

# Flat space, deep learning



ISO TL Invited Scholar Series  
University of British Columbia  
Vancouver, BC, 22 January 2015



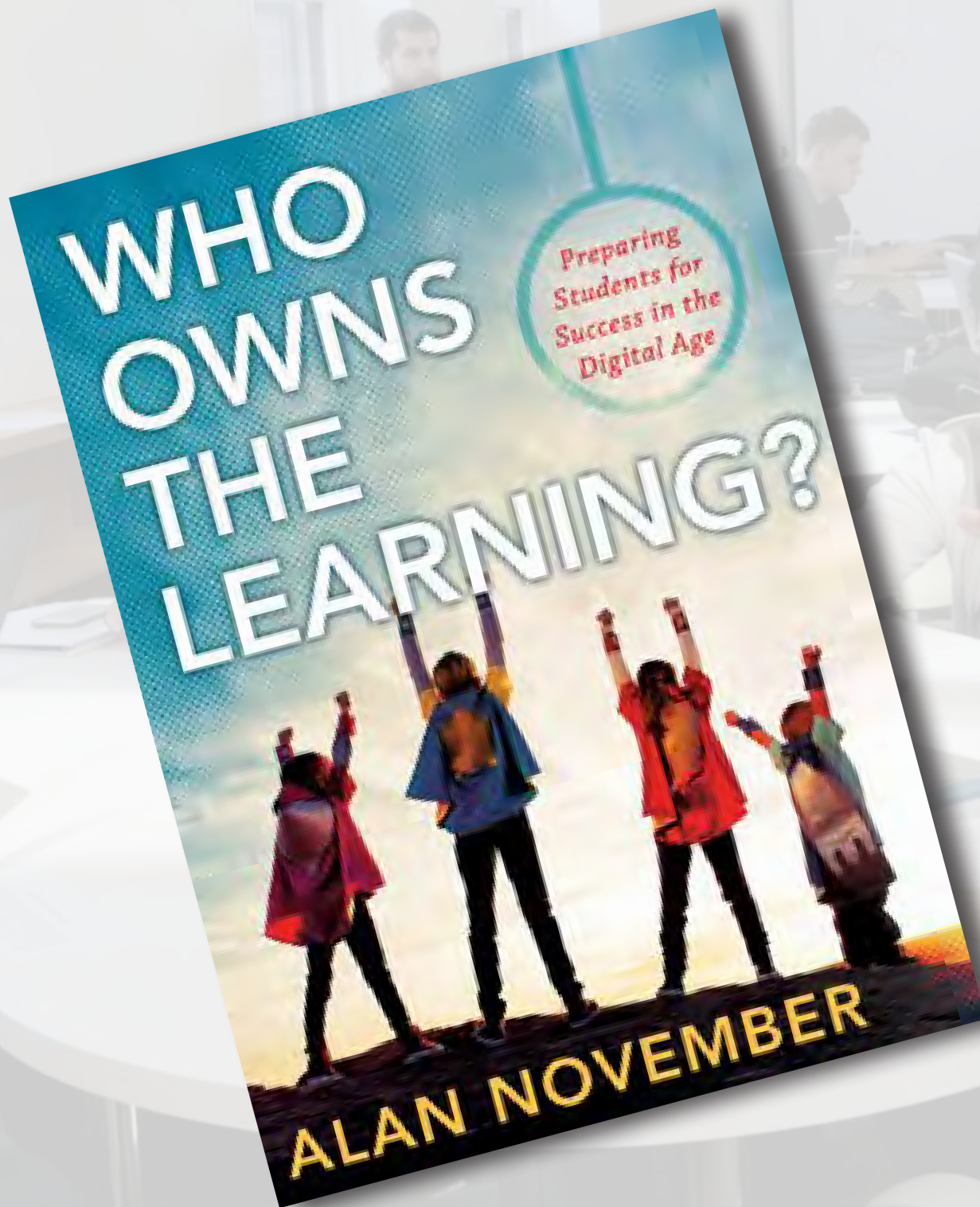
# Flat space, deep learning



@eric\_mazur

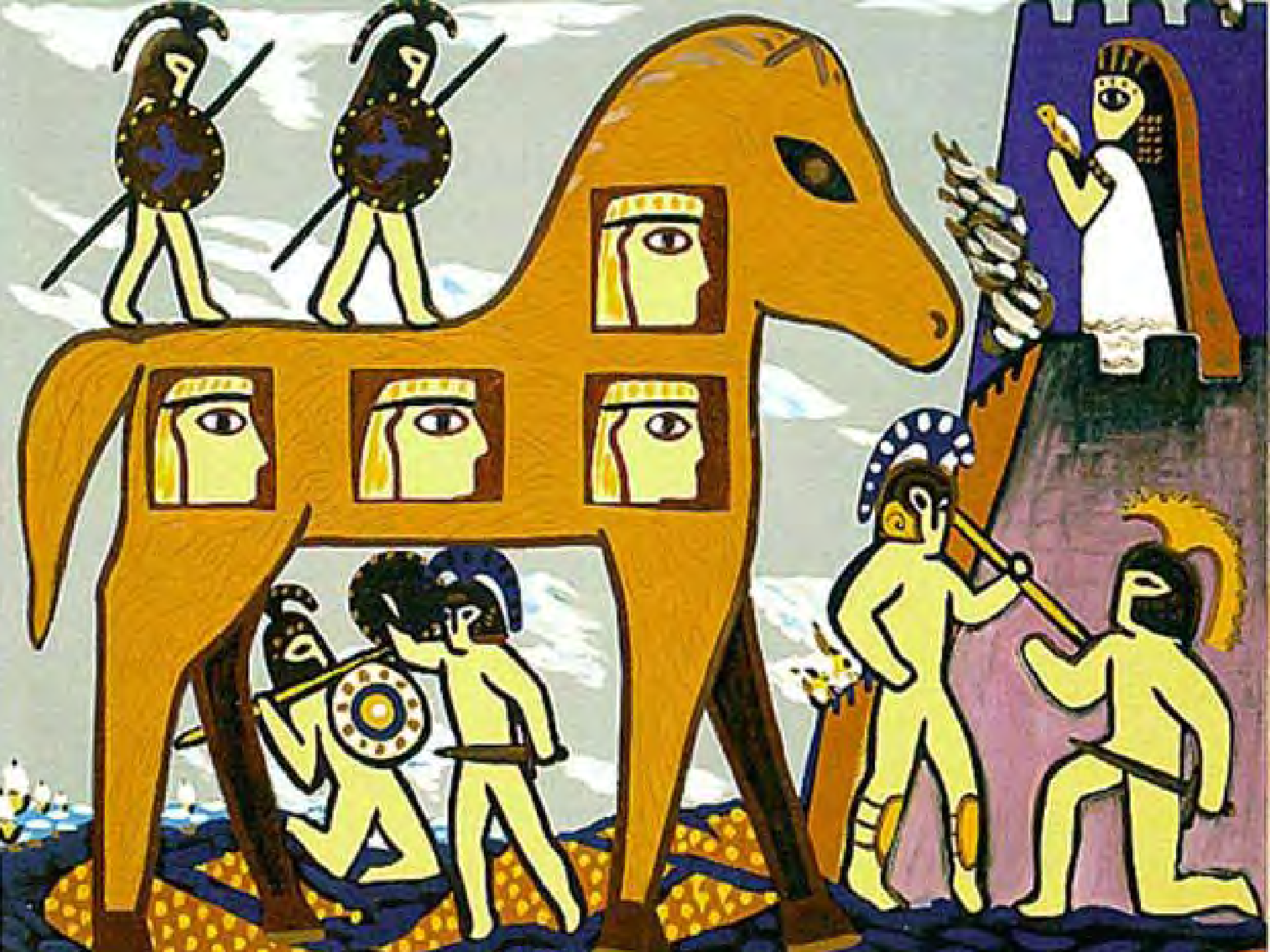
ISOtL Invited Scholar Series  
University of British Columbia  
Vancouver, BC, 22 January 2015





A group of students are gathered around a white circular table in a bright, modern classroom. Several laptops are open on the table, and students are engaged in discussion and work. In the foreground, a woman with dark hair is looking at a laptop screen, while another woman with blonde hair is looking towards her. In the background, other students are working on laptops, and a man is standing near a whiteboard. The overall atmosphere is collaborative and focused.

**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 white tables, working on laptops. Some students are looking at their screens, while others are engaged in discussion. The room has large windows and a bright, airy feel. The text "Four tracks, all modeled after standard course for majors" is overlaid in the center of the image.

