Workshop: Active Learning

CTL Teaching+Learning Lunch
Spring 2023

Marty Samuels, msamuels@brandeis.edu
he/him/his
What is **active learning**, and why should we use it?
Passive vs Active Learning

**Passive learning:** Students listen to a traditional lecture, watch a video, or read a book.

**Active learning:** Students perform activities during class that inspire student learning by asking them to reflect upon, discuss, and apply the course material.
Meta-analysis of 225 controlled experiments comparing student performance in STEM courses under traditional lecturing or active learning (AL).

Measured student performance by reporting either student exam scores or failure rates.
Active learning increases student performance in science, engineering, and mathematics

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![Diagram showing exam scores for Biology and Chemistry with effect size calculation]

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\textbf{Exam scores:}

\begin{itemize}
  \item Biology: 33
  \item Chemistry: 22
  \item Computer Science: 8
\end{itemize}

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Exam scores:

- Biology: 33
- Chemistry: 22
- Computer Science: 8
- Engineering: 19
- Geology: 2

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• Meta-analysis of 225 controlled experiments comparing student performance in STEM courses under traditional lecturing or active learning (AL).
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Found:
AL improves student performance more than traditional lecture
• AL improves average exam scores improved by about 6%.
• These results hold across the STEM disciplines.
• AL is effective across all class sizes

Effect of active learning versus traditional lecturing on the learning achievement of college students in humanities and social sciences: a meta-analysis

Anastassis Kozanitis1, 2 · Lucian Nenciovici1

Accepted: 25 November 2022 © The Author(s) 2022

Abstract
A previous meta-analysis found that active learning has a positive impact on learning achievements for college students in STEM fields of study. However, no similar meta-analyses have been conducted in the humanities and social sciences. Because major dissimilarities may exist between different fields or domain of knowledge, there can be issues with transferring research findings or knowledge across fields. We therefore meta-analyzed 104 studies that used assessment scores to compare the learning achieved by college students in humanities and social science programs under active instruction versus traditional lecturing. Student performance on assessment scores was found to be higher by 0.489 standard deviations under active instruction ($Z = 6.521, p < 0.001, k = 111, N = 15,896$). The relative beneficial effect of active instruction was found to be higher for some course subject matters (i.e., Sociology, Psychology, Language, Education, and Economics), for smaller ($\leq 20$ students) rather than larger class or group sizes, and for upper level rather than introductory courses. Analyses further suggest that these findings are not affected by publication bias.
Active learning increases student performance in science, engineering, and mathematics. There are also at least two ways to view an odds ratio of 1.95 for the risk of failing a STEM course:

1) If the experiments analyzed here had been conducted as randomized controlled trials of medical interventions, they may have been stopped for benefit—meaning that enrolling patients in the control condition might be discontinued because the treatment being tested was clearly more beneficial. For example, a recent analysis of 143 randomized controlled medical trials that were stopped for benefit found that they had a median relative risk of 0.52, with a range of 0.22 to 0.66 (15). In addition, best-practice directives suggest that data management committees may allow such studies to stop for benefit if interim analyses have large sample sizes and $P$ values under 0.001 (16). Both criteria were met for failure rates

"Effect size" = (AL - Trad. Lec.) / SD

So let’s get familiar with some active learning techniques!

In a small group:

1. You will receive a set of 3-5 active learning techniques (and some examples).

2. Discuss each technique.
   - Generally speaking, what kinds of skills or topics could you teach with each technique?
   - When or why during class would each technique be most useful?
   - What are the strengths and weaknesses of each activity? When would these activities be most useful?
   - What do you think students will learn by doing each technique?
   - How would you deploy each technique in class?

3. Identify one strategy that is your favorite and be ready to share it.
Examples of active learning techniques

1. Activities to Learn Concepts and Practice Skills Taught in Class
   a. Doing Practice Problems or Discussing Guiding Questions to Analyze a Text in Small Groups
   b. Statement Correction, or Intentional Mistakes
   c. Strip Sequence, or Sequence Reconstruction of a process, argument, or dialogue

2. Activities to Increase Student Involvement, Engagement, and Inclusion
   a. Minute Paper, or Quick Write
   b. Think-Pair-Share
   c. Anonymous Cards
   d. Brainstorm
   e. Polling

3. Activities to Help Students Synthesize and Review a Week’s Worth of Content
   a. Concept Map
   b. Venn Diagram
   c. Compare and Contrast
Active Learning

Almost any activity, preferably one that is cooperative and with timely feedback, that requires students to recall, think about, apply, and verbalize concepts.

