End of Lecture: The Future of Evidence-Based Teaching

Mary Pat Wenderoth
University of Washington
Discussion Question:

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

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

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

We strongly believe that lecture leads to deeper understanding.... (Rosenthal 1995)
We think that our objective of teaching the students to think was well-accomplished. (Miller & Cheetham 1990)

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

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

We strongly believe that lecture leads to deeper understanding.... (Rosenthal 1995)
Discussion Question:

What is active learning?
(aka Evidence-Based Teaching)
Characteristics of active learning strategies

1. Students involved in learning.
2. Students engaged in activities
3. Less information transmission and greater focus on cognitive skills
4. Student motivated to learn.
5. Students have immediate feedback from instructor
6. Students use higher order thinking (analysis, synthesis, evaluation)

Does active learning really work?

Is there DATA?

Started project: 2 January 2008

“Ended” project: 12 May 2014

Scott Freeman, Sarah L. Eddy, Miles McDonough, Michelle K. Smith, Nnadozie Okoroafor, Hannah Jordt, & Mary Pat Wenderoth. 2014
A meta-analysis:
**Five criteria** for admission

1. active learning vs traditional lecturing
2. regularly scheduled course
3. conduct of class sessions
4. undergraduate STEM courses
5. data on academic performance
   DFW or Exam scores
1. Hand-search every issue 55 STEM education journals from 6/1/1998 to 1/1/2010; (read titles/abstracts)

2. Query seven online databases using 16 terms;

3. Mine 42 bibliographies and qualitative or quantitative reviews;

4. “Snowballing”
A meta-analysis:  
**Five criteria** for admission
A meta-analysis:

**Five criteria** for admission

1. active learning vs traditional lecturing
2. regularly scheduled course
3. conduct of class sessions
4. undergraduate STEM courses
5. data on academic performance
Coding: **642** papers—one researcher reads

Do they meet 5 criteria?

- **no**
  - 244 “easy rejects”
  - **no**
    - reject

- **yes**
  - 398 two coders (SF + MPW, MKS, MM, DO, HJ)
    - confirm 5 criteria
      - identical assessments?
      - student academic ability?
      - instructor?
      - meta-analyzable data? *(DFW: exam scores)*
  - **no**
    - Missing data search (91 papers, 19 successful)

Data analysis: **225** studies
Results:

Failure Rate DFW
(67 studies)

Risk ratio = 1.5;
students in lecture are 1.5x more likely to fail
Results: Failure Rate
(67 studies)

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 by Discipline

<table>
<thead>
<tr>
<th>STEM Discipline</th>
<th>Number of Independent Studies</th>
<th>95% Confidence Interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biology</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Chemistry</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>CS</td>
<td>7</td>
<td>7</td>
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<tr>
<td>Engineering</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td>Geology</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Math</td>
<td>15</td>
<td>12</td>
</tr>
<tr>
<td>Physics</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Overall</td>
<td>67</td>
<td>67</td>
</tr>
</tbody>
</table>

Traditional lecture
What is conclusion from this data?

There is a statistically significant decrease in failure rate in:

1. every STEM discipline > 7 studies
2. biology but not other STEM disciplines
There is a statistically significant decrease in failure rate in:

1. every STEM discipline (≥ 7 studies)
2. biology but not other STEM disciplines

What is conclusion from this data?
Student Performance: **Exams**

- **Biology**: 33 studies
- **Chemistry**: 22 studies
- **Computer Science**: 8 studies
- **Engineering**: 19 studies
- **Geology**: 2 studies
- **Math**: 29 studies
- **Physics**: 31 studies
- **Psychology**: 14 studies
- **Overall**: 158 studies

95% confidence interval

Number of independent studies

Used to determine small, med, large effect size

In K-12, 0.2 is large effect size
Student Performance: **Exams**

In which disciplines does Active Learning improve exam performance?

1. All disciplines
2. Only CS and Geology
3. All but CS and Geology
In which disciplines does Active Learning improve exam performance?

