Active learning in the biology classroom

UBC

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CWSEI

What is the goal of biology education?

How do we develop expertise?

How do we develop expertise?

Practice

Expert feedback

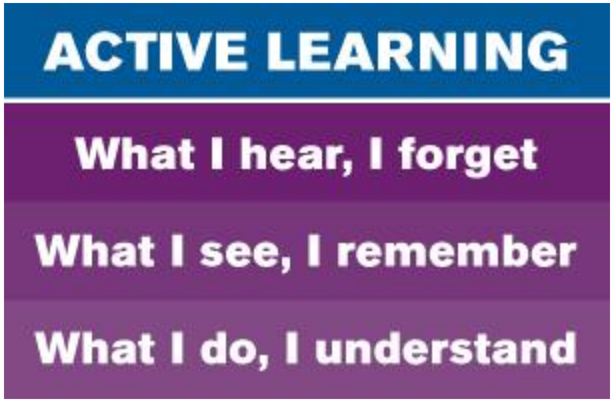
How do we develop expertise?

Individual coaching is highly effective

How can we make the experience in our biology classes more similar to individual coaching?

Biology teaching and learning

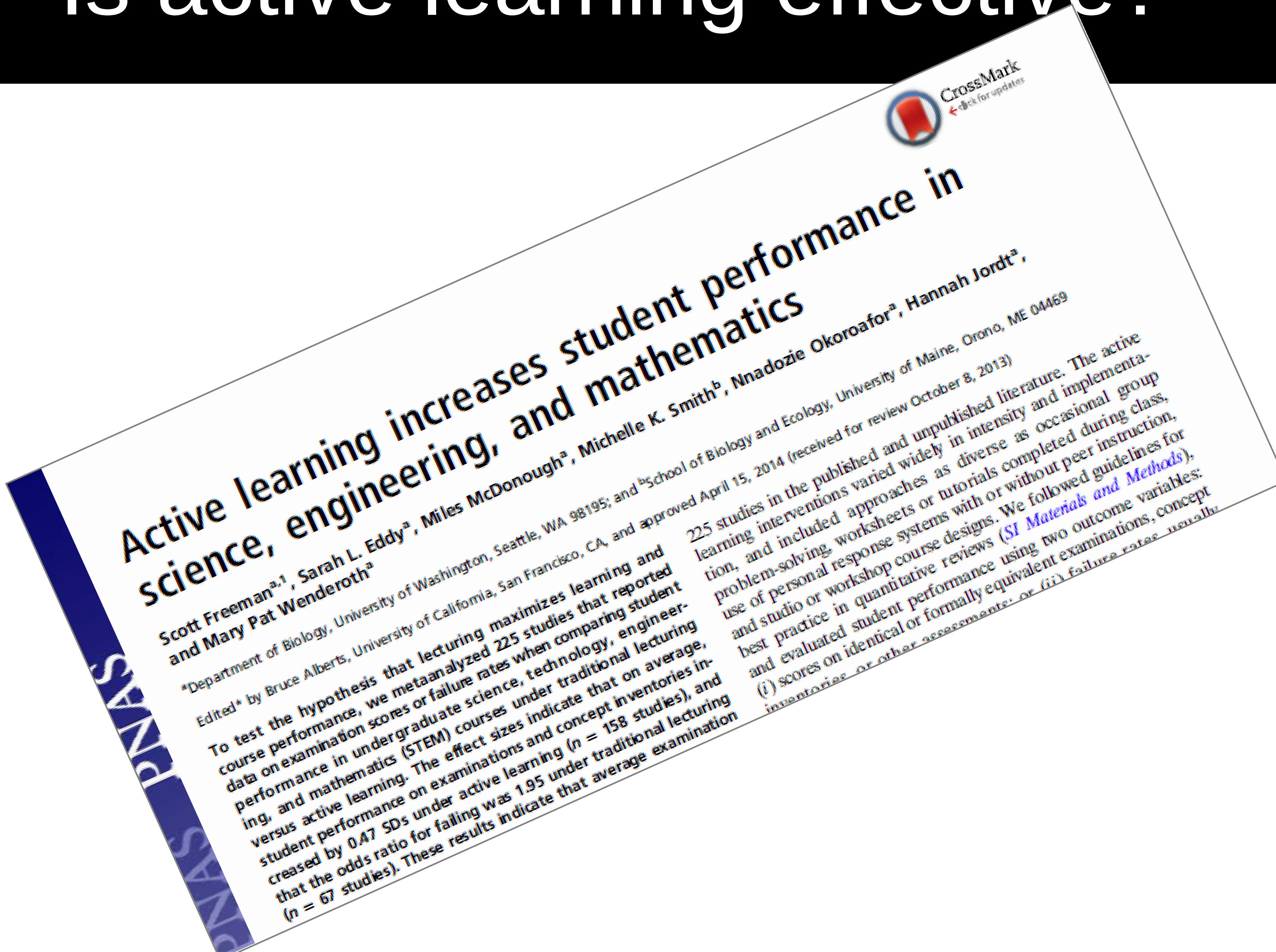
Active learning



"Not hearing is not as good as hearing, hearing is not as good as seeing, seeing is not as good as knowing, knowing is not as good as acting; true learning continues until it is put into action."

- Yunxi

Is active learning effective?



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PNAS

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

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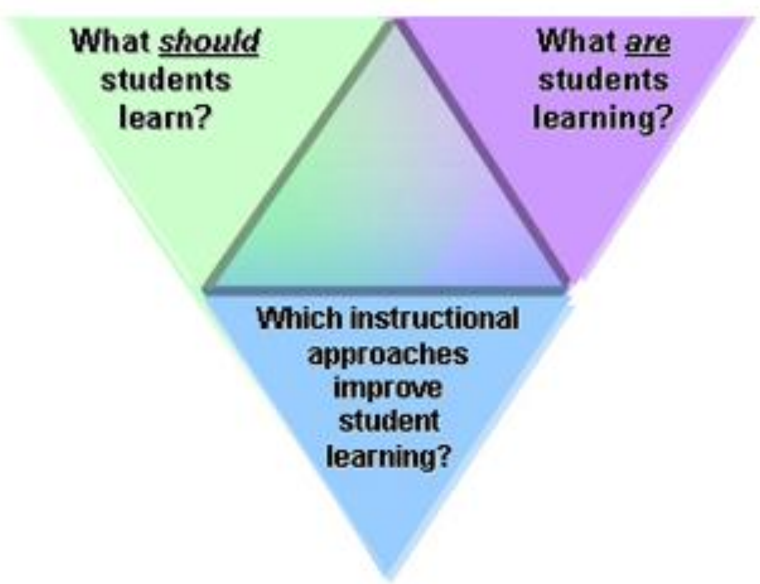
Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student performance in undergraduate science, technology, engineering, and mathematics (STEM) courses under traditional lecturing versus active learning. The effect sizes indicate that on average, student performance on examinations and concept inventories increased by 0.47 SDs under active learning (n = 158 studies), and that the odds ratio for failing was 1.95 under traditional lecturing (n = 67 studies). These results indicate that average examination

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group problem-solving, worksheets or tutorials completed during class, use of personal response systems with or without peer instruction, and studio or workshop course designs. We followed guidelines for best practice in quantitative reviews (*SI Materials and Methods*), and evaluated student performance using two outcome variables: (i) scores on identical or formally equivalent examinations, concept inventories, or other assessments; or (ii) failure rates, usually

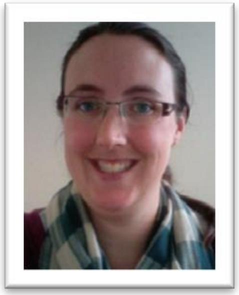
Science education research at UBC

The Carl Wieman Science Education Initiative (CWSEI)



http://www.cwsei.ubc.ca/

CWSEI Life Sciences



Megan Barker

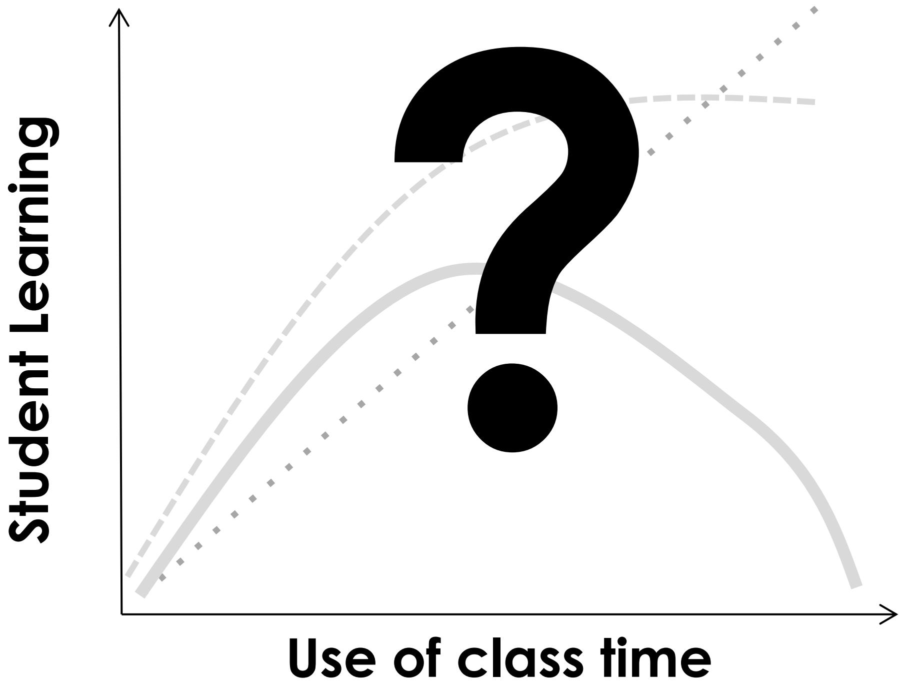
Lisa McDonnell

Tammy Rodela

Natalie Schimpf

Science teaching and learning fellows (STLFs)

Measuring the effectiveness of instructional practices



How we assessed student learning

- **Assembled a series of multiple choice questions (total 242)**
- **Designed to assess key concepts in Biology**
- **Diagnostic tests compiled and aligned to each course**
- **Administered before and after the course**

Q4B

Questions For Biology


Chapter 5
Evaluating a Genetics Concept Inventory

How we profiled the use of class time

CBE—Life Sciences Education
Vol. 12, 618–627, Winter 2013

Article

COPUS

The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices

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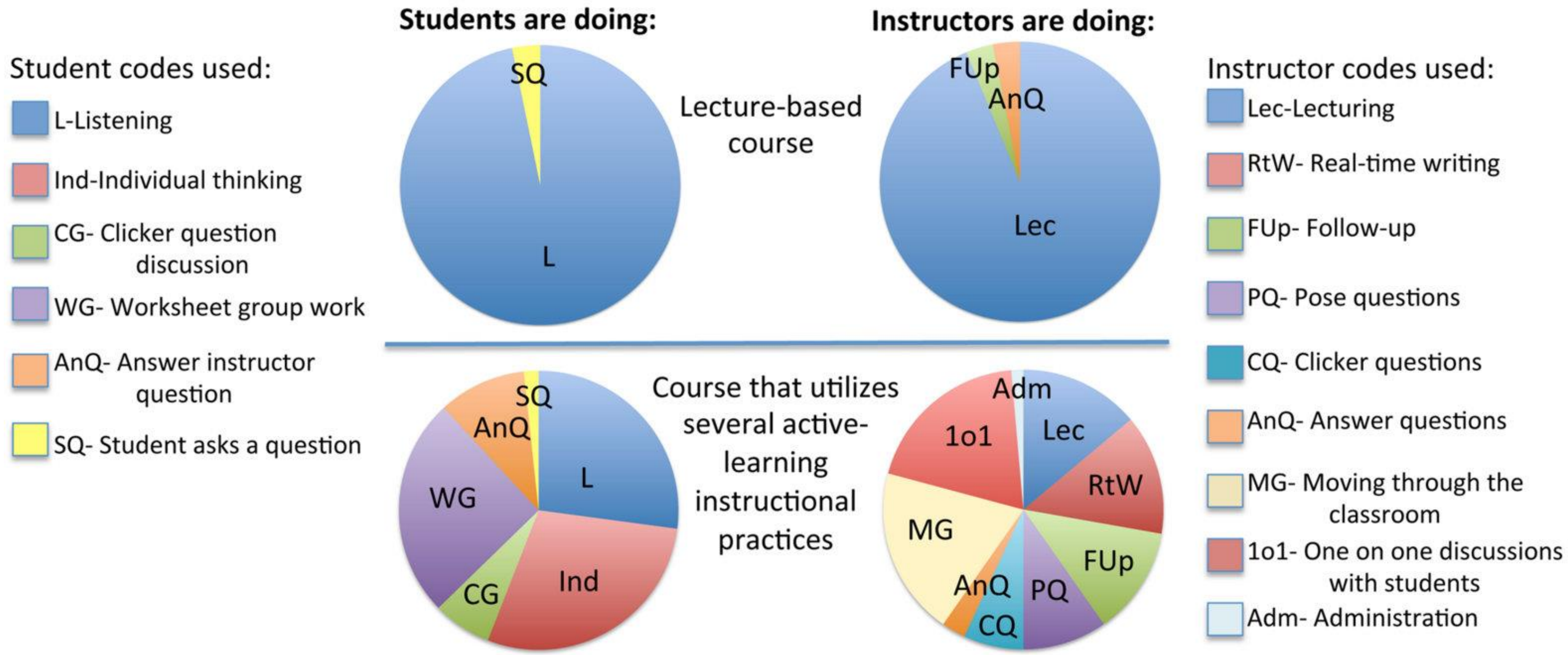
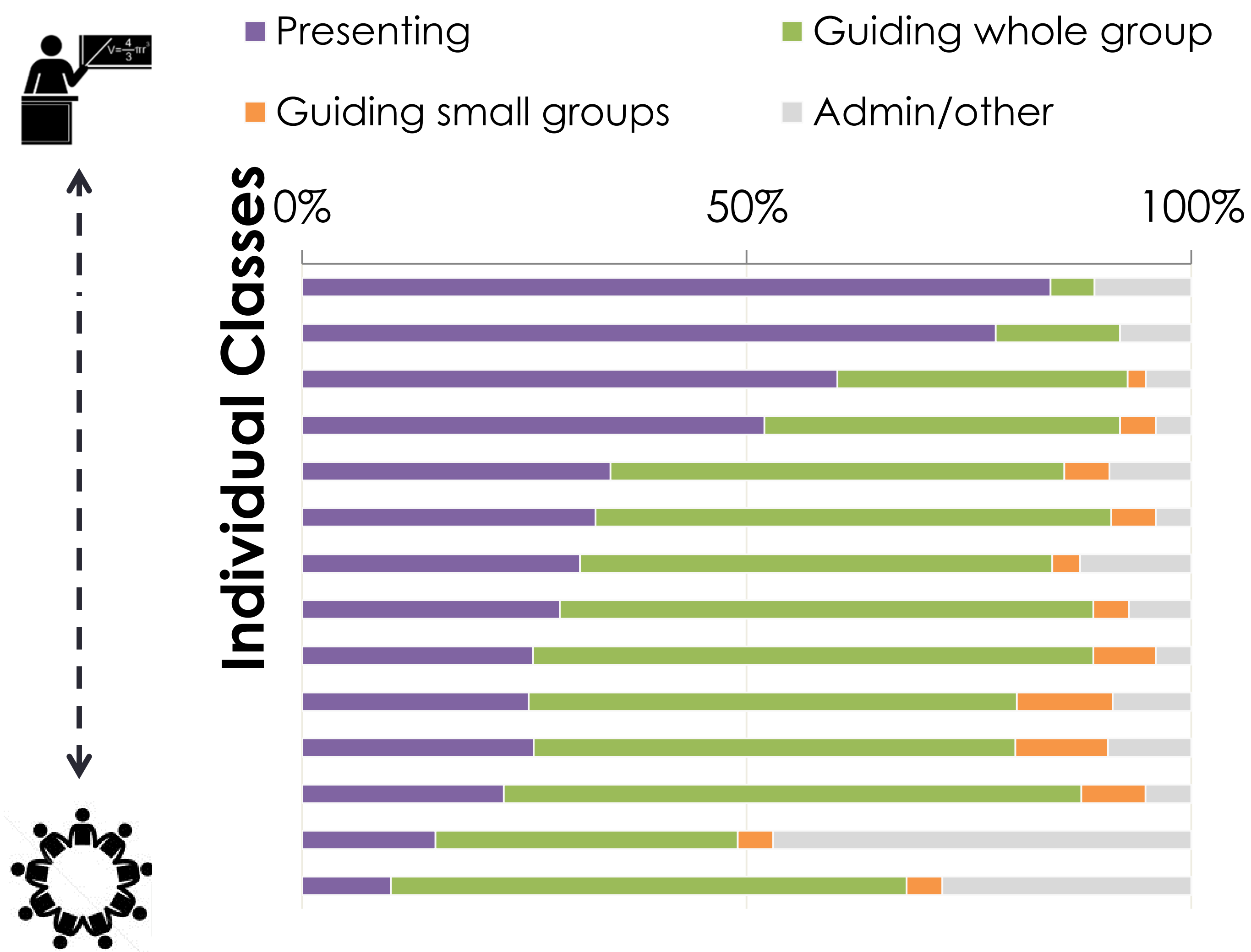