**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.

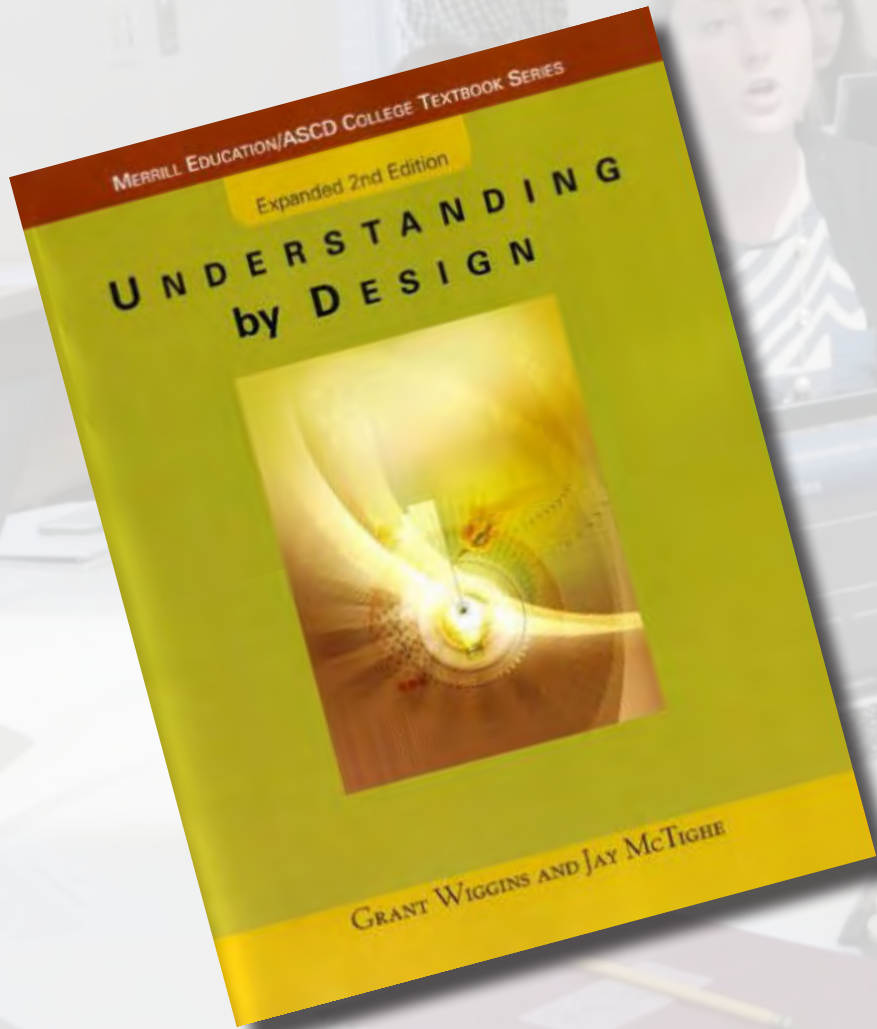
**Four tracks, all modeled after standard course for majors  
(don't satisfy needs of non-majors)**

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:**

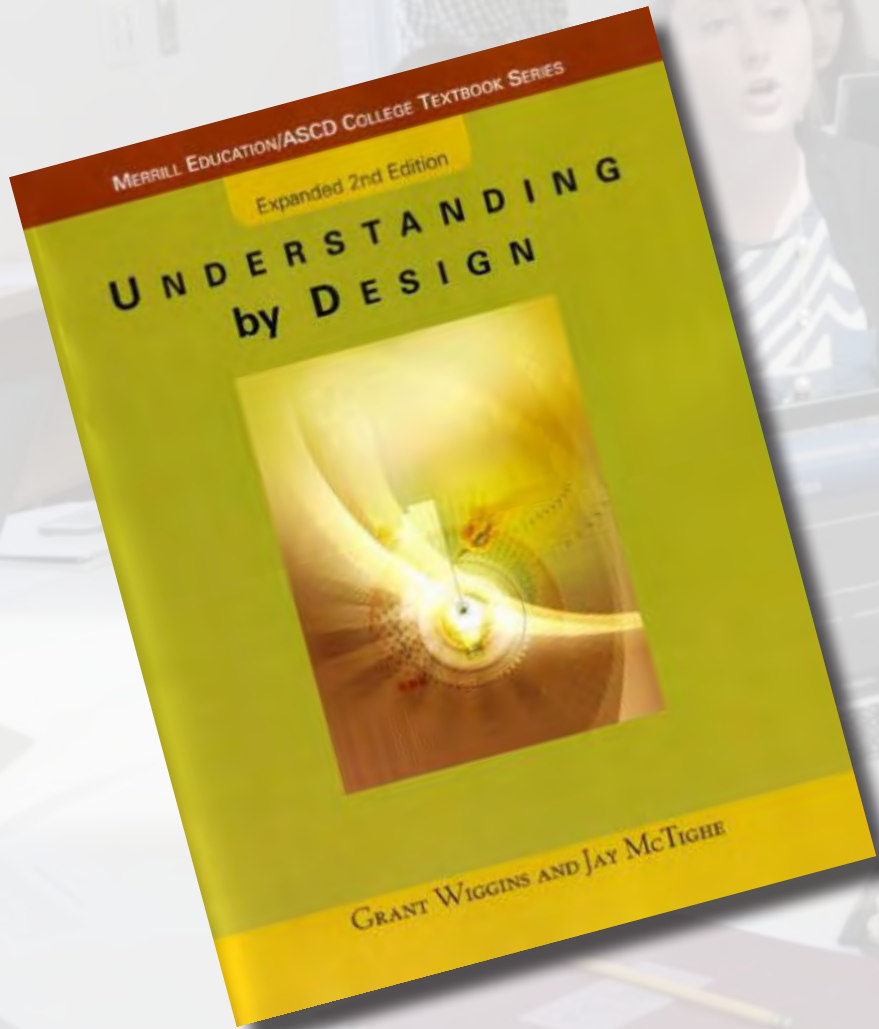
- **align goals to students' needs and expectations**
- **change the approach**
- **redesign the learning space**