1. All disciplines
2. Only CS and Geology
3. All but CS and Geology
Results: Exam Data

Overall effect size = 0.47

With active learning, exam scores increase by about half a SD

In intro STEM classes @ University of Washington

6% increase in exam scores;
0.3 increase in average grade (4.0 scale)
Which of the following can you conclude from this graph?

Active learning works
1. only in small classes
2. only in large classes
3. across a variety of class sizes
Which of the following can you conclude from this graph?

Active learning works
1. only in small classes
2. only in large classes
3. across a variety of class sizes
Which class do you want to take?

1  
Active Learning course
lower fail rate
higher grades

2  
Traditional lecture course
higher fail rate
lower grades
Active learning increases student performance in science, engineering, and mathematics

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

*Department of Biology, University of Washington, Seattle, WA 98195; and *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)

As of April 7, 2016

Downloads

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<tbody>
<tr>
<td>PDF</td>
<td>69,315</td>
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</tbody>
</table>

Altmetric Score

99% of all PNAS articles of similar age
99% of all tracked Journal articles of similar age
Active learning increases student performance in science, engineering, and mathematics

Scott Freeman\textsuperscript{a,1}, Sarah L. Eddy\textsuperscript{a}, Miles McDonough\textsuperscript{a}, Michelle K. Smith\textsuperscript{b}, Nnadozie Okoroafor\textsuperscript{a}, Hannah Jordt\textsuperscript{a}, and Mary Pat Wenderoth\textsuperscript{a}

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NY Times letter
What does traditional lecturing look like in a classroom?
What does active learning look like in a classroom?

Instructor posing questions

Students discussing clicker questions

Instructor discussing worksheets with students
Key Elements of Active Learning

1. Practice with feedback

2. Accountability

“Ask, Don’t Tell”

Practical Observation Rubric to Assess Active Learning:
PORTAAL  Eddy, Converse, Wenderoth 2015 CBE-LSE
Practice with feedback

Effective use of clickers

1. Pose a challenging question (< 60% correct)
2. Students answer alone
3. Do not show results
4. Peer discussion
5. Revote
6. Instructor led student debrief

Smith et al. Science 2009
Smith et al. CBE- Life Science Education 2011
Mazur Peer- Instruction
Accountability & Equity

1. Pose a challenging question
2. Allow peer discussion
3. Call on a student to answer

Volunteer or random call?
In Intro biology courses at UW, females are 60% of class.

What % of students who volunteer to answer instructor’s questions are female?

1. ~ 60%
2. > 60%
3. < 60%
Using Random Call

Males Under-Estimate Academic Performance of Their Female Peers in Undergraduate Biology Classrooms

Daniel Z. Grunspan¹, Sarah L. Eddy², Sara E. Brownell³, Benjamin L. Wiggins⁴, Alison J. Crowe⁴, Steven M. Goodreau¹
Does Active Learning only help the bottom of the class?

2003

2005
+ Clicker Q
+ reading quiz

Freeman et al. 2007
### Increased Course Structure Improves Performance in Introductory Biology

<table>
<thead>
<tr>
<th>LOW</th>
<th>MEDIUM</th>
<th>HIGH</th>
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<tbody>
<tr>
<td>Fall 2002</td>
<td>Spring 2005</td>
<td>Fall 2009</td>
</tr>
<tr>
<td>lecturing</td>
<td>lecturing</td>
<td>No lecturing (at all)</td>
</tr>
<tr>
<td>Socratic method</td>
<td>clicker Q</td>
<td>6+ clicker Q</td>
</tr>
<tr>
<td></td>
<td>reading Q</td>
<td>weekly practice exam</td>
</tr>
<tr>
<td></td>
<td></td>
<td>daily reading Q</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 random calls</td>
</tr>
</tbody>
</table>

Bloom ALL exam questions from Fall 2002 - 2009

Bloom level increased from 2.7 to 3.1

Freeman, Hake, & Wenderoth (2011) CBE—LSE 10, 175–186
Key element of active learning

“Ask, Don’t Tell”

The person doing the talking is doing the learning.

Become a Cognitive Coach.
Why is active learning more effective?