As students participate in these activities, they construct new knowledge and build new skills.
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As students participate in these activities, they construct new knowledge and build new skills.

“Anything that involves students in doing things and thinking about the things they are doing.”

-Bonwell & Eison, (1991)
Students **Fail Less** and **Learn More** through Active Learning

Students *Fail Less* and *Learn More* through Active Learning

Data from Freeman S *et al.* *Proc Natl Acad Sci U S A.* 2014 Jun 10; 111(23): 8410-5.
Example Study of “Traditional Lecture” vs “Active Learning”


**Figure 1.** Final course point distributions (% of possible maximum) in traditional (F’ 03, blue) and interactive (S’04, red) classes. The number of students achieving a final score is shown for five ranges of scores.
Example Study of “Traditional Lecture” vs “Active Learning”

Active learning decreases performance gaps


Active learning decreases performance gaps


Active learning decreases performance gaps


Active learning decreases performance gaps


Research comparing the two methods has consistently found that students overall perform better in active-learning courses than in traditional lecture courses. However, women, minorities, and low-income and first-generation students benefit more, on average, than white males from more affluent, educated families.
Benefits of using active learning

- Improves exam scores (+6%) (Freeman et al., 2014; Kozanitis and Nenciovici, 2022.)

- Students are less likely to fail vs. traditional lecturing (Freeman et al., 2014)

- Decreases achievement gap for first generation and underrepresented students (Eddy and Hogan, 2014; Ballen et al., 2017)

No Sleeping Students

It's fun!
Active Learning Applies the “Constructivist” View of Learning

**Transmissionist** view of learning (**Passive**)

**Lecturer:** I know a lot about this topic, so I will transmit my knowledge to you by telling you about it.
Active Learning Applies the “Constructivist” View of Learning

Transmissionist view of learning (Passive)

Lecturer: I know a lot about this topic, so I will transmit my knowledge to you by telling you about it.
Active Learning Applies the “Constructivist” View of Learning

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Lecturer: I know a lot about this topic, so I will transmit my knowledge to you by telling you about it.

Constructivist view of learning (Active)

Facilitator: I know a lot about this topic, so I will create situations and present challenges for you so that you construct your own knowledge and understanding.
Active Learning Applies the “Constructivist” View of Learning

**Transmisionist** view of learning (Passive)

*Lecturer:* I know a lot about this topic, so I will transmit my knowledge to you by telling you about it.

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**Constructivist** view of learning (Active)

*Facilitator:* I know a lot about this topic, so I will create situations and present challenges for you so that you construct your own knowledge and understanding.

“students encounter safe yet challenging conditions in which they can try, fail, receive feedback, and try again without facing a summative evaluation.”

-Ken Bain, *What the Best College Teachers Do*
Let’s Practice Making Some Active Learning Exercises!

1. Choose a topic you have taught or expect to teach.

2. From the list of activities, choose one of the active learning techniques that is new to you.

3. Spend a few minutes planning an activity that you could use to help your students learn your chosen topic.
How often should I do active learning?
Student engagement during class time

BERI:
Behavioral Engagement Related to Instruction

COPUS: Characterizes student and instructor behaviors during class

Student codes used:
- L-Listening
- Ind-Individual thinking
- CG- Clicker question discussion
- WG- Worksheet group work
- AnQ- Answer instructor question
- SQ- Student asks a question

Instructor codes used:
- Lec-Lecturing
- RtW- Real-time writing
- FU- Follow-up
- PQ- Pose questions
- CQ- Clicker questions
- AnQ- Answer questions
- MG- Moving through the classroom
- 1o1- One on one discussions with students
- Adm- Administration

Lecture-based course

Students are doing:

Instructors are doing:

2 example courses

COPUS: Characterizes student and instructor behaviors during class

2 example courses

Energy II

What’s a pirate’s favorite amino acid?

ARRRRGININE

a pirate’s favorite amino acid

LPS A

Biology 2e, Chapter 6
**Learning Goal:** To understand the relationship between the free energy change of a chemical reaction and its equilibrium constant, and to understand how enzymes affect reactions.

**Learning Objectives:**

- Define “chemical equilibrium.”

- Interpret a free energy diagram to determine whether products or reactants will be favored at equilibrium.

- Relate the concepts of $K_{eq}$ and $\Delta G^*$ to the spontaneity of a reaction.