## Setting learning goals



Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

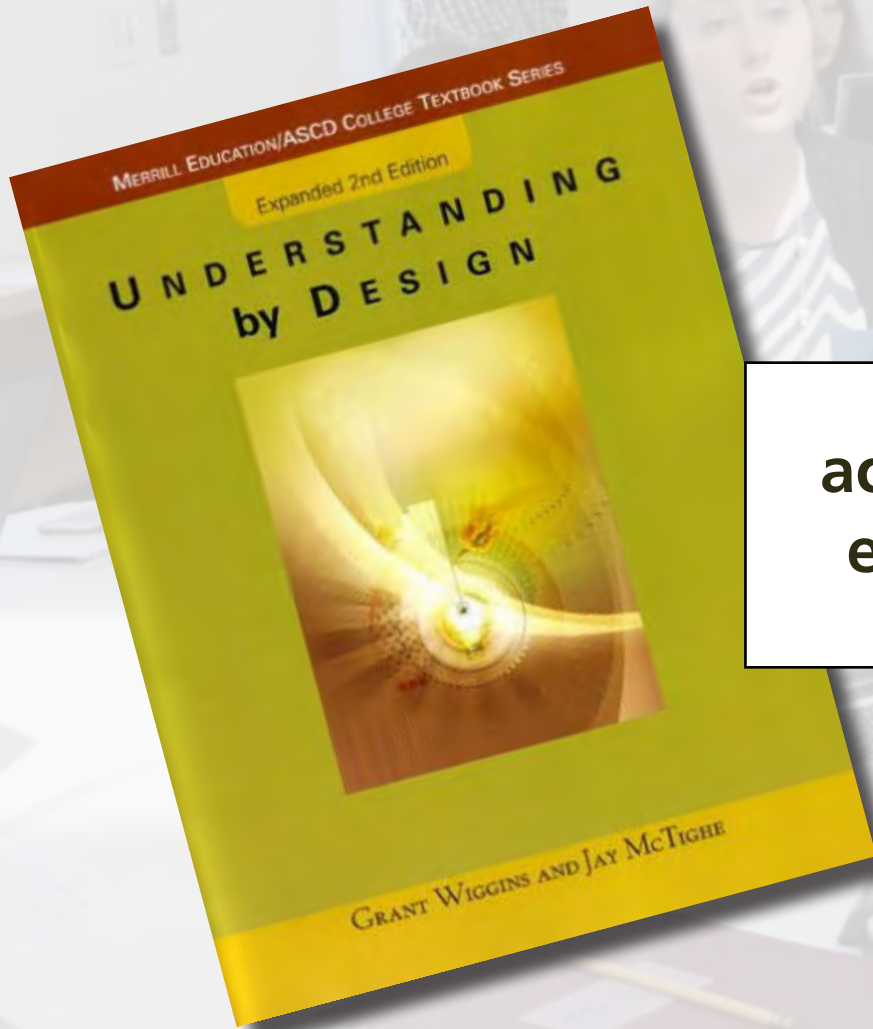
## Backward design



**desired  
outcomes**

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

## Backward design



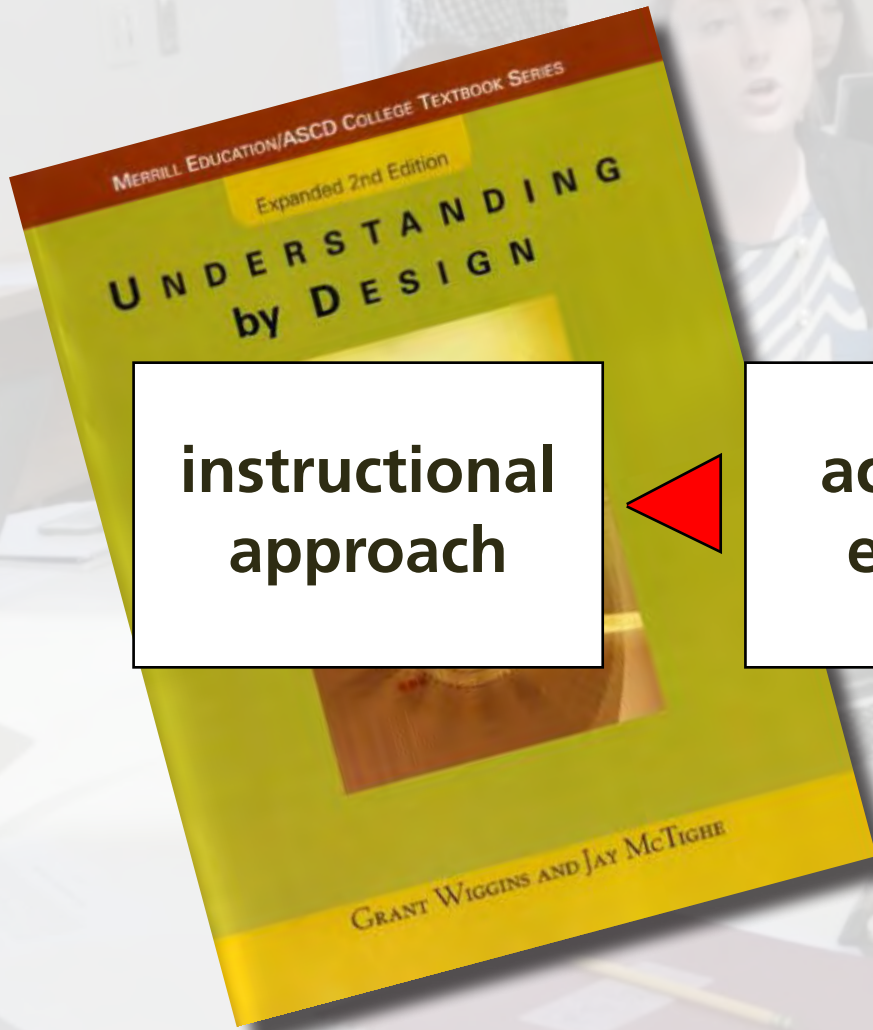
acceptable  
evidence



desired  
outcomes

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

## Backward design



**instructional  
approach**

**acceptable  
evidence**

**desired  
outcomes**

Grant Wiggins and Jay McTighe, *Understanding by Design* (Prentice Hall, 2001)

# Backward design

A screenshot of a web browser displaying an 'INTRO PHYSICS COURSE SURVEY' form. The browser's address bar shows the URL 'https://docs.google.com/spreadsheet/viewform?hl=en\_US&'. The form itself has a title 'INTRO PHYSICS COURSE SURVEY' and a message: 'Thank you for participating in this survey. Your answers are confidential.' Below this, there are two required fields: 'Your name: \*' and 'Your e-mail address: \*'. The next question is 'Which course(s) do you teach that list(s) Physical Sciences, Physics 11, or Physics 15 as a prerequisite? \*'. It includes instructions to 'List the course number only (for example, Physics 153). Course list url: http://www.registrar.fas.harvard.edu/fasro/courses/index.jsp?cat=ugrad&subcat=courses'. There is a large text area for the answer. At the bottom, there is a table for rating the prerequisite physics courses. The table has columns for 'In your experience, how well do the prerequisite physics courses prepare students for your course? \*', 'Not a prerequisite', 'Not at all', 'Somewhat', and 'Very well'. The first row is for 'PS1'.

Grant Wiggins and Jay McTighe

# 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 v
  - 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 measu
  - Describe how a measurement is performed and the limitation
  - Use software to control simple experiments and accumulatio
  - Identify sources of uncertainty, and minimiz
  - measurement in order to develo
  - and presentat

## course goals

# content-specific goals

<http://bit.ly/ap50visitor>





**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

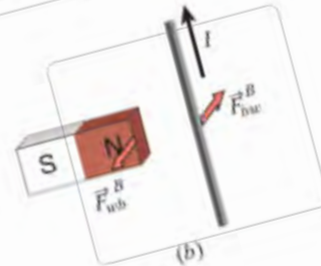
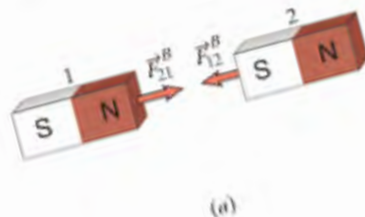
In this chapter we investigate further the relationship between the motion of charged particles and the occurrence of magnetic fields. As we shall see, all magnetism is due to charged particles in motion, whether moving along a straight line or spinning about an axis. It takes a moving or spinning charged 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) or between two stationary charged particles (Figure 28.1g). 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



nb.mit.edu

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

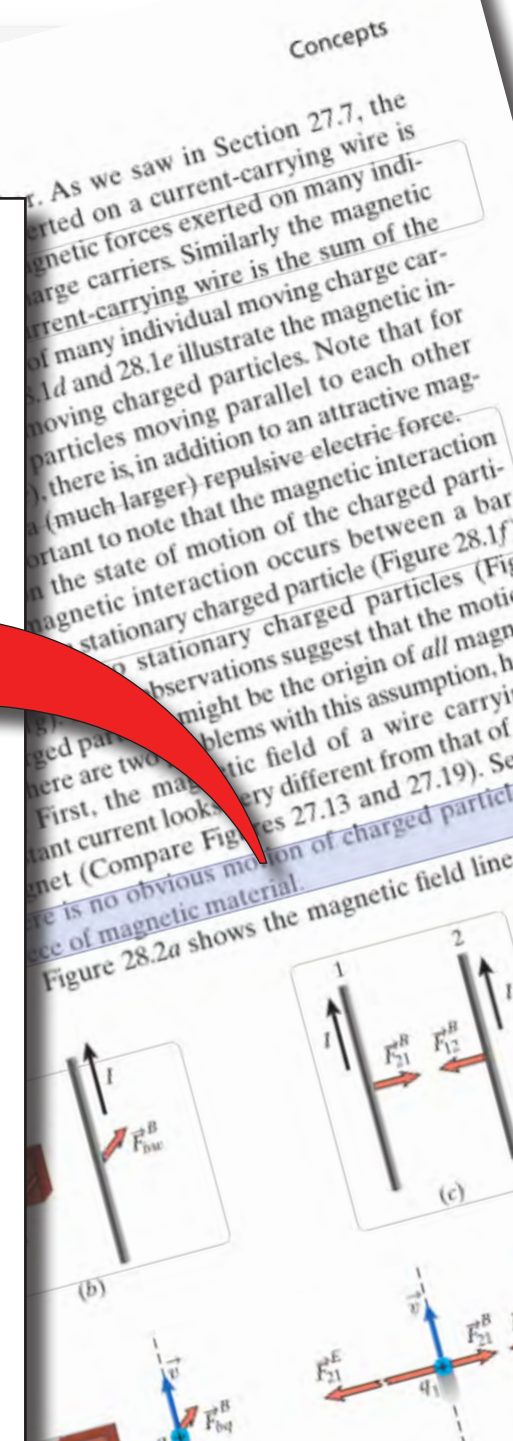
I agree that the motion is not "obvious" in that it is not visible to the naked eye. The cause must be atomic.

## 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..." even though there is no obvious motion of charged particles in a piece of magnetic material (e.g., magnet, e.g., iron sample?). How does this reconcile?

**Student 2 – 26 Feb, 12:12PM**

Maybe they're saying that there is no OBTAINABLE motion, but they are in fact moving via a quantum effect. Therefore, it meets their definition that it takes moving particles to create a magnetic field.

**Student 3 – 2 Mar, 09:00AM**

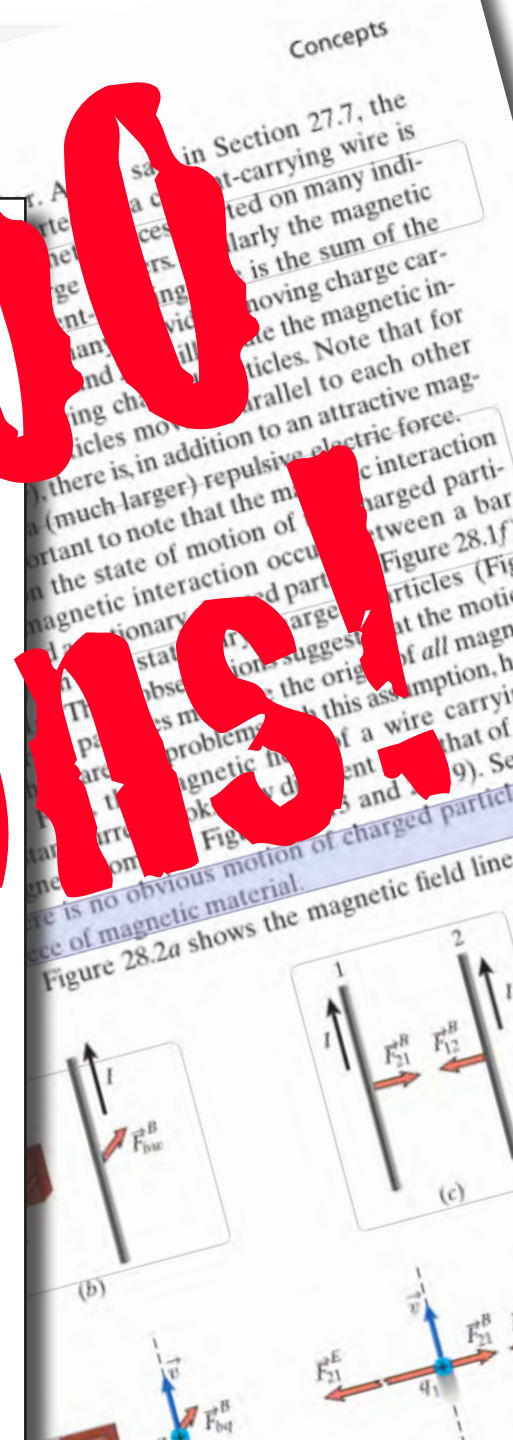
I agree that the motion is not "obvious" in that it is not visible to the naked eye. The cause must be atomic.

