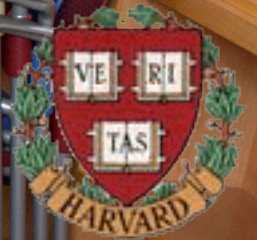


- 
- A group of students are seated around a white circular table in a bright, modern classroom or lab. Several laptops are open on the table, and a notebook with a yellow pencil lies in the foreground. The students are engaged in a collaborative activity, with some looking at the laptops and others talking. The background shows more students and large windows letting in natural light.
- 1. Get onto the Wifi (see instructions on table)**
 - 2. Go to: <http://LCatalytics.com>**
 - 3. Create student account with signup code DEMO**
 - 4. Join session 1234567**

Flat space, deep learning



1ère journée de l'innovation pédagogique
Université de Lausanne
Lausanne, Suisse, 28 novembre 2013

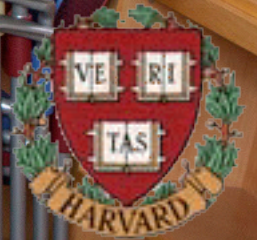


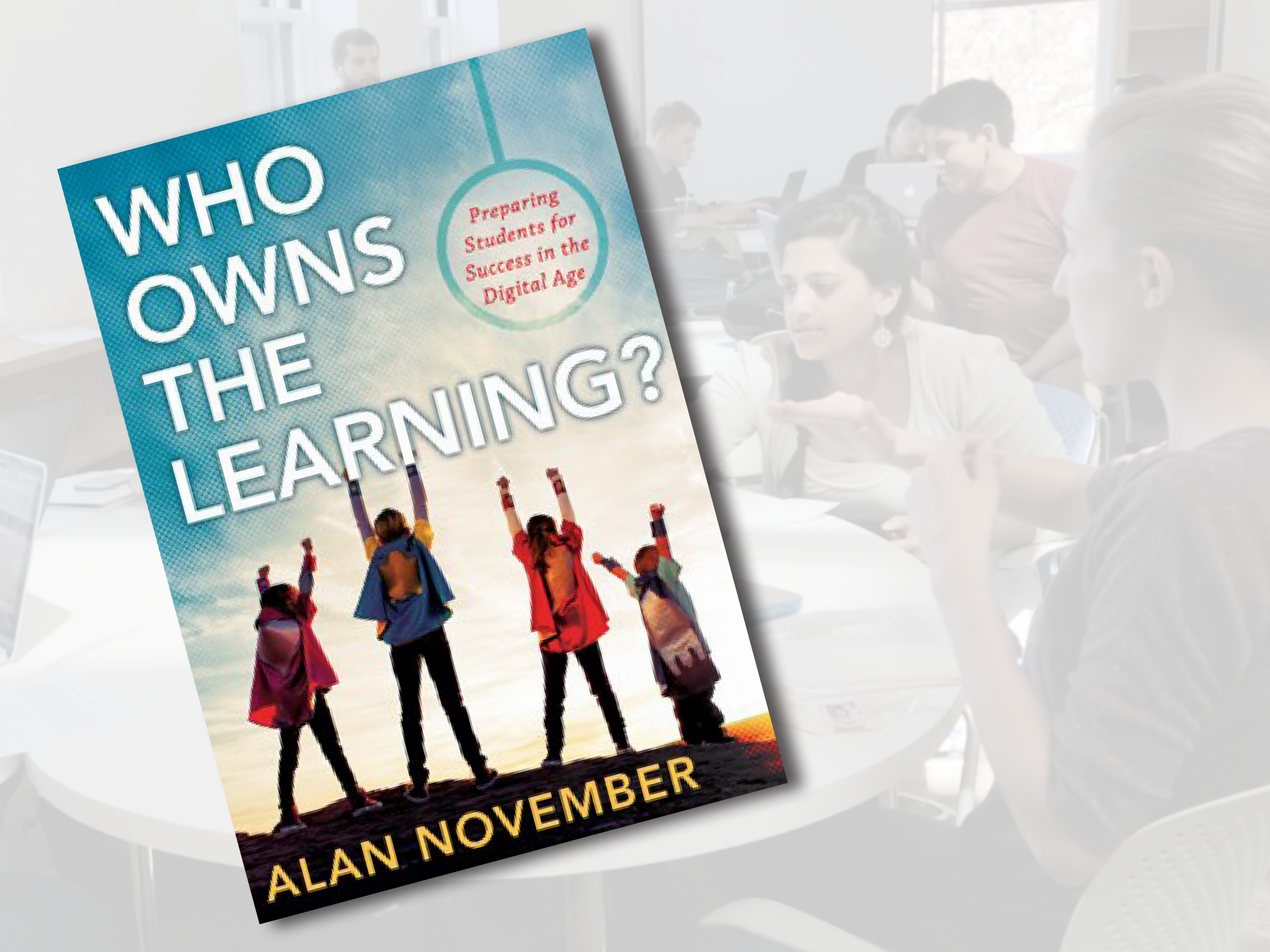
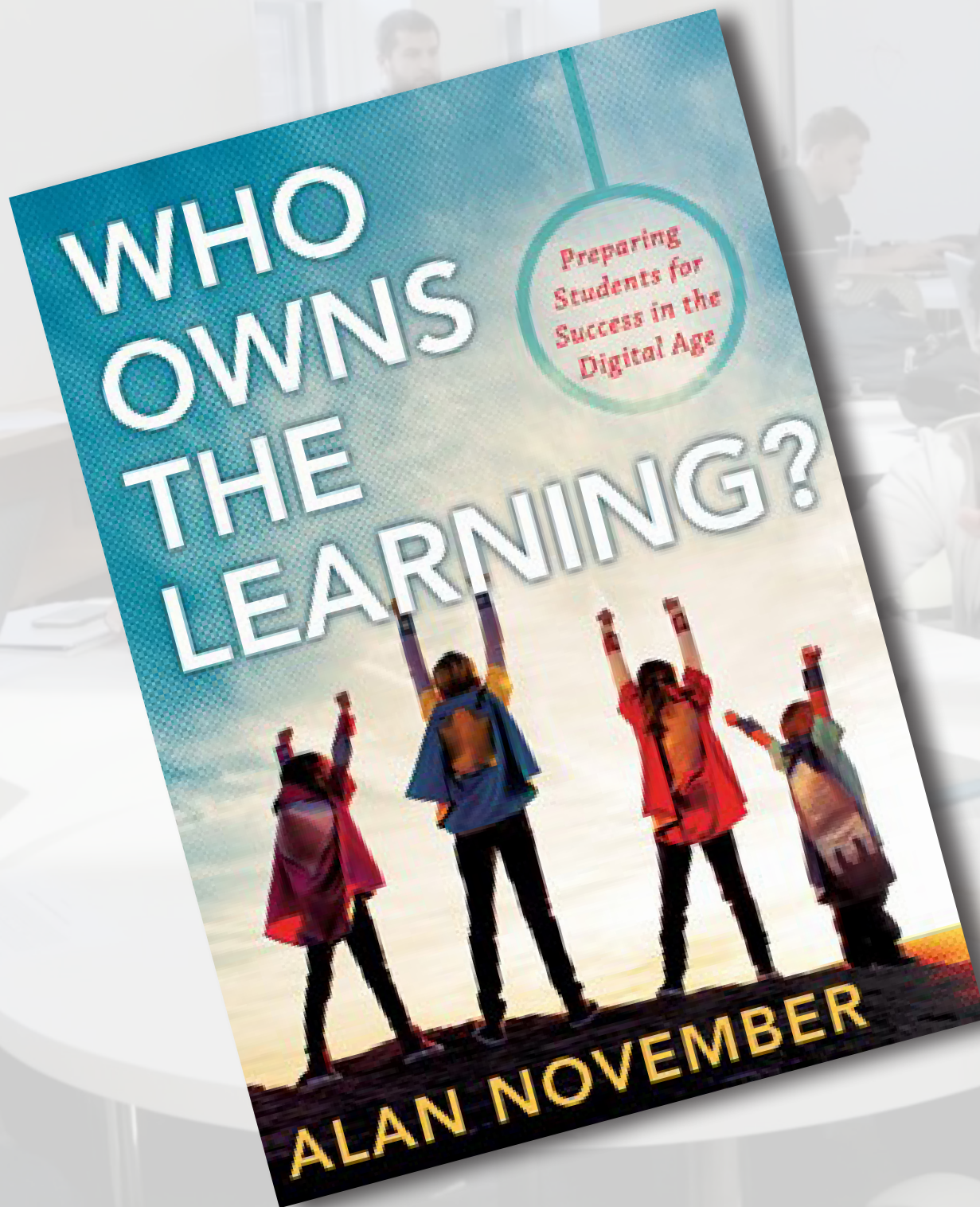
Flat space, deep learning



@eric_mazur

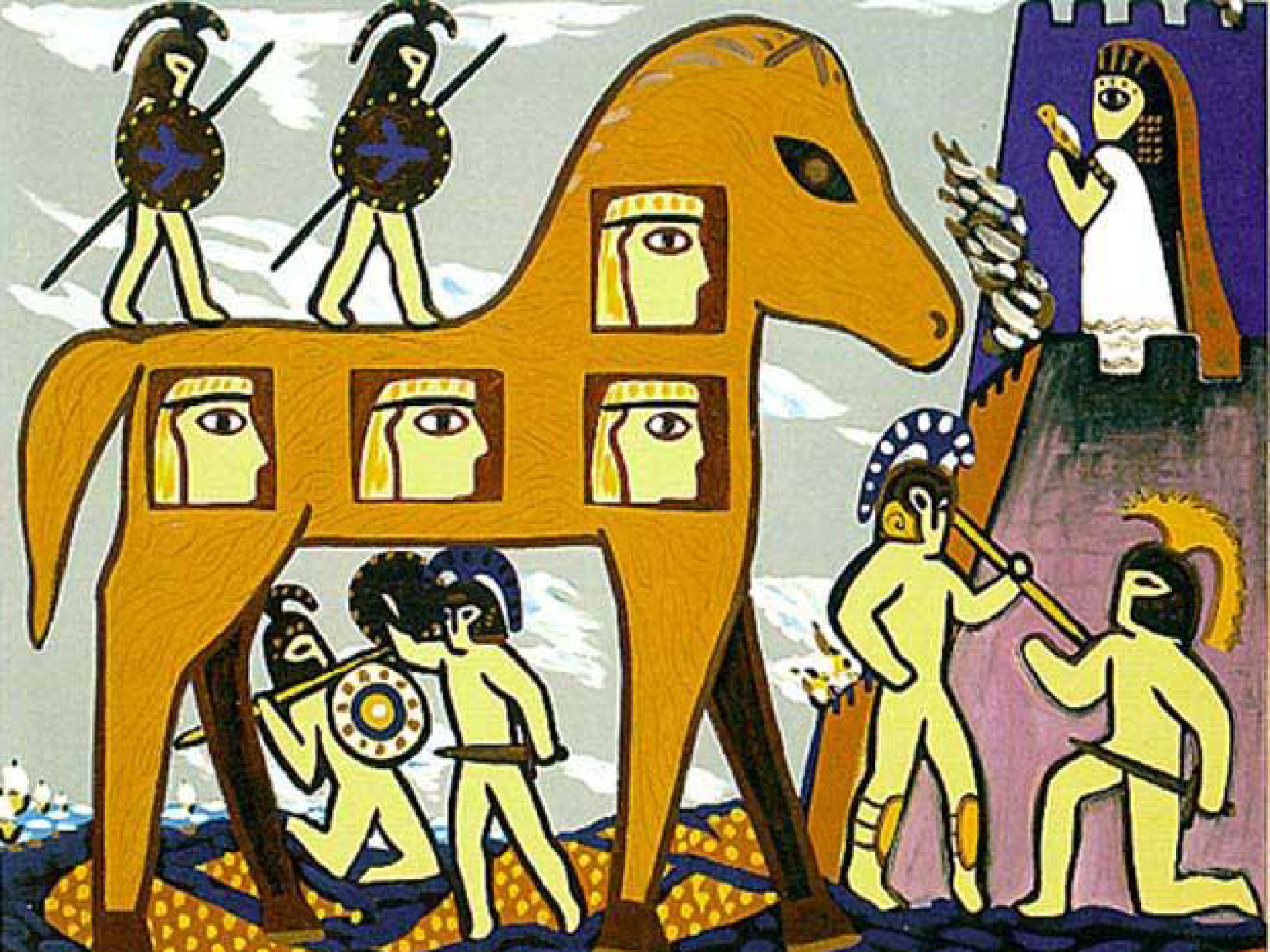
1ère journée de l'innovation pédagogique
Université de Lausanne
Lausanne, Suisse, 28 novembre 2013





A group of students are in a modern, bright classroom or lab. They are seated at round white tables, working on laptops. In the foreground, a woman with dark hair is looking at a laptop screen, while a man with a beard stands in the background. The text "Ownership of learning *physics*?" is overlaid in the center.

Ownership of learning *physics*?





team & project-based approach





1 design

2 approach



1 design

2 approach

3 results

A background image showing a group of students in a modern classroom or lab. They are seated at round tables, working on laptops. One student in the foreground is looking at a laptop screen displaying a website with the title 'learning catalysis'. Other students are engaged in discussion or working on their devices. The scene is brightly lit with large windows in the background.

Four tracks, all modeled after standard course for majors

A background image showing a group of students in a modern classroom or lab. They are seated at round white tables, working on laptops. Some students are looking at their screens, while others are engaged in discussion. The room has large windows in the background, letting in natural light. The overall atmosphere is collaborative and focused.

Four tracks, all modeled after standard course for majors
(don't satisfy needs of non-majors)

A background image showing a group of students in a modern, bright learning space. They are seated at round white tables, working on laptops and discussing. The atmosphere is collaborative and focused. The text is overlaid on this image.

Need to:

- **align goals to students' needs and expectations**
- **change the approach**
- **redesign the learning space**

competencies

COURSE GOALS

- After successful completion of this course, you will be able to... (within)
- Use independent study and research to tackle a problem
 - Apply the scientific method to advance your knowledge and to design
 - Use a variety of techniques to get a handle on problems: represent
 - perform order of magnitude estimates, use dimensional analysis
 - symmetries, evaluate limits, and/or relate the problem to cases w
 - Set up, solve, and interpret relevant equations
 - Know how to evaluate the correctness of a solution
 - Explain assumptions made in a model and know how to justify
 - Analyze a system, explain why it works, and how to optimize
 - Use information to build a case for a specific design or measur
 - Describe how a measurement is performed and the limitations
 - software to control simple experiments and accumulation
 - identify sources of uncertainty, and minimizing
 - measurement in order to develop
 - results and presentation

course goals

content-specific goals





information transfer

faculty-centered





interaction
student-centered



1 design

2 approach



CLASS

1st exposure



ROOM

deeper understanding

1 design

2 approach



1st exposure



deeper understanding



1st exposure



deeper understanding



no lectures

no exams

1 design

2 approach



Three major components:

- **information transfer (out of class)**
- **in-class activities**
- **projects**

Information transfer

social document annotation system

nb.mit.edu

1 design

2 approach

Information transfer

CHAPTER 28 Magnetic fields of charged particles in motion

2

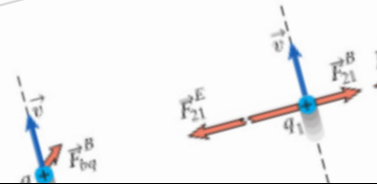
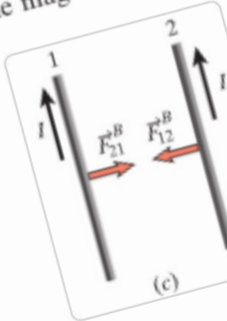
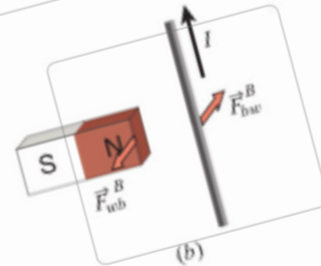
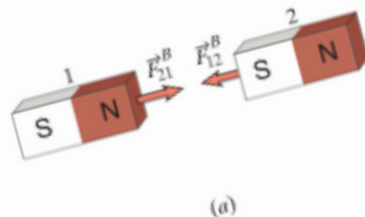
In this chapter we investigate further the relationship between the motion of charged particles and the occurrence of magnetic fields. As we shall see, all magnetism is due to charged particles in motion, whether moving along a straight line or spinning about an axis. It takes a moving or spinning charged particle to create a magnetic field, and it takes another moving or spinning charged particle to "feel" that magnetic field. We shall also discuss various methods for creating magnetic fields, which have wide-ranging applications in electromechanical machines and instruments.

28.1 Source of the magnetic field

As we saw in Chapter 27, magnetic interactions take place between magnets, current-carrying wires, and moving charged particles. Figure 28.1 summarizes the interactions we have encountered so far. Figures 28.1a–c show the interactions between magnets and current-carrying wires. The sideways interaction between a magnet and a current-carrying wire (Figure 28.1b) is unlike any other interaction we have encountered. The forces between the wire and the magnet are not central — they do not point directly from one

object to the other. As we saw in Section 27.7, the magnetic force exerted on a current-carrying wire is the sum of the magnetic forces exerted on many individual moving charge carriers. Similarly the magnetic field due to a current-carrying wire is the sum of the magnetic fields of many individual moving charge carriers. Figures 28.1d and 28.1e illustrate the magnetic interactions of moving charged particles. Note that for two charged particles moving parallel to each other (Figure 28.1e), there is, in addition to an attractive magnetic force, a (much larger) repulsive electric force. It is important to note that the magnetic interaction depends on the state of motion of the charged particles. No magnetic interaction occurs between a bar magnet and a stationary charged particle (Figure 28.1f). These observations suggest that the motion of charged particles might be the origin of all magnetism. There are two problems with this assumption, however. First, the magnetic field of a wire carrying a constant current looks very different from that of a magnet (Compare Figures 27.13 and 27.19). Second, there is no obvious motion of charged particles in a piece of magnetic material.

