
ROOM
1st exposure
deeper understanding
ROOM
CLASS
1st exposure
deeper understanding

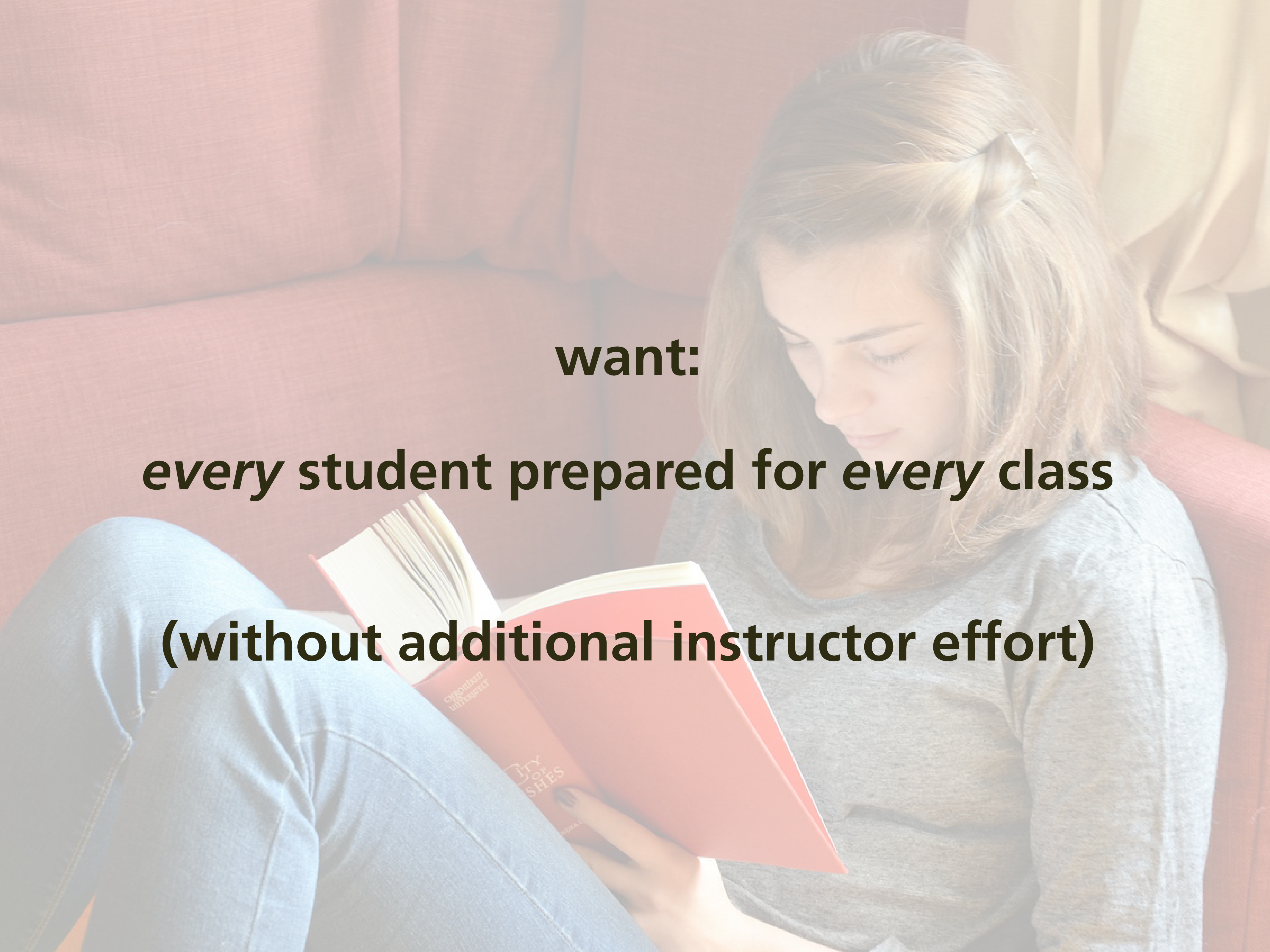
how to effectively transfer information outside classroom?