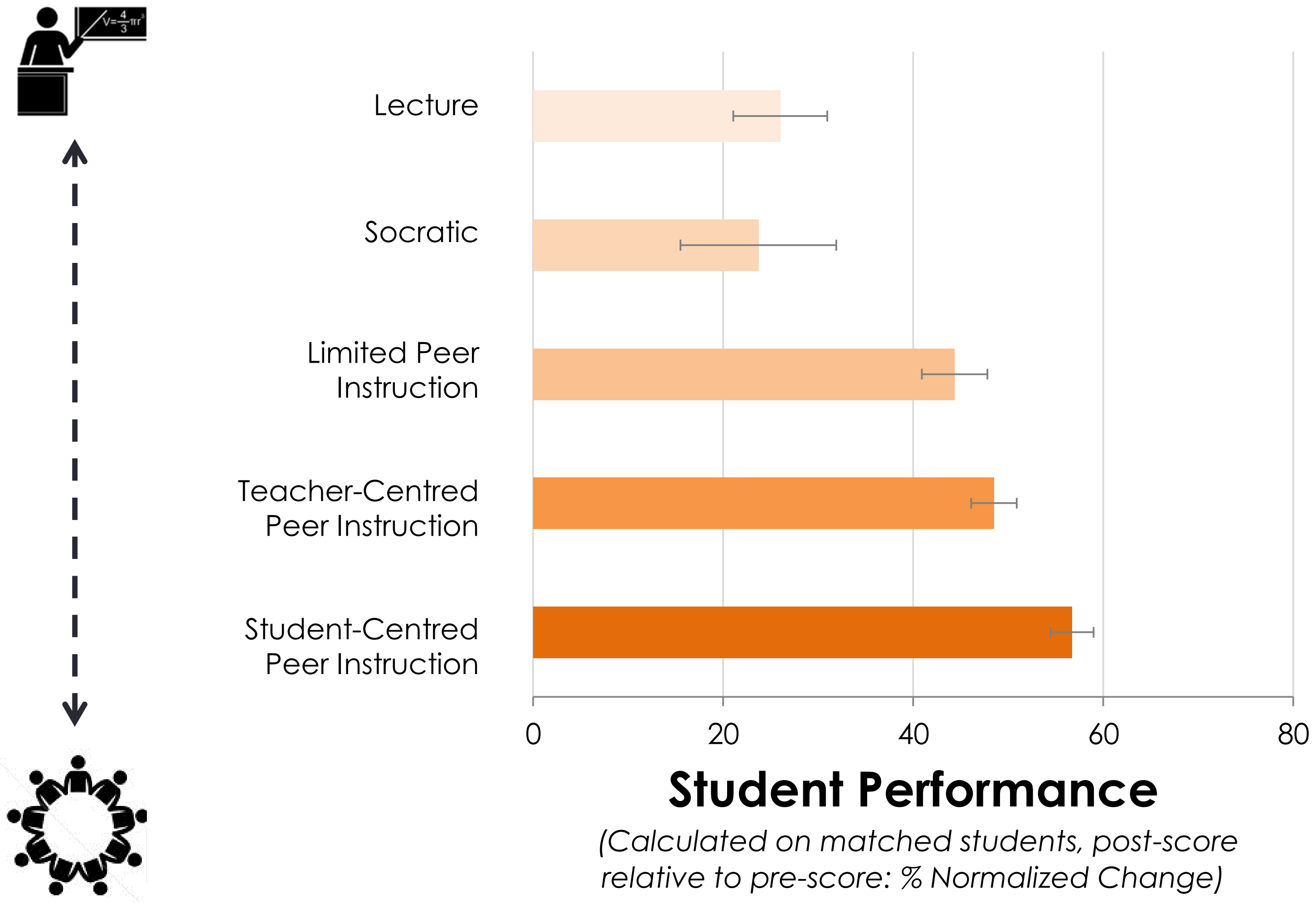
Data collected

Course Level	# of Course sections			# of Students		
	Term 1	Term 2	Total	Term 1	Term 2	Total
100	7	6	13	966	880	1846
200	7	5	12	1052	865	1917
300	2	3	5	197	260	457
400	2	3	5	51	85	136
Totals:	18	17	**35**	2266	2090	**4356**

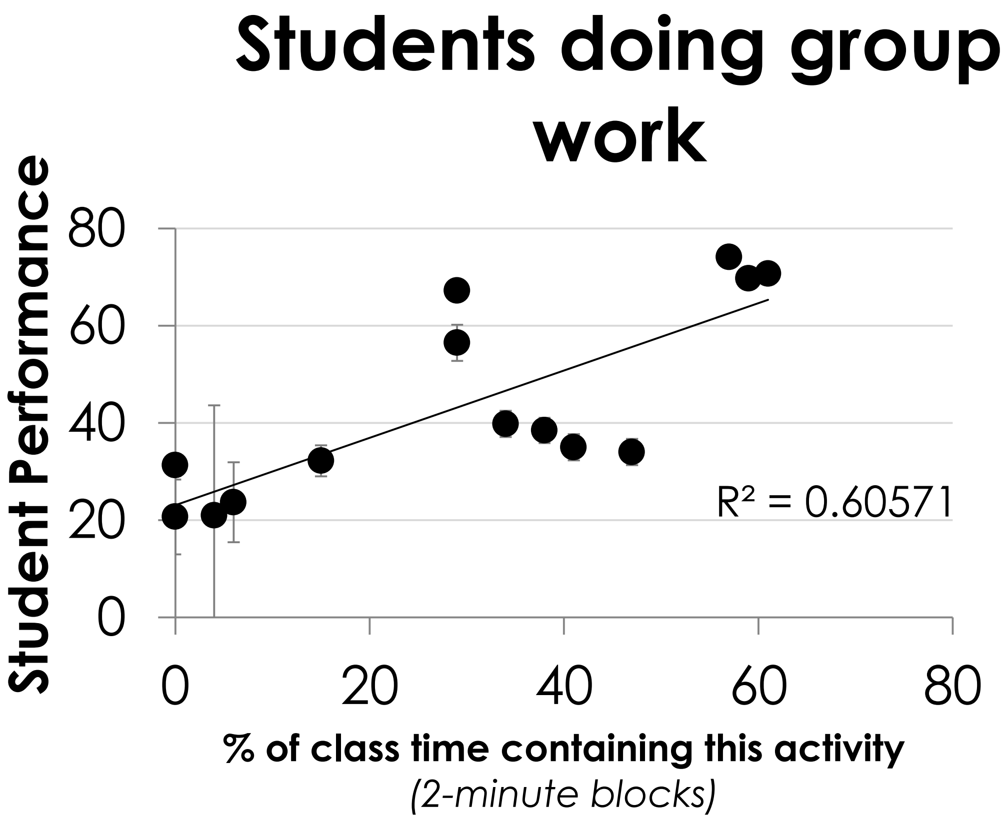
Classroom practices



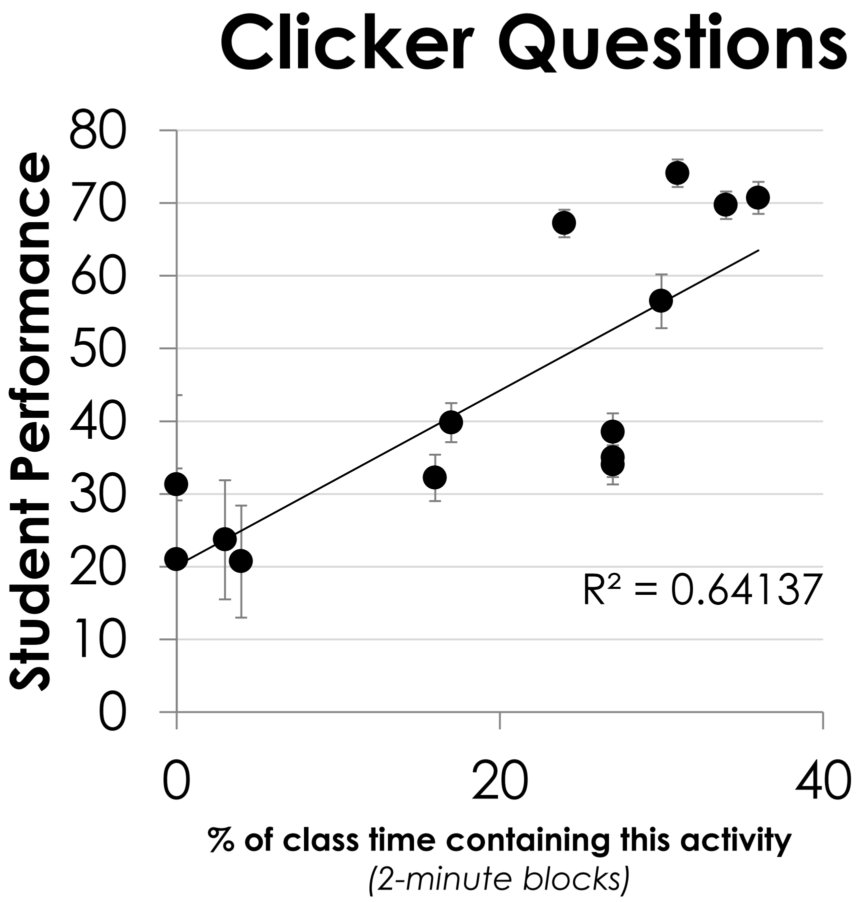
Teaching effectiveness



Teaching effectiveness



Teaching effectiveness



How to implement active learning

What does an active class look like?