Figure 28.2a shows the magnetic field lines



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1 design

2 approach

Information transfer

Student 1 – 25 Feb, 04:55PM

Yeah, this is where I'm confused. From the first paragraph: "It takes a moving or spinning charged particle to create a magnetic field..." however there is no obvious motion of charged particles in a piece of magnetic material (bar magnet for example?). How does this reconcile?

Student 2 – 26 Feb, 08:29PM

Maybe they are trying to say that there is no OBVIOUS motion, but they are moving via a current. Therefore, it meets their definition that it takes moving particles to create a magnetic field

Student 3 – 2 Mar, 09:00AM

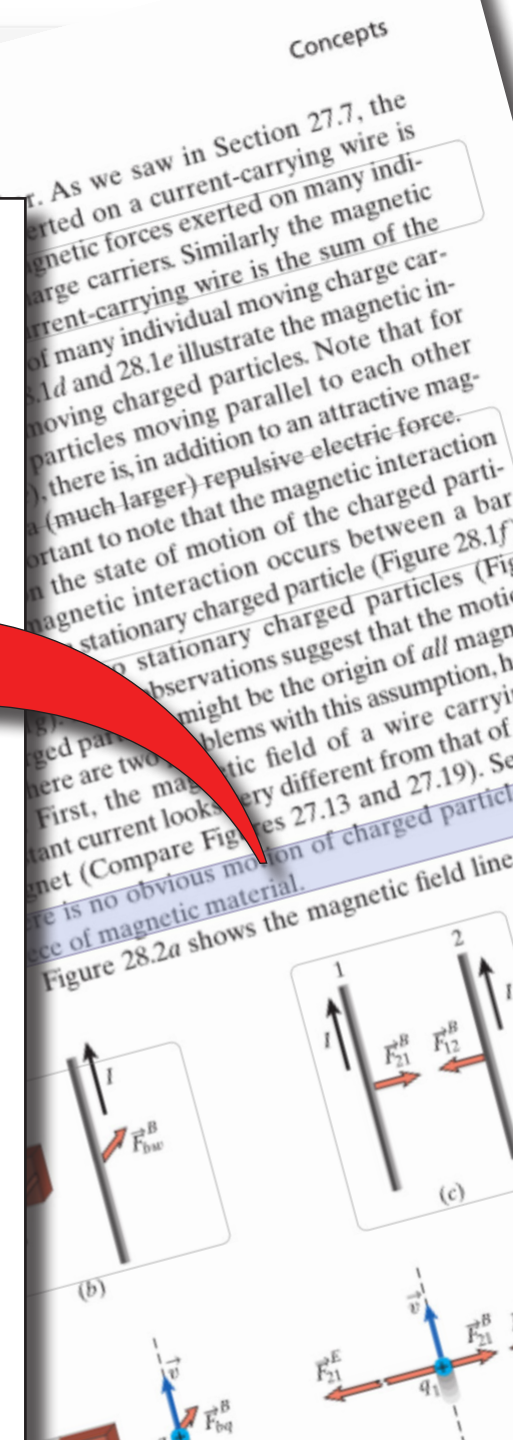
I agree that the motion is not "obvious" in that it is not visible to the naked eye. The cause must be atomic.

Student 2 – 2 Mar, 11:37AM

Oh the answers to this question kind of address my question above - I guess there isn't a force if the particle is stationary, but since even when an object is stationary (thus no obvious motion), there is a magnetic force. It's when everything, including the particles, are stationary that there is no obvious motion.

Student 4 – 4 Mar, 01:05PM

Is there ever a situation in reality where everything, even the particles are not ...



Information transfer

Student 1 – 25 Feb, 04:55PM

Yeah, this is where I'm confused. From the first paragraph: "It takes a moving or spinning charged particle to create a magnetic field... (however there is no obvious motion of charged particles in a piece of magnetic material like a bar magnet for example?). How does this come?"

Student 2 – 26 Feb, 08:29PM

Maybe they are trying to say that there is no OBVIOUS motion, but there is an invisible motion via a current. Therefore, it meets their definition that it takes moving particles to create a magnetic field

Student 3 – 2 Mar, 10:00AM

I agree that the motion is not "obvious" in that it is not visible to the naked eye. The cause must be atomic

Student 2 – 2 Mar, 11:37AM

Oh the answers to this question kind of address the question but I guess there isn't a force if the particle is stationary, but there is when a object is stationary (thus no obvious motion), there is a magnetic force. It's when everything, including the particles, are stationary that there is no obvious motion.

Student 4 – 4 Mar, 04:03PM

Is there ever a situation in reality where everything, even the particles are not ...



In-class activities



1 design

2 approach

In-class activities

2 weekly 3-hour class periods

1 design

2 approach

In-class activities

blend of best practices

1 design

2 approach

In-class activities

estimation

blend of best practices

1 design

2 approach

In-class activities

estimation

blend of best practices

reflection

1 design

2 approach

In-class activities

estimation

blend of best practices

reflection

readiness assurance

In-class activities

learning catalytics

estimation

blend of best practices

reflection

readiness assurance

1 design

2 approach

In-class activities

learning catalytics

estimation

tutorials

blend of best practices

readiness assurance

reflection

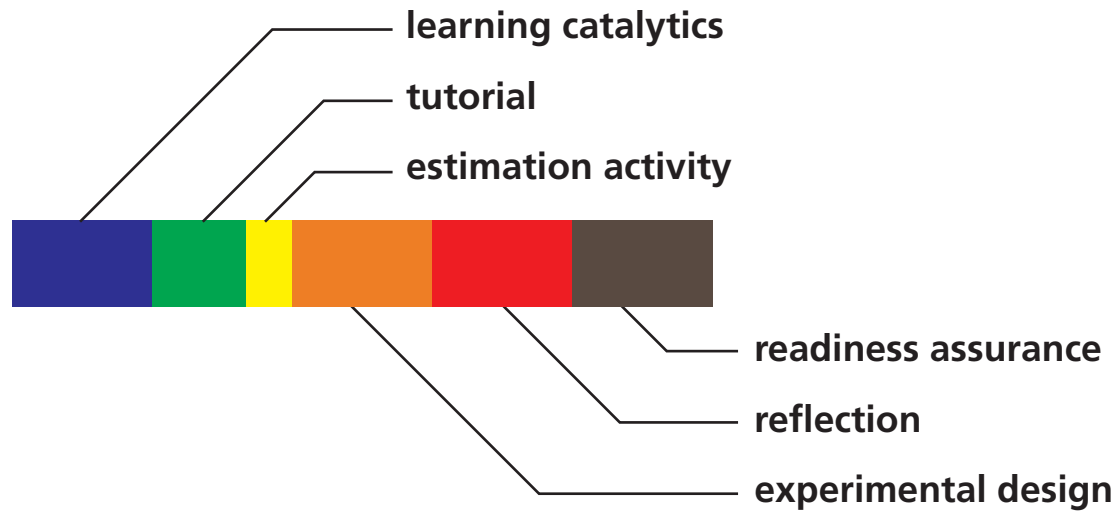
In-class activities

learning catalytics
estimation
tutorials
blend of best practices
experimental design
reflection
readiness assurance