- Calculate a $K_{eq}$ value from a $\Delta G^*$ value, and vice versa.

- Write a rate expression of a one-step chemical reaction and determine when a reaction is fastest.

- Identify $\Delta G^*$ and $E_A$ on a free energy diagram.

- Use a free energy diagram to describe how an enzyme catalyzes a chemical reaction.

- Describe the molecular mechanism by which an enzyme works.
At equilibrium, the rate of the forward reaction equals the rate of the reverse reaction.

- At equilibrium, the concentrations of reactants and products stop changing.

  - Rate of a reaction = $k \times [\text{reactant}]$
  - We call $k$ the rate constant.

- Different reactions have different rate constants.
- The larger the rate constant, the faster the reaction.

For reaction $A + B \rightarrow C$,
the rate of the reaction = $k[A][B]$. 

An example
Since the forward and reverse rates are equal at equilibrium, we can also solve for the $K_{eq}$ in terms of the rate constants.

- For the reaction $A + B \rightleftharpoons C + D$

there are two rate constants.

- $k_{for}$ is the rate constant for the “forward” reaction (the conversion of reactants $A$ and $B$ into products $C$ and $D$)

- $k_{rev}$ is the rate constant for the “reverse” reaction

Working with a neighbor, write an expression of $K_{eq}$ for this reaction.

Next, write the rate equations for both the forward and reverse rates.

Finally, substitute your rate equations into your $K_{eq}$ expression, and solve for $K_{eq}$ in terms of the rate constants.
When is the forward rate the fastest? When is the reverse rate the fastest?

Consider the favorable reaction diagrammed below. The reaction began with pure reactant (i.e., no product was initially present).

Working with a neighbor, answer questions 1 - 3 below.

1. At which time (A, B, or C) is the forward rate the fastest?

2. At which time (A, B, or C) is the reverse rate the fastest?

3. At which time (A, B, or C) are the forward and reverse rates equivalent?
Learning Goal: To understand the relationship between the free energy change of a chemical reaction and its equilibrium constant, and to understand how enzymes affect reactions.

Learning Objectives:
• Define “chemical equilibrium.”

• Interpret a free energy diagram to determine whether products or reactants will be favored at equilibrium.

• Relate the concepts of $K_{eq}$ and $\Delta G^*$ to the spontaneity of a reaction.

• Calculate a $K_{eq}$ value from a $\Delta G^*$ value, and vice versa.

• Write a rate expression of a one-step chemical reaction and determine when a reaction is fastest.

• Identify $\Delta G^*$ and $E_A$ on a free energy diagram.

• Use a free energy diagram to describe how an enzyme catalyzes a chemical reaction.

• Describe the molecular mechanism by which an enzyme works.
The rate constant $k$ is inversely proportional to the energy of activation for a chemical reaction.

- Recall that chemical reactions involve making and breaking bonds.
- The “transition state” is a very high energy ("unstable") species of a chemical reaction in which some bonds are partially formed, and some bonds are partially broken.
- The energy of activation ($E_a$) tells us how fast a reaction is. The higher the energy of activation, the slower the reaction.
- The rate constant $k$ is inversely proportional to the energy of activation for a chemical reaction.
An example

Which free energy diagram(s) depict the exergonic reaction(s)?

Challenge Q: Which free energy diagram(s) depict the fastest reaction(s)?

a. I
b. II
c. III
d. IV
e. I + II
f. I + III
g. I + IV
h. III + IV
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• Calculate a $K_{eq}$ value from a $\Delta G^\circ$ value, and vice versa.

• Write a rate expression of a one-step chemical reaction and determine when a reaction is fastest.

• Identify $\Delta G^\circ$ and $E_A$ on a free energy diagram.

• Use a free energy diagram to describe how an enzyme catalyzes a chemical reaction.

• Describe the molecular mechanism by which an enzyme works.
Instructors who reported a decrease in student evaluations reported a lower percentage of lecture (47%) than instructors who reported an increase in student evaluations (55%) or no change in student evaluations (65%).

→ Don’t lecture less than 55% of the time.

**Fig. 6.** Changes in student evaluations compared to the amount of class time spent in lecture. Decreasing student evaluations become more likely when the percentage of class time spent in lecture drops below 20%.
Side Note: TeachFX (https://portal.teachfx.com/)
Relationship between teacher strategies and student evaluations

Table 6: Average evaluation score within each explanation and facilitation quartile.