**Student 2 – 2 Mar, 11:37AM**

Oh the answers to the question and the 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, is 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 ...



1 design

2 approach

# 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

1 design

2 approach

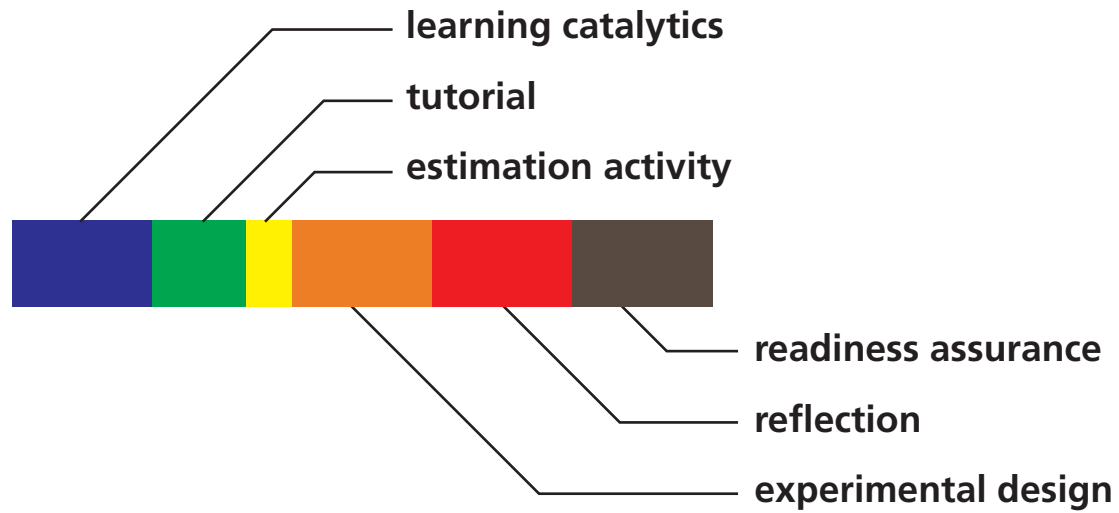
# In-class activities



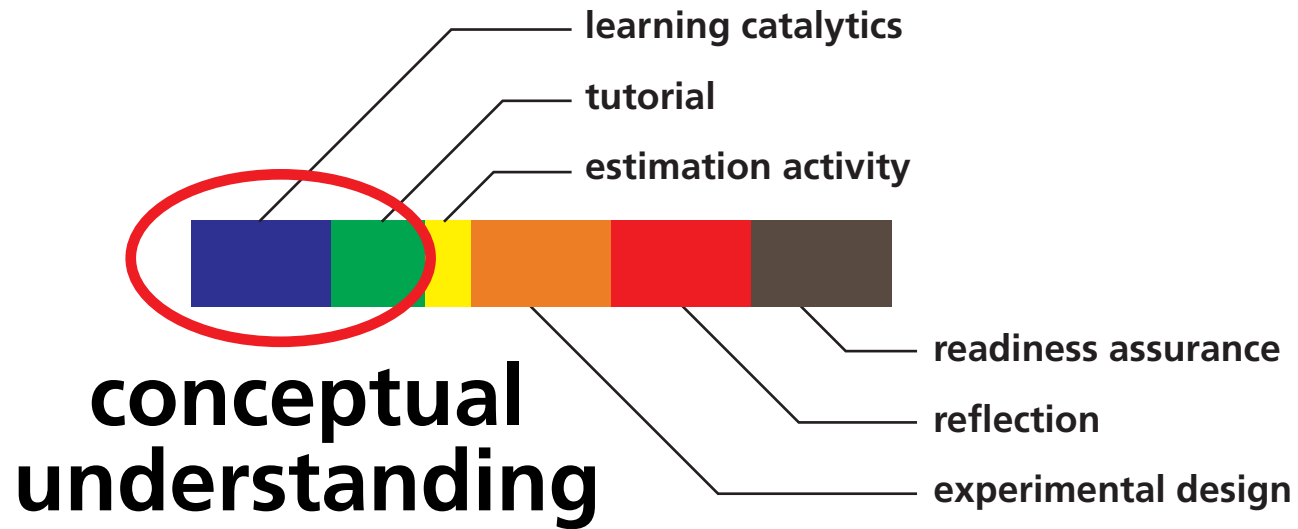
1 design

2 approach

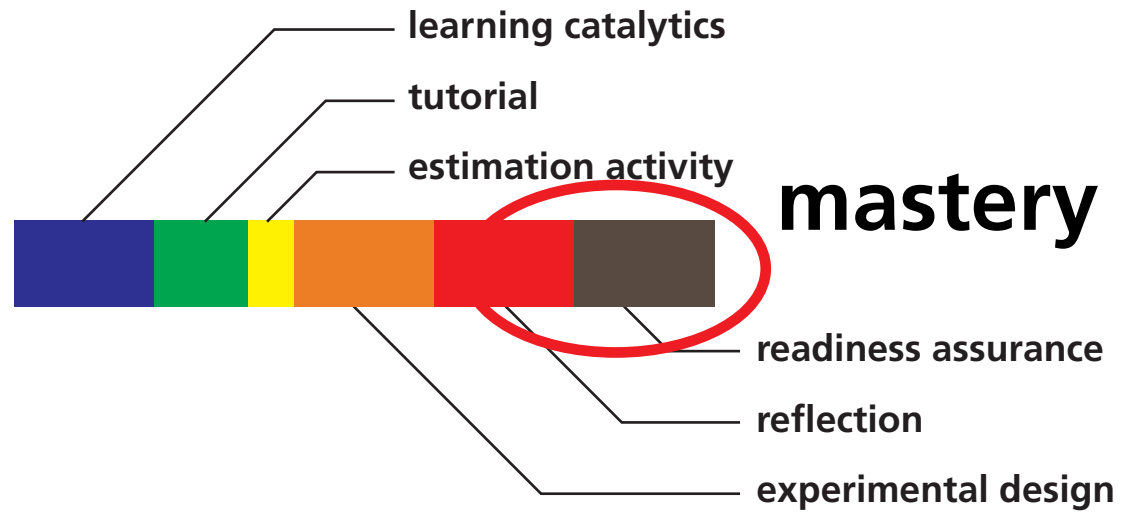
# In-class activities



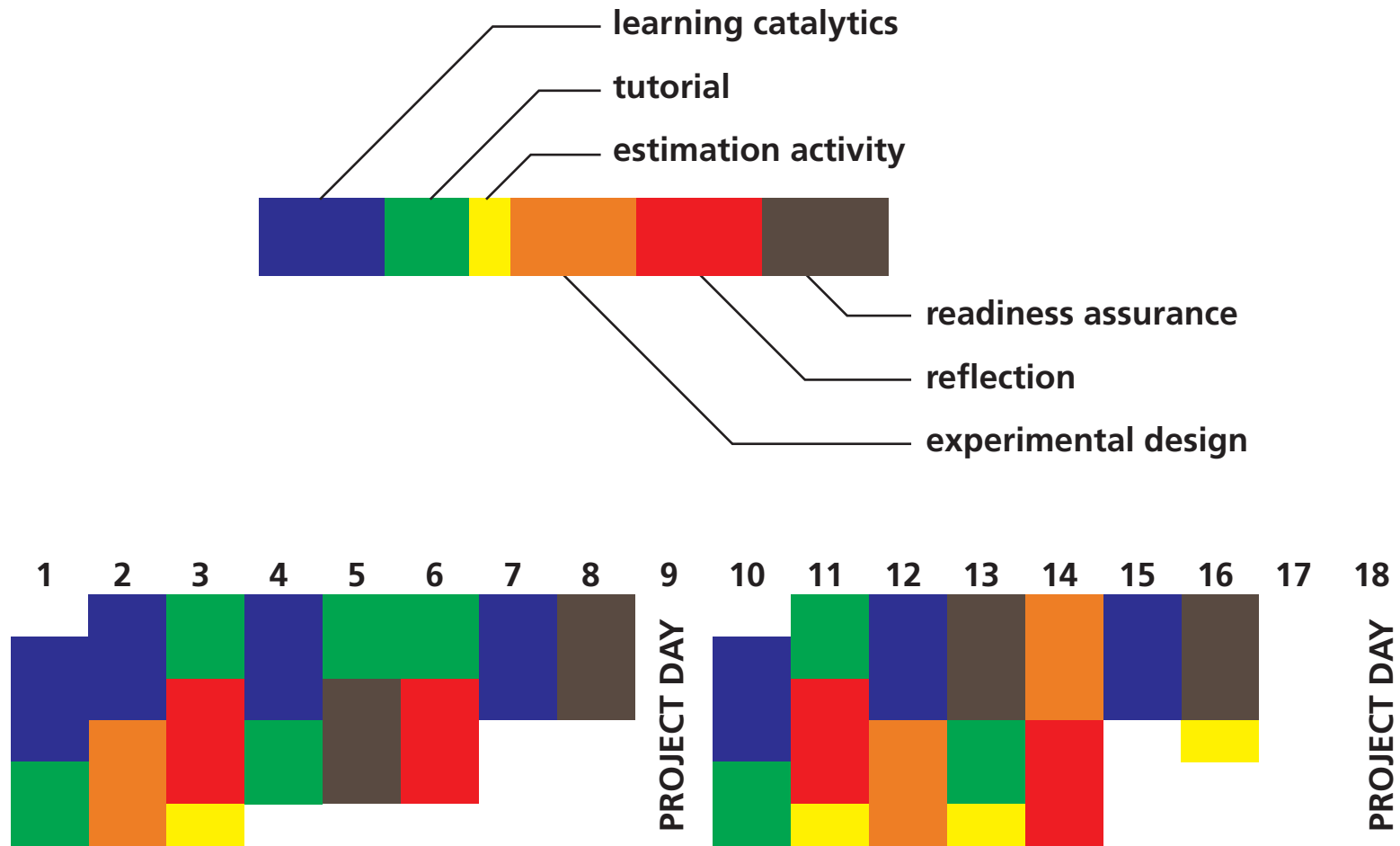
# In-class activities



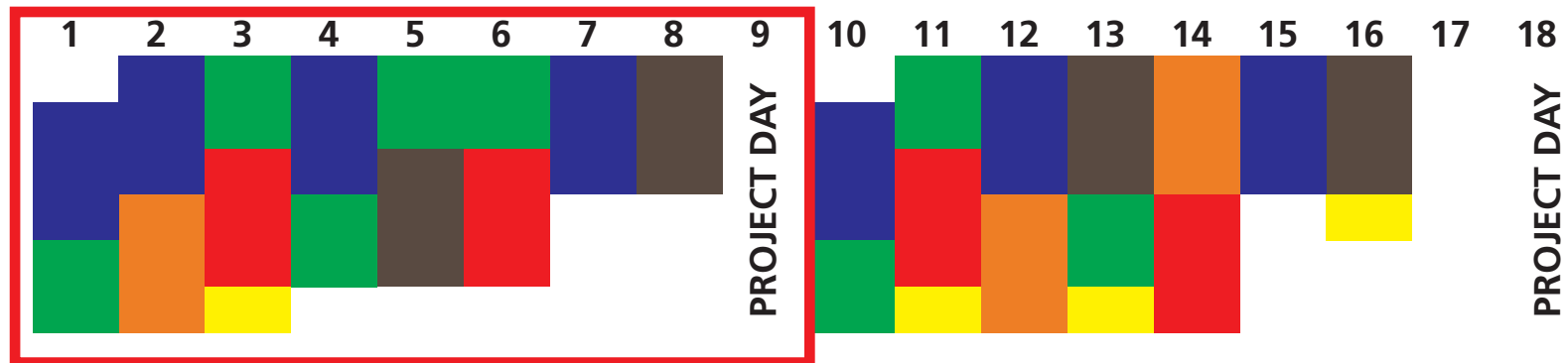
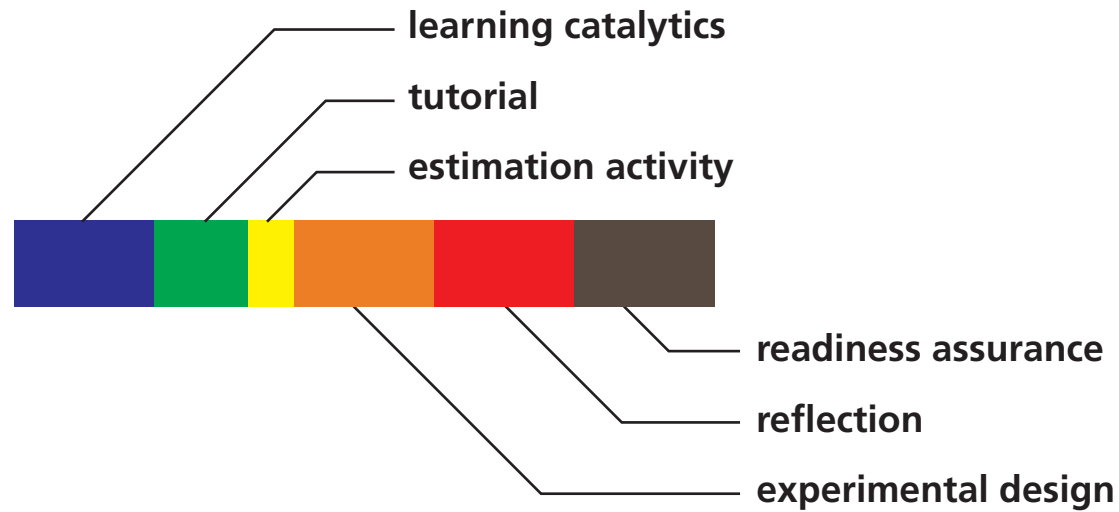
# In-class activities