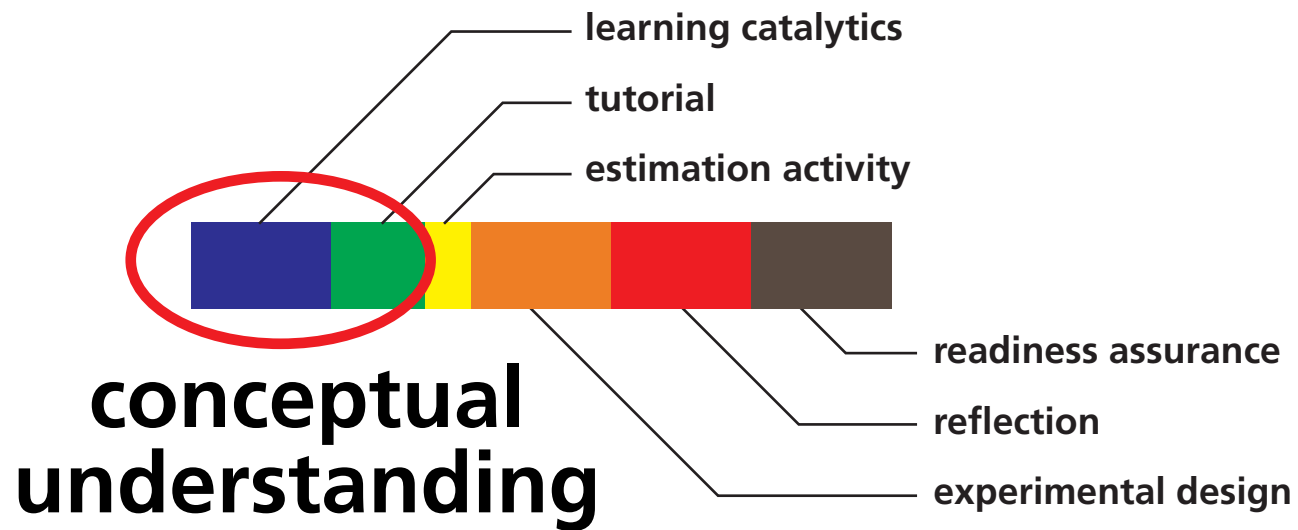
1 design

2 approach

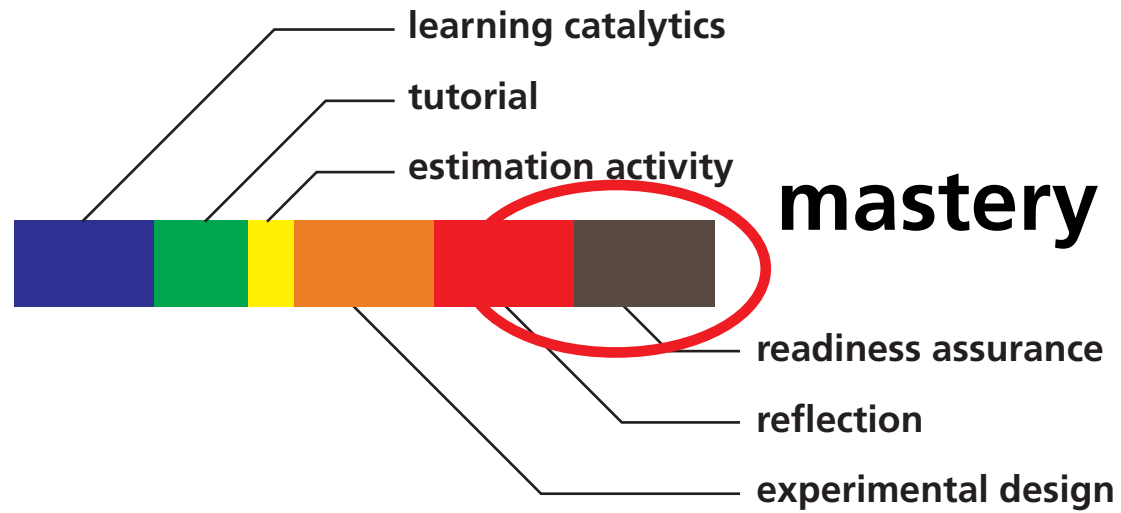
In-class activities



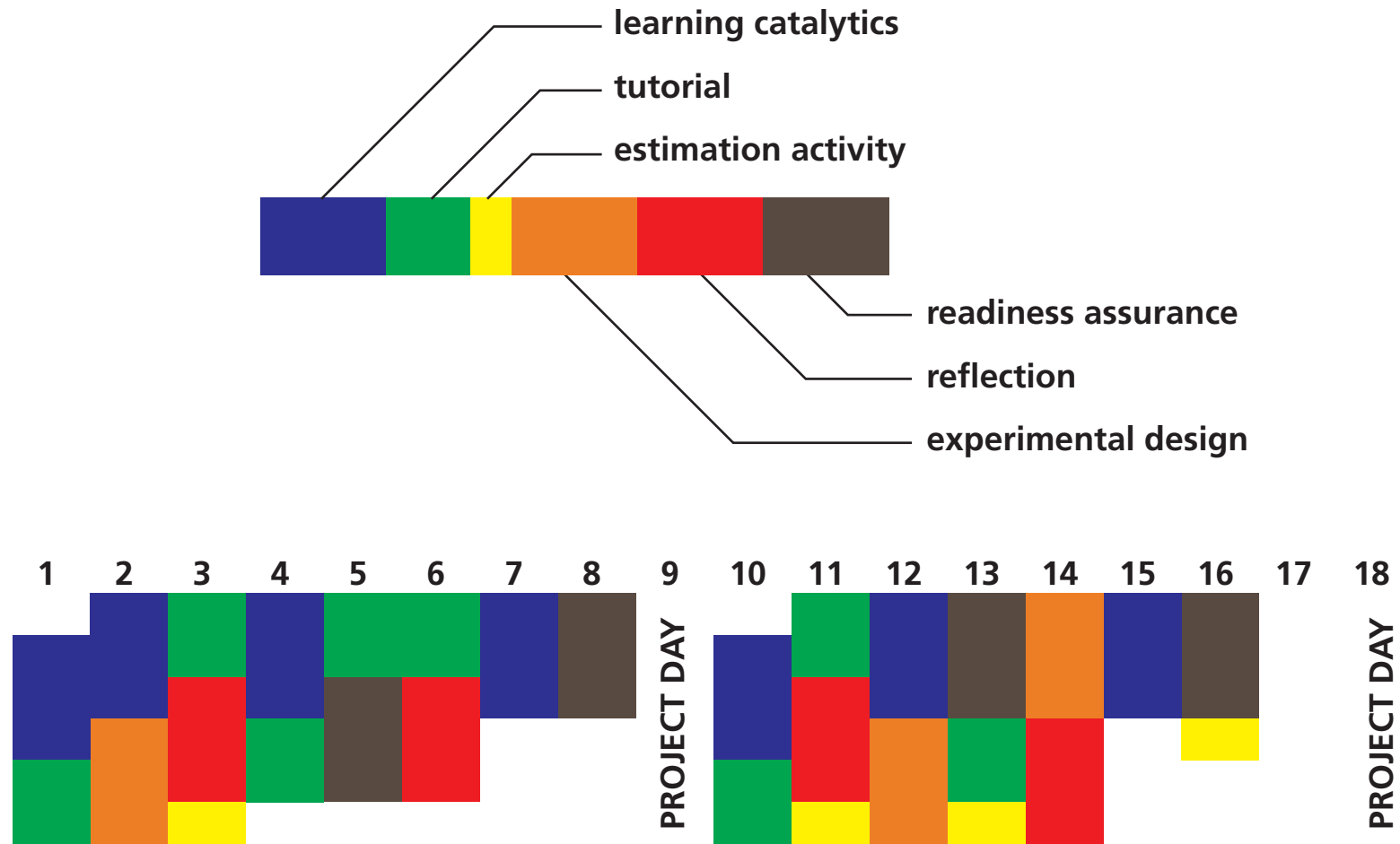
In-class activities



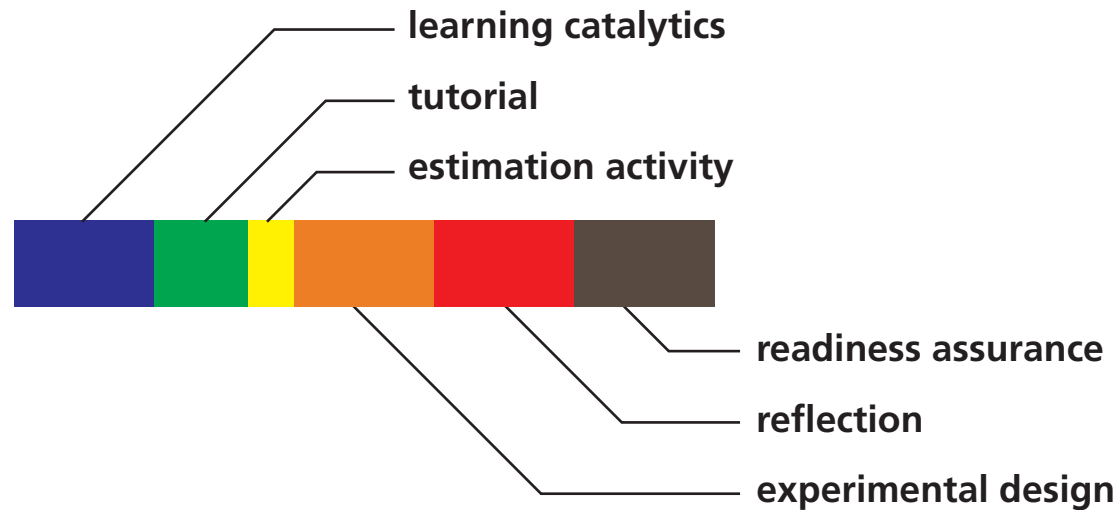
In-class activities



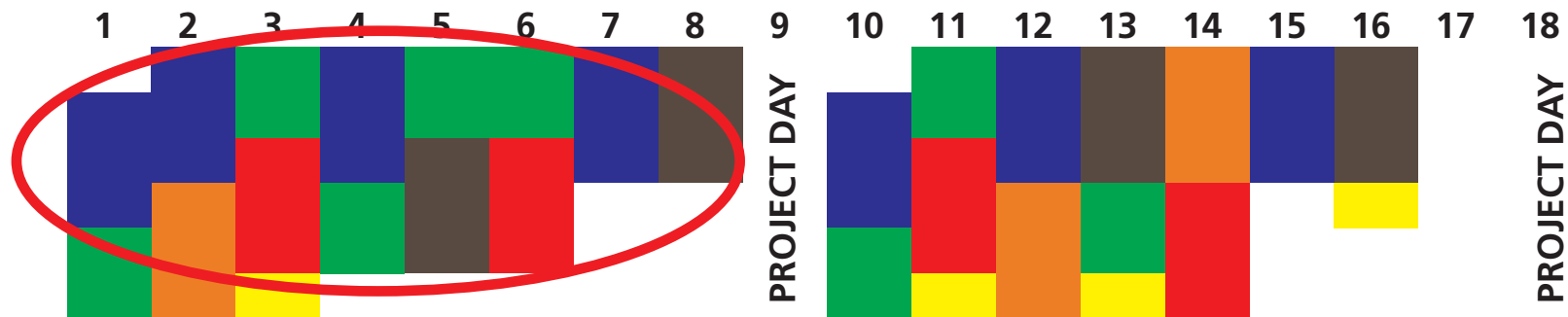
In-class activities



In-class activities



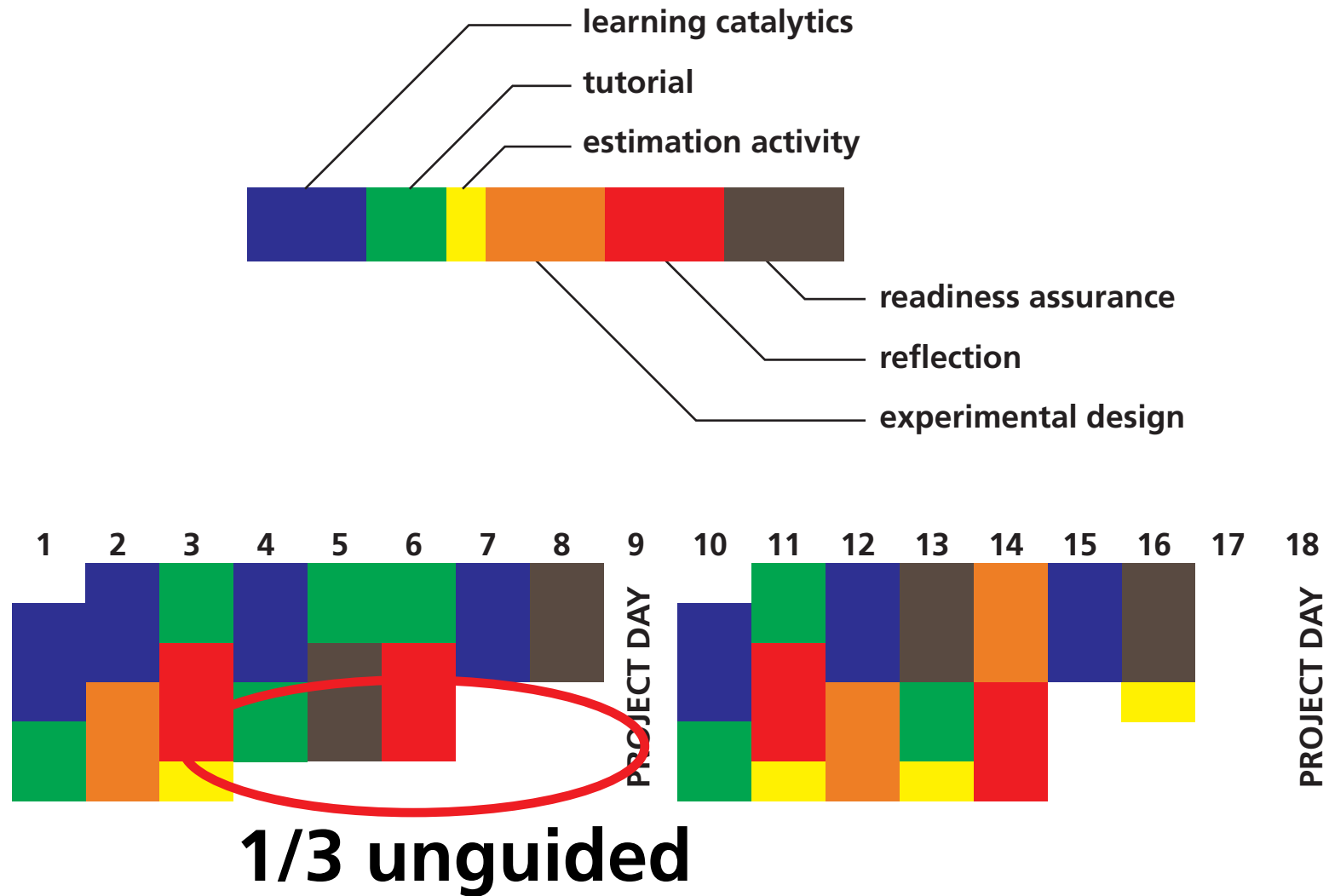
2/3 scaffolded, guided



1 design

2 approach

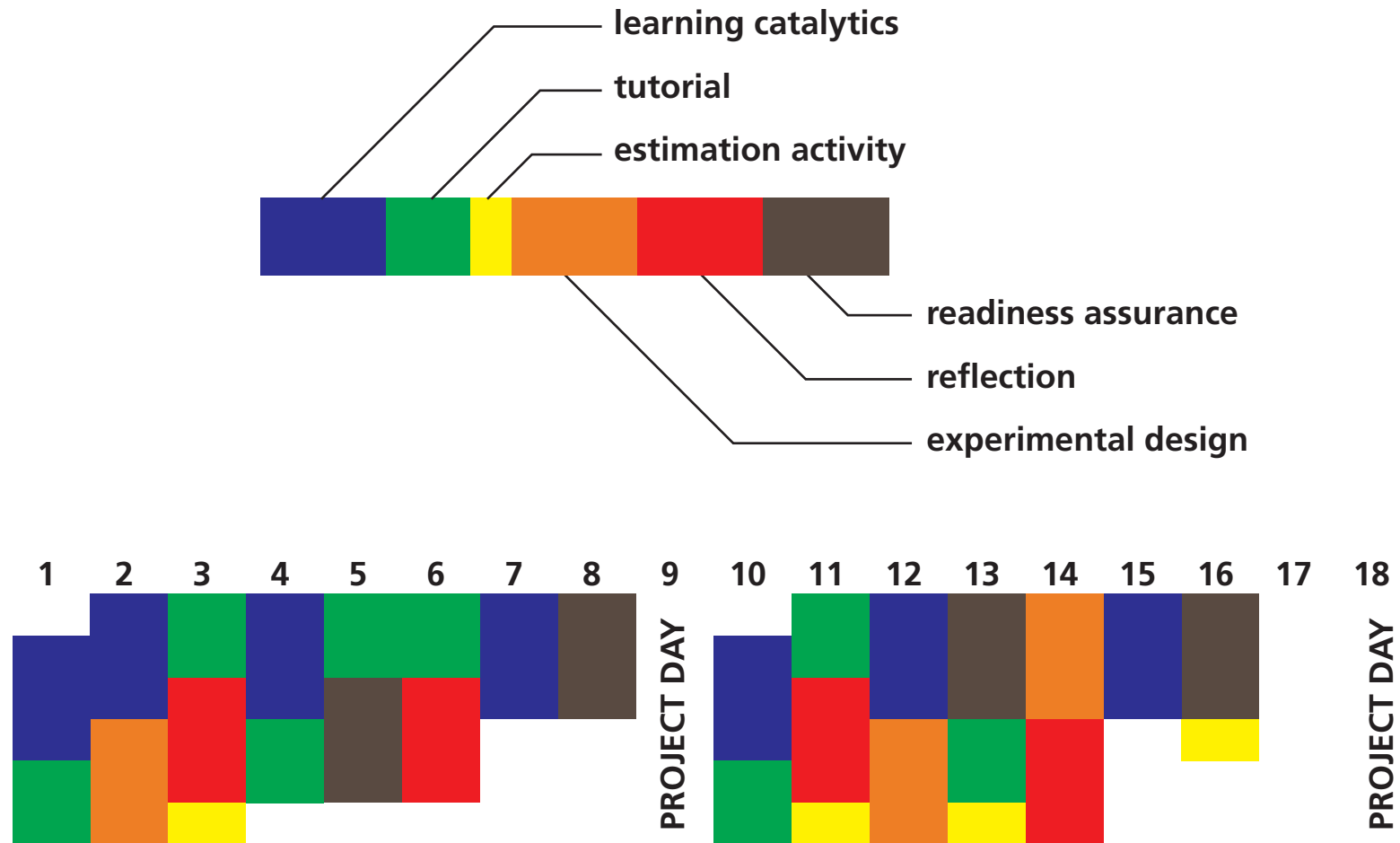
In-class activities



1 design

2 approach

In-class activities



learning catalytics

1 design

2 approach

learning catalytics

goal: develop conceptual understanding

1 design

2 approach

learning | catalytics

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optics i

current session: **766079** | 69 students[Back to all lectures](#) [Stop session](#) [Review results](#) [Seat map](#) [Show floating session ID](#) [Edit](#) [Delete](#)

Jump to ▼

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15

**4.** direction Light enters horizontally into the combination of two perpendicular mirrors as shown below.[Deliver](#) [Show all results](#)

Indicate the direction of the incident light after it reflects off of both mirrors.



feedback & support

1 design**2** approach

learning | catalytics

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optics i

current session: **766079** | 69 students[Map](#) [Show floating session ID](#) [Edit](#) [Delete](#)

6 7 8 9 10 11 12 13 14 15

perpendicular mirrors as shown below.

[Deliver](#) [Show all results](#)

Carrier 10:40 PM session 766079 Logout

Light enters horizontally into the combination of two perpendicular mirrors as shown below. Indicate the direction of the incident light after it reflects off of both mirrors.



Submit response

[Switch to text response](#)[feedback & support](#)**1** design**2** approach

learning | catalytics

[Courses](#) [Participate](#) [Review](#) [Classifications](#) [Purchases](#) [Users](#) [Tour](#) [Help](#)

optics i

current session: **766079** | 69 students[Map](#) [Show floating session ID](#) [Edit](#) [Delete](#)

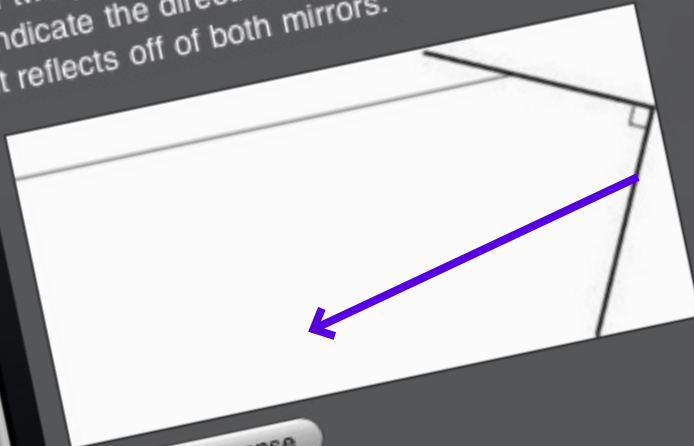
6 7 8 9 10 11 12 13 14 15

perpendicular mirrors as shown below.

[Deliver](#) [Show all results](#)

Carrier 10:40 PM session 766079 Logout

Light enters horizontally into the combination of two perpendicular mirrors as shown below. Indicate the direction of the incident light after it reflects off of both mirrors.



Submit response

[Switch to text response](#)[feedback & support](#)

1 design

2 approach

learning | catalytics

[Courses](#) [Participate](#) [Review](#) [Classifications](#) [Purchases](#) [Users](#) [Tour](#) [Help](#)current session: **766079** | 69 students[Map](#) [Show floating session ID](#) [Edit](#) [Delete](#)

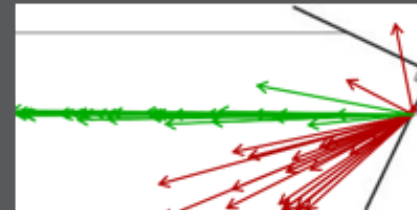
6 7 8 9 10 11 12 13 14 15

perpendicular mirrors as shown below.

[Deliver](#) [Show all results](#)

Round 1

57 responses, 58% correct



feedback & support

1 design**2** approach

learning | catalytics

[Courses](#) [Participate](#) [Review](#) [Classifications](#) [Purchases](#) [Users](#) [Tour](#) [Help](#)current session: **766079** | 69 students[Map](#) [Show floating session ID](#) [Edit](#) [Delete](#)

6 7 8 9 10 11 12 13 14 15



perpendicular mirrors as shown below.

[Deliver](#) [Show all results](#)

Round 1

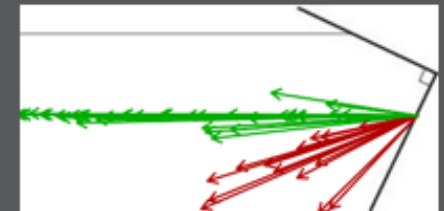
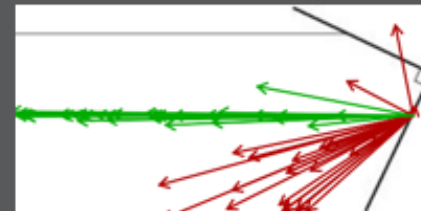


57 responses, 58% correct

Round 2



51 responses, 73% correct



✓ 8 get it now

✗ 0 still don't get it



feedback & support

Indicate the d

1 design

2 approach

learning | catalytics

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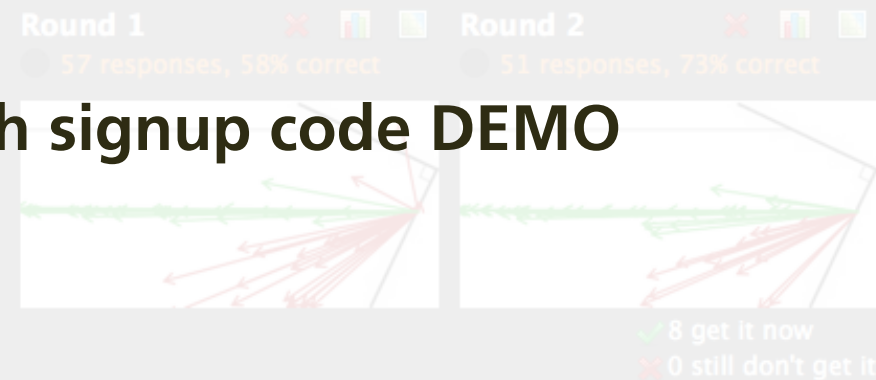
13

14

15



4. direction Light enters from the left and is shown below.

[Deliver](#) [Show all results](#)**1. Get onto the Wifi (see instructions on table)****2. Go to: <http://LCatalytics.com>****3. Create student account with signup code DEMO****4. Join session 1234567**

Indicate the direction of the incident light after it reflects off of both mirrors.

[feedback & support](#)**1 design****2 approach**

The background of the slide is an abstract painting featuring concentric, swirling patterns in shades of blue, green, and yellow, resembling a vortex or a stylized eye. On the left side, there is a vertical bar with five colored squares: light purple, green, yellow, orange, and red. The word "tutorials" is written in a bold, black, sans-serif font in the upper left area.

tutorials

1 design

2 approach



tutorials

goal: address documented misconceptions

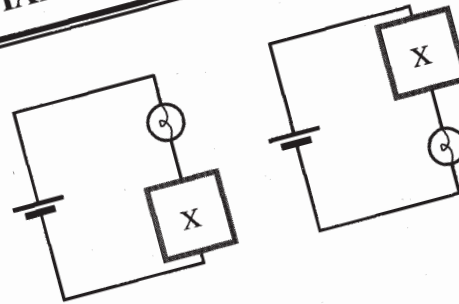
1 design

2 approach

A MODEL FOR CIRCUITS PART 2: POTENTIAL DIFFERENCE

I. Current and resistance

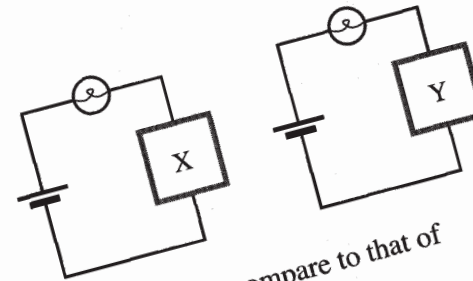
- A. The circuits at right contain identical batteries, bulbs, and unknown elements labeled X.



How do the bulbs compare in brightness? Explain.

In each circuit, how does the current through the bulb compare to the current through element X? Explain.

- B. The circuits at right contain identical batteries and bulbs. The boxes labeled X and Y represent different unknown elements. (Assume there are no batteries in either box.)



It is observed that the bulb on the left is brighter than the bulb on the right.

- Based on this observation, how does the resistance of element X compare to that of element Y? Explain.
- In each circuit, how does the current through the bulb compare to the current through the unknown element?
- In each circuit, how does the current through the bulb compare to the current through the battery?

McDermott et al., *Tutorials in Introductory Physics* (Prentice Hall, 2002)

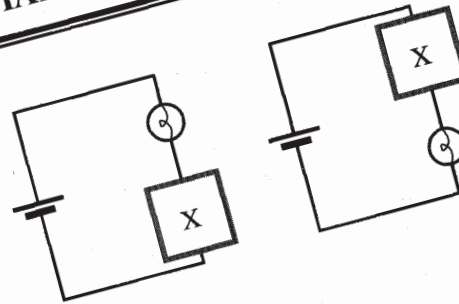
brightness



A MODEL FOR CIRCUITS PART 2: POTENTIAL DIFFERENCE

I. Current and resistance

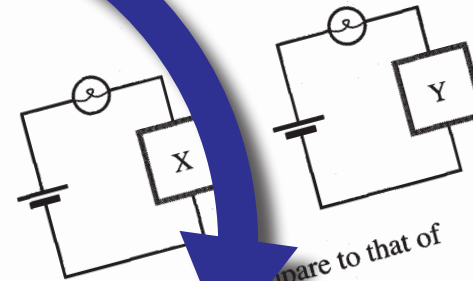
- A. The circuits at right contain identical batteries, bulbs, and unknown identical elements labeled X.



How do the bulbs compare in brightness? Explain.

In each circuit, how does the current through the bulb compare to the current through element X? Explain.

- B. The circuits at right contain identical batteries and bulbs. The unknown elements labeled X and Y represent different unknown elements. (Assume there are no batteries in either box.)



It is observed that the bulb on the left is brighter than the bulb on the right.