Prepare for Class

- Short, targeted reading
- Pre-quizzes
- Online content (videos, animations, pen casts)

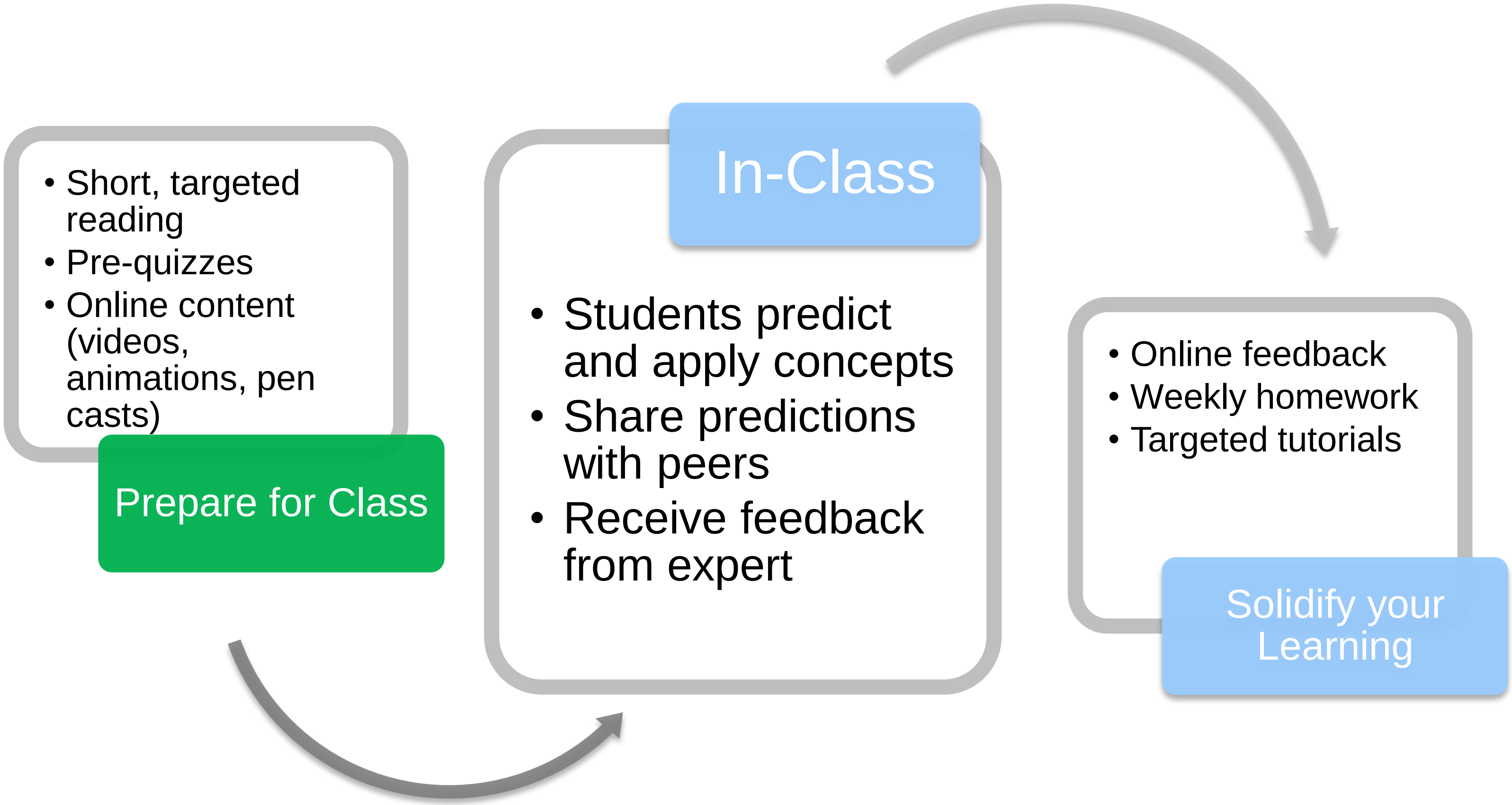
In-Class

- Students predict and apply concepts
- Share predictions with peers
- Receive feedback from expert

Solidify your Learning

- Online feedback
- Weekly homework
- Targeted tutorials

Pre-class activities



- Pre-reading exercises and quizzes

The role of pre-readings

GOAL: Get the students to become familiar with some of the material before class, so that time in class is better used, e.g., for activities, discussions, and peer instruction

How?

Tell the students to read … but how many students regularly read the textbook before class?

Pre-readings for introductory courses

- Short weekly reading (~1 hour) with **explicit prompts**
- an **online quiz** ~ 5-10 multiple choice questions

  - *Refer to pre-reading in lecture, but don't re-teach*
  - *Reasonable expectations (short reading, straightforward questions)*

Targeted pre-reading example

LS CWSEI

general instructions

Read section 46.5 (Movement) of **Chapter 46: *Animal sensory systems and movement*** from your text book (p. 1095-1100) and take the corresponding pre-reading quiz. The pre-reading quiz for Tuesday's lecture closes 9am Tuesday, April 3rd

Questions posed to focus reading: specific figures, equations, and examples;

Skim the sub-headings "movement" and "skeletons" on p. 1095-1096. We will not be covering this material in any depth, so just focus on being able to answer the following questions:

- Why are muscles organized into antagonistic muscle groups?
- How does this facilitate locomotion?

Read section the next section ("How do muscles contract") p. 1097-1100 carefully. This is the most important part of the chapter, and will be the main focus of the in-class activities

In the section "The sliding filament model" make sure you understand:

- The relationship between muscle tissue, muscle fibers, myofibrils and sarcomeres (Figure 46.19)
- Why striated muscle has bands (striations) (compare Figure 46.19 to 46.20)
- What happens to the size of the bands during contraction

In the section "How do actin and myosin interact?" focus on:

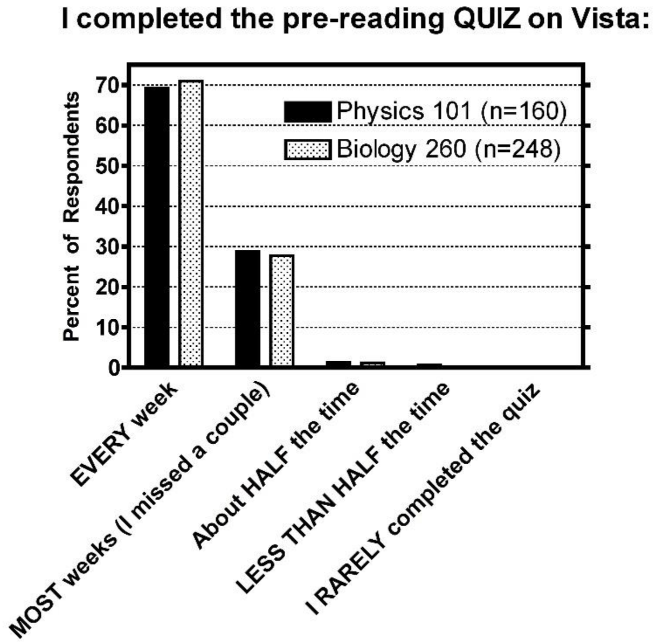
- The steps shown in Figure 46.22
- Making sure you understand the role of ATP in the process

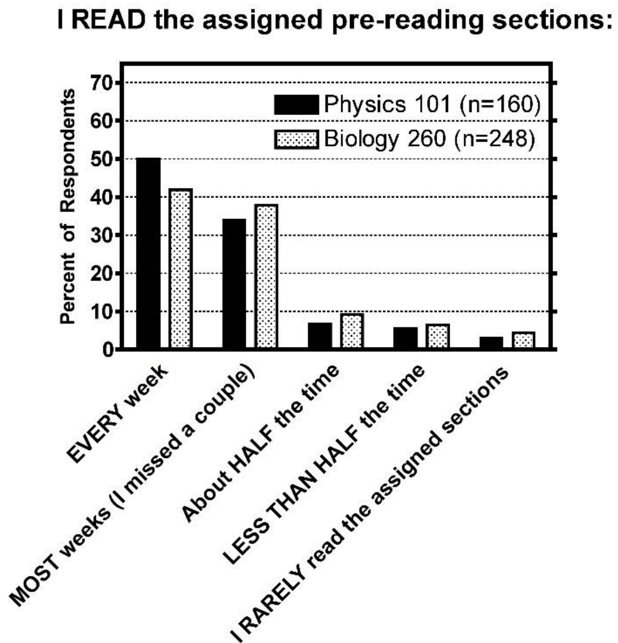
selective reading (value their time)

- You can skip Figure 46.21

You can skip the section "Muscle Types" (p. 1101)

Student survey data: pre-readings





98% of the students report taking the quiz on a regular basis

82% of the students report reading the textbook on a regular basis

Heiner, C.E., **A.I. Banet** and C. Wieman (2014). Preparing students for class: How to get 80% of students reading the textbook before class. American Journal of Physics. 82:989-996

Student motivation for pre-reading

When you did the pre-reading assignments, what MOTIVATED you to do so?

"I learn better in class if I have previous knowledge of the topic. I find that I pay more attention <u>and my brain can make more connections and build on previous knowledge</u>."

"It's for marks and ... it helps me to distinguish what I know and what I have troubles with <u>so I can be all ears in the parts where I am struggling with in class</u>."

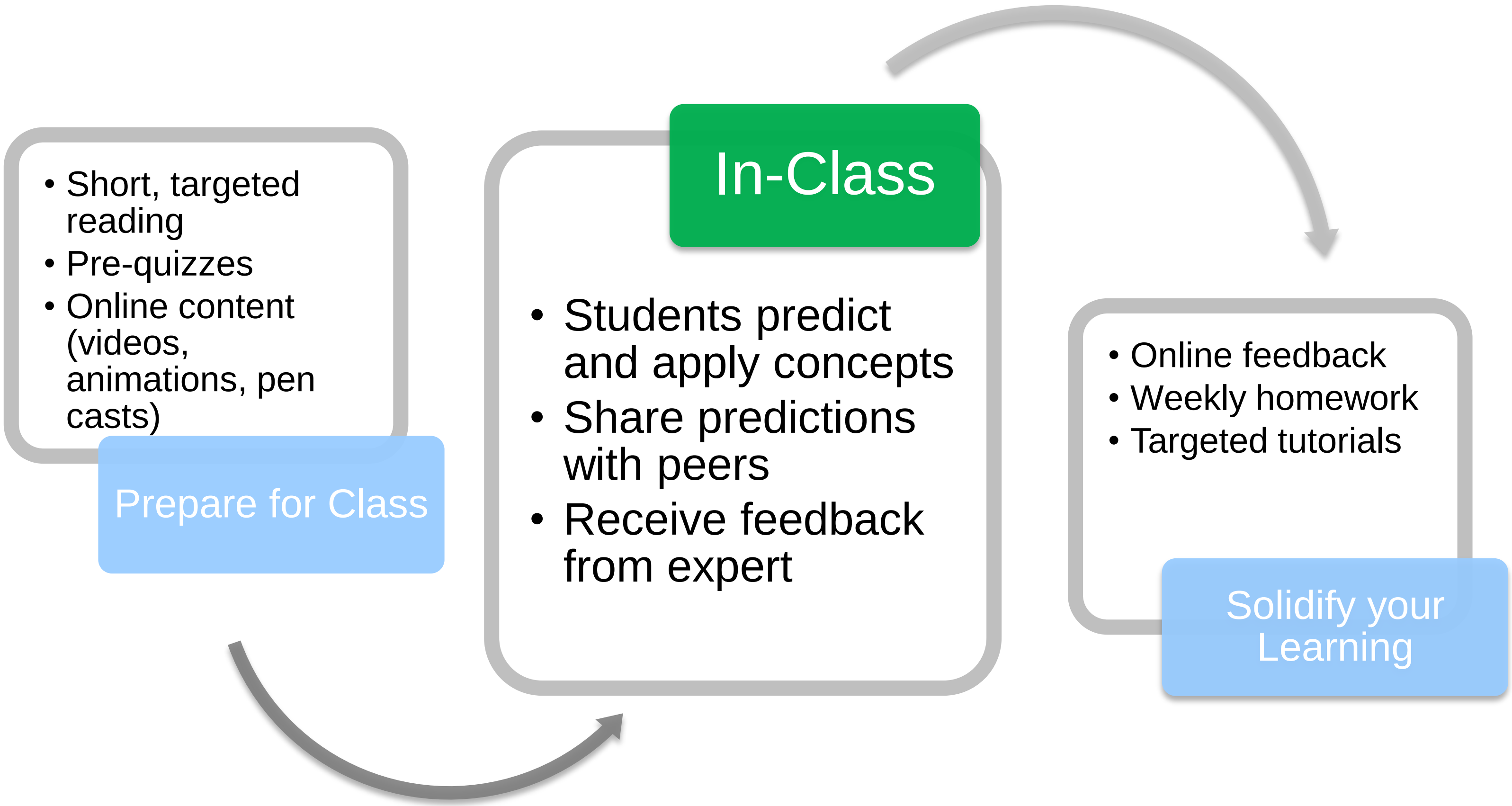
"…so if I have any questions, they would be <u>knowledgeable and well-founded questions</u>."

Pre-reading is an opportunity for feedback

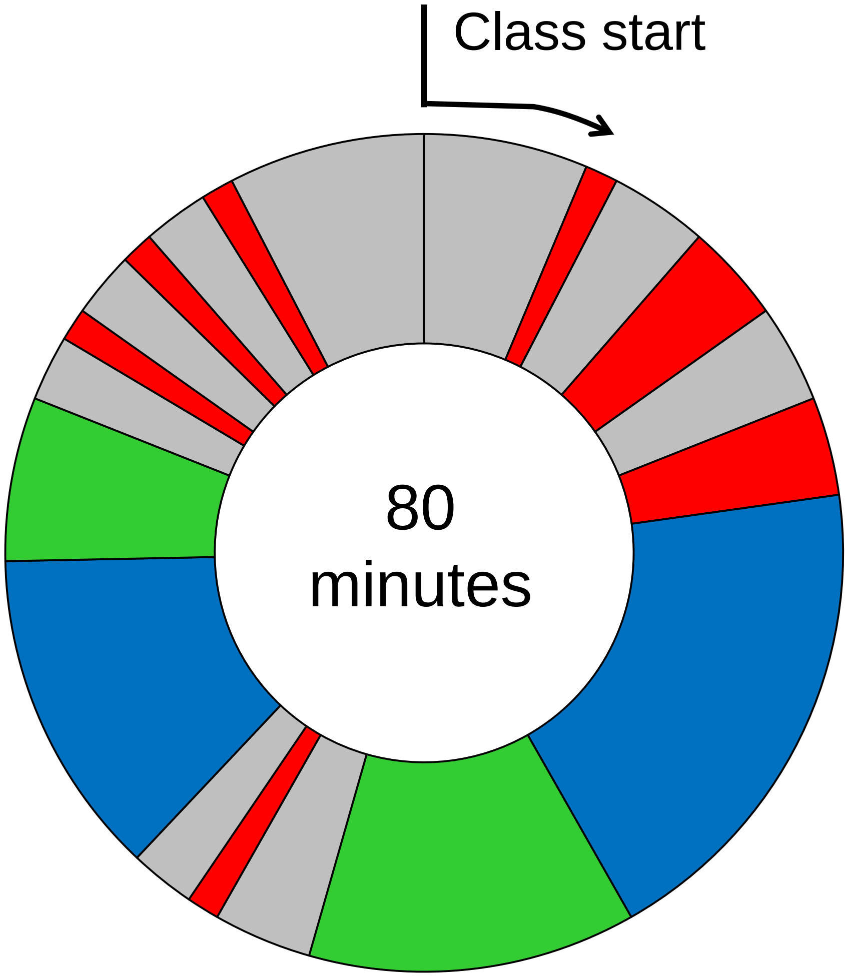
Each pre-reading quiz contains this question:

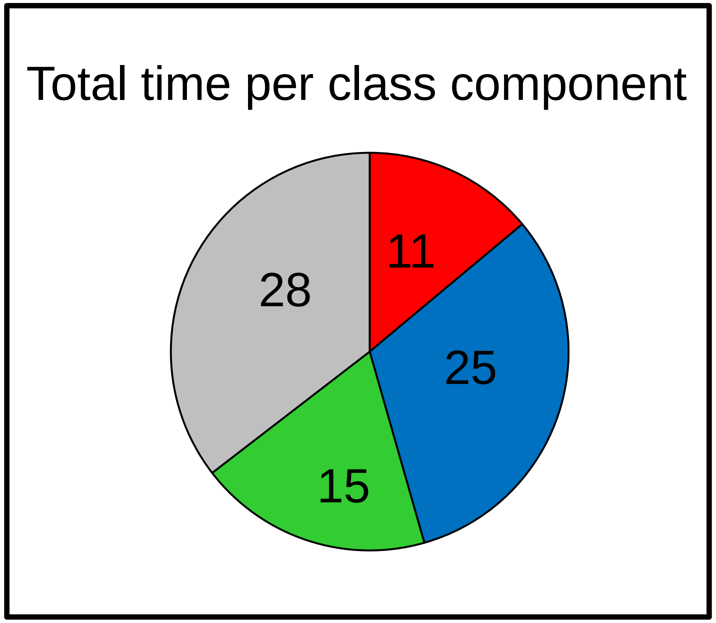
Was there any material in this pre-reading that you found particularly unclear or difficult?