Cognitive Science Research

McDaniel @ Wash U.
Roediger @ Wash U
Bjork @ UCLA
Karpicke @ Purdue
Schwartz @ Stanford
Chi @ ASU
Dweck @ Stanford
Beilock @ U. Chicago
12 word pairs  
Swahili-- English

<table>
<thead>
<tr>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
<th>Group 4</th>
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<tbody>
<tr>
<td>S</td>
<td>S</td>
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<tr>
<td>S</td>
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<td>T</td>
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</table>

S = study word pairs for 5 sec each
T = Swahili word only- you fill in English word-
No feedback
12 word pairs
Swahili-- English

Who thought they would do best?
Who did best?

<table>
<thead>
<tr>
<th>Group 1 -- S</th>
<th>S</th>
<th>S</th>
<th>S</th>
<th>S</th>
<th>Test</th>
</tr>
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<tbody>
<tr>
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<td>S</td>
<td>S</td>
<td>T</td>
<td>T</td>
<td>Test</td>
</tr>
<tr>
<td>Group 3 -- S</td>
<td>S</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>Test</td>
</tr>
<tr>
<td>Group 4 -- S</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>Test</td>
</tr>
</tbody>
</table>

S = study word pairs for 5 sec each
T = Swahili word only- you fill in English word
12 word pairs  Swahili-- English

Who thought they would do best?
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<table>
<thead>
<tr>
<th>Group 1</th>
<th>S</th>
<th>S</th>
<th>S</th>
<th>S</th>
<th>Test</th>
<th>----</th>
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<tbody>
<tr>
<td>Group 2</td>
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<td>S</td>
<td>T</td>
<td>Test</td>
<td>----</td>
<td>Test</td>
</tr>
<tr>
<td>Group 3</td>
<td>S</td>
<td>S</td>
<td>T</td>
<td>T</td>
<td>Test</td>
<td>----</td>
<td>Test</td>
</tr>
<tr>
<td>Group 4</td>
<td>S</td>
<td>T</td>
<td>T</td>
<td>T</td>
<td>Test</td>
<td>----</td>
<td>Test</td>
</tr>
</tbody>
</table>

Learners poor judges of their learning

“Testing Effect”-- Retrieval
Testing enhances learning

<table>
<thead>
<tr>
<th>Condition</th>
<th>5 min</th>
<th>1 week</th>
<th>Forgetting</th>
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<tbody>
<tr>
<td>SSSS</td>
<td>.83</td>
<td>.40</td>
<td>.43</td>
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<tr>
<td>SSST</td>
<td>.78</td>
<td>.56</td>
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<tr>
<td>STTT</td>
<td>.71</td>
<td>.61</td>
<td>.10</td>
</tr>
</tbody>
</table>
“Deliberate Practice”
K. A. Ericsson

1. Activity **designed specifically** to improve performance
2. It can be **repeated** a lot
3. Continuous **feedback**
4. Mentally **demanding**
5. Isn’t fun
“Ask, Don’t Tell”

Questioning is form of testing.

Challenging students to solve problems is deliberate practice.
References


How People Learn
Peer Instruction
How We Learn
Self-Theories
Choke
Switch
Thanks to Education researchers for producing the evidence that will make our faculty better teachers and our students better learners.
Questions
Questions
Impact on the Achievement Gap

UNC - Intro Biology course
3yr Traditional vs 2 yr Active Learning

Regression model ---- PREDICTED EXAM performance
Compare 4 students with same SAT math & reading score

Black vs White student
First gen. vs Continuing

Eddy and Hogan 2014 CBE-LSE
Take home message

Active Learning = \uparrow \text{performance for}\ \textit{ALL} \text{ students}

Disproportionate increase for
African-American students
First-Generation students
What would you do?

A job candidate presents his/her research seminar

While listening to their talk you realize that

- They have ignored the research literature of the past 40 years
- They are using methods that are 700 years old
- These methods are known to be ineffective

Would you hire them?
End of Lecture?

The Future of Evidence-Based Teaching

Mary Pat Wenderoth—H. Rossi Lecture- Univ Utah 5-8-2016