1. Based on this observation, how does the resistance of element X compare to that of element Y? Explain.
2. In each circuit, how does the current through the bulb compare to the current through the unknown element?
3. In each circuit, how does the current through the bulb compare to the current through the battery?

McDermott et al., *Tutorials in Introductory Physics* (Prentice Hall, 2002)

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored squares: purple, green, yellow, orange, and red.

estimation activity

1 design

2 approach

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a tunnel-like effect. On the left side, there is a vertical bar with five colored squares: purple, green, yellow, orange, and red.

estimation activity

goal: develop qualitative reasoning skills

AP50b Spring 2013

Estimation Activity 2

M March 11

Instructions: estimate (not guess!) the quantities below to the nearest order of magnitude. The first team to correctly enter all values wins.

1. Design a solenoid that can generate the same amount as the Earth's magnetic field.
2. How much current can one wearing a silver bracelet generate by walking in front of a microwave? (Assume you are wearing thick layer of clothes and your arms/bodies somehow act as insulators)
3. Estimate the flux of the Earth's magnetic field through the top of the table you are working on now.
4. Estimate the time for a radio signal to travel around the Earth.
5. As an undergrad in the 60s, Nobel Laureate claims to have built the "world's largest solenoid" by wrapping some copper wire around a football field 3 times and by plugging it into a car battery. What kind of currents and fields do you expect this coil generated?
6. What is the potential difference that causes a lightning strike?

"What is the potential difference that causes a lightning strike?"

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored squares: purple, green, yellow, orange, and pink, from top to bottom.

experimental design activity

1 design

2 approach

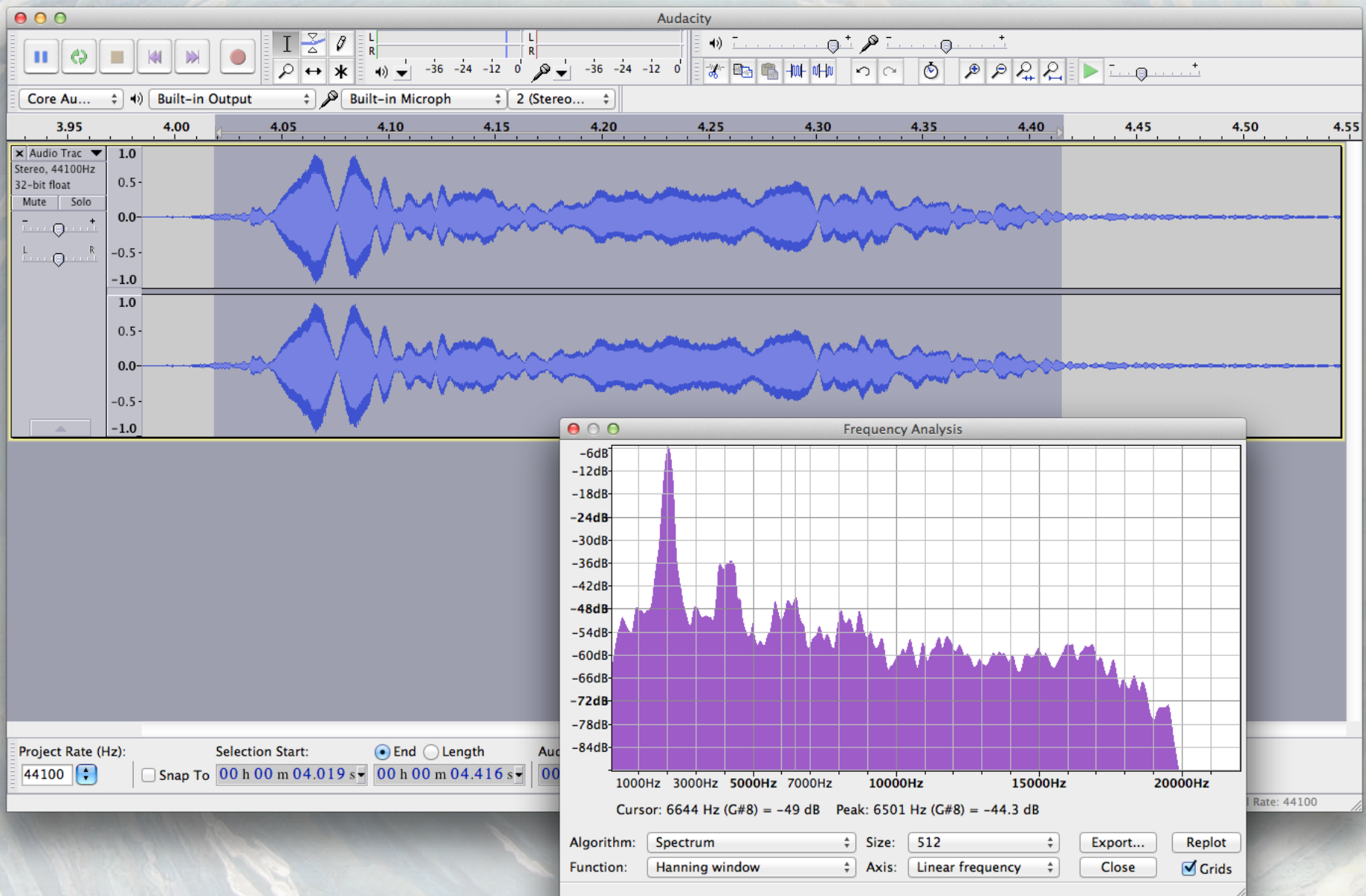
The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored segments: purple, green, yellow, orange, and pink.

experimental design activity

goal: develop experimental skills

1 design

2 approach



1 design

2 approach

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored segments: purple, green, yellow, orange, and red.

homework reflection

1 design

2 approach



**goal: develop problem solving
and metacognitive skills**

homework reflection

AP50b Fall 2013

Problem Set 1

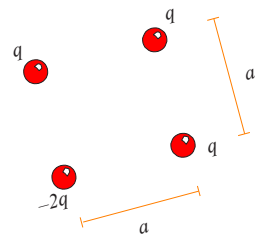
due W Feb 6 in class

Instructions: as we need to quickly scan your work so we can return it before the end of class, please:

- use 8.5 x 11" paper
- no-dog ears or torn out of ring-bound notebook
- dark ink (no light pencils)
- no staples
- name on each page
- single-sided (no writing on back)
- leave margins blank

1. **Ink-Jet Printing.** In an inkjet printer, letters are built up by squirting drops of ink at a piece of paper from a rapidly moving nozzle. The ink drops leave a nozzle and travel toward the paper, passing through a charging unit that gives each drop a positive charge by removing some electrons from it. The drops then pass between parallel deflecting plates where there is a uniform vertical electric field (to be discussed in Chapter 23). Estimate the number of atoms present in a droplet of ink.
2. **Levitation.** One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of $-3.0 \mu\text{C}$. The upper one has a charge q_A that can be adjusted. A 30-mg particle with a charge of $+8.0 \mu\text{C}$ can move freely on the pole below the other two. You wish to levitate (i.e., float) this particle at a distance of 1.0 m below the lower fixed charge. What should the adjustable charge q_A be to achieve this feat?

3. **Charge Square.** Four charged particles are arranged in a square as shown in the figure to the right, with $q = 3.9 \times 10^{-4} \text{ C}$ and $a = 6.9 \text{ mm}$. What is the net force on the particle at the upper right corner due to the other three?



AP50b Fall 2013

Problem Set 1

due W Feb 6 in class

homework

goal

solve at home

skills development

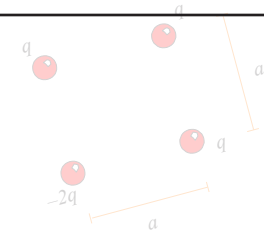
reflect in class

metacognition

- Instructions: Please use 8.5 x 11 inch paper, no staples, no dog ears or torn corners, and use dark ink (no light pencils) to quickly scan your work so we can return it before the end of class, please:
- use 8.5 x 11 inch paper
 - no dog ears or torn corners
 - dark ink (no light pencils)
 - no staples
 - single-sided (no writing on back)
 - leave margins blank

- Ink-Jet Printing.** In an inkjet printer, letters are built up by squirting drops of ink at a piece of paper from a tiny nozzle. The ink drops leave a nozzle and travel toward the paper, passing through a charging unit that gives each drop a positive charge by removing some electrons. The drops then pass between two parallel deflecting plates. There is a uniform vertical electric field (discussed in Chapter 23). Estimate the number of atoms present in a droplet of ink.
2. **Levitation.** One possible way of levitating an object might be to use the forces associated with charged objects. For example, you have two charged particles that are fixed on a vertical pole 0.5 m apart. The lower one has a fixed charge of $-3.0 \mu\text{C}$. The upper one has a charge q_A that can move freely on the pole below the other two. A 30-mg particle with a charge of $+8.0 \mu\text{C}$ can move freely on the pole below the other two. You wish to make it (i.e., float) this particle at a distance of 1.0 m below the lower fixed charge. What should the adjustable charge q_A be to achieve this feat?

3. **Charge Square.** Four charged particles are arranged in a square as shown in the figure to the right, with $q = 3.9 \times 10^{-4} \text{ C}$ and $a = 6.9 \text{ mm}$. What is the net force on the particle at the upper right corner due to the other three?



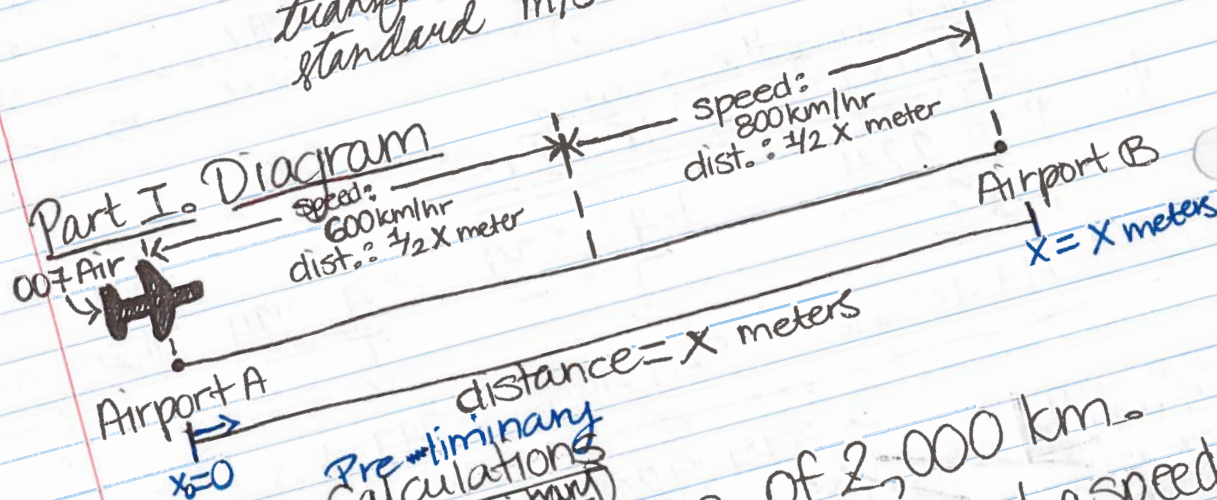
1 design

2 approach

EFFORT

Criterion	Majority of problems/solutions	About half the problems/solutions	Less than half the problems/solutions
Expectations for each solution to a problem articulated before diving into the details?	3	2	1
Were longer problems broken down into smaller, more manageable pieces?	3	2	1
Were solutions checked for reasonableness?	3	2	1
Were solutions well organized?	3	2	1
Appropriate use of diagrams, graphical, tabular representations?	3	2	1
Are symbols defined and diagrams adequately labeled?	3	2	1

2. expectations:
- b/c averaging of displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
 - note: will have to remember to transfer units of velocity to the standard m/s



Part II: Preliminary Calculations (arbitrary)

Assume a distance of 2,000 km.

L> For 1,000 km, 007 Air flies at a speed of $600 \frac{\text{km}}{\text{hr}}$
 which takes: $1,000 \text{ km} \left(\frac{1 \text{ hr}}{600 \text{ km}} \right) = \boxed{1 \frac{2}{3} \text{ hrs}}$

L> For the second 1,000 km, 007 Air speed = $800 \frac{\text{km}}{\text{hr}}$
 $1,000 \text{ km} \left(\frac{1 \text{ hr}}{800 \text{ km}} \right) = \boxed{1.25 \text{ hrs}}$

calculation error

time taken = $1 \frac{2}{3} + 1 \frac{1}{4} \text{ hrs.}$
 $= 2 \frac{11}{12} = 2.92 \text{ hrs}$

2. expectations: • b/c averaging of displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
 • note: will have to remember to transfer units of velocity to the standard m/s

10 pages!

Part I. Displacement

$x=0$

distance = x meters

$x = x$ meters

Part II: Preliminary Calculations (arbitrary)

Assume a distance of 2,000 km.

L> For 1,000 km, 007 Air flies at a speed of 600 $\frac{\text{km}}{\text{hr}}$

which takes:

L> For the second 1,000 km, 007 Air

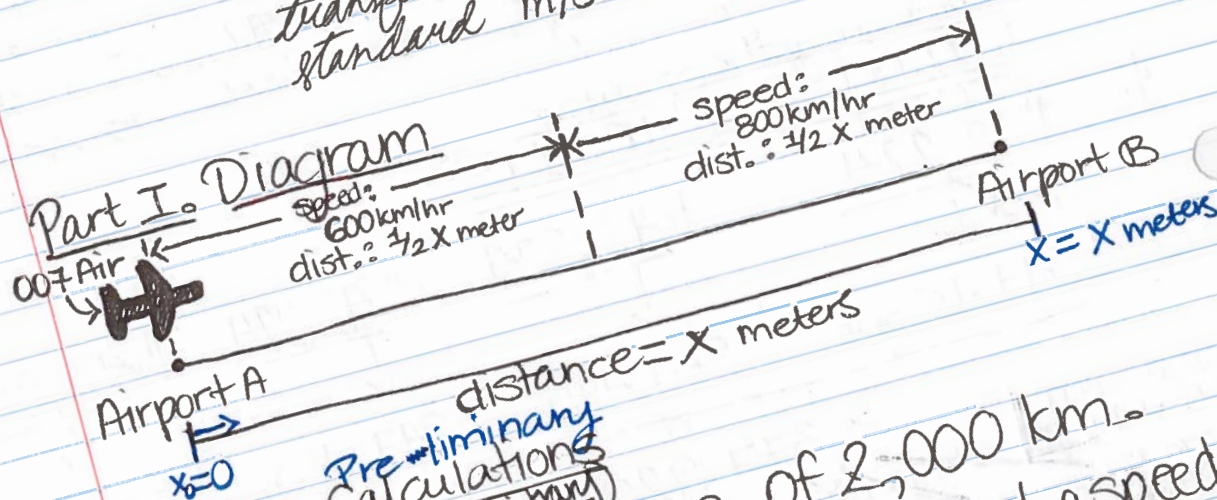
$1,000 \text{ km} \left(\frac{1 \text{ hr}}{600 \text{ km}} \right) = 1 \frac{2}{3} \text{ hrs}$

calculation error

time taken = $1 \frac{3}{12} + 1 \frac{8}{12} \text{ hrs.}$
 $= 2 \frac{11}{12} = 2.92 \text{ hrs}$

2. expectations:

- b/c average displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
- note: will have to remember to transfer units of velocity to the standard m/s



Part II: Preliminary Calculations (arbitrary)

Assume a distance of 2,000 km.

→ For 1,000 km, 007 Air flies at a speed of 600 $\frac{\text{km}}{\text{hr}}$
 which takes: $1,000 \text{ km} \left(\frac{1 \text{ hr}}{600 \text{ km}} \right) = 1 \frac{2}{3} \text{ hrs}$

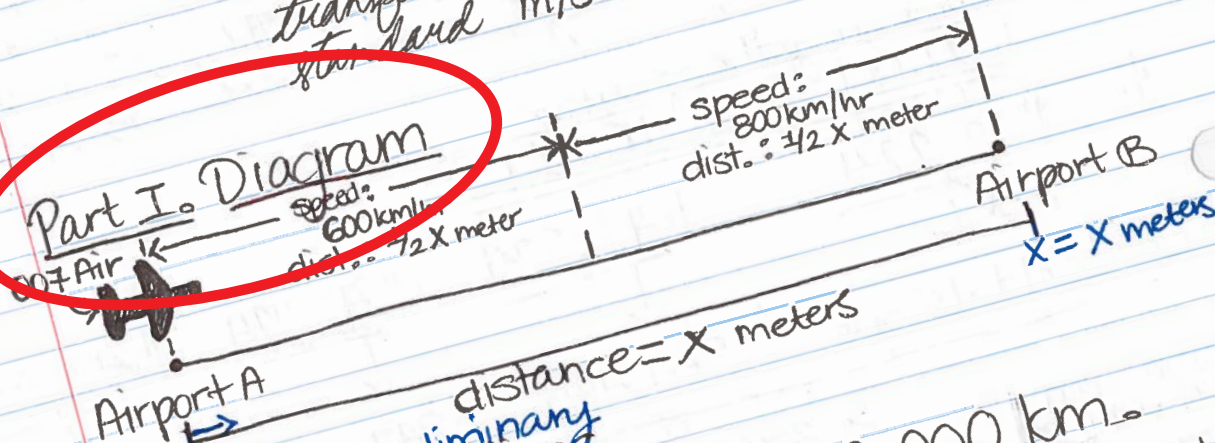
→ For the second 1,000 km, 007 Air speed = 800 $\frac{\text{km}}{\text{hr}}$
 $1,000 \text{ km} \left(\frac{1 \text{ hr}}{800 \text{ km}} \right) = 1.25 \text{ hrs}$

calculation error

$$\text{time taken} = 1 \frac{2}{3} + 1 \frac{1}{4} \text{ hrs.} = 2 \frac{11}{12} = 2.92 \text{ hrs}$$

2. expectations:
- b/c averaging of displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
 - note: will have to remember to transfer units of velocity to the standard m/s

Part I. Diagram



Part II: Preliminary Calculations (arbitrary)

Assume a distance of 2,000 km.