Active learning in class



What does an active class look like?



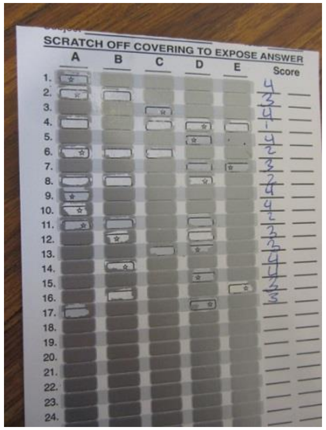


In class activities - examples

- **Two stage review activity**
- **Clicker questions**
- **In class problems**
- **Worksheets and case studies**

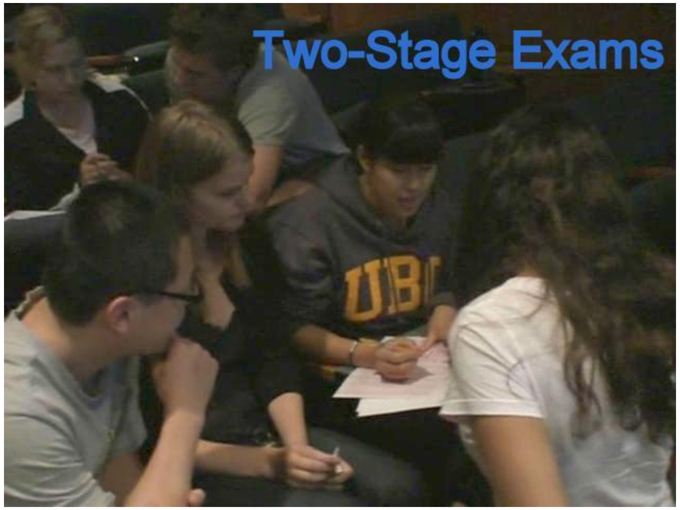
Example #1 – two stage review

- At the beginning of a new unit (or as a pre-test review session)
  - Students work individually, then in groups, then taken up as a class
- Benefits?
  - Primes them to pay attention
  - Identifies gaps in their knowledge
  - Gives them practice on the tools they'll need coming up
  - Takes the same amount of class time as traditional review

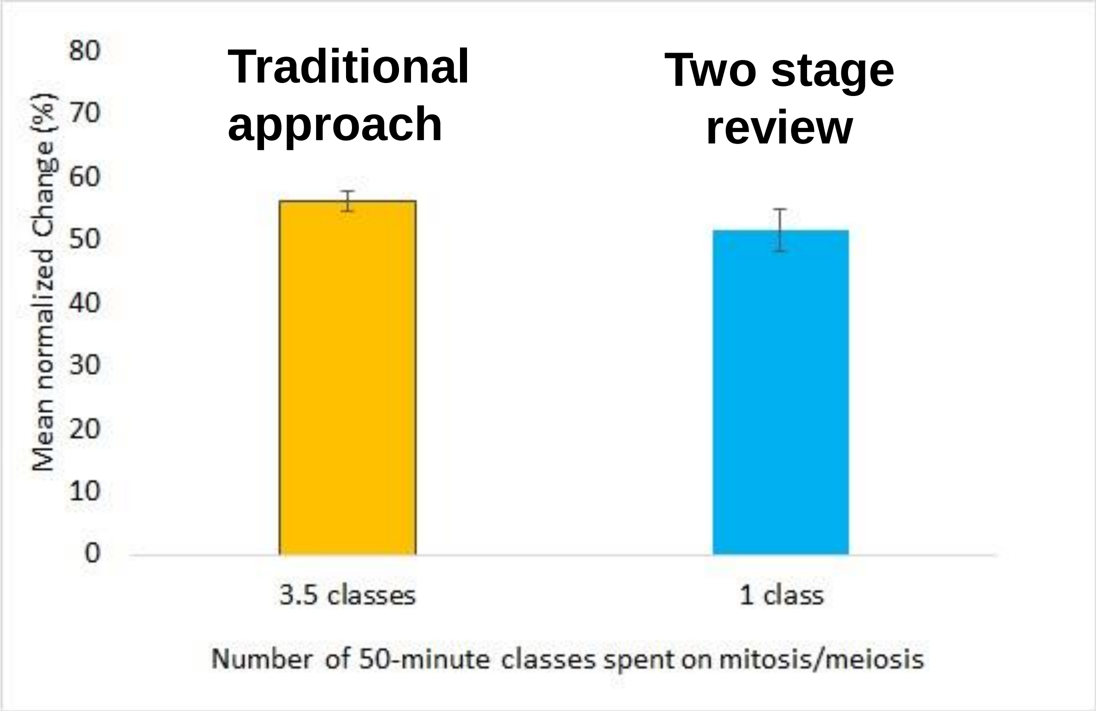


iFAT scratch card

http://www.epsteineducation.com/home/about/



Effectiveness – two stage review



Reducing the amount of in-class time spent on mitosis and meiosis does not negatively impact student performance.

Example #2 – clicker questions

Multiple choice questions

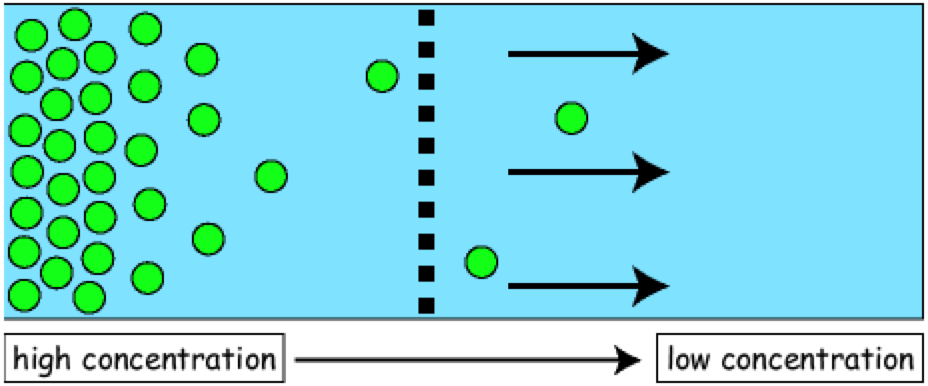
- **Can be used to quickly review important concepts from pre-reading**
- **Target specific misconceptions**

Clicker questions that target misconceptions

How to identify misconceptions:

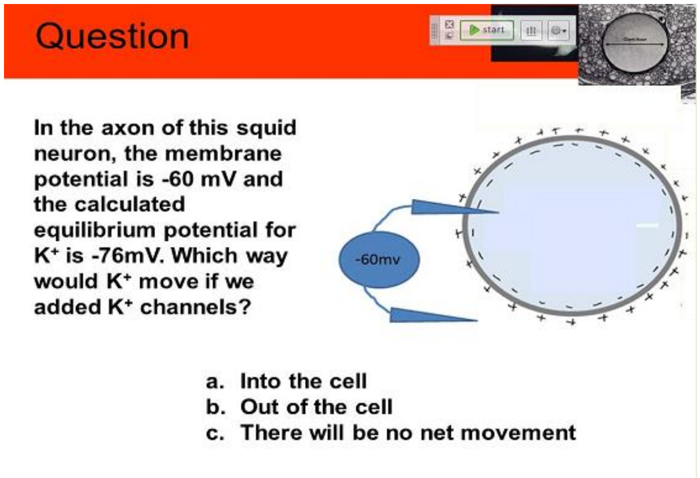
- Known misconceptions from the literature
- Misconceptions we have detected in final exams or in previous years
- Misconceptions uncovered through open-ended questions (e.g. responses in pre-readings)

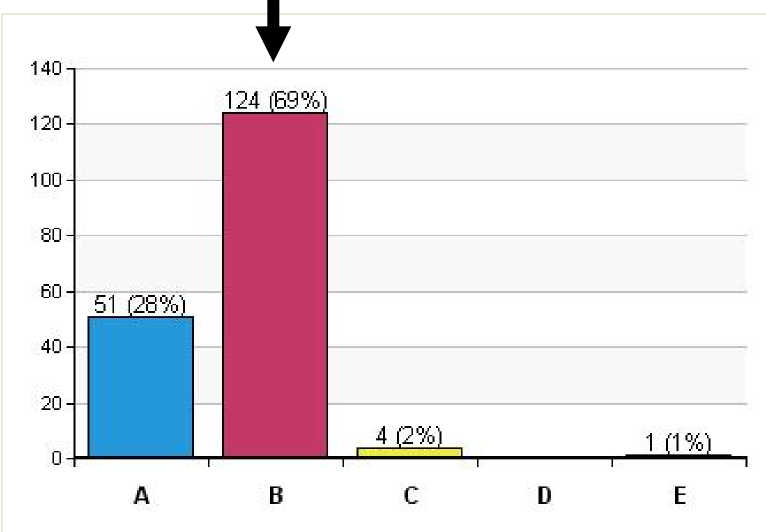
Fundamental misconception

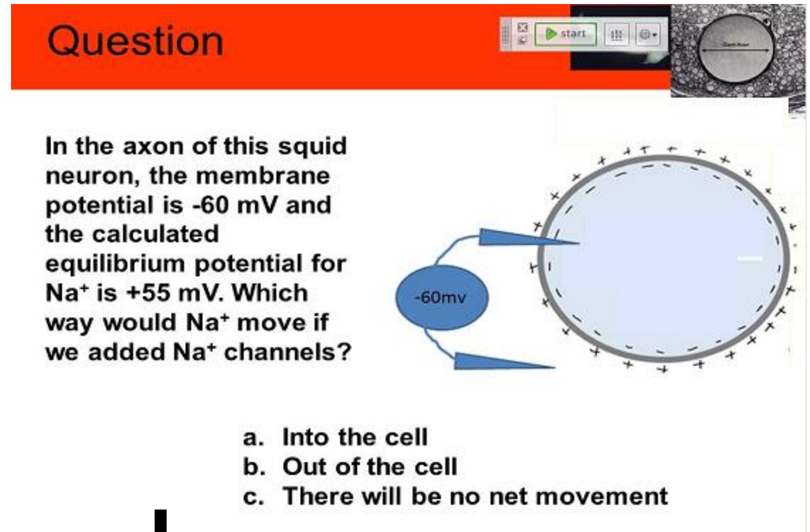


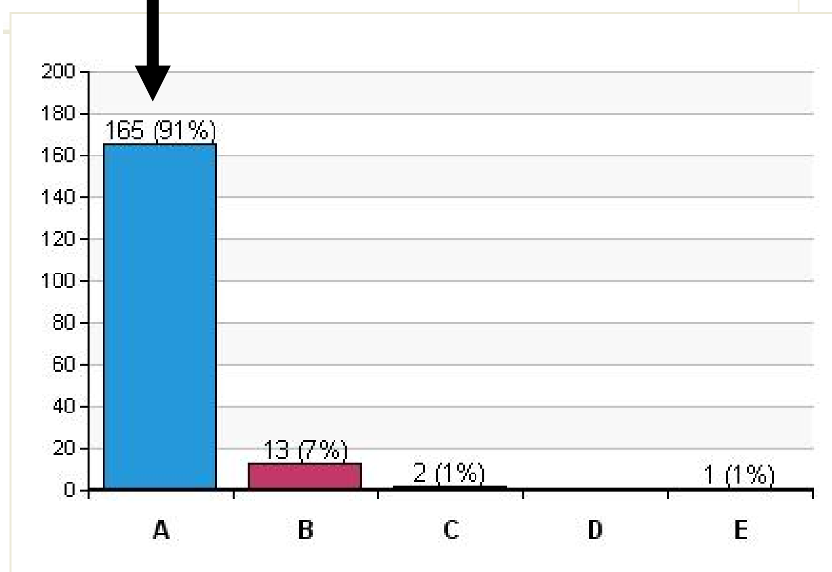
- Students have memorized the “fact” that substances move from areas of high concentration to low concentration
- Have difficulty accepting that an ion can move against its concentration gradient if there is an opposing charge difference across a membrane

Approach – clickers and peer discussion





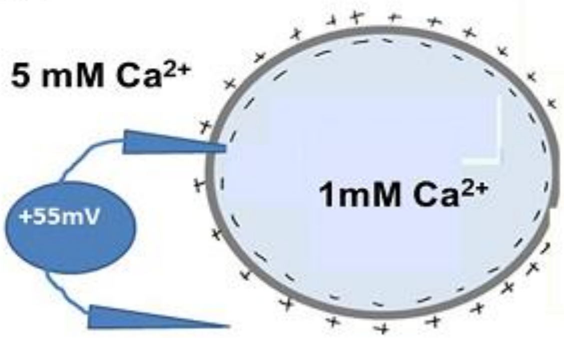




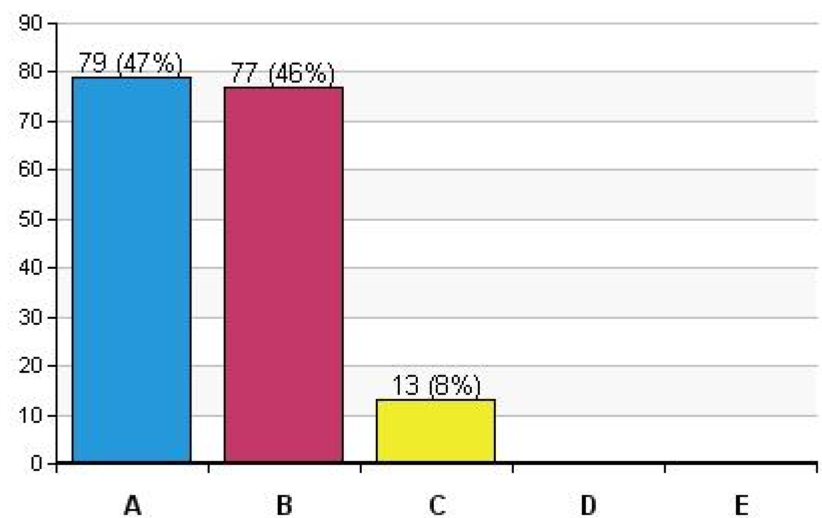
Approach-clickers and peer discussion

Question

In this hypothetical neuron, the intracellular [Ca^{2+}] is 1 mM and extracellular [Ca^{2+}] is 5mM. The calculated equilibrium potential for Ca^{2+} is +22mV. The membrane potential is +55mV. Which way would Ca^{2+} move if we added Ca^{2+} channels?