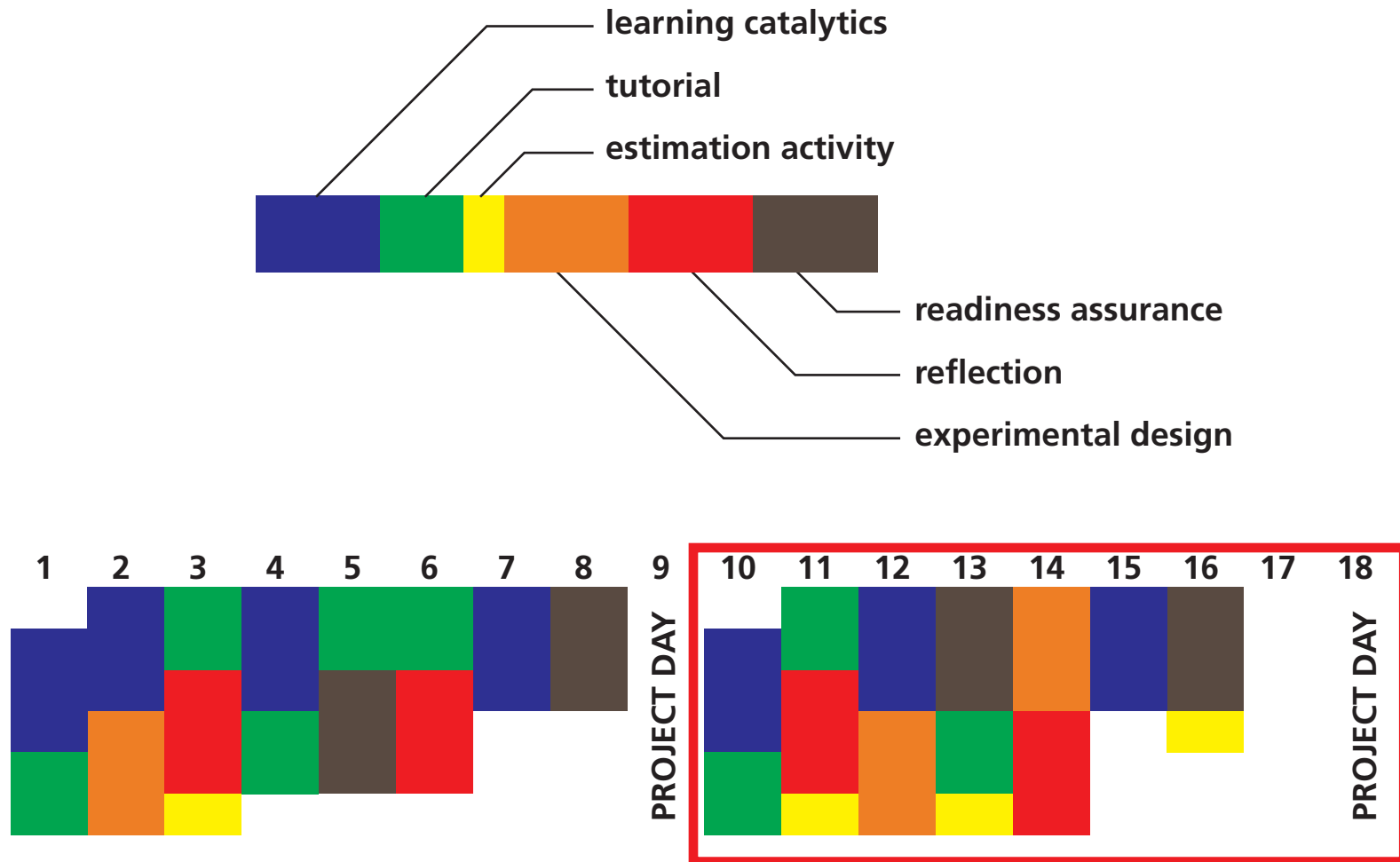
# In-class activities



# In-class activities



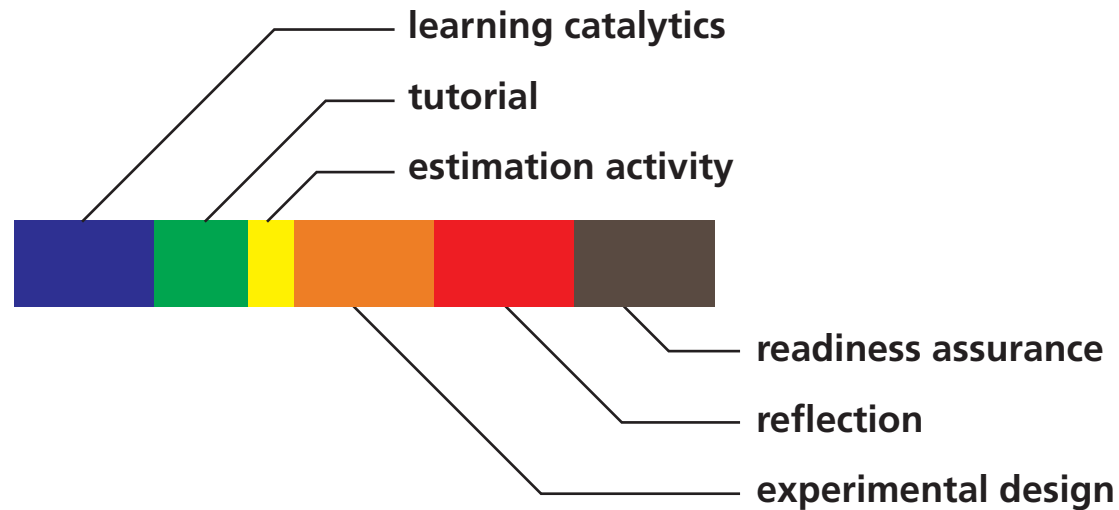
# In-class activities



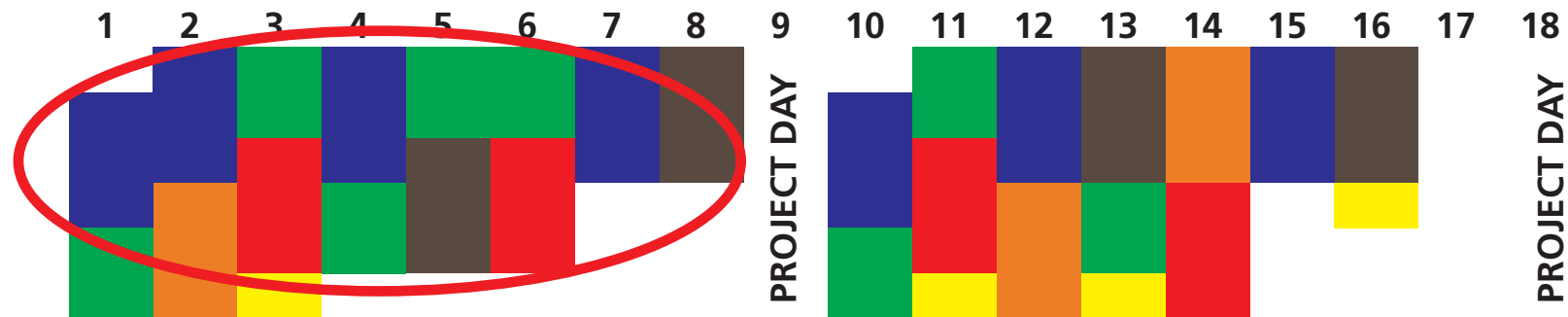
1 design

2 approach

# In-class activities



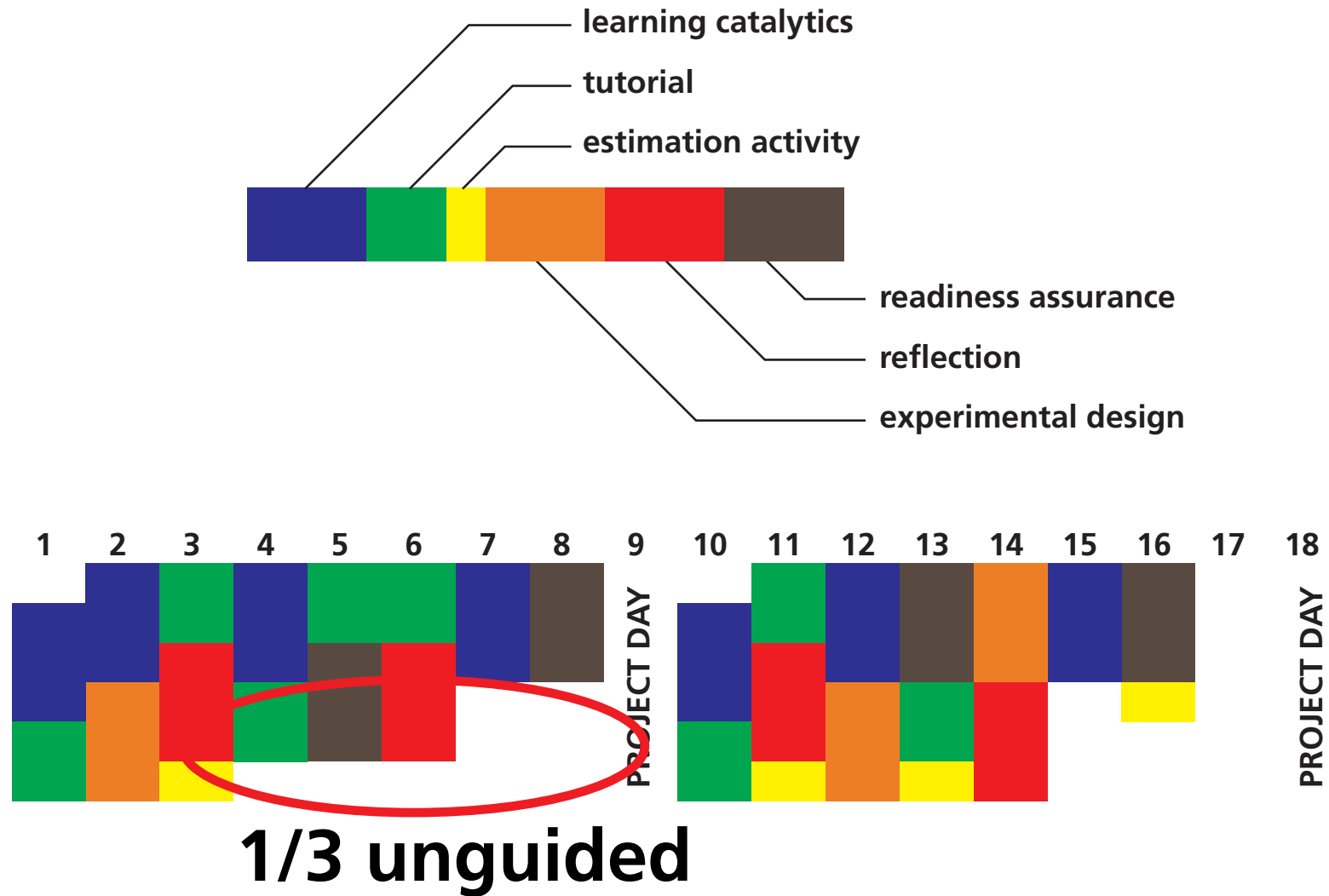
**2/3 scaffolded, guided**



**1** design

**2** approach

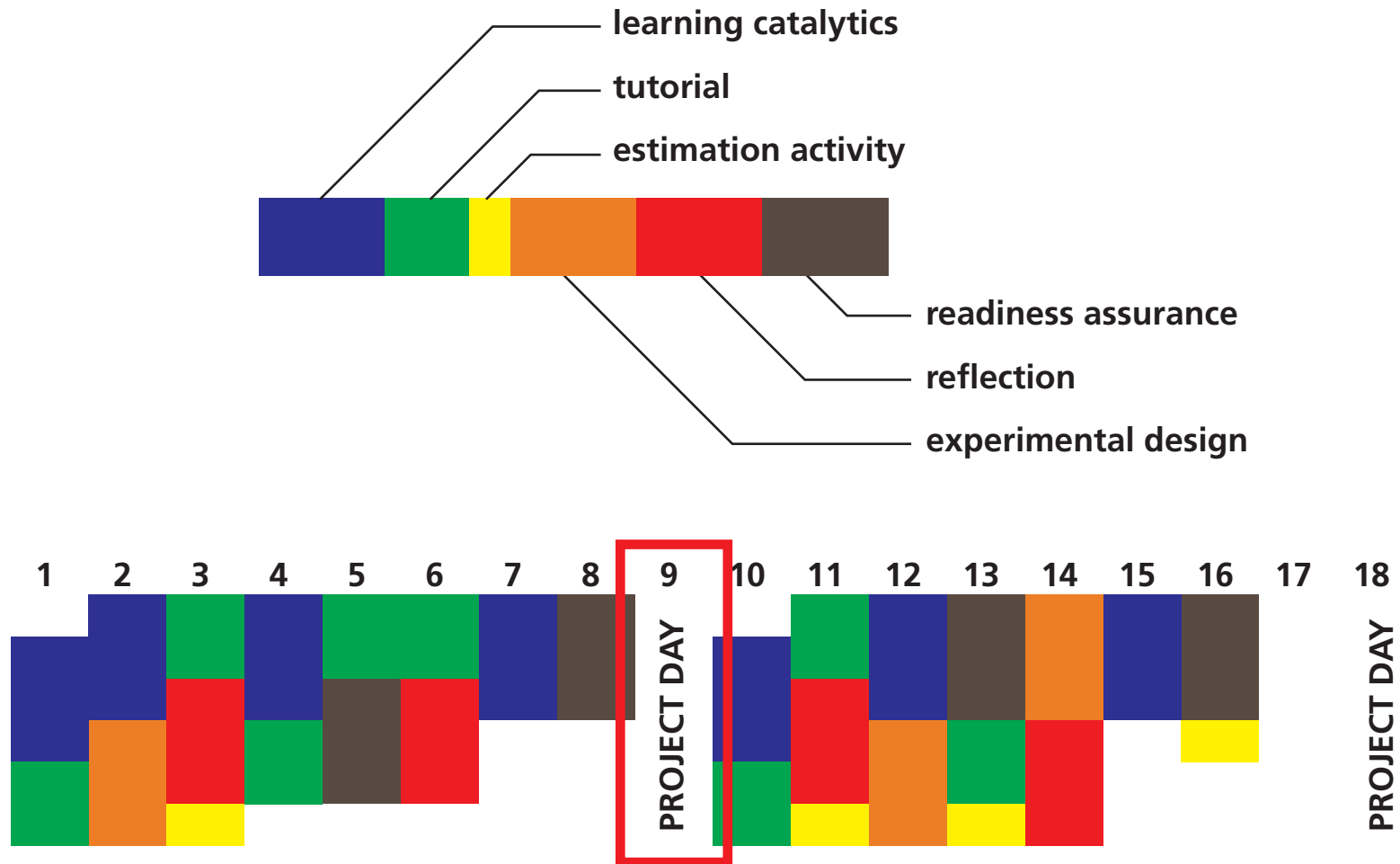
# In-class activities



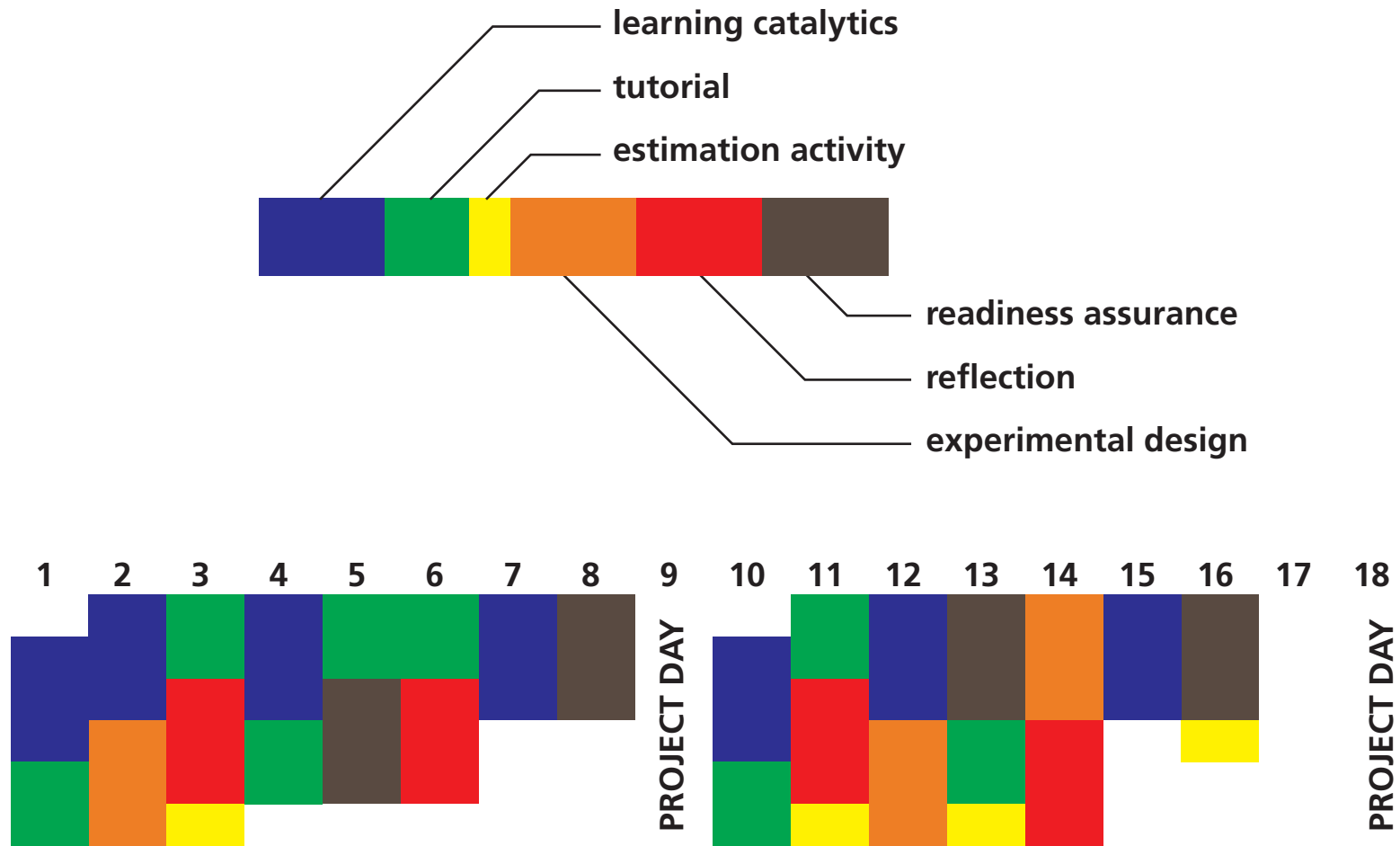
1 design

2 approach

# In-class activities



# In-class activities



# learning catalytics

1 design

2 approach

# learning catalytics

**goal: develop conceptual understanding**

**1 design**

**2 approach**

# learning | catalytics

[Courses](#) [Participate](#) [Review](#) [Classrooms](#) [Account](#) [Institutions](#) [Purchases](#) [Users](#) [Tour](#) [Help](#)

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 ▼

1

2

3

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14

15



4. direction Light enters horizontally into the combination of two perpendicular mirrors as shown below.