→ For 1,000 km, 007 Air flies at a speed of 800 km/hr

which takes:

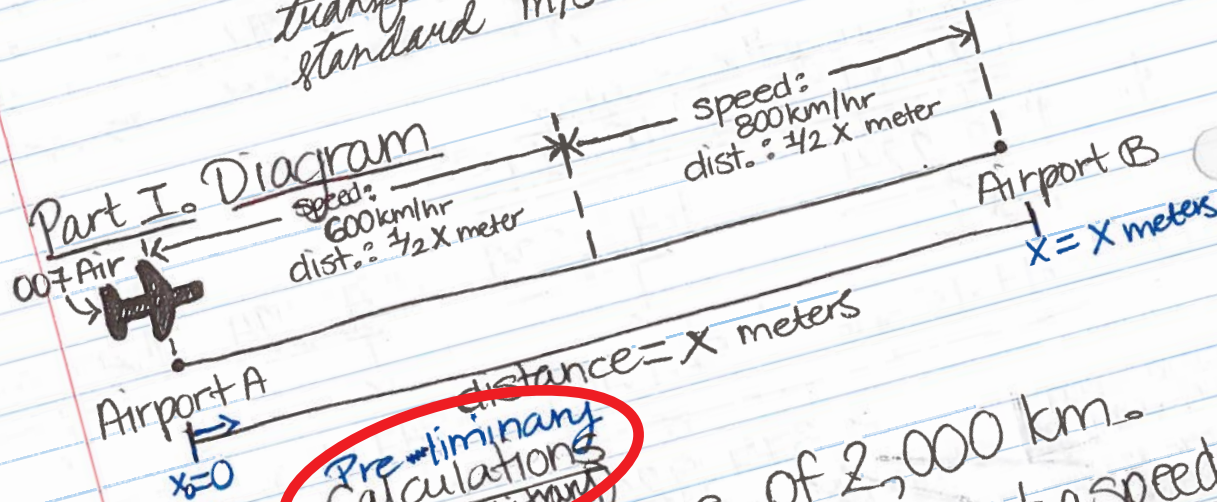
→ For the second 1,000 km, 007 Air

$$1,000 \text{ km} \left(\frac{1 \text{ hr}}{800 \text{ km}} \right) = 1.25 \text{ hrs}$$

calculation error

$$\text{time taken} = 1 \frac{3}{12} + 1 \frac{8}{12} \text{ hrs.} = 2 \frac{11}{12} = 2.92 \text{ hrs}$$

2. expectations:
- b/c averaging of displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
 - note: will have to remember to transfer units of velocity to the standard m/s



Part II: Preliminary Calculations

Assume a distance of 2,000 km.

L> For 1,000 km, 007 Air flies at a speed of $600 \frac{\text{km}}{\text{hr}}$
 which takes: $1,000 \text{ km} \left(\frac{1 \text{ hr}}{600 \text{ km}} \right) = \boxed{1 \frac{2}{3} \text{ hrs}}$

L> For the second 1,000 km, 007 Air speed = $800 \frac{\text{km}}{\text{hr}}$
 $1,000 \text{ km} \left(\frac{1 \text{ hr}}{800 \text{ km}} \right) = \boxed{1.25 \text{ hrs}}$

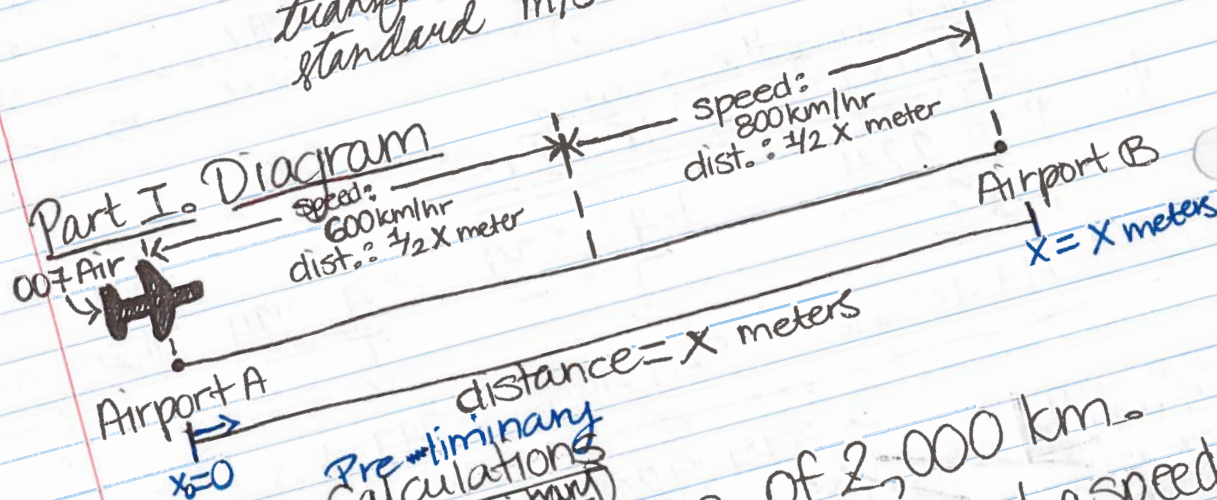
calculation error

time taken = $1 \frac{2}{3} + 1 \frac{1}{4} \text{ hrs.}$
 $= 2 \frac{11}{12} = 2.92 \text{ hrs}$

reflection process

1. list assistance
2. mark up solution (blue/red)
3. list what learned
4. rate understanding (traffic light)
5. plan for review

2. expectations:
- b/c averaging of displacement to time is matter, simply how much distance (measured in displacement from point A to point B) could be covered in a specific amt of time
 - note: will have to remember to transfer units of velocity to the standard m/s



Part II: Preliminary Calculations
(arbitrary)

Assume a distance of 2,000 km.

L> For 1,000 km, 007 Air flies at a speed of 600 $\frac{\text{km}}{\text{hr}}$

which takes:


$$1,000 \text{ km} \left(\frac{1 \text{ hr}}{600 \text{ km}} \right) = \boxed{1 \frac{2}{3} \text{ hrs}}$$

$$\text{L> For the second } 1,000 \text{ km, } 007 \text{ Air speed} = 800 \frac{\text{km}}{\text{hr}}$$

$$1,000 \text{ km} \left(\frac{1 \text{ hr}}{800 \text{ km}} \right) = \boxed{1.25 \text{ hrs}}$$

calculation error

$$\text{time taken} = \frac{1}{2} + \frac{1}{2} \text{ hrs.} = 2 \frac{11}{12} = 2.92 \text{ hrs}$$



“I was inspired and encouraged to do these problems on my own with the promise of collaborative work [the next day]”

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored squares: purple, green, yellow, orange, and red.


**“I felt less pressure to find the right answer
and more freedom to explore”**

The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a tunnel-like effect. On the left side, there is a vertical bar with five colored segments: purple, green, yellow, orange, and red.

readiness assurance activity

1 design

2 approach



goal: formative assessment
collaborative learning

readiness assurance activity

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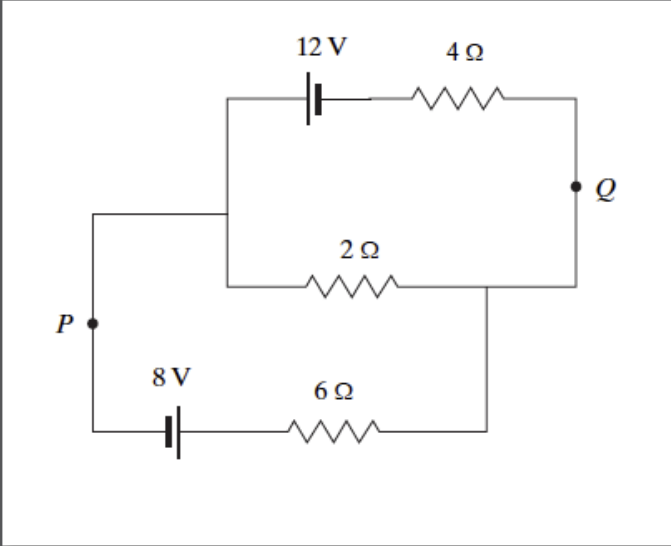
session 500941

This is the individual round; work on these questions on your own.

◀ Jump to ▼ 1 2 3 ▶

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q . (Include units)



Submit response

Current team: Blue Team [Change team](#) Current seat: A1 [Change seat](#) [Send a message to the instructor](#) [Join another session](#)

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1 design

2 approach

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session 500941

This is the individual round; work on these questions on your own.

Jump to 1 2 3

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q . (Include units)

9 V Submit response

Current: A1 Change team

Current seat: A1 Change seat

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1 design

2 approach

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session 500941

This is the individual round; work on these questions on your own.

Jump to 1 2

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q .

9 V Submit response

Current team: Blue Team [Change team](#) Current seat: A1

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Carrier 5:58 PM session 500941 Logout

This is the individual round; work on these questions on your own.

1 2 3

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q . (include units)

1 design

2 approach

learning catalytics

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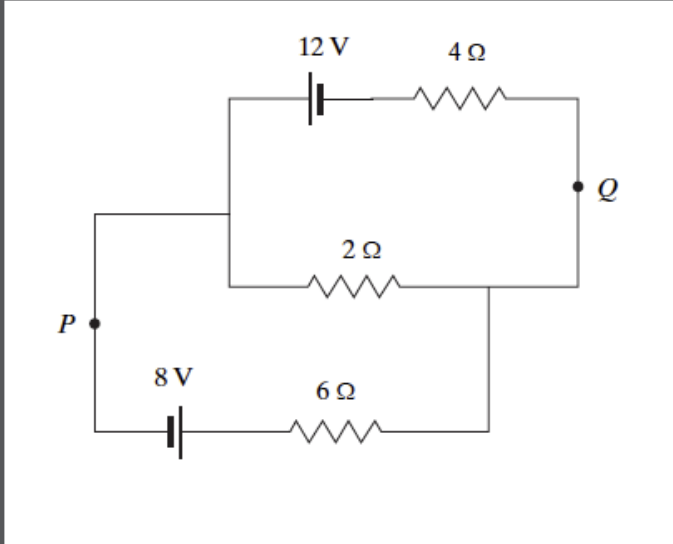
session 500941

This is the individual round; work on these questions on your own.

Jump to 1 2

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q



9 V Submit response

Current team: Blue Team [Change team](#)


Current seat: A1 [Change seat](#)

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Carrier (include units) 5:59 PM



1 design

2 approach

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session 500941

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

Jump to 1 2 3

+ Show my team's responses

9 V	1.82 V	1.816 V
Brian Lukoff	Kieran Jones	Beth Connors

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q . (include units)

Submit response

1 design

2 approach

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This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

Jump to 1 2 3

+ Show my team's responses

9 V	1.82 V	1.816 V
Brian Lukoff	Kieran Jones	Beth Connors

numerical question

For the circuit shown at right, calculate the power dissipated in the $2\ \Omega$ resistor.

Submit response

+ Show my team's responses

9 V	1.82 V	1.816 V
Brian Lukoff	Kieran Jones	Beth Connors

1 design

2 approach



1 design

2 approach

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session 500941

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (your response will count as multiple attempts).

Sorry, your response to Question 3 was not correct. You can attempt this question 2 more times.

Jump to 1 2 3

[+ Show my team's responses](#)

numerical question

For the circuit shown at right, calculate the potential difference between points P and Q . (include units)

Submit response

1/3 questions attempted. 0/4 possible points so far in team round. [Score details](#)

1 design

2 approach

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session 500941

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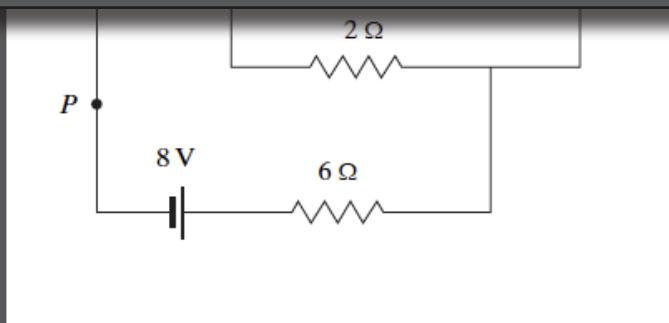
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Jump to 1 2 3

Show my team's responses

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Sorry, your response to Question 3 was not correct. You can attempt this question 2 more times.



Submit response

1/3 questions attempted. 0/4 possible points so far in team round. Score details

1 design

2 approach

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Courses Questions Classrooms Licenses Tour Help Student view

session 500941

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (your response will count as multiple attempts).

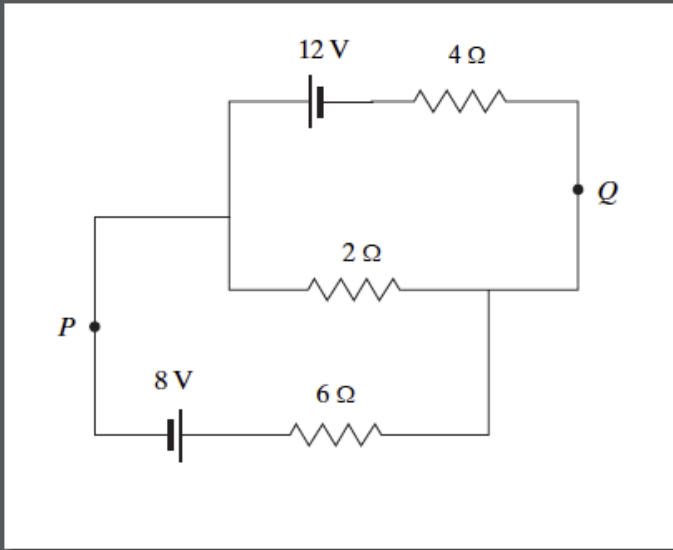
Your team answered Question 3 correctly!

Jump to 1 2 3

You have already answered this question correctly!

Question

For the circuit shown at right, calculate the potential difference between points P and Q . (include units)



Correct Answer

1.2 V

1 design

2 approach

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Courses Questions Classrooms Licenses Tour Help Student view

session 500941

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

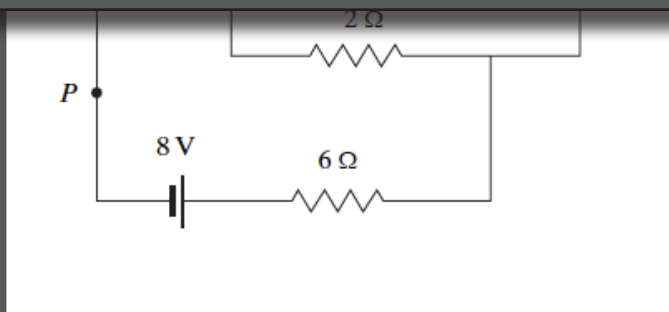
Your team answered Question 3 correctly!

Jump to 1 2 3

You have already answered this question correctly!

This is the team round. If you respond to a question, it will count for your entire team. Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

Your team answered Question 3 correctly!



Correct Answer

1.2 V

1 design

2 approach

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

Your team answered Question 3 correctly!



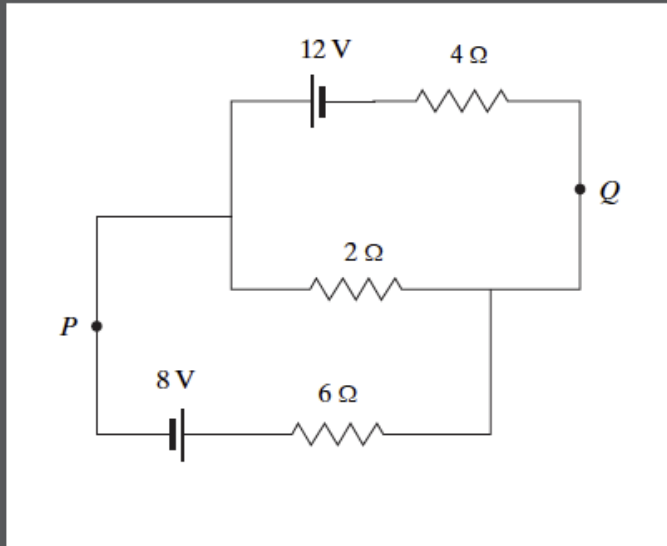
Jump to ▼ 1 2 3



You have already answered this question correctly!

Question

For the circuit shown at right, calculate the potential difference between points P and Q . (include units)



Correct Answer

1.2 V

1 question attempted, 2/4 possible points so far in team round [Score details](#)

Question	Team Result	Points
1	No response	
2	No response	
3	Correct (on attempt 2)	2
Total		2

Current team: Blue Team [Change team](#)

Current seat: A1 [Change seat](#)

[Send a message to the instructor](#)

[Join another session](#)

1 design

2 approach

This is the team round. If you respond to a question, it will count for your entire team (you, Kieran Jones, and Beth Connors). Only one member of your team should respond to each question (otherwise it will count as multiple attempts).

Your team answered Question 3 correctly!



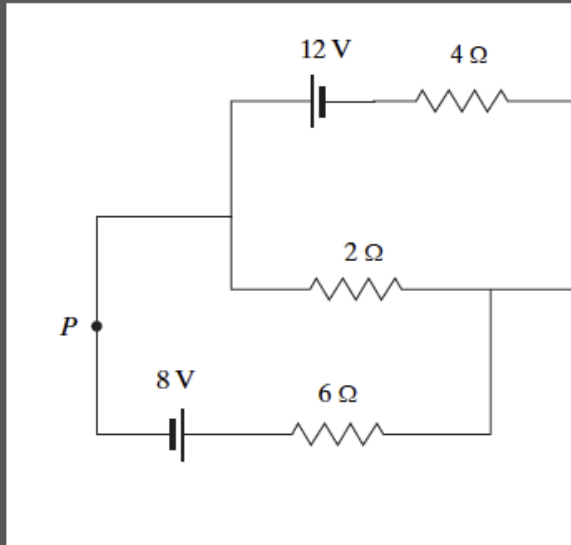
Jump to ▼ 1 2 3



You have already answered this question correctly!