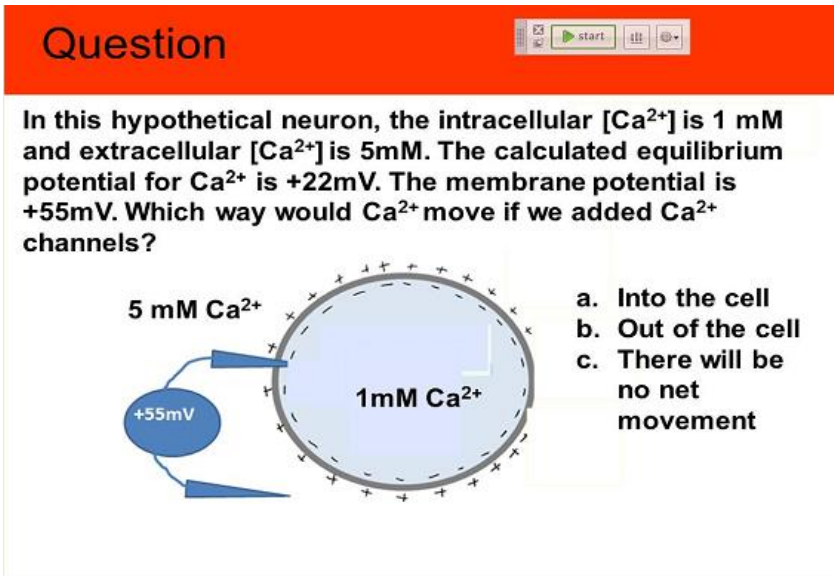


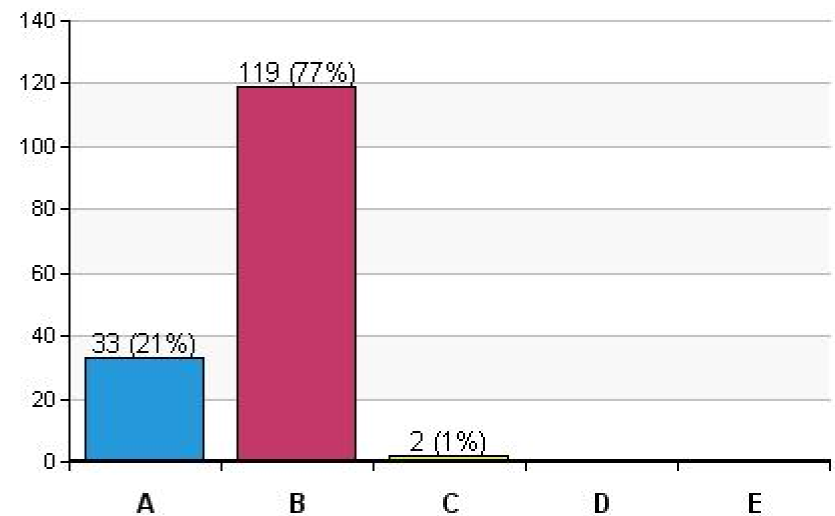
a. Into the cell
b. Out of the cell
c. There will be no net movement



Approach – clickers and peer discussion

Re-poll the following class session





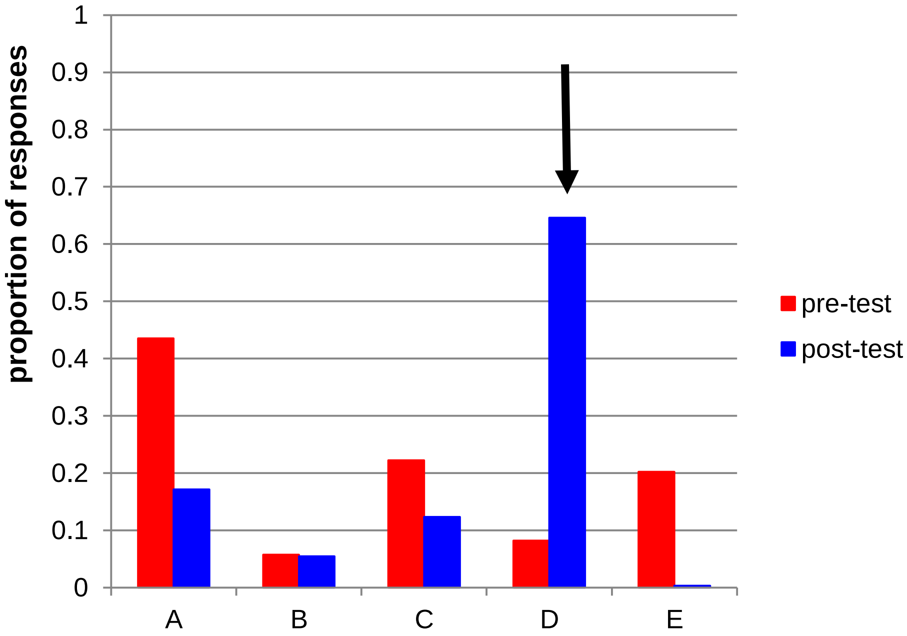
Estimating retention

When asked the same question at the end of the course, ~60% of the class were able to answer an equivalent question correctly

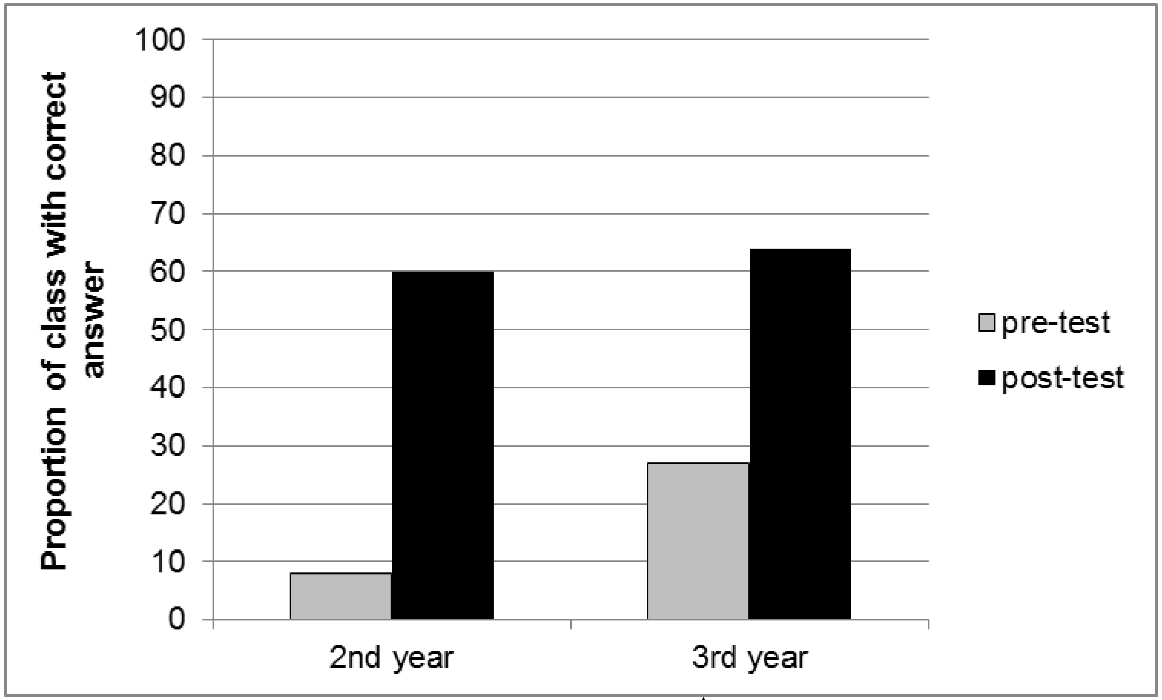
What direction will Ca^{2+} ions move when Ca^{2+} channels open in a cell under the following conditions:

Extracellular Ca^{2+} = 5mM
Intracellular Ca^{2+} = 1 mM
Resting membrane potential = +55mV
Equilibrium potential for Ca^{2+} = +21.5mV

a. Into the cell along (i.e., in the same direction as) its concentration gradient
b. Out of the cell along (i.e., in the same direction as) its concentration gradient
c. Into the cell along its (i.e., in the same direction as) electrical gradient
d. Out of the cell along (i.e., in the same direction as) its electrical gradient

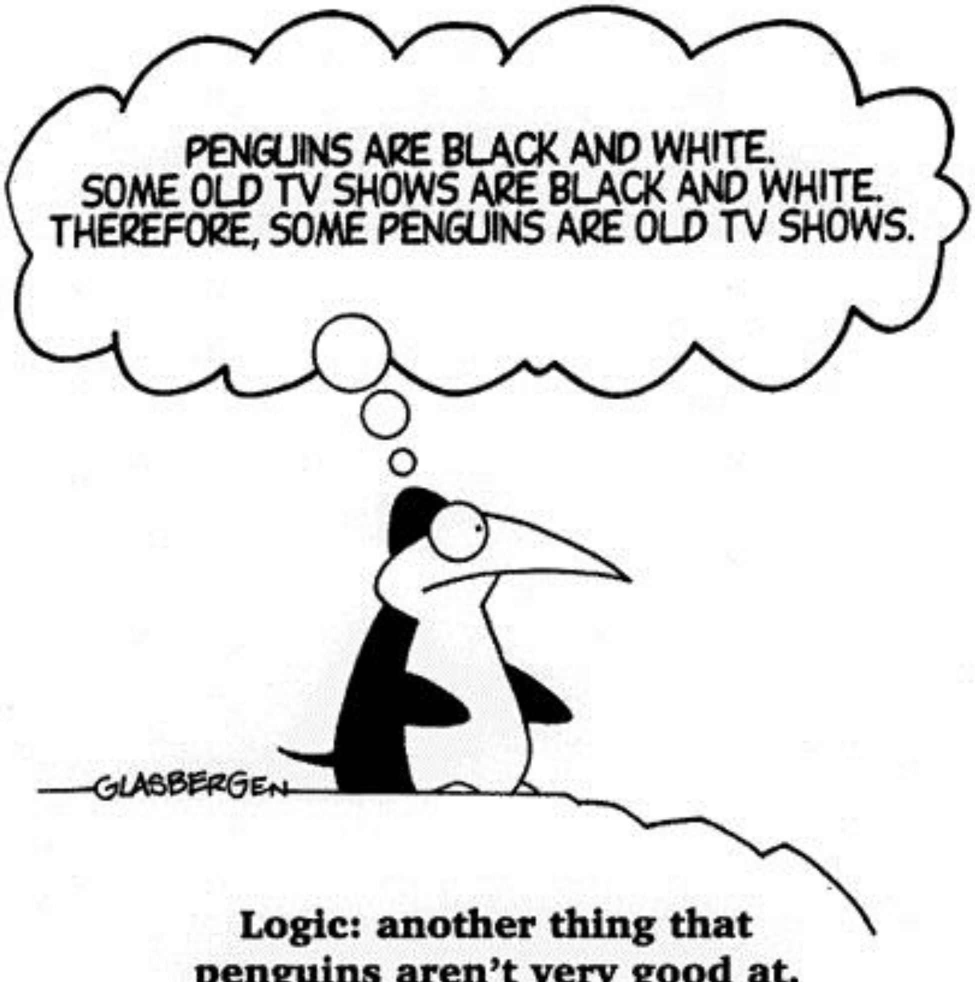


Long term retention



Four months later

Example #3: In class problems



- Students struggle to construct logical answers to questions
- Exam answers reveal fundamental misconceptions and flaws in assigning causality

A → B → C → D

Example #3 – in class problems

- Using student writing to develop questions in “real time”

Liane Chen

- Pose a question that requires a written answer.
- Create multiple choice options using examples of student answers.
- Have students select the best possible answer.
- Discuss what makes a good answer.
- (Discuss exposed misconceptions.)

Workshop: Practice makes perfect: Clickers as a tool for student writing and feedback – Sunday 9am

Inclusion-cell (I-cell) disease

In patients with I-cell disease, fibroblasts do not digest material in their lysosomes, undigested material accumulates as "inclusions".

- **The lysosomal enzymes are found in the patients blood.**
- **A single gene defect is found in the enzyme which adds phosphate to mannose-6-phosphate oligosaccharides in Golgi.**

- **Why are the lysosomal enzymes in the blood?**
- **Why would this defect lead to the formation of inclusions within lysosomes?**

➢ **Write down your answers and hand these in.**

Which of these best explains why lysosomal proteins are in the blood?

A. Lysosomal enzymes are found in blood because instead of being targeted to lysosome, it has no signal. This causes it to go to extracellular space therefore into blood.

