End of Lecture:
The Future of Evidence-Based Teaching

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EDUCAUSE Talk
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Poll Question #1: Which of the following best describes your position?

A. STEM faculty member
B. Non-STEM faculty member
C. Administrator
D. Educational technology specialist
E. Other
Poll Question #2: What percentage of the STEM faculty at your institution lecture for the majority of the class period?

A. 0-25%
B. 25-50%
C. 51-75%
D. 76-100%
I don’t believe that active learning can work in a large lecture. (UW professor, 8/12)

I just know that students .... (UW professor, 3/09)

Although it did not occur to us .... to collect data, we consistently observed ... (Barzilai 2000)

... we feel that our junior-senior cell biology course ... works extraordinarily well ...” (Lodish et al. 2005)

We think that our objective of teaching the students to think was well-accomplished. (Miller & Cheetham 1990)

We strongly believe that they lead to deeper understanding.... (Rosenthal 1995)
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Today’s question: Is the First Generation of Research on Undergrad STEM Education Over? 
aka: Does active learning really work?

Started this project on: 2 January 2008

“Ended” this project on: 12 May 2014

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A Meta-Analysis: Five Criteria for Admission

1. Contrast any **active learning** intervention with **traditional lecturing** (same class and institution);
   - cooperative group activities in class, worksheets/tutorials, clickers, PBL, studios …
What does a traditional lecturing classroom look like?
What does an active learning classroom look like?

Students discussing clicker questions

Instructor posing discussion questions

Instructor discussing worksheet activities with students
A Meta-Analysis: Five Criteria for Admission

1. Contrast any active learning intervention with traditional lecturing (same class and institution);
   cooperative group activities in class, worksheets/tutorials, clickers, PBL, studios …

2. Occurred in a regularly scheduled course for undergrads;

3. Limited to changes in the conduct of class sessions (or recitation/discussion);

4. Involved a course in STEM: Astronomy, Bio, Chem, CompSci, Engineering, Geo, Math, Physics, Psych, Stats;

5. Included data on some aspect of academic performance—exam/concept inventory scores or failure rates (DFW).
Poll Question #3: Which of the following studies meet the criteria for admission?

A. A physics study which compares student learning gains on the Force Concept Inventory in a class that uses clickers vs. a class that uses colored cards

B. A geology study which compares a class where students had weekly graded online homework to a class where students did not

C. A biology study which examines how students perform on clicker questions after they engage in discussion with their peers

D. A math study which compares student learning in a recitation section that includes worksheet activities vs a section where the instructor shows students how to work problems
Searching

1. Hand-search (read titles/abstracts) every issue in 55 STEM education journals from 6/1/1998 to 1/1/2010;

2. Query seven online databases using 16 terms;

3. Mine 42 bibliographies and qualitative or quantitative reviews;

4. “Snowballing”—check citation lists of all pubs in study.
Coding 642 papers—one researcher reads

Do they meet the 5 criteria?

- 244 “easy rejects”
- 398 two coders

Reject

- confirm 5 criteria?
- identical assessment, if exam data?

Yes

- students?
- instructor?

No

- meta-analyzable data? (exam scores; DFW)

Missing data search (91 papers, 19 successful)

Data analysis: 225 studies
Results: Failure Rate Data

67 studies reported failure rate data

- Risk ratio = 1.5; **students in lecture are 1.5x more likely to fail**

- Average failure rate 21.8% vs. 33.8% = a **55% increase with lecturing**
Poll Question:
You do a study where you compare a class section taught with clickers to a class section taught without clickers.

If students in the class with clickers have a lower failure rate the data would be included in the:
A. The black bars
B. The blue bars
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If this was a biomedical randomized control trial, it would be stopped in our sample: 3,516 fewer students would fail;

~$3.5M in saved tuition.
Failure Rate Effect Sizes by Discipline

- Biology: 7 independent studies, 95% confidence interval
- Chemistry: 14 independent studies, 95% confidence interval
- Computer science: 7 independent studies, 95% confidence interval
- Engineering: 12 independent studies
- Geology: 2 independent studies
- Math: 15 independent studies
- Physics: 10 independent studies
- Overall: 67 independent studies

Reference point = traditional lecture
Poll Question #4: What is the conclusion from the graph?