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



feedback &amp; support

**1** design**2** approach

# learning | catalytics

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6 7 8 9 10 11 12 13 14 15

perpendicular mirrors as shown below.

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

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

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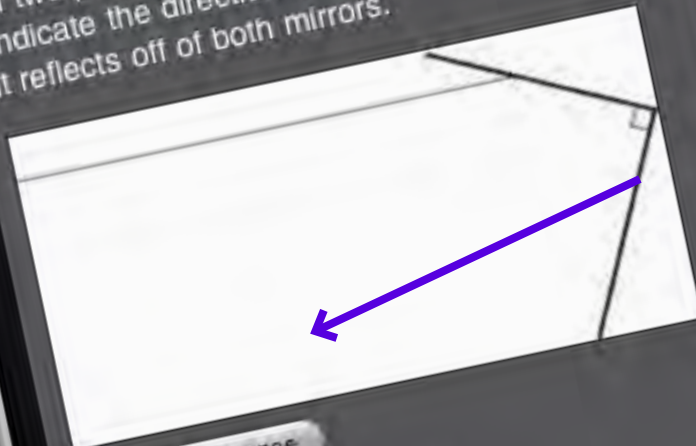
6 7 8 9 10 11 12 13 14 15

perpendicular mirrors as shown below.

[Deliver](#) [Show all results](#)[feedback & support](#)

Indicate the d

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](#)**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.

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Round 1

57 responses, 58% correct

[feedback & support](#)

Indicate the d

1 design

2 approach

## learning | catalytics

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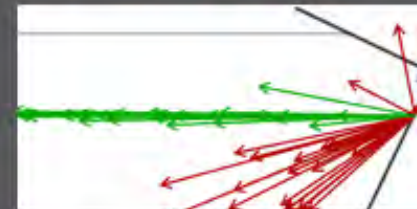
6 7 8 9 10 11 12 13 14 15

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](#)

1 design

2 approach