Question

For the circuit shown at right, calculate the potential difference



Correct Answer

1.2 V

1/3 questions attempted, 2/4 possible points so far in team round [Score details](#)

Question	Team Result	Points
1	No response	
2	No response	
3	Correct (on attempt 2)	2
Total		2

1/3 questions attempted, 2/4 possible points so far

Question	Team Result	Points
----------	-------------	--------

1	No response	
---	-------------	--

2	No response	
---	-------------	--

3	Correct (on attempt 2)	2
---	------------------------	---

Total		2
-------	--	---

Current team: Blue Team [Change team](#)

Current seat: A1 [Change seat](#)

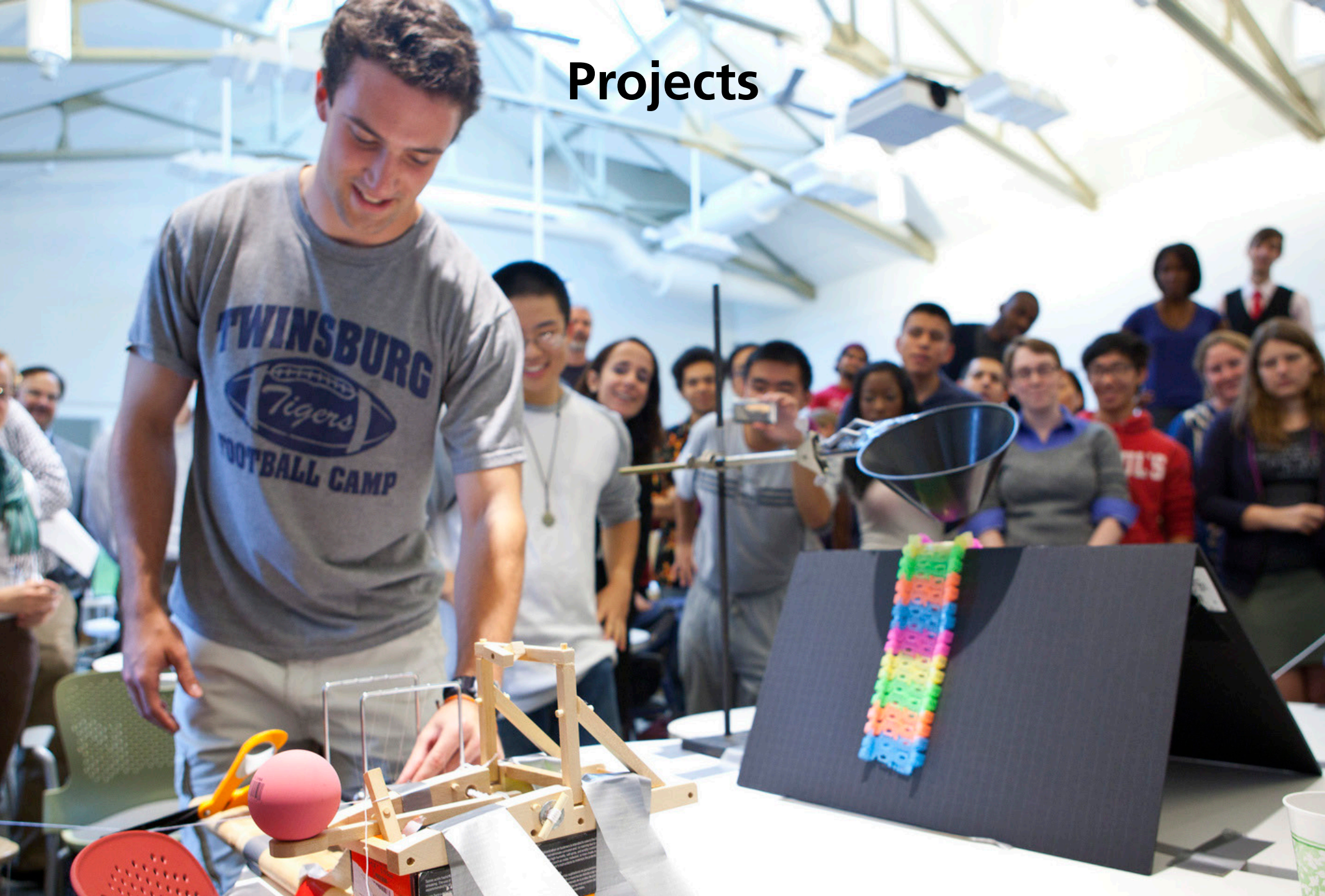
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1 design

2 approach

Projects



1 design

2 approach

Projects

- 3 projects/semester
- each project roughly one month long
- different team formation for each project
- projects not prescriptive, but open-ended
- 3 types of project “fairs”

Projects

Project fair types:

- design competition
- oral presentation
- poster presentation

Projects

To be successful, the projects must

- **require practical application of skills**
- **be linked to real world problems**
- **have compelling narrative (help/do good)**

Projects

The background image shows a young man in a grey t-shirt with 'TWINSBURG FOOTBALL CAMP' on it, working on a wooden mechanical project on a table. He is smiling and looking down at his work. In the background, a large group of students is gathered, some looking at the camera and others looking towards the project. The setting appears to be an outdoor or semi-outdoor event with a large tent structure visible in the background.

Fall

Rube Goldberg

Mission to Mars

Musical Instrument

Spring

Environment

Safe cracking

Energy

Projects

Week 1 team formation

1 design

2 approach

Projects

Week 1

team formation

project brief

1 design

2 approach

Projects

Week 1 **team formation**

project brief

Week 2 **proposal review**

1 design

2 approach

Projects

Week 1

team formation

project brief

Week 2

proposal review

planning begins

1 design

2 approach

Projects

Week 1

team formation

Week 2

project brief


proposal review

planning begins

Week 3


increased planning time

Projects

A background image showing a young man in a grey t-shirt with 'TWINSBURG FOOTBALL CAMP' printed on it, working on a project. He is using a funnel to pour something into a container. In the foreground, there is a pink ball on a wooden stand. Other students are visible in the background, some looking at the camera.


Week 1	team formation project brief
Week 2	proposal review planning begins
Week 3	increased planning time
Week 4	project fair

Projects



Week 1	team formation project brief
Week 2	proposal review planning begins
Week 3	increased planning time
Week 4	project fair project report

Projects



Week 1	team formation project brief
Week 2	proposal review planning begins
Week 3	increased planning time
Week 4	project fair project report peer assessment

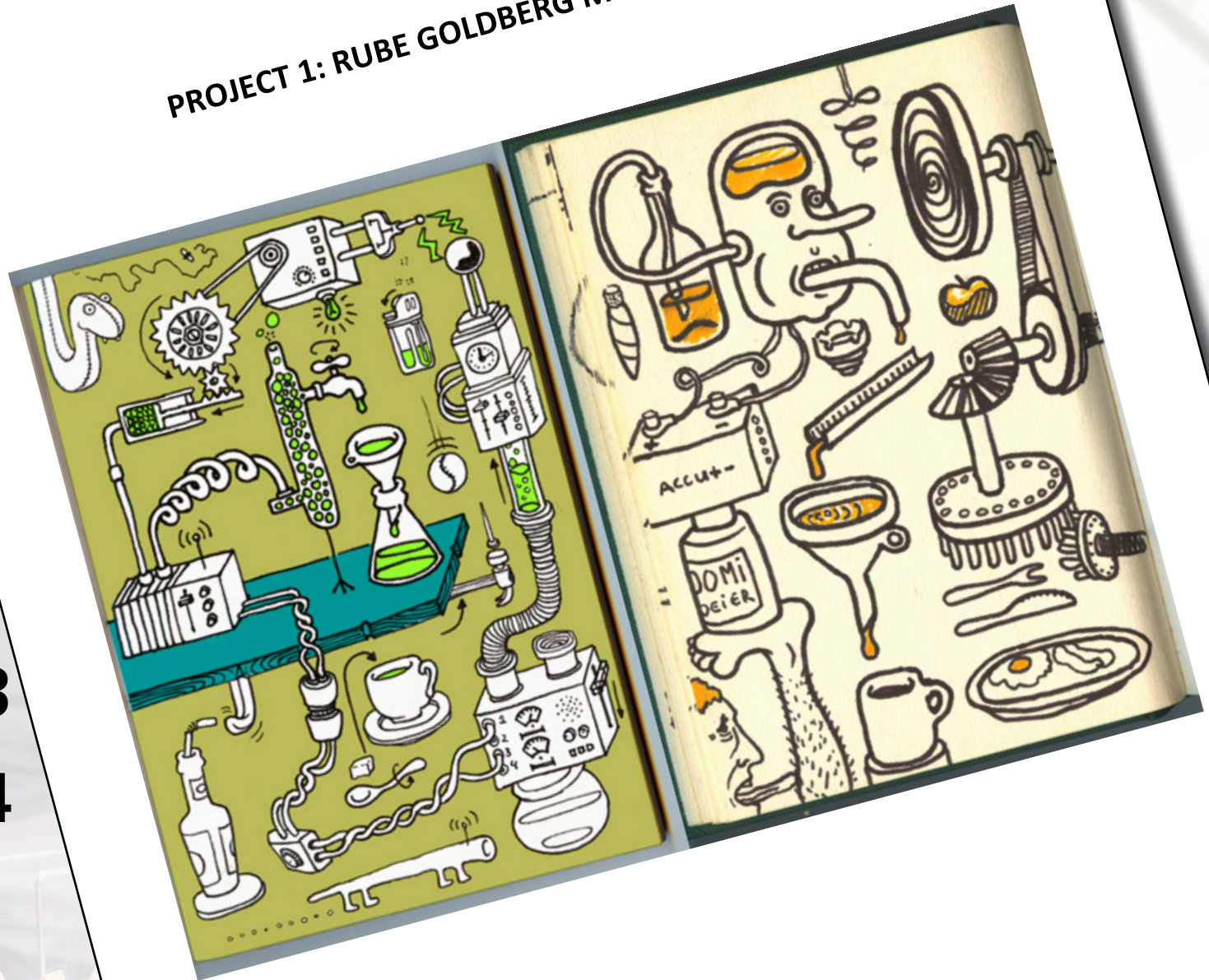
AP50a FALL
PROJECT 1: RUBE GOLDBERG MACHINE

Week

Week

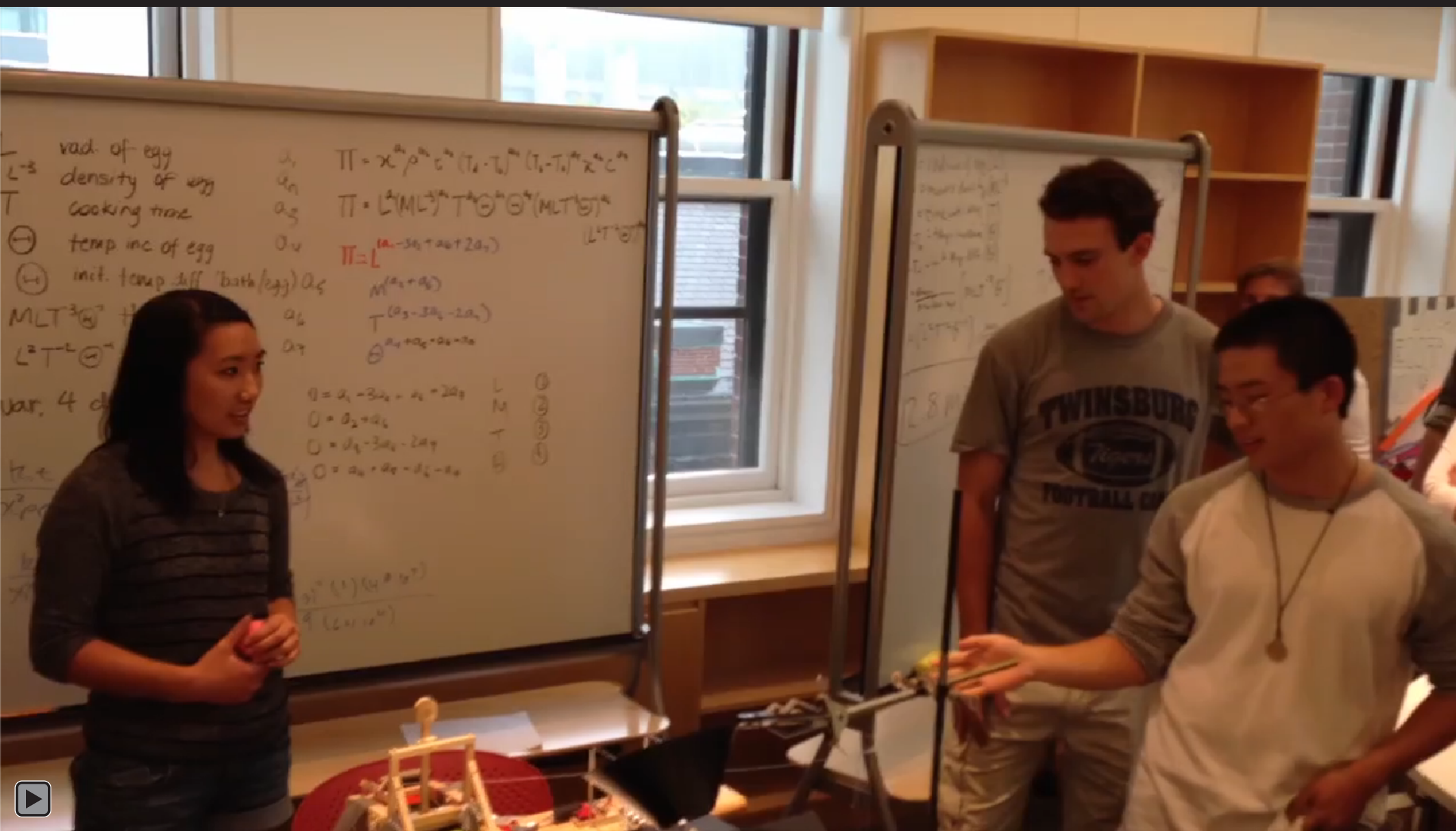
Week 3

Week 4



Important dates:

9/24 Project proposals due
10/10 Project reports due
10/23 Project presentations



1 design

2 approach



CRACK-A-THON

AP50

Wed Apr 10 • 2–5 pm • Pierce 301

1 design

2 approach



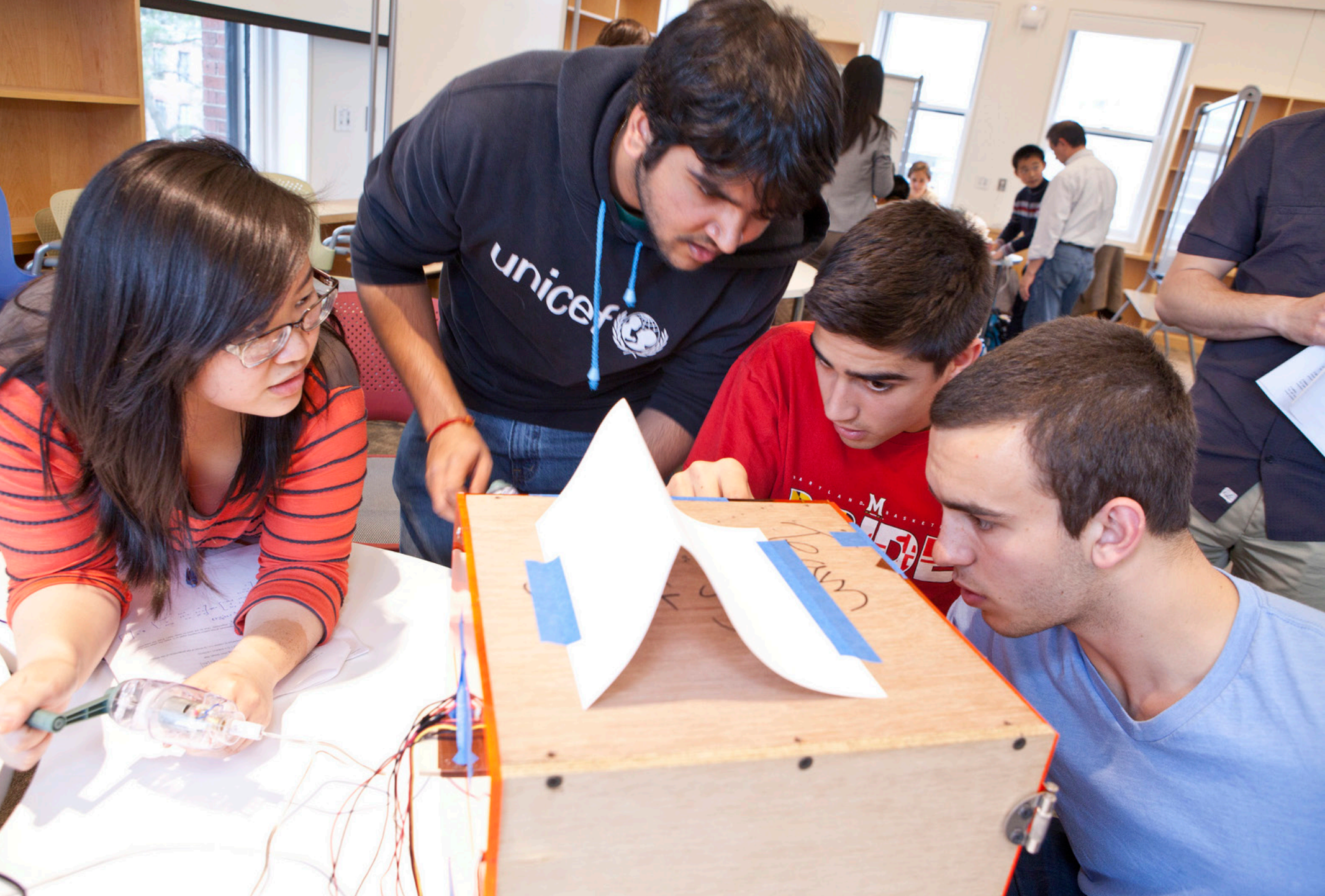
1 design

2 approach



1 design

2 approach



1 design

2 approach



1 design

2 approach

Peer Assessment

Team work is central in your projects and it is important to provide positive feedback to people who truly worked hard for the good of the team and to also make suggestions to those you perceived not to be working as effectively on team tasks. You may want to review the sections entitled on Teamwork and Peer Assessment in the syllabus to refresh your memory on why we stress teamwork and how to maximize the benefit from work together. Please complete the form below to assess your own contributions and those of your team members.

