Traditional Lecturing:
An instructional approach that has been around a long time...
Problems in Science, Technology, Engineering, and Math (STEM) Education

Undergraduate students are struggling to learn in STEM fields
  - low content retention
  - shallow understanding
  - unable to transfer knowledge to new situations

High drop out rate (2014 CSRDE STEM retention report)
  - 46% of first-year students who declare a STEM major at the beginning graduate with a STEM degree in six years
  - Half the students who leave do so between the 1\textsuperscript{st} and 2\textsuperscript{nd} years
Answering a Call to Action: Incorporating Active Learning in the Classroom

Clicker Questions

Discussion Questions

Worksheet Activities
First Generation Research: Comparing Traditional Lecturing vs. Active Learning

Traditional Lecture vs. Clicker Questions

Common Assessment Performance/Failure Rates
Today’s question: Is the First Generation of Research on Undergrad STEM Education Over?

aka: Does active learning really work?

Started this project on: January 2008

“Ended” this project on: May 2014

Mary Pat Wenderoth  Sarah Eddy  Nnadozie Okoroafor  Scott Freeman  Michelle Smith  Hannah Jordt  Miles McDonough
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

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, Biology, Chemistry, Computer Science, Engineering, Geology, Math, Physics, Psychology, Statistics;

5. Included data on some aspect of academic performance—exam/concept inventory scores or failure rates.
Finding Articles for the Meta-Analysis

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.
642 papers-one researcher reads

Do they meet the 5 criteria?

- yes
  - two coders
  - confirm 5 criteria
    - yes
      - if exam data, identical assessment?
      - equivalent students?
      - same instructor?
      - meta-analyzable data? (failure rates, exam scores)
    - no
      - reject

- no
  - reject

244 “easy rejects”

Missing data search (91 papers, 19 successful)

Data analysis: 225 studies
Results: 67 Studies Report Failure Rate

Data

Increased failure

Decreased failure

Number of Studies

Percent Change in Failure Rate with Active Learning

A
Active Learning Decreases Failure Rate

- Average failure rate 21.8% active learning vs. 33.8% traditional lecturing
- Risk ratio = 1.5; **students in traditional lecture courses are 1.5x more likely to fail**

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
Active Learning Increases Student Performance on Exams Across Disciplines

Number of independent studies

95% confidence interval

Overall effect size = 0.47
Students in active learning classes have higher grades (½ SD or ~half a letter grade)

Used to determine effect size
Units=SD
In K-12, 0.2 is a notable effect size
Two Fundamental Results About Active Learning

• Students in active learning classes are 1.5 times more likely to pass, compared to students in sections that use traditional lecturing.

• Students in active learning classes have higher grades (½ SD) compared to students in traditional lecture sections, students in active learning sections have exam scores that are almost half a standard deviation higher—raising grades by half a letter.
One Active Learning Strategy: Clickers
How do you use a clicker?

- Turn it on (you can leave it on for the entire time)

- Press A, B, C, D, or E

- You can change your answer, only the last one entered counts
I ask ~4 questions in a 50 minute period, students get points for participating
Your sister calls to say that she’s having twins. Which of the following is the most likely? Assume she’s not having identical twins

A) Twin boys
B) Twin girls
C) One girl and one boy
D) All are equally likely
Your sister calls to say that she’s having twins. Which of the following is the most likely? Assume she’s not having identical twins.

A) Twin boys
B) Twin girls
C) One girl and one boy
D) All are equally likely

Probability of boy = 1/2; of girl = 1/2, for any one embryo.

Girl/Girl is 1/4
Girl/Boy is 1/4
Boy/Girl is 1/4
Boy/Boy is 1/4
Clicker Questions and Peer Discussion

Students answer a clicker question individually

Students talk to neighbors and answer the same clicker question again

Are students just copying their “knowledgeable” neighbor rather than actually learning from the discussion?

Physicist
Eric Mazur, 1997
http://vig-fp.prenhall.com/bigcovers/0135654416.jpg
Students answer a clicker question individually (Q1).

Students talk to neighbors and answer Q1 again (Q1\textsubscript{AD} for Q1 “After Discussion”).

Students answer a different question individually (Q2). Q2 is asking about the same concept as Q1.

n = 350 students
What is the recombination frequency between the *black* and *green* genes?

A. 0.15  
B. 0.13  
C. 0.28  
D. 0.51  
E. 0.72

*Wild-type female*  
\[ b^+ b, \ g^+ g \]  

*Black, green eye male*  
\[ b\ b, \ g\ g \]  

**Offspring:**  
- 36 wild-type  
- 36 black, green eyes  
- 15 gray, green eyes  
- 13 black, white eyes

100 total fish

Normal dominant over mutant for both

\[ b = \text{mutant version of black} \]  
\[ b^+ = \text{normal version of black} \]  
\[ g = \text{mutant version of green} \]  
\[ g^+ = \text{normal version of green} \]
What is the recombination frequency between curly and purple genes?

A. 0.16  
B. 0.32  
C. 0.49  
D. 0.52  
E. 0.68

Offspring:

155 Wild-type  
165 curly wings, purple eyes  
330 normal wings, purple eyes  
350 curly wings, normal eyes

1,000 total flies

Normal dominant over mutant for both curly and purple genes.
Students answer a clicker question individually (Q1).

Students talk to neighbors and answer Q1 again (Q1\textsubscript{AD} for Q1 “After Discussion”).

Students answer a different question individually (Q2). Q2 is asking about the same concept as Q1.

The histograms are displayed for the first time and the answers to Q1/Q1\textsubscript{AD} and Q2 are explained to students.

Predict the results
A. Q2 scores > Q1\textsubscript{AD}
B. Q2 scores = Q1\textsubscript{AD}
C. Q2 scores < Q1\textsubscript{AD}

n= 350 students
Experimental Design

Students answer a clicker question individually (Q1).

Students talk to neighbors and answer Q1 again (Q$_{1\text{AD}}$ for Q1 “After Discussion”).

Students answer a different question individually (Q2). Q2 is asking about the same concept as Q1.

The histograms are displayed for the first time and the answers to Q1/Q$_{1\text{AD}}$ and Q2 are explained to students.

n= 350 students
“I skip peer discussion, because my explanation to clicker questions is clearer and more informative than what students hear in conversations with each other.”
Which presentation mode leads to the greatest improvement in student performance:

1. Having a peer discussion
2. Listening to an instructor explanation
3. Engaging in peer discussion followed by an instructor explanation (combination)
Students answer a question individually (Q1) followed by either:

- **Peer Discussion**

\[ Q_{1_{AD}} \]

- **Instructor Explanation**

Students answer a similar question individually (Q2)

- **Combination of Peer Discussion and Instructor Explanation**

\[ Q_{1_{AD}} \]

**Learning gain** = How much performance increased/possible increase

**-With your neighbor, predict the outcome by drawing in the bar graph**
Combination of Peer Discussion and Instructor Explanation Improves Student Understanding

Students answer a question individually (Q1) followed by either:

- Peer Discussion
- Instructor Explanation

Students answer a similar question individually (Q2)

Learning gain = How much performance increased/possible increase

Combination of Peer Discussion and Instructor Explanation

Majors Genetics

Mean Q1 to Q2 Learning Gain

- Peer Discussion
- Inst. Explain
- Combination
How Can You Encourage Students to Talk?

• Write challenging clicker questions
  – Move away from simple quizzes—do not just test memorized facts
  – Use questions that emphasize reasoning or process
  – Use images for answer choices
  – Use tempting wrong answers

• Keep encouraging students to talk

• Show students how talking to their neighbor benefits them