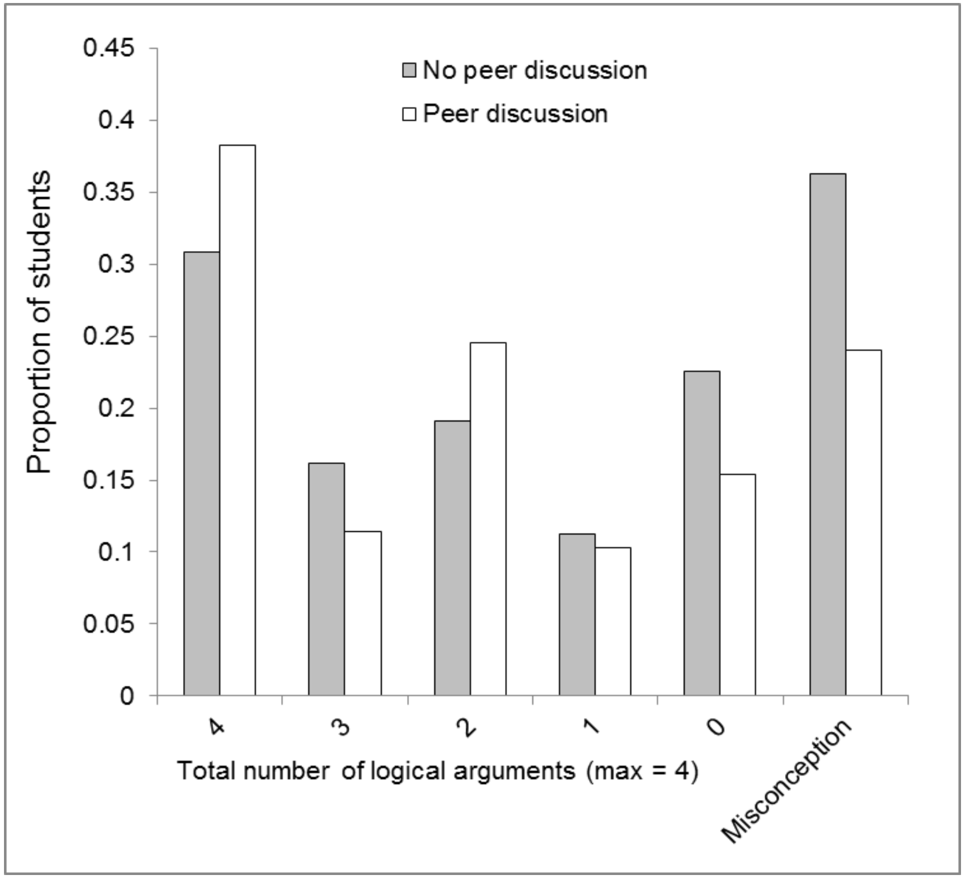
B. The addition of mannose without the phosphate signals for the enzymes to be exported from the cell so lysosomal enzymes end up in the blood.

C. Lysosomal enzymes are in the blood because they are secreted by the cell. The binding of phosphate to M6P prevents the receptor from recognizing the enzyme so that it will not be targeted to the lysosomes but secreted instead.

A and B are mostly correct but need editing to make them more accurate.

C contains incorrect information – Could be that this system is not fully understood, or it could be that the author had a different meaning in mind.

Does peer discussion help with causal reasoning?



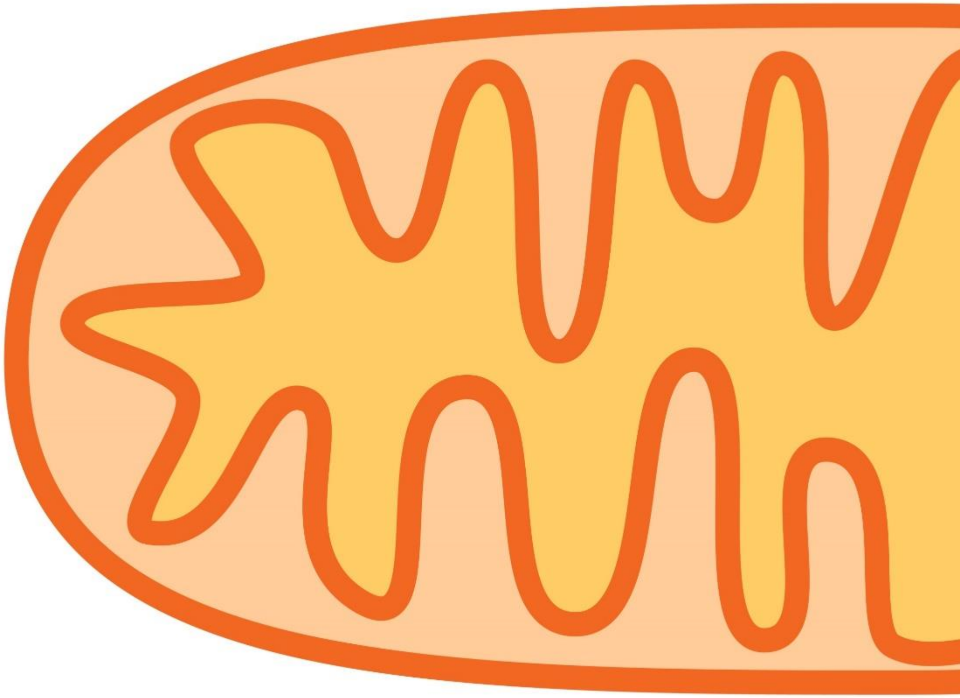
The influence of peer discussion on the development of logical arguments in BIOL 260

Dr. Mandy Banet

Dr. Laura Weir

Example #4 – worksheets and case studies

Robin Young

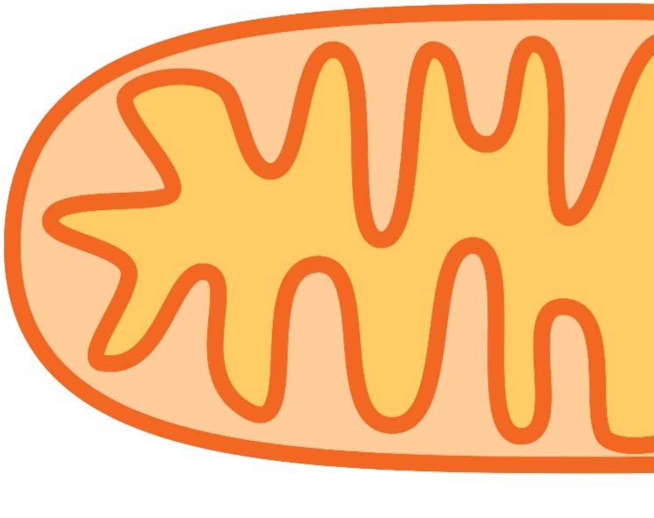


Simple worksheets to help students organize complex information

In-class exercise: Can you place all the parts of oxidative phosphorylation in the mitochondria?

Structural components:
- Outer membrane
- Inner membrane/ cristae
- Intermembrane space
- Matrix
- Porins
- Pyruvate transferase
- ATP exporter
- DNA
- Ribosomes
- TIM/TOM complex for protein import

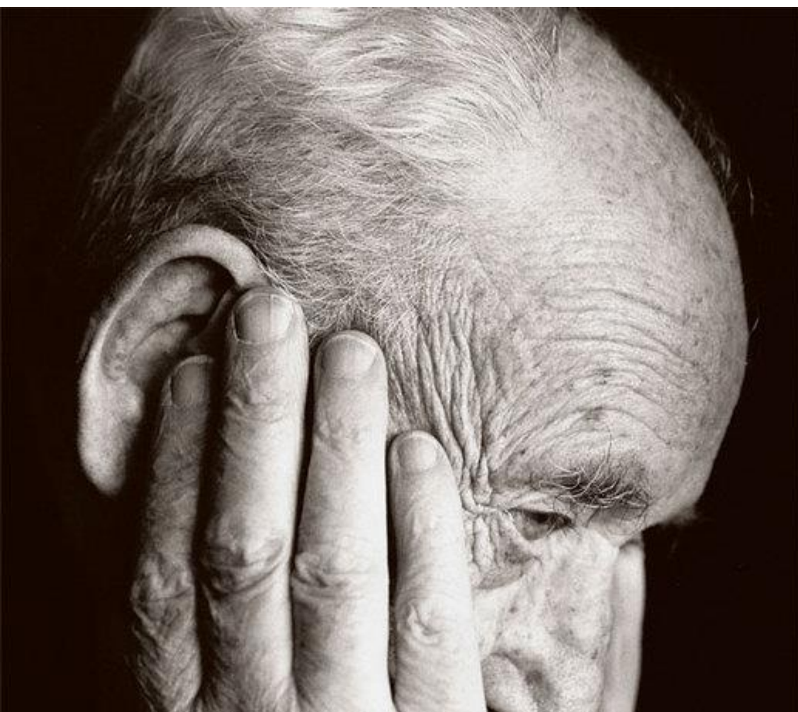
Functional components:
- Electron transport chain
- Citric acid cycle
- ATP synthase
- Site of ATP production
- Site of proton gradient



Example #4 Worksheets and case studies

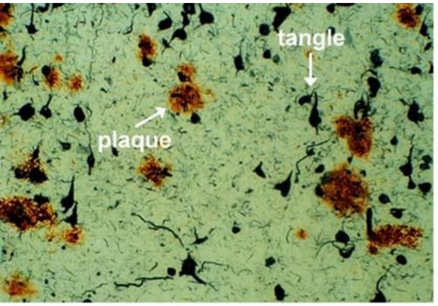
Case Study:

Alzheimer’s Disease and Chronic Traumatic Encephalopathy



Student task

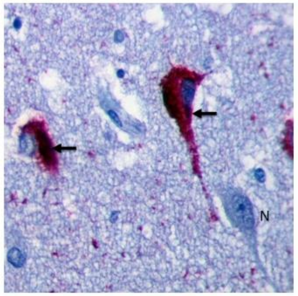
Examine the evidence presented and try to make a connection between this evidence and the neuronal dysfunction of these diseases.

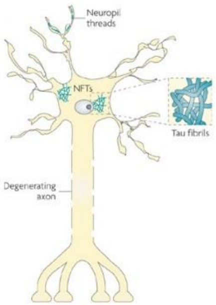


What you know

1. Images of the brain tissue in both diseases show intracellular, proteinaceous 'tangles' in the cytosol, which are composed of the microtubule associated protein, Tau.

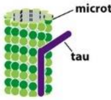
Ignore the plaques for today's exercise.





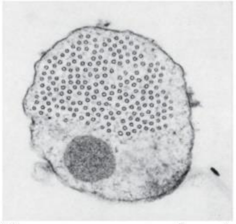
2. Immunohistochemistry for tau protein in the brain of an individual with Alzheimer's shows neurofibrillary tangles (red) visible in some neurons (arrows) but not in others (N).

Cartoon from: Brunden KR, et al. 2009 Nat Rev Drug Discov. Oct;8(10):783-93.



What you know

(B)



(D)

300 nm

10 µm

3. Figure 16-51 of our textbook tells us that Tau is involved in the formation of the MT network in the axon of neurons

Example of student work

Students work through a series of directed tasks

For this Case Study, you are required to come up with a hypothesis that attempts to answer the central question, as well as a short rationale for your hypothesis. To help you with this, we have built the following worksheet for you to use. You may fill out your answers directly in this worksheet and hand it in.

Hypothesis = [Subject] + [claim/interpretation]
Rationale = paragraph (ish) that explains how
the data connects to your hypothesis

Part 1. (10% of total time, 1 pt) Look at the Central Question of your Case Study. Based on the central question:
1A. What do you think the subject of your hypothesis should be?
Hyper-phosphorylated Tau

1B. Based on the Central Question, where should you focus your attention when interpreting the experimental evidence?
How phosphorylated Tau disrupts microtubule organization

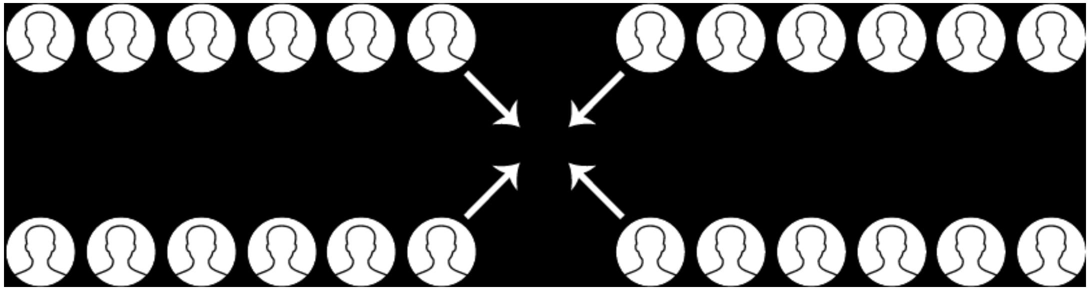
Part 2. (50% of total time, 5 pts) Now look at each slide that presents experimental evidence in this case study. For each slide summarize the main conclusion of that experimental evidence, using the same format as your hypothesis (H=[S]+[C]). List each one below.
Slide 1: Tau causes protein tangles in the brain tissues of AD and CTE patients.
Slide 2: Tau fibrils in some neurons are shown in high density in the cell body of in Alzheimer's patients, which causes axon degeneration.
Slide 3: Tau is involved in formation of microtubule networks by forming links between the sides of the filaments.
Slide 4: Hyper-phosphorylated tau leads to neural tangles while dephosphorylated tau in vitro regain normal shape and function.
Slide 5: Hyper-phosphorylated tau expressing axon profiles have no microtubules and are tightly organized, lacking space