Complete the paper based form, then enter the data online at: <http://bit.ly/AP50Teameval>

How we will use your evaluation: In computing the (multiplicative) weight we give to your team scores, we will take into account:

1. Your team members' assessment of your contributions,
2. the quality of your self assessment (that is, how well it matches that of your team members' evaluation of your contribution), and
3. the quality of your assessment of your team members (that is, how well it matches the evaluations of that team member's contribution by the remainder of the team).

Please first complete the individual forms for each team member (including yourself), then complete the table below. When completing the table below, be sure that the **total of all relative contributions must be zero**.

		RELATIVE CONTRIBUTION							
		Total must equal ZERO							
	Name	Below Average			Average	Above average			
		-3	-2	-1	0	1	2	3	
	Me								
	Member 1								
	Member 2								
	Member 3								
	Member 4								

Assessment

- reading — quality of NB contribution
- problem solving — effort & self-assessment
- readiness assurance — indiv. & team scores
- projects — meeting project criteria



1 design

2 approach

3 results

Ownership



1 design

2 approach

3 results

Ownership

Course evaluation: 4.2/5

1 design

2 approach

3 results



Ownership

“The structure of the class made what was my least-favorite subject into one of my favorites.”

1 design

2 approach

3 results

Ownership

“The structure of the class made what was my least-favorite subject into one of my favorites. I was worried that people, including myself, would just slack off and do the bare minimum, but you really need to be on top of your readings and concepts in order to contribute to your team. GREAT CLASS!!!!!!”

Ownership

“Dear Harvard students, this class will be unlike any class you’ve taken at Harvard, and it will, hopefully, shift the entire foundation upon which you’ve based your education. I truly believe everyone should take this course; prepare to take full ownership of your learning.”

Ownership

Attendance: 94% (AP50a), 97% (AP50b)

Ownership

Attendance: 94% (AP50a), 97% (AP50b)

3 hours and they don't *leave*!

1 design

2 approach

3 results

Ownership

"I don't think I am well enough to make it through class. I feel terrible because I don't want to let my team down by not being there, but I don't think I'd be very helpful in my current state."

(via email)

Self-efficacy



1 design

2 approach

3 results



Self-efficacy

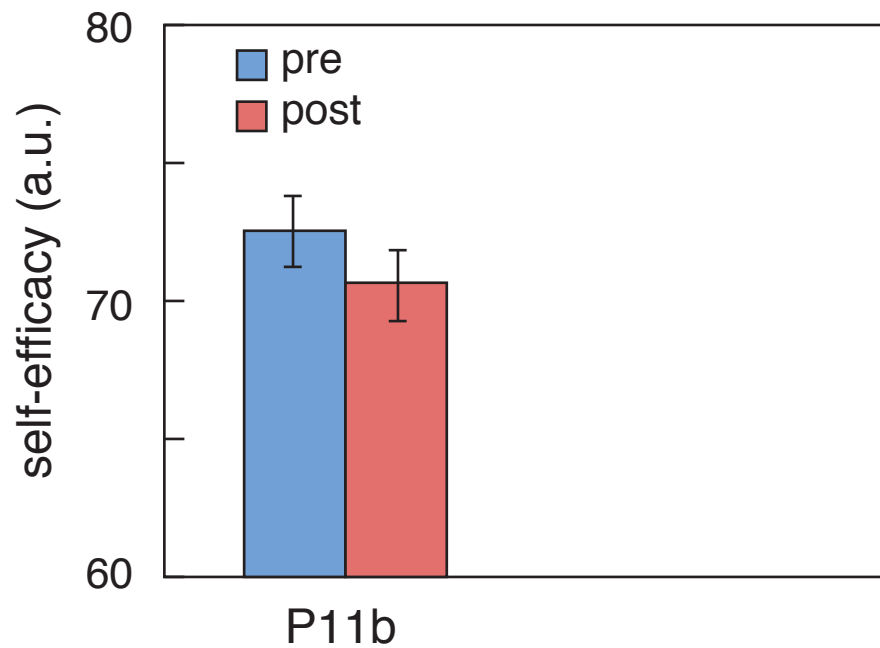
(students' belief in their ability to succeed)

1 design

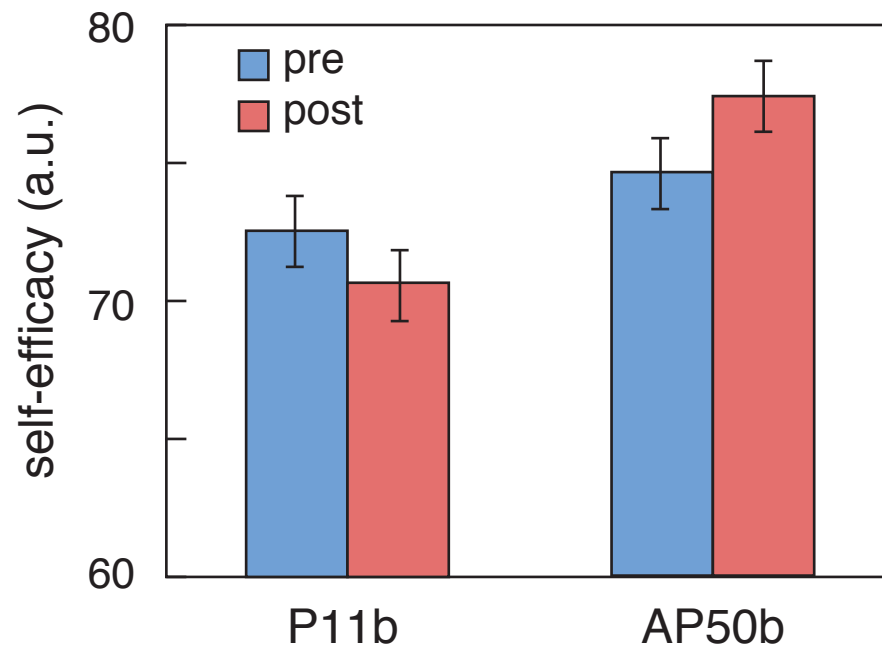
2 approach

3 results

Self-efficacy



Self-efficacy





Self-directed learning

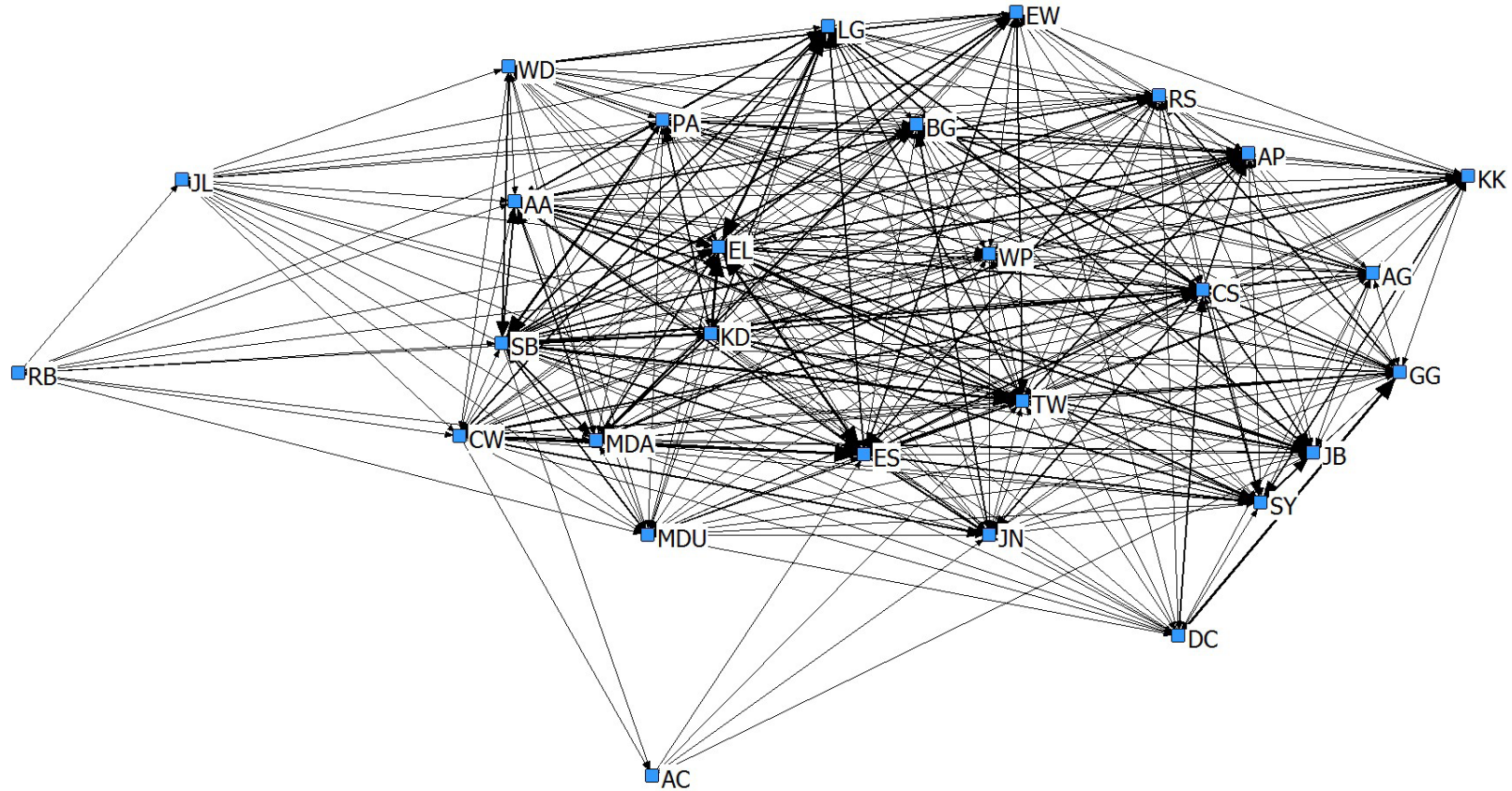
3 results

Self-directed learning

NB data shows:

- **student spend on average 2.3 hrs/chapter**
- **160–230 annotations/chapter (5–7/stu)**