<table>
<thead>
<tr>
<th>Explanation</th>
<th>First quartile (n = 343)</th>
<th>Second quartile (n = 231)</th>
<th>Third quartile (n = 209)</th>
<th>Fourth quartile (n = 269)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fourth quartile (n = 254)</td>
<td>3.76 (n = 17)</td>
<td>3.98 (n = 31)</td>
<td>4.02 (n = 60)</td>
<td>4.25 (n = 146)</td>
</tr>
<tr>
<td>Third quartile (n = 196)</td>
<td>3.63 (n = 29)</td>
<td>3.70 (n = 63)</td>
<td>3.72 (n = 45)</td>
<td>3.72 (n = 50)</td>
</tr>
<tr>
<td>Second quartile (n = 336)</td>
<td>3.21 (n = 128)</td>
<td>2.99 (n = 89)</td>
<td>3.15 (n = 74)</td>
<td>3.90 (n = 45)</td>
</tr>
<tr>
<td>First quartile (n = 266)</td>
<td>2.70 (n = 169)</td>
<td>2.99 (n = 48)</td>
<td>3.15 (n = 30)</td>
<td>3.77 (n = 19)</td>
</tr>
</tbody>
</table>

[“Quartile” corresponds to student perception of instructor use of strategies.]

Anatomy of STEM teaching in North American universities

Lecture is prominent, but practices vary

What are the best ways to design active learning exercises?
ICAP Hypothesis

(Menekse et al., 2013; Chi et al., 2014; Wiggins et al., 2017; Smith G, 2020.)

<table>
<thead>
<tr>
<th>Active</th>
<th>Passive</th>
</tr>
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<td>Students activate their own knowledge <em>within the boundaries of what has been taught in class</em></td>
<td>Students receive information without overtly engaging</td>
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</tr>
<tr>
<td>-----------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Interactive</strong></td>
<td>Students exchange ideas and perspectives Build off each other’s understanding</td>
</tr>
<tr>
<td><strong>Constructive</strong></td>
<td>Students work <em>alone</em> to provide explanations beyond what is presented in class</td>
</tr>
<tr>
<td><strong>Active</strong></td>
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<td><strong>Passive</strong></td>
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</table>
**ICAP Hypothesis**

---

**Interactive**
Student pairs shared one activity sheet and completed it collaboratively

**Constructive**
Students interpreted graphs and figures as they answered questions on a worksheet

**Active**
Students read an 8pg text and highlighted most critical sentences

**Passive**
Students read an 8pg text

---

The degree to which a structure deforms or strains depends on the magnitude of an imposed stress. For most metals that are stressed in tension and at relatively low levels, stress and strain are proportional to each other through the relationship $E = \sigma/\varepsilon$ where $E$ is the elastic modulus, $\sigma$ (sigma) represents stress, and $\varepsilon$ (epsilon) represents strain. For example, assume we have three metals: metal A, metal B and metal C. The metal A has the greatest elastic modulus among all three and the metal B has greater elastic modulus than metal C. This relationship also implies that the metal A has the greatest slope in a stress-strain curve and the metal C has the smallest slope in the same curve.

**Figure 1** Exemplary text scrap (left) and graph for the elastic modulus concept (right).

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(Menekse et al., 2013; Chi et al., 2014; Wiggins et al., 2017; Smith G, 2020.)
How can I incorporate active learning into my class tomorrow?

- Incorporate a homework problem or practice problem or part of a homework assignment into class time as group work.
- Whenever you ask your students a question in class, give them 1 min to write an answer before asking for volunteers to share, or let them chat with their neighbors for 1-2 min before asking for volunteers.
- Begin class by asking students to answer a question that they won’t be able to answer until the end of your lesson, and give them a few minutes to try to answer it- it will inspire their curiosity and prime their learning.
Ask students to answer a question at the beginning of class that they won’t be able to answer until after you teach them that day’s lesson

- Flip the common “lecture then ask comprehension question” paradigm
- I.e., introduce content with a question

Students who are asked to “invent” a solution to a problem + hear a lecture outperform students who hear a lecture and then do a practice problem

\[ \sigma = \sqrt{\frac{\sum(x - \bar{x})^2}{n}} \]

Thank you!

Stay in touch and let us know how we can help!

- Farber 2
- ctl@brandeis.edu
- msamuels@brandeis.edu
- CTL Events page
- Keep an eye out for our CTL Newsletter

Some very cool resources:

https://teaching.tools/activities
https://ablconnect.harvard.edu/