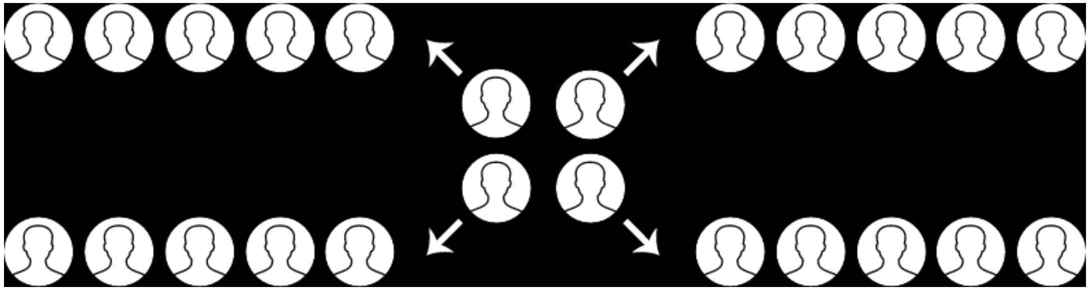
Part 3. (30% of total time, 3 pts) Look at your summaries of the experimental evidence. Try to find the thread that links them to each other and the Central Question.
3A. Look at Part 1 again to see what the question tells you about the subject of your hypothesis. Do you still agree with your answer there? Explain your answer.
Yes, we agree that hyper-phosphorylated tau is the subject. Hyper-phosphorylation of tau changes the conformation of the tau protein. Tau is associated with microtubules. In CTE and AD patients, there are a high number of hTau proteins, and a lower number of correctly organized microtubules

Example #4 – worksheets and case studies

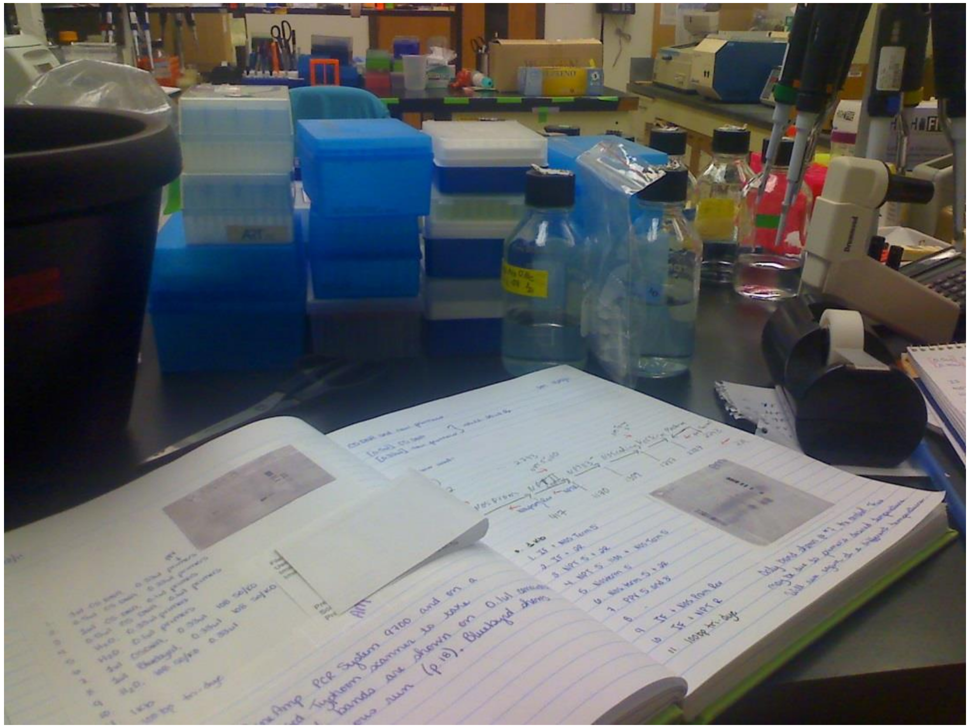
Jigsaw activities

Tammy Rodela





Example #5 – worksheets for skill building



Keeping a lab notebook

Example #4 – worksheets for skill building

- **Lab notebooks collected from a variety of labs across campus**
- **Each student given a notebook to look at during class**

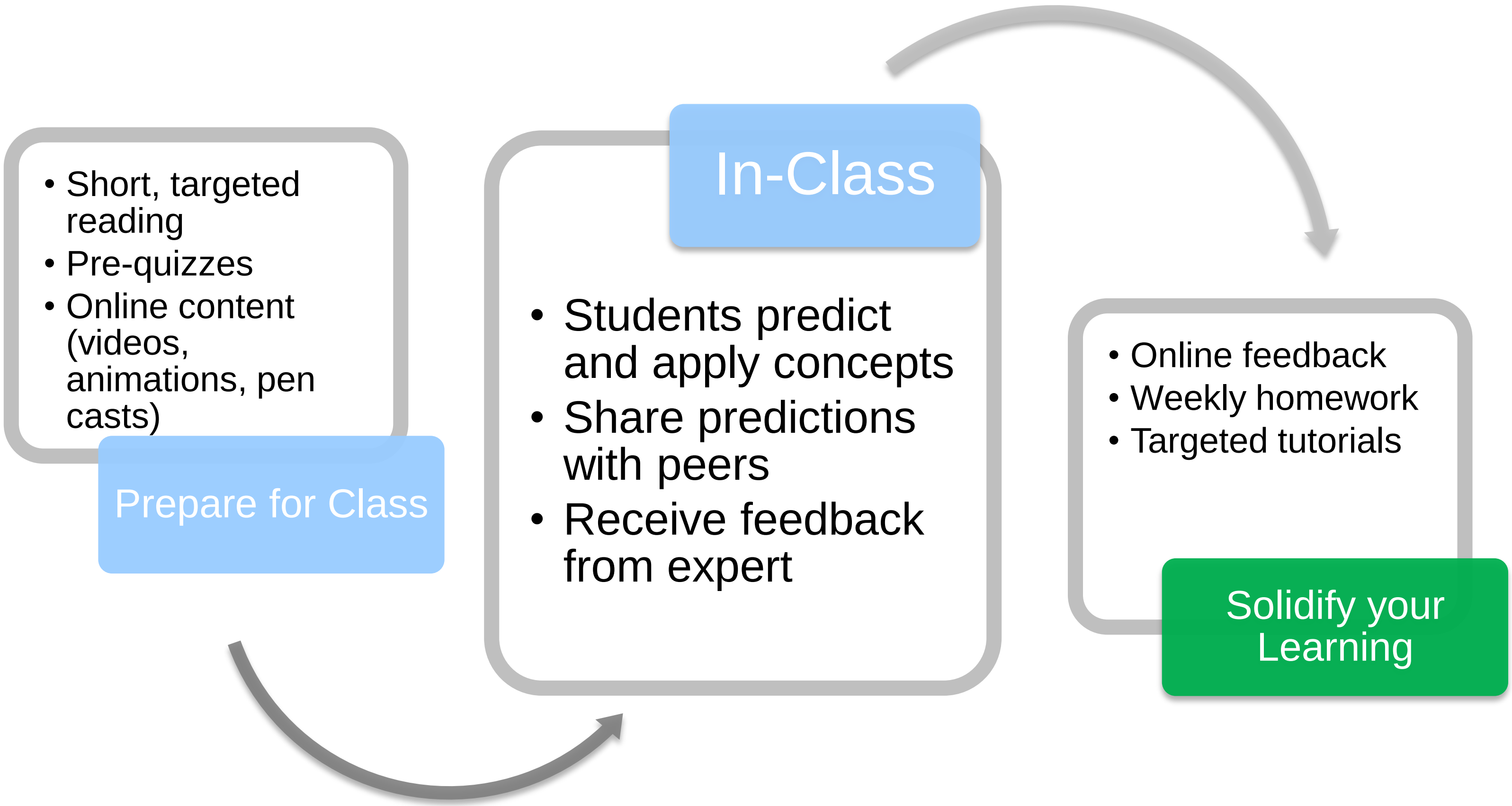
Task:

What (in general) was this scientist trying to do? What were the best/most useful things in this notebook that helped you figure out what was going on?

In class activities - examples

- **Two stage review activity**
- **Clicker questions**
- **In class problems**
- **Worksheets and case studies**

Homework activities



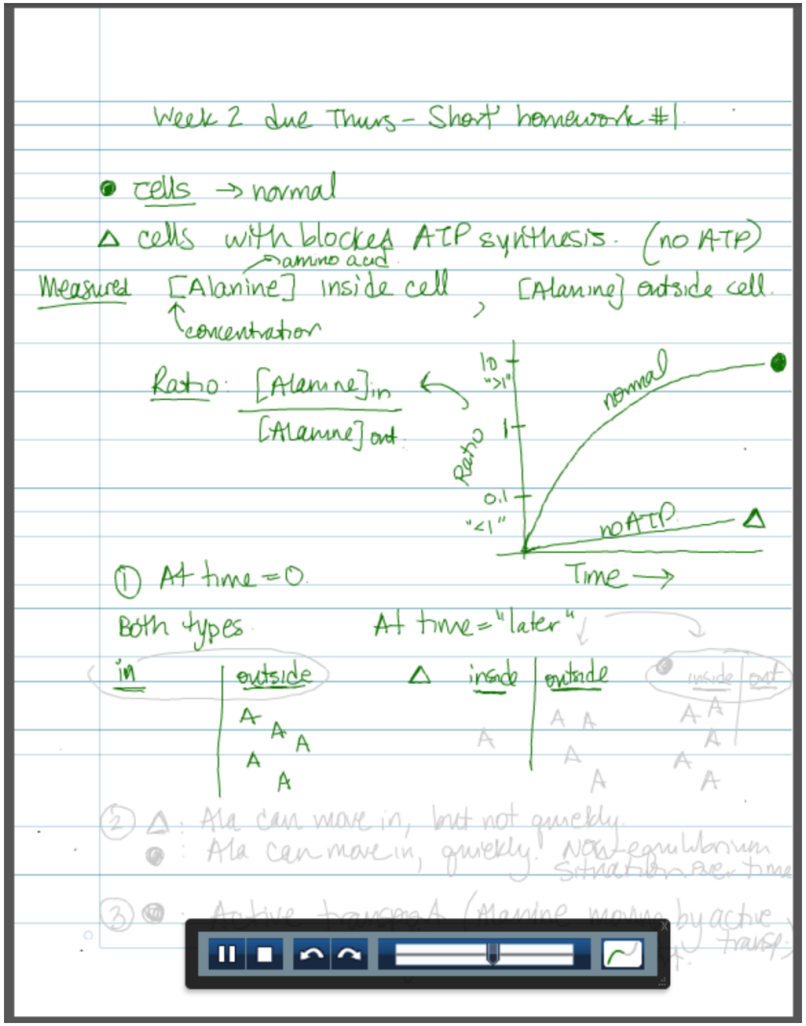
- Develop homework activities and online feedback to reinforce learning

Providing feedback on homework

How can we efficiently provide feedback?

