Toward Scientific Teaching:  
Active Learning in the Classroom

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Note: PowerPoint slides will be posted on the ASCB website via the Education Committee page.
Intended Learning Outcomes

Should be able to:

• Defend the benefits of active learning
• Develop a repertoire of learner-centered group activities
• Use clickers effectively for active learning (and formative assessment)
• Defend the value of group discussion
• Find ways to deal with the “coverage” problem
What are practical "constructivist" alternatives to lecturing in large classes?

Almost any activity, preferably cooperative and with timely feedback, that requires students to recall, think about, apply, and verbalize concepts in the course, rather than simply record facts for later memorization.

I.e. active learning activities rather than or in addition to lecturing.
Active Learning and Formative Assessment

Formative assessment ____________ includes active learning.

A) always
B) often
C) sometimes
D) seldom
How many active-learning ("brains-on") activities can you think of that you could use in a large class?

(Brainstorm: shout them out!)
A small repertoire of "brains-on" activities that can involve group work

Brainstorming
Think-pair-share
Correction detection
Concept questions with clickers
Strip sequencing
Concept mapping
Working with models
Solving problems - tightly or loosely structured
Analyzing a paper from the literature
Activity:

convert a lecture topic to a student-centered active learning activity  (5 min)

(see handout, page 7)
Passive to Active Lecture

Spend 5 minutes with a partner to choose one of the passive lecture concepts below and convert it into an activity that would engage students in learning that concept (active lecture).

<table>
<thead>
<tr>
<th>Passive Lecture</th>
<th>Active Lecture</th>
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<tbody>
<tr>
<td>Every cell in an organism has the same DNA but different genes are expressed at different times and under various conditions. This is called gene expression.</td>
<td>If every cell in a plant has the same DNA, why do different parts of the plant look different? Work with a neighbor to generate a hypothesis.</td>
</tr>
<tr>
<td>Different parts of your body can do different things. For example, your hand has fine motor skills and your leg does not. This is due to different motor units.</td>
<td></td>
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<tr>
<td>The proton is located in the center (or nucleus) of an atom, each atom has at least one proton. Protons have a charge of +1, and a mass of approximately 1 atomic mass unit (amu). Elements differ from each other in the number of protons they have.</td>
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Clickers:
“the greatest new teaching tool since chalk”
Have you used clickers before, as an instructor or a student?

A) Yes
B) No
For those who have used clickers in teaching, how successful did you and your students find them in facilitating learning?

A) Highly successful.
B) Somewhat successful.
C) Not much of an effect.
D) They had a negative impact on the course.
E) They were a waste of time and effort.
Why clickers can fail to please

Technology glitches seriously dampen the clicker experience

Factual recall questions are neither fun nor helpful

Good clicker questions:

"EnGuage" and challenge students are conceptual

include plausible distractors based on common misconceptions

can't be easily "gamed"

Wieman et al. Clicker Resource Guide
http://www.cwsei.ubc.ca/resources/clickers.htm
An example of clicker use:

maternal effect mutations in invertebrates

Early events in the embryo must be programmed by mRNAs and proteins that were made under control of maternal genes and stored in the egg.

A mutation in one of these genes can lead to a defect in an essential gene product, which can cause death of the embryo. These are called maternal-effect embryonic lethal mutations because the survival of the embryo depends on the genotype of the maternal parent.
Clicker question:

If a strict maternal-effect embryonic-lethal mutation is segregating in a mating population of *C. elegans*, the viability of an embryo will depend on

A) its genotype.

B) the genotype of its maternal parent.

C) the genotype of its paternal parent.

D) the genotypes of both parents.

> 90% correct
Maternal-effect lethal mutants

PO     +/+    mutagenize
       ↓
F1     m/+   ↓
F2 embryos   +/+     m/+    m/m
embryo will:   live    live    ?

Question: If \( m \) is a strict maternal-effect recessive mutation:
A) F2 \( m/m \) embryo will live.
B) F2 \( m/m \) embryo will die.

initial individual answers

Class: 4
first prev. 1 2 3 4 next last
Question: 6
first prev. 1 2 3 4 5 6 7 8 9 10 next last

n=70

49% 51%
A    B
0%  0%  0%
What to do when you find out that half the class doesn't understand?
Video of classroom during discussion
Maternal-effect lethal mutants

\[ P_0 \quad +/+ \quad \text{mutagenize} \]
\[ \quad \downarrow \]
\[ F_1 \quad m/+ \]
\[ \quad \downarrow \]
\[ F_2 \text{ embryos} \quad +/+ \quad m/+ \quad m/m \]

embryo will: live live ?

**Question:** If \( m \) is a strict maternal-effect recessive mutation:

A) F2 \( m/m \) embryo will live.