want:

every student prepared for *every* class



want:

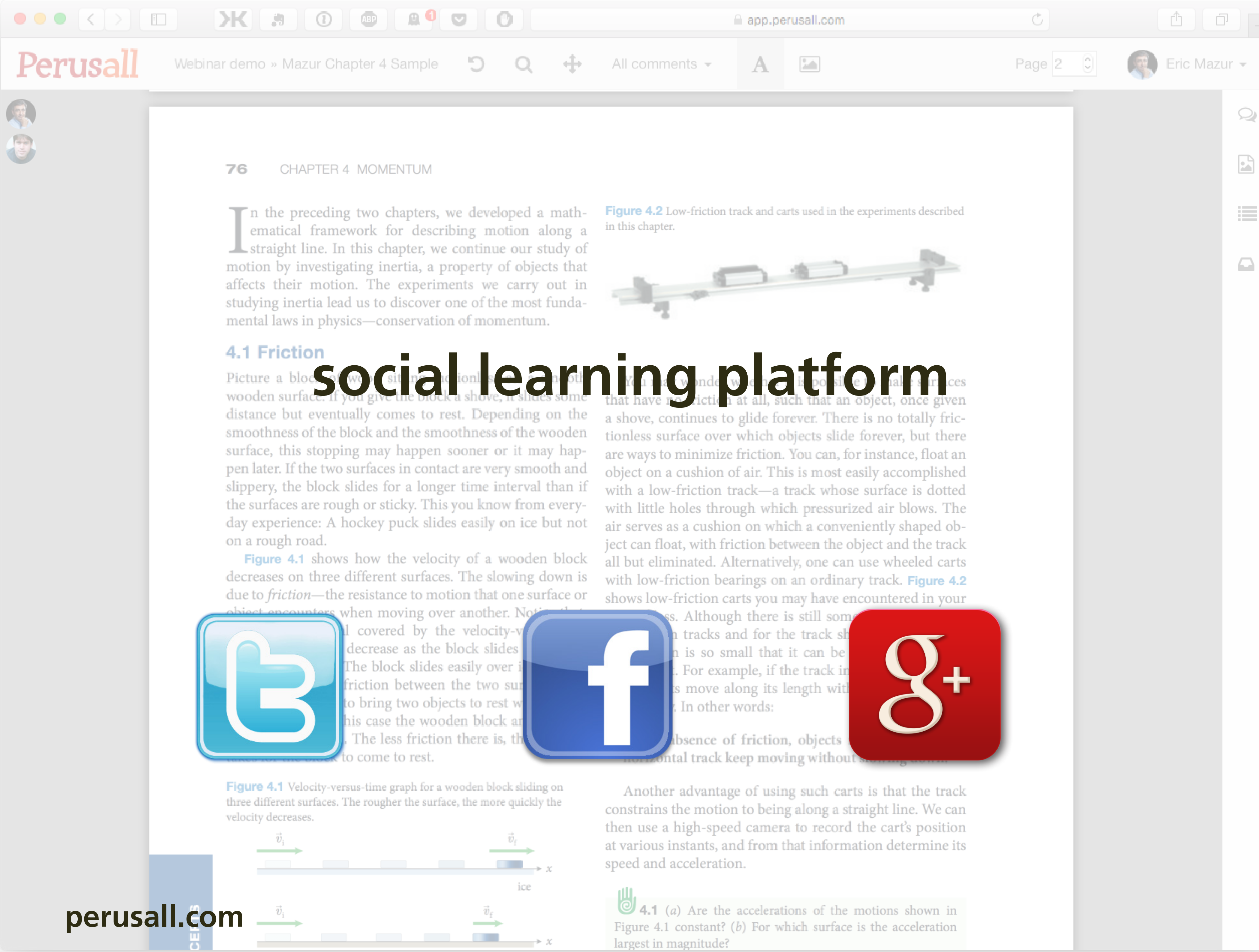
every student prepared for *every* class

(without additional instructor effort)

Solution

turn out-of-class component

also into a social interaction!