Self-directed learning

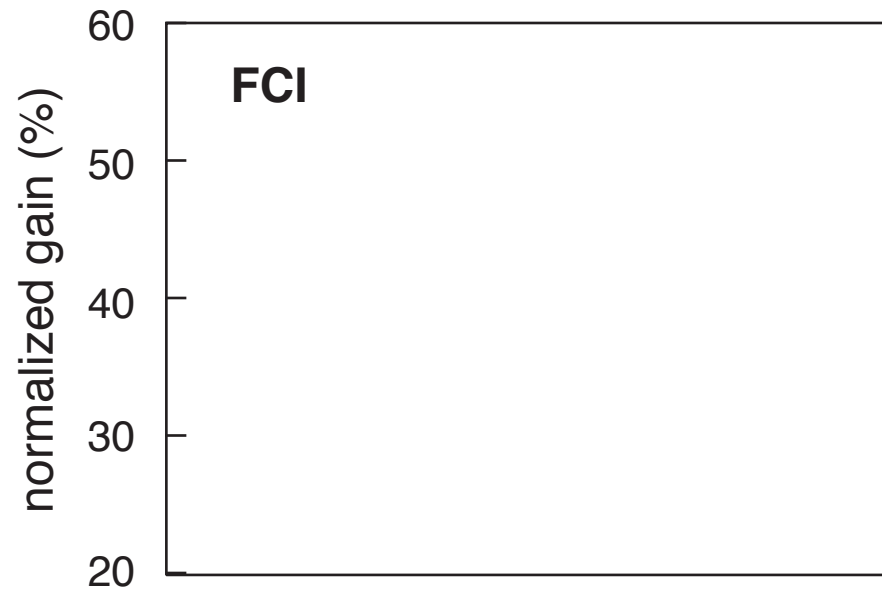


1 design

2 approach

3 results

Conceptual Mastery

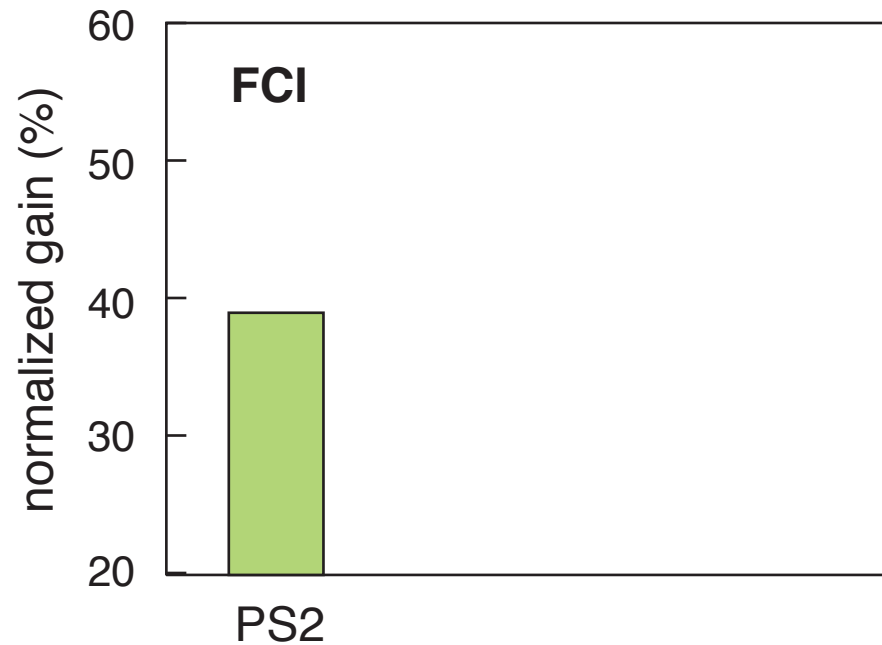


1 design

2 approach

3 results

Conceptual Mastery

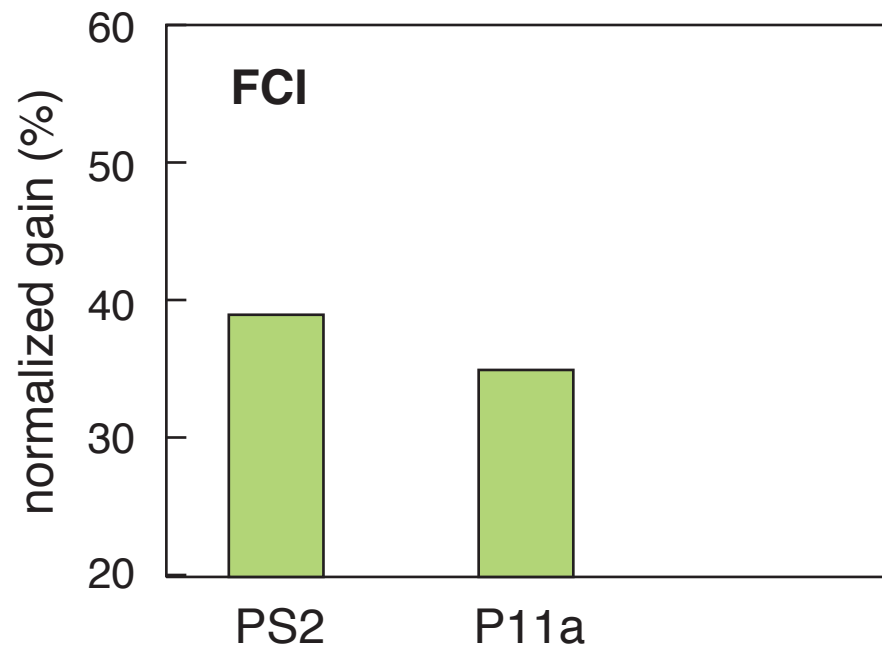


1 design

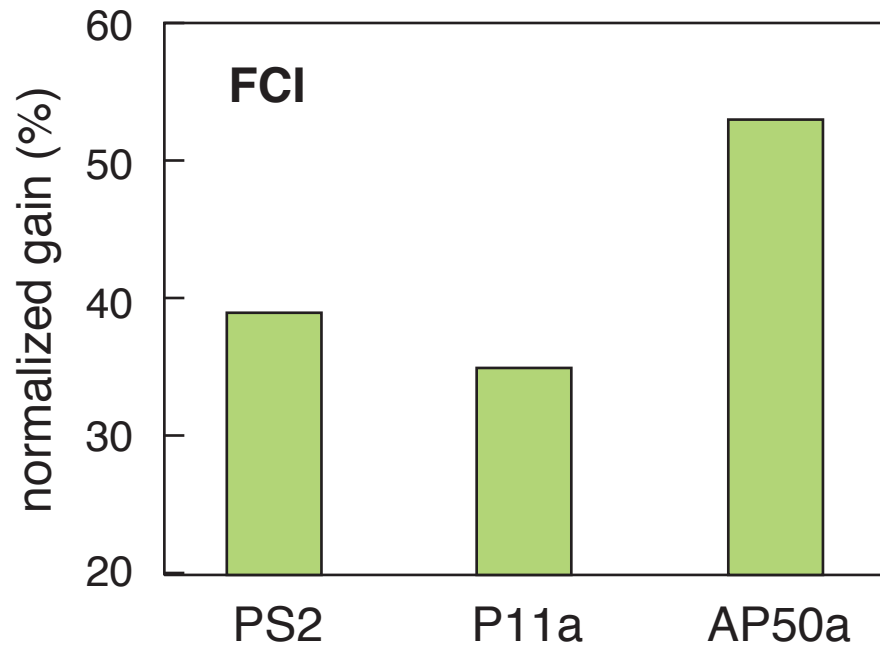
2 approach

3 results

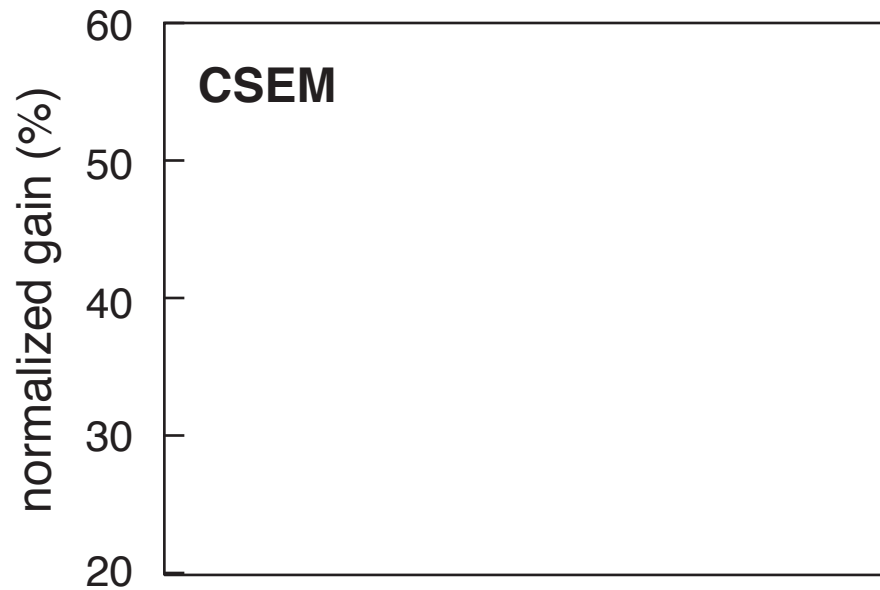
Conceptual Mastery



Conceptual Mastery



Conceptual Mastery

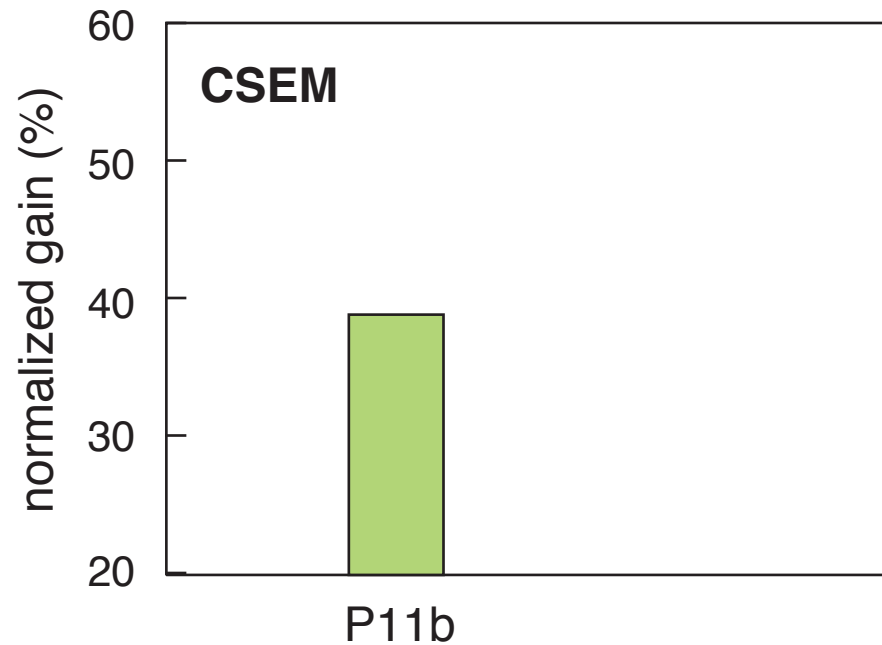


1 design

2 approach

3 results

Conceptual Mastery

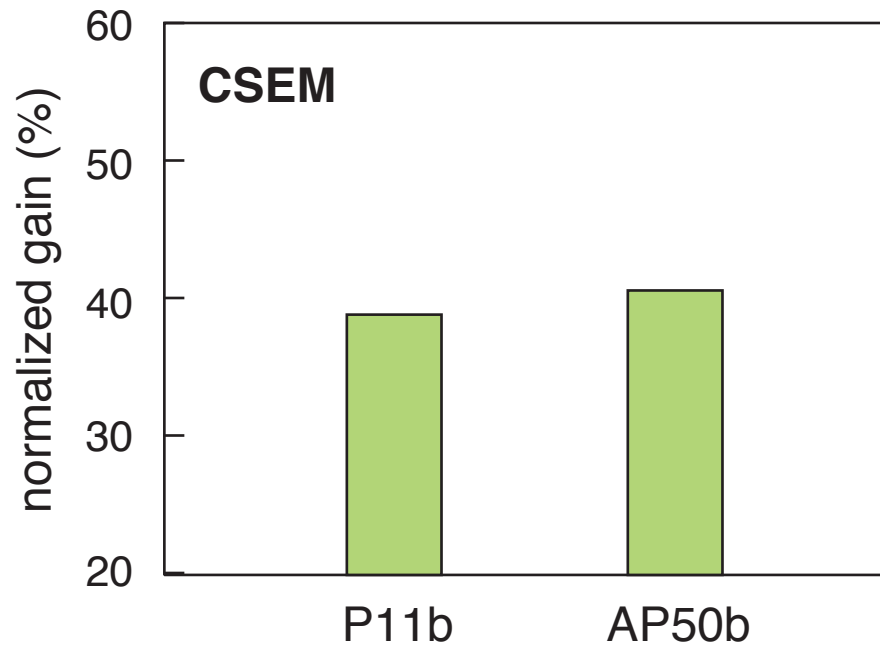


1 design

2 approach

3 results

Conceptual Mastery



“Problem-solving” ability



1 design

2 approach

3 results



“Problem-solving” ability

(very preliminary)

1 design

2 approach

3 results



“Problem-solving” ability

(very preliminary)

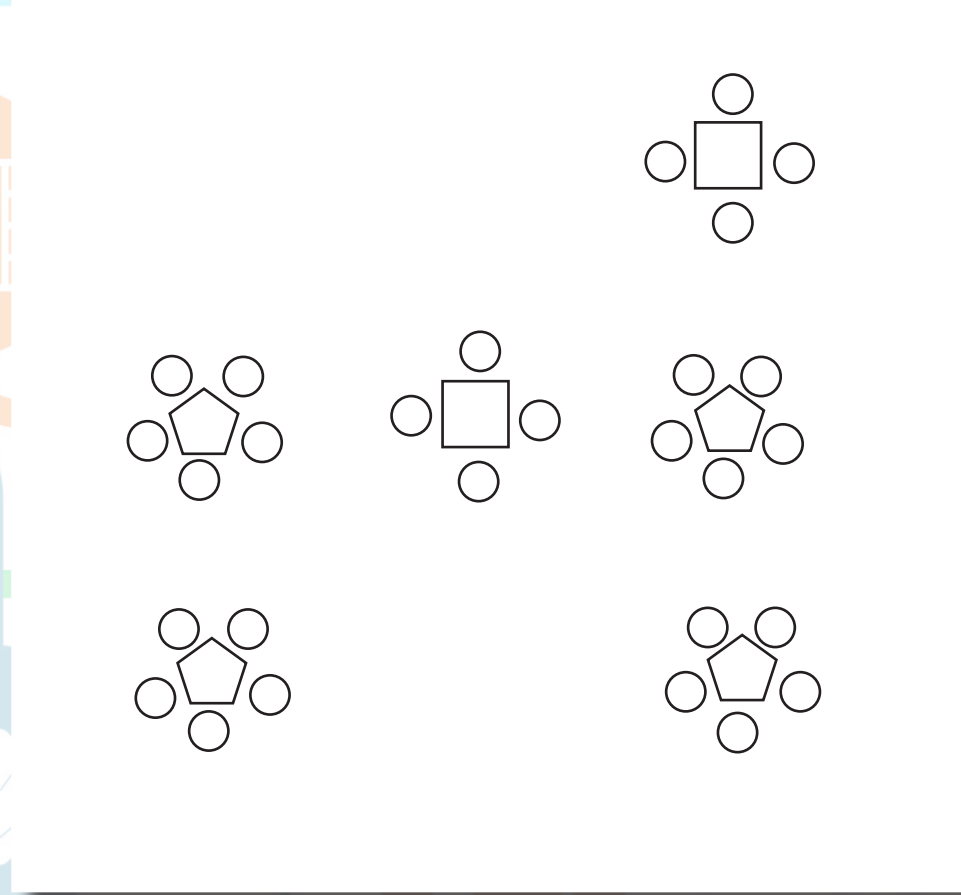
AP50b students do *twice as well* as Phys11b!

1 design

2 approach

3 results

Team skills

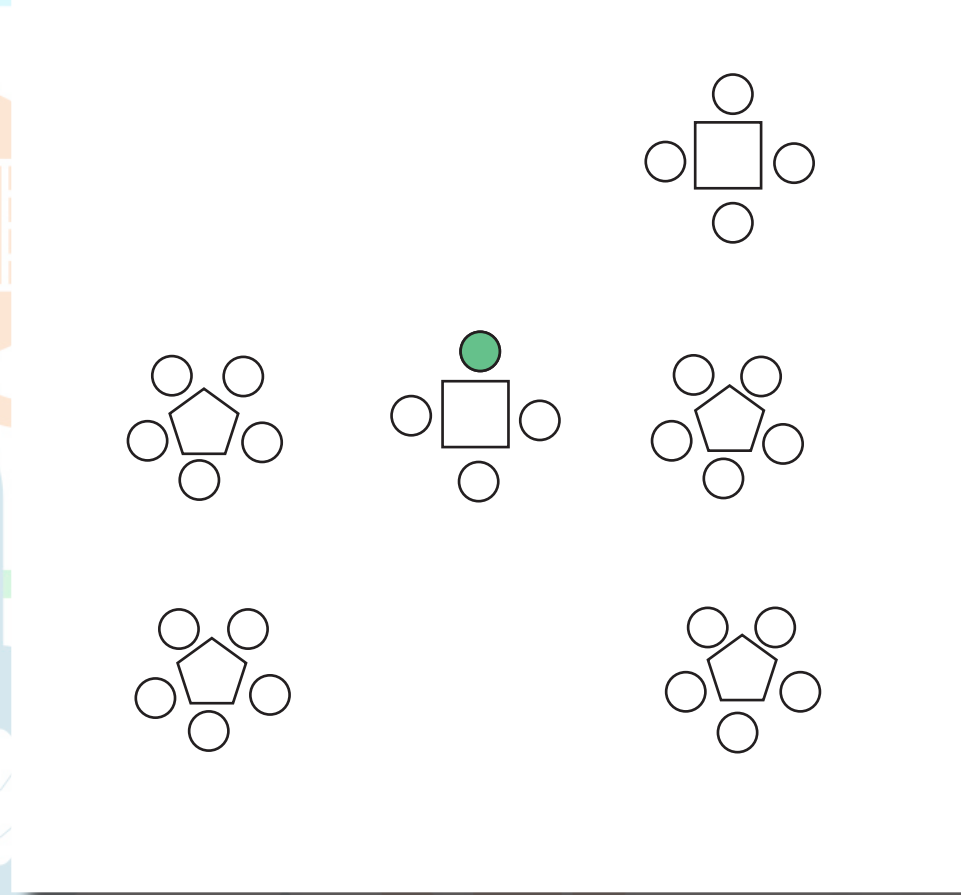


1 design

2 approach

3 results

Team skills



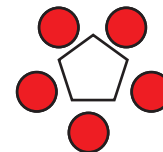
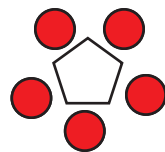
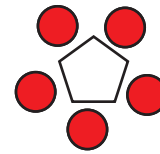
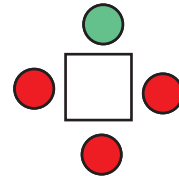
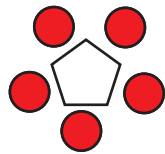
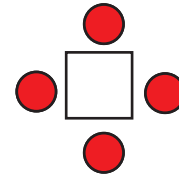
1 design

2 approach

3 results

Team skills

individual: 4%



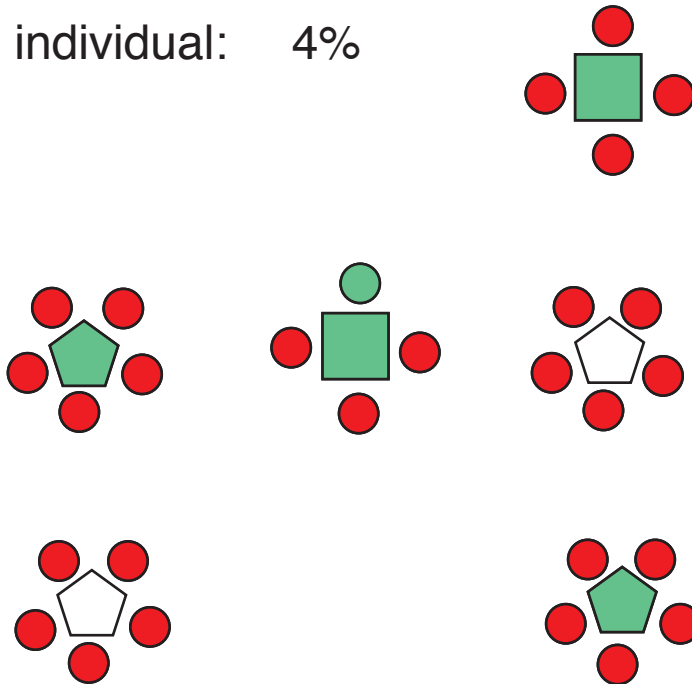
1 design

2 approach

3 results

Team skills

individual: 4%



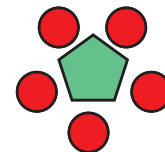
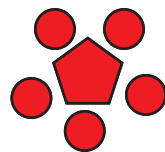
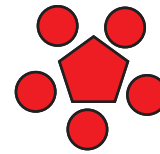
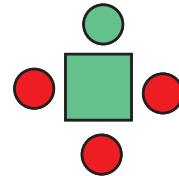
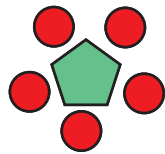
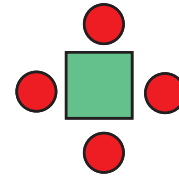
1 design

2 approach

3 results

Team skills

individual: 4%
team: 64%





1 design

2 approach

3 results

A group of four students are gathered around a wooden box containing a physics experiment. A female student with glasses is pouring liquid from a white cup into a container inside the box. Another female student is smiling and looking at the experiment. A male student in a plaid shirt is standing and smiling. A female student in a maroon hoodie is sitting and looking at the experiment. The box contains various components, including a circuit board with many small lights, a blue bowl, and other electronic parts. The background shows a classroom or lab setting with a whiteboard and other students.

Can create ownership of learning physics!

1 design

2 approach

3 results

A group of four students are gathered around a table in a classroom or lab, working on a project. A female student with glasses is pointing at a circuit board on the table. A male student is smiling and looking at the project. Another female student is also smiling. A male student in a plaid shirt is standing and looking on. The table is covered with various electronic components, wires, and a breadboard. The background shows a typical classroom setting with a whiteboard and other students.

Can create ownership of learning physics!

1 design

2 approach

3 results

A group of four students are gathered around a wooden box containing electronic components. A female student with glasses is using a soldering iron to work on a circuit board inside the box. Another female student is smiling and looking at the project. A male student in a plaid shirt is standing and smiling. A female student in a maroon hoodie is sitting and looking at the project. The background shows a classroom setting with a whiteboard and other students.

“you come out with so much knowledge and experience and fun”

1 design

2 approach

3 results

A background image showing three students in a classroom or workshop setting. A female student with glasses is leaning over a wooden box, using a tool to work on a circuit board. Two other students, a female and a male, are standing behind her, looking on with interest and smiling. The box contains various electronic components and wires.

Support

Cherry Murray

Course planning

Kelly Miller

Orad Reshef

Co-instructor

Carolann Koleci

Teaching staff

Kelly Miller

Orad Reshef

Michael Moebius

Sally Kang

Logistical support

Anas Challah

Peter Kjeer

Jordan Stephens

Wolfgang Rueckner

Nils Sorensen

Education Research

Marcelo Barros

Messias Borges-Silva

Brian Lukoff

Kelly Miller

Alvaro Neves

Julie Schell

Laura Tucker

Fauzy Wan

Junehee Yoo

1 design

2 approach

3 results

A background image showing three students in a classroom setting. A female student with glasses is leaning over a table, working on a project inside a wooden box. Two other students, a female and a male, are standing behind her, looking on with interest and smiling. The male student is wearing a plaid shirt and yellow pants. The female student is wearing a white top. The project inside the box appears to be a circuit board with various components and wires. The classroom has a whiteboard and other furniture visible in the background.

Support

Cherry Murray

Course planning

**Kelly Miller
Orad Reshef**

Co-instructor

Carolann Koleci

Teaching staff

**Kelly Miller
Orad Reshef
Michael Moebius
Sally Kang**

Logistical support

**Anas Challah
Peter Kjeer
Jordan Stephens
Wolfgang Rueckner
Nils Sorensen**

Education Research

**Marcelo Barros
Messias Borges-Silva
Brian Lukoff
Kelly Miller
Alvaro Neves
Julie Schell
Laura Tucker
Fauzy Wan
Junehee Yoo**

and the students pioneers in AP50!

1 design

2 approach

3 results

A group of four students are gathered around a wooden box containing electronic components. One student is using a soldering iron on a circuit board. The others are looking on with interest and smiles. The background shows a classroom or lab setting with whiteboards and other equipment.

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mazur.harvard.edu

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1 design

2 approach

3 results