The background of the slide is a complex, abstract pattern of concentric, swirling lines in shades of blue, green, and yellow, resembling a topographical map or a stylized eye. On the left side, there is a vertical bar with five colored segments: 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**

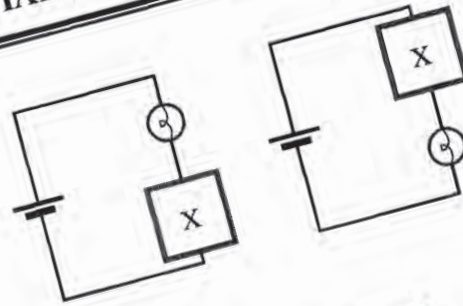
**1 design**

**2 approach**

## A MODEL FOR CIRCUITS PART 2: POTENTIAL DIFFERENCE

### I. Current and resistance

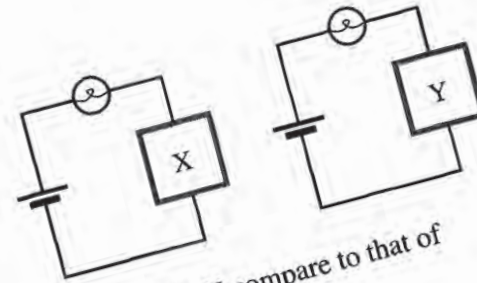
- A. The circuits at right contain identical batteries, bulbs, and unknown elements labeled X.



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.

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?

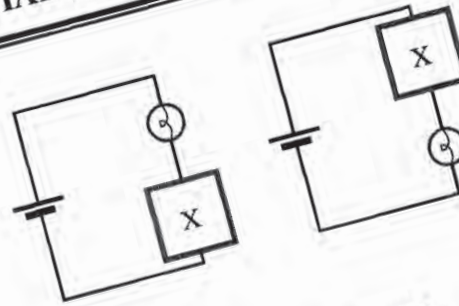
McDermott et al., *Tutorials in Introductory Physics* (Prentice Hall, 2002)

## A MODEL FOR CIRCUITS PART 2: POTENTIAL DIFFERENCE

### I. Current and resistance

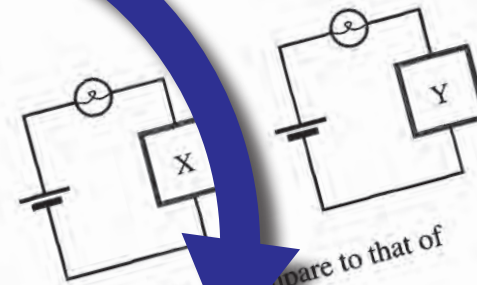
- A. The circuits at right contain identical batteries, bulbs, and unknown elements labeled X.

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.)