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Page 2
Eric Mazur
76 CHAPTER 4 MOMENTUM
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.
Figure 4.2 Low-friction track and carts used in the experiments described in this chapter.
4.1 Friction
social learning platform
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?
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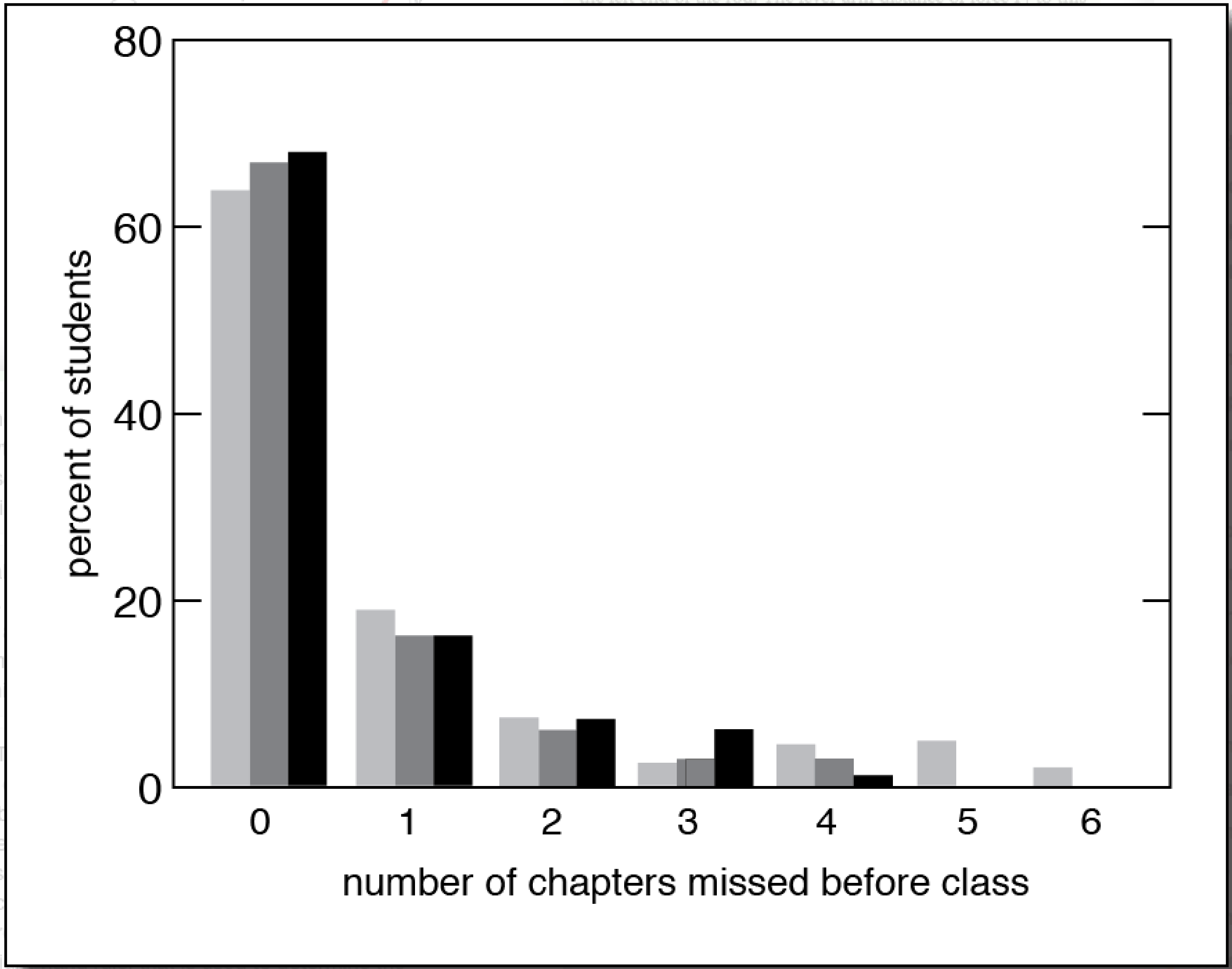
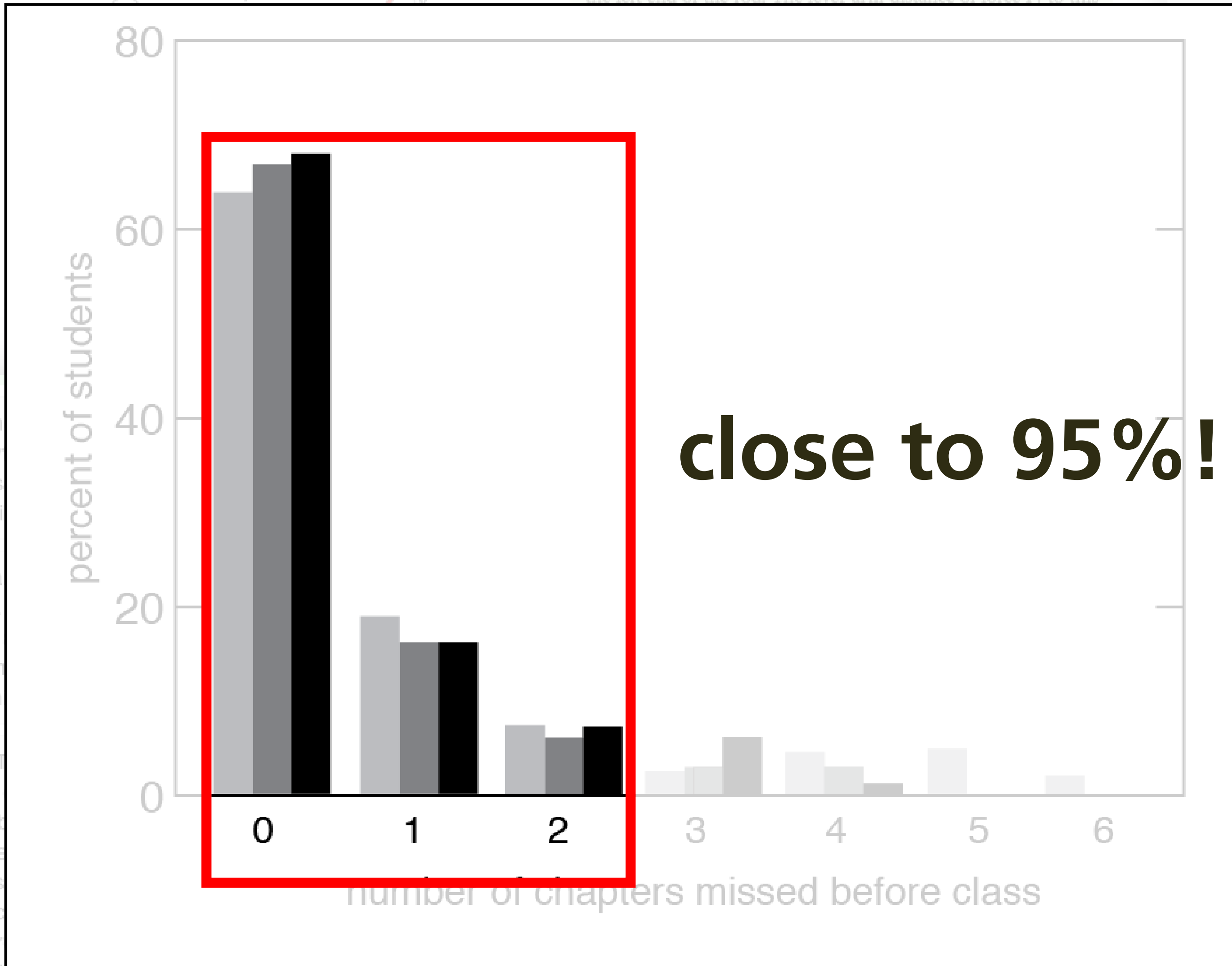
thoughtful reading and interpretation



thoughtful reading and interpretation




social engagement
in & out of classroom a must


• overwhelming evidence
• research data is essential

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