Using pencasts for feedback

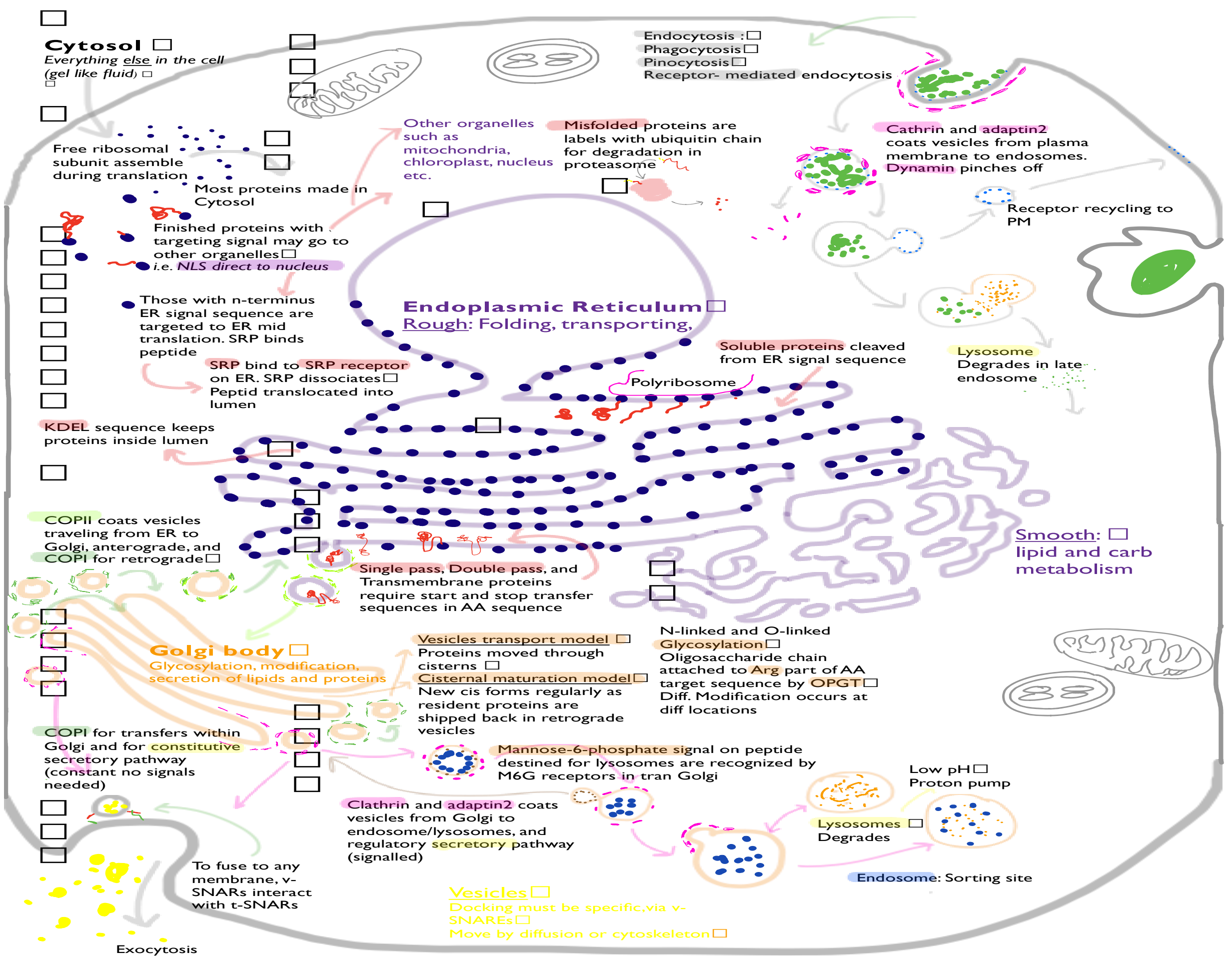
http://www.livescribe.com/



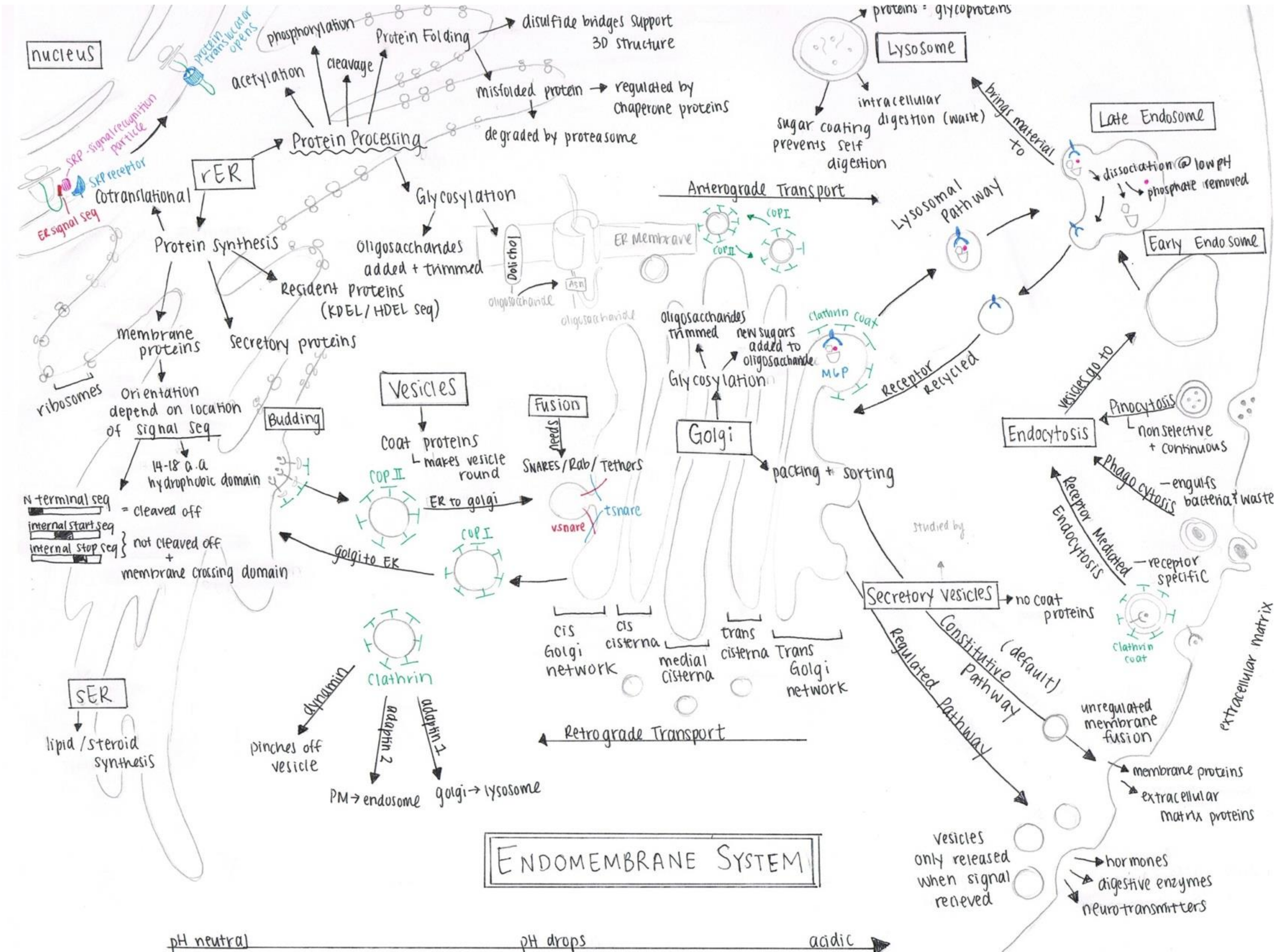
Providing feedback on homework

- Your task is to build a concept map of Unit 5, take a picture and post it to the Discussion board by the **end of Friday (Oct 31st)**.
- **Over the weekend**, you should go in and take a look at all of the concept maps and rate them (0-5 stars), based on how well you think they cover Unit 5.
- On **Tuesday (Nov 4th)** we will look at the top 4 together, and vote on which one is the best.
- **The will be a prize** for the best Unit 5 Concept map, as voted on by you.

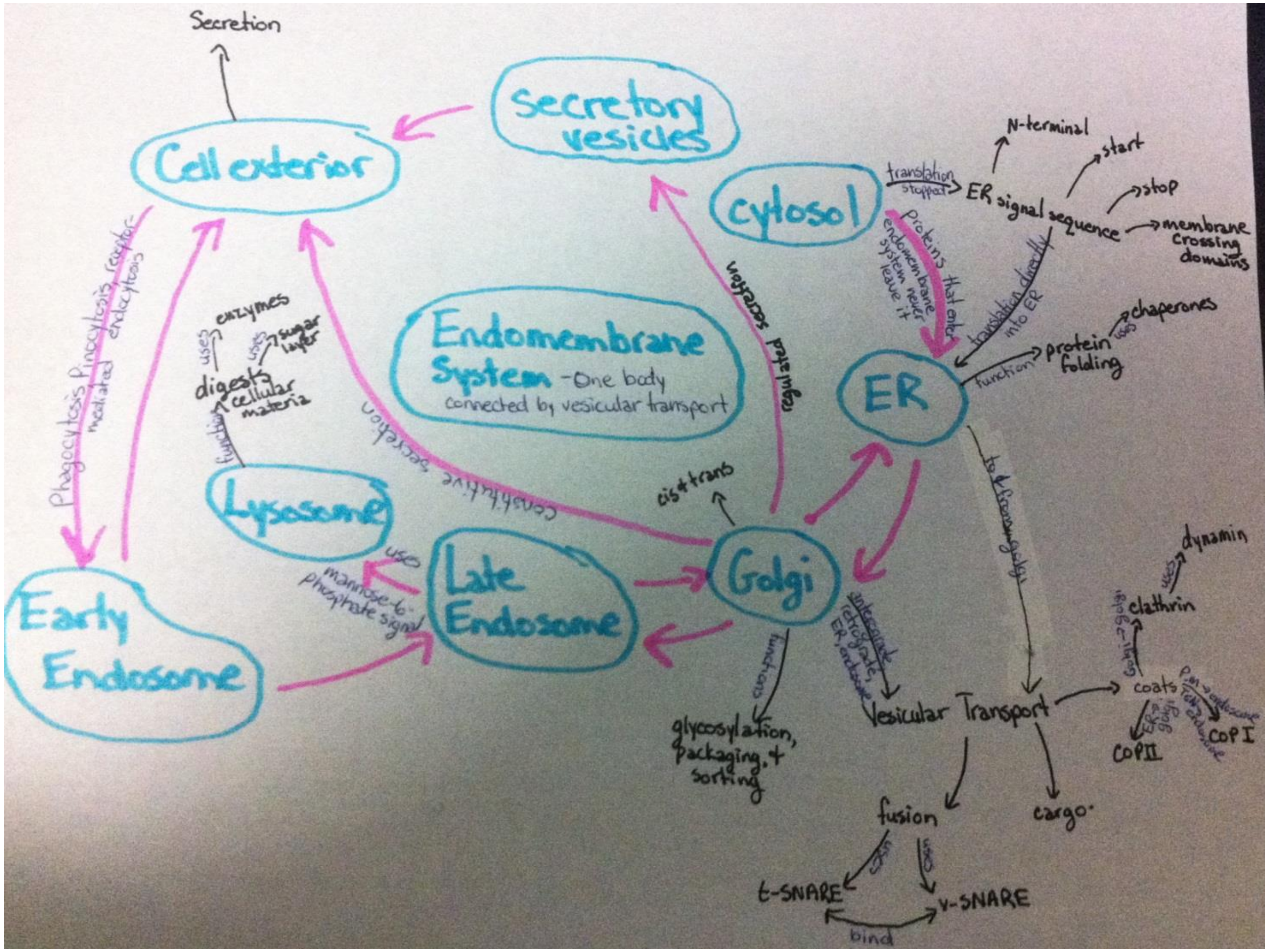
Examples of student work



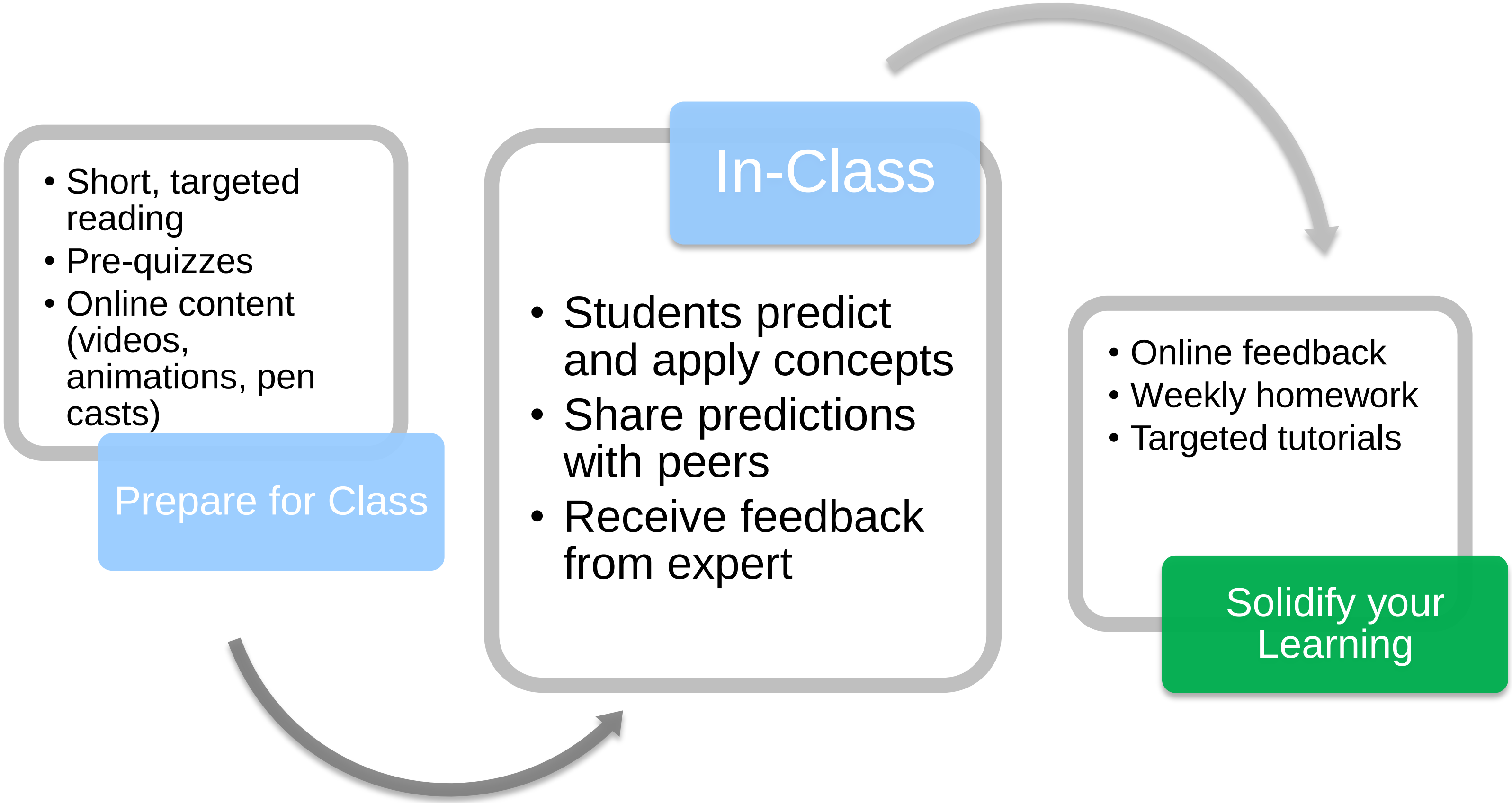
Examples of student work



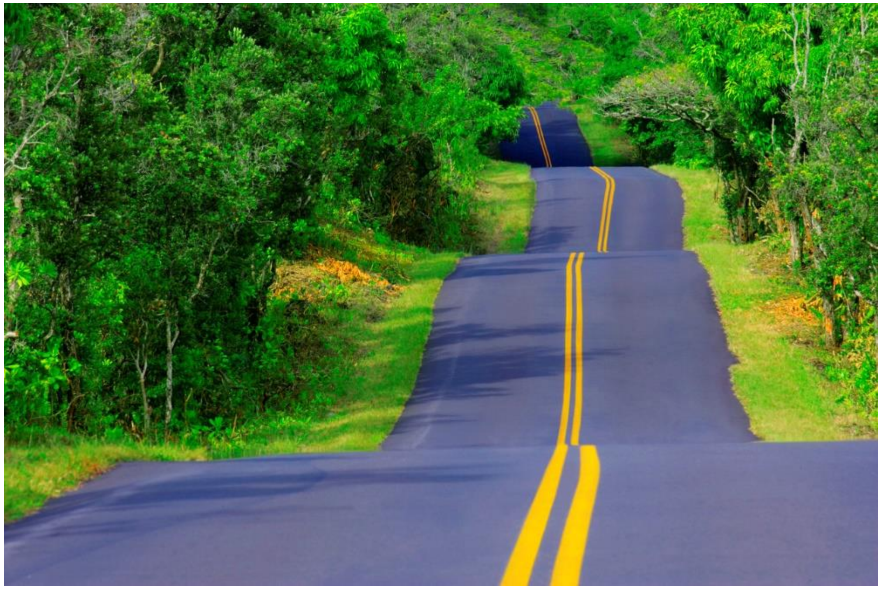
Examples of student work



Transforming your class



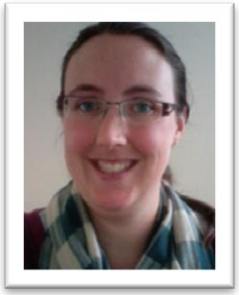
Take home messages



- ***Even small changes can have a big effect***
- ***There are proven approaches that facilitate change***
- ***Transformation is an iterative process***

CWSEI Life Sciences

Jared Taylor



Megan Barker

Lisa McDonnell

Tammy Rodela

Natalie Schimpf

Laura Weir

Martha Mullally

Mandy Banet

Bridgette Clarkston

Malin Hansen

http://ls-cwsei.biology.ubc.ca/

http://www.cwsei.ubc.ca/

http://www.cwsei.ubc.ca/resources/instructor_guidance.htm