A. There is a statistically significant decrease in failure rate in every STEM discipline where at least 7 studies were examined

B. There is a statistically significant decrease in failure rate in biology but not in other STEM disciplines

C. Active learning increases failure rate in geology

Active Learning Increases Student Performance Across STEM Disciplines
Active Learning Increases Student Performance on Exams Across STEM Disciplines

- Biology: 33 studies, 95% confidence interval
- Chemistry: 22 studies, 95% confidence interval
- Computer Science: 8 studies, 95% confidence interval
- Engineering: 19 studies, 95% confidence interval
- Geology: 2 studies, 95% confidence interval
- Math: 29 studies, 95% confidence interval
- Physics: 31 studies, 95% confidence interval
- Psychology: 14 studies, 95% confidence interval
- Overall: 158 studies, 95% confidence interval

- Hedges's $g$ values used to determine small, med, large effect
- In K-12, 0.2 is a large effect size
Results: Exam Data

Overall effect size = 0.47

Student performance increased in active learning classrooms by just under ½ standard deviation

• In intro STEM classes at the University of Washington
  6% increase in exam scores;
  0.3 increase in average grade

Students in 50\textsuperscript{th} percentile under lecturing would improve to 68\textsuperscript{th} percentile.
Poll Question: Which of the following can you conclude from this graph?

A. Active learning only works in small classes
B. Active learning only works in large classes
C. Active works across a variety of class sizes

Lots of great examples in the literature for how to do active learning in large classes

Resources: http://www.cwsei.ubc.ca/resources/index.html
Two Fundamental Results

• **Students in lecture sections are 1.5 times more likely to fail**, compared to students in sections that include active learning;

• **Students in traditional lecture classes have lower grades (½SD)** i.e., compared to students in active learning sections, students in traditional lecture sections have exam scores that are almost half a standard deviation lower—lowering grades by half a letter.
Active learning classroom
lower fail rate
higher grades

Traditional lecture classroom
higher fail rate
lower grades

Which class do you want to take?
Who is Taking Note of the Meta-analysis Work?
Who is Taking Note of the Meta-analysis Work: **Students!**

Can’t beat Chris Hatfield’s video

We are here

BUT!

We top the Pope baptizing aliens & Sean Connery’s soccer career
Who is Taking Note of the Meta-analysis Work: Students!

That's the biggest reason I struggled this semester. One of my classes is all about applied trig and physics, but my professor teaches by standing in front of a board and doing example problems. He didn't explain why he chose the method he did, or how he approached the problem, just stood up there, put some equations on the board, did a couple examples, and assigned us homework.

It was frustrating because the professor is a really nice guy, but that is far from how I learn. In order for me to be able to solve some of the more complex problems, I need to understand WHY we take the moment of inertia at a certain point, rather than a different one. Why we choose this process over another one... not just "well this is how we solve this one to get the right answer".

It's really impossible for a professor to win here. If he spent time on the "why", your classmates would complain that he was wasting time on boring abstract stuff that they don't need to know for the test.

Some suggestions for you since you are interested in the "why":

- Read your textbook. It probably explains a lot of things in a lot more depth than any lecture ever could.
- Leverage the Internet. If you just type your questions into Google, you'll probably find dozens of answers in written and video form. /r/homeworkhelp and the ask* subs are great when you can't find the answers on your own.
- Go to office hours. Your professor would probably be overjoyed to engage with a student who is actually interested in learning.
This meta-analysis makes a powerful case that any college or university that is teaching its STEM courses by traditional lectures is providing an inferior education to its students.
Who is Taking Note of the Meta-analysis Work: Professional Press
A US meta-analysis has put the case for active learning techniques with lecture-hall students scoring 55 percent higher than with active learning techniques.

The study, published in the journal *Science*, provides a comprehensive analysis of studies comparing understanding and retention of material in lecture hall compared to active learning techniques, finding a huge difference in results, active learning outperforming lecture hall.

“If you have a course with 100 students, replace the 50% who fail with the 50% who succeed with active learning techniques, you’re going to improve the results significantly,” said Scott Freeman, a professor at Oberlin College in Ohio, one of the study authors.
Is it really the **End of Lecture**?

Note:
In the K-12 world, effect sizes of **0.20** are considered grounds for policy interest.

Note:
Research has shown that active learning has **disproportionate benefits** for students from disadvantaged background - it closes the achievement gap.

*Is change possible in the university setting?*
1. **The Rider** is the evidence that change is good—the knowledge.

2. **The Elephant** is the emotional element—the ganas.

3. **The Path** is the tools and resources that make change possible—the how-to.
1. **The Rider** is the data.

Now we need …

2. **The Elephant** is a commitment to evidence-based teaching, and a system that rewards it.

3. **The Path** is reading, listening asking, copying … and a willingness to experiment—to start small and fail at first.
Policy-makers have been trying to advocate change from the top-down for 30 years.

If students (and parents) demanded excellence—meaning, evidence-based teaching—change would happen in a **HURRY**.
Thanks to:

Education researchers for producing the evidence that will make our faculty better teachers and our students better learners.