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**Initial individual answers**

Class: 4
first prev. 1 2 3 4 next last
Question: 6
first prev. 1 2 3 4 5 6 7 8 9 10 next last

```
Responses (%)

<table>
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<th>49%</th>
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n=70

**After group discussion**

Class: 4
first prev. 1 2 3 4 next last
Question: 7
first prev. 1 2 3 4 5 6 7 8 9 10 next last

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Responses (%)

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5%
Peer instruction works!

Two critical pointers for clicker questions:

1) Don't leave out student discussion!

2) Don't forget to discuss what happened!
A small acorn over time can grow into a huge oak tree. The wood in such a tree can weigh many tons, even after it has been cut into logs and dried. Where does most of this mass come from as the tree grows?

A) Minerals in the soil
B) Organic matter in the soil
C) Gases in the air
D) Sunlight

No feedback. Just ask another question
To slow down global warming, scientists believe it is crucial to stop cutting down the Amazon rain forest, mainly because

A) Many plant and animal species will disappear if the rain forest ecosystem is destroyed.

B) Removal of the forest will lead to wide-spread erosion and degradation of the environment.

C) Living trees remove carbon dioxide ($CO_2$) from the atmosphere.

D) Deforested land will be used for purposes that add to global warming.
A small acorn over time can grow into a huge oak tree. The wood in such a tree can weigh many tons, even after it has been cut into logs and dried. Where does most of this mass come from as the tree grows?

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<table>
<thead>
<tr>
<th>Question 7</th>
<th>Initial responses</th>
<th>Question 8</th>
<th>After second question</th>
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<td>14%</td>
<td>E</td>
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</table>
Which way was transcription going?

A) left to right.

B) right to left.
Three identical plates of radish seeds are incubated under three different conditions, with results as shown. How will the dry weights of the three plates compare at the end of the experiment?

A) 1 < 2 < 3
B) 1 < 3 < 2
C) 1 = 3 < 2
D) 3 < 1 < 2
E) 1 = 2 = 3
Three identical plates of radish seeds are incubated under three different conditions, with results as shown. How will the dry weights of the three plates compare at the end of the experiment?

A) $1 < 2 < 3$
B) $1 < 3 < 2$
C) $1 = 3 < 2$
D) $3 < 1 < 2$
E) $1 = 2 = 3$

Bloom's level?
Benefits of clickers

For me, the instructor:

• I know you’re there (later)
• I can find out how you answered (later)
• I know instantly what fraction of you didn’t understand!

For you, the student:

• Responses are anonymous
• Instant comparison to your peers
• You’re active and engaged!

(Active learning and formative assessment.)
Group work

How important is peer discussion following a challenging clicker question?

You’ve just experienced some evidence!

Why does peer discussion improve student performance on in-class concept questions?

See Smith et al. (2009) Science 323:122-4
Strip sequences

Give students a shuffled ranking or sequence of sequential steps in a process (e.g. meiosis), and ask them to come up with the correct sequence.

Following two slides ask students to discover Bloom’s taxonomy for themselves by ranking questions, as an alternative to just telling them about it.
Exercise: Exam questions from a virology course

Strip sequence: list in decreasing order of the level of understanding required to answer each question correctly.

A. What features distinguish the replication processes of RNA and DNA viruses?
B. Would you argue that viruses are alive? Why or why not?
C. Diagram the life cycle of a typical lytic DNA animal virus.
D. Propose a way that viruses could be used to treat a human disease.
E. Name the coat components of a typical DNA animal virus.
F. Based on your knowledge of viral life cycles, predict one possible mechanism by which an antiviral drug might work.

A good answer: B, D, A, F, C, E.
Exercise: Exam questions from a virology course

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E. **Name** the coat components of a typical DNA animal virus.
F. Based on your knowledge of viral life cycles, **predict** one possible mechanism by which an antiviral drug might work.

(This could be done as a clicker question if your system has alphanumeric entry capability)
What is your experience with concept maps?

I have

A) used them in my classes and find them helpful.

B) tried them but didn't find them useful.

C) heard of them but never tried them.

D) never heard of them before today.
Concept mapping example

**Transcription**
- RNA Polymerase binds to the Promoter
- Transcription Factors interact with Transcription
- Transcription catalyzes the interaction of Transcription Factors
- Regulatory elements bind to Transcription
- Transcription is initiated at regulatory elements or upstream or downstream of promoters

Concept map of transcription
Make a concept map of active learning
Coverage anxiety:

Active learning activities take time: how can I cover all the material?
The pervasive myth of "coverage" - mutually reinforcing misconceptions of faculty and students

**Faculty:**

"Students won't/can't learn the material unless I tell them about it."

"The more I cover in lecture, the more they will learn."

**Students:**

"I can't learn from the textbook."

"It's not fair to examine us on things you haven't told us in class."
The coverage fallacy: which curve is most likely?
If you ask students why they read the textbook, they say it’s to help them understand the lectures.

It should be the other way around: students should be coming to class in order to get help understanding the reading!

(E. Mazur)
Learn before Lecture: A Strategy That Improves Learning Outcomes in a Large Introductory Biology Class

Marin Moravec, Adrienne Williams, Nancy Aguilar-Roca, and Diane K. O'Dowd

Just-in-Time Teaching puts more of the responsibility for content learning on the students.

Instructor assigns pre-class work to be submitted online.

Instructor can assess it in advance, gauge the level of understanding, and plan use of class time accordingly.
Students may object, but . . .

They need to learn how to learn, to reason, to assimilate information for themselves, to critically evaluate the information they encounter, and to understand how science is done,

more than they need to know much of the factual knowledge we ask them to memorize.

So JiTT solves the coverage problem AND gives students practice in skills they need to master.
Recap: Intended Learning Outcomes

Should be able to:

• Defend the benefits of active learning
• Develop a repertoire of learner-centered group activities
• Use clickers effectively for active learning (and formative assessment)
• Defend the value of group discussion
• Find ways to deal with the “coverage” problem
Active Learning

Conceptual Clicker Questions

Deeper Understanding

Formative Assessment

Higher Bloom's Levels

Active Learning are a form of can be done with

promotes occurs during

leads to understanding at

leads to results from

provide an opportunity for can test for

Concept map of active learning - one possible set of descriptors