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)

1 design

2 approach

The background of the slide is an abstract painting featuring concentric, swirling patterns in shades of blue, green, and yellow, creating a sense of depth and movement. On the left side, there is a vertical bar with five colored squares: purple, green, yellow, orange, and red. The text "estimation activity" is written in a bold, black, sans-serif font, positioned to the right of the yellow square.

**estimation activity**

**1 design**

**2 approach**



**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?

**"Estimate the amount of charge generated by connecting a AA battery to a large capacitor."**

**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 squares: purple, green, yellow, orange, and pink.

# **experimental design activity**

**1** design

**2** approach

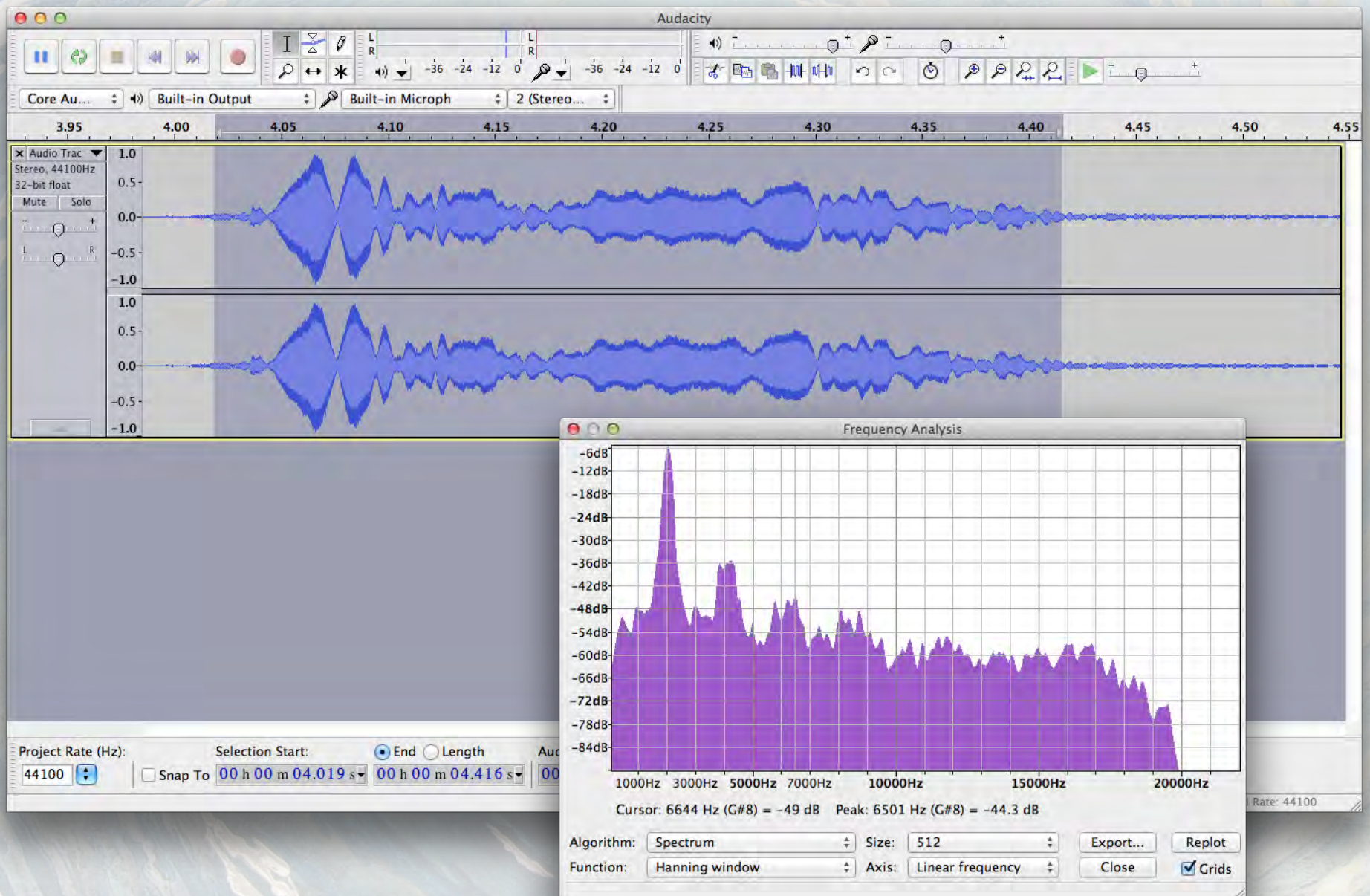
The background features a series of concentric, hand-painted circles in shades of blue, green, and yellow, creating a vortex-like effect. On the left side, there is a vertical bar with five colored segments: purple, green, yellow, orange, and pink.

**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 ripple 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

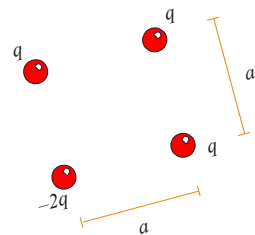
due W Feb 6 in class

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

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 corners
- dark ink (no light pencils)
- no staples
- single-sided printing (back)
- leave margins blank

phase

goal

solve (at home/individual)

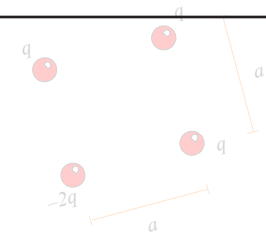
skills development

reflect (in class/team)

metacognition

- Ink-Jet Printing.** In an inkjet printer, letters are printed by starting drops of ink at a piece of paper and directing them 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 two parallel deflecting plates that create a uniform vertical electric field (discussed in chapter 23). Estimate the number of atoms in a single drop 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 make the particle float (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

## Problem Set Rubric

The goal of the problem sets is to develop problem-solving skills, not just to test your ability to obtain the right answer. You will receive the problem sets a week before they are due. Each problem set involves both individual and team work. The rubric mirrors the 4-step procedure used in all Worked Examples in the textbook (see also Section 1.8).

**Individual phase (at home):** From the time you receive a problem set to the time it is due in class at 10 am, you are to work on the problem set **alone**. You can consult the textbook and online resources, but you may not consult other people, nor collaborate with your peers. Treat this stage of the problem-solving process as an open-book/open-notes exam (except that your work done at home is not evaluated on correctness—see below). It's ok to try hard and not succeed at first, but you must attempt every problem. If you get stuck, try to describe your thought process so you are prepared for a discussion with your team in class. You may only use **blue or black ink**.

**Team phase (in class):** On the due date of the problem set, you will work with your team in class to complete, improve, and/or correct your solutions, and plan what you need to review (if anything). During this stage, you may only use **red ink** to write on your problem sets (pens will be provided in class). After the first 45 minutes, your team will be provided with a solution set which you may use to confirm your solutions. After an additional 45 minutes, your team must submit the team's corrected problem sets together with each team member's self-evaluation and indication which problems need to be reviewed in a Learning Clinic.

**Important:** It is the team's responsibility to ensure that *all* team members provide complete solutions, because your team's submitted problem sets will result in a shared team score. Therefore it is your responsibility to ensure that your entire team understands the material.

### Scoring

Your problem set will be evaluated on the five domains below, using the standard 0–3 scale (3 = all problems; 2 = more than 70% of the problems, 1 = more than 50% of the problems, 0 = 50% or fewer of the problems). For the first two domains we will only evaluate the work you did **before coming to class** (anything not written in red).

#### Getting Started

State the important information and summarize the problem. If possible, include a diagram.  
Note any assumptions you're making.

#### Devise Plan

Write down a plan of attack before diving into the solution. Break down smaller, manageable segments. Identify which physical relations apply.

#### Execute Plan

Carry out your plan, explaining each step.  
Articulate your thought process clearly defined, and can be followed by others.

Evaluate

first two domains we will only evaluate the work you did **before coming to class**.

**Getting Started** State the important information and summarize the problem.  
Note any assumptions you're making.

**Devise Plan** Write down a plan of attack before diving into the solution.  
Divide the problem into smaller, manageable segments. Identify which physical relationships are relevant.

**Execute Plan** Carry out your plan, explaining each step in writing. You should be able to explain each step.  
Articulate your thought process at each step (including any calculations).  
Your diagrams should be clearly defined, and your diagrams should be labeled. If you get stuck, ask for help.  
You can complete this part in class with help from your team.

**Evaluate Plan** Check each solution for reasonableness. There are many ways to check a solution:  
- Check the symmetry of the solution, evaluate limiting or extreme cases.  
- Compare your solution to situations with known solutions, check units, use dimensional analysis.  
- Check the magnitude of an answer. If you get stuck on this step, ask for help.  
You can complete this part in class with help from your team.

**Reflection** Clearly identify and explain any conceptual errors you made.  
Explain any difficulties you worked on the problem alone, as well as any mechanical errors you made.  
Explain any parts of the solution completed in class.

### Getting Started

State the important information and summarize the problem. Note any assumptions you're making.

### Devise Plan

Write down a plan of attack before diving into the solution. Break the problem into smaller, manageable segments. Identify which physical principles apply.

### Execute Plan

Carry out your plan, explaining each step in writing. You should be able to articulate your thought process at each step (including any calculations). Your work should be clearly defined, and your diagrams should be labeled. If you get stuck, you can complete this part in class with help from your team.

### Evaluate Plan

Check each solution for reasonableness. There are many ways to check: compare the symmetry of the solution, evaluate limiting or extreme situations with known solutions, check units, use dimensional analysis, check the magnitude of an answer. If you get stuck on this step, you can complete this part in class with help from your team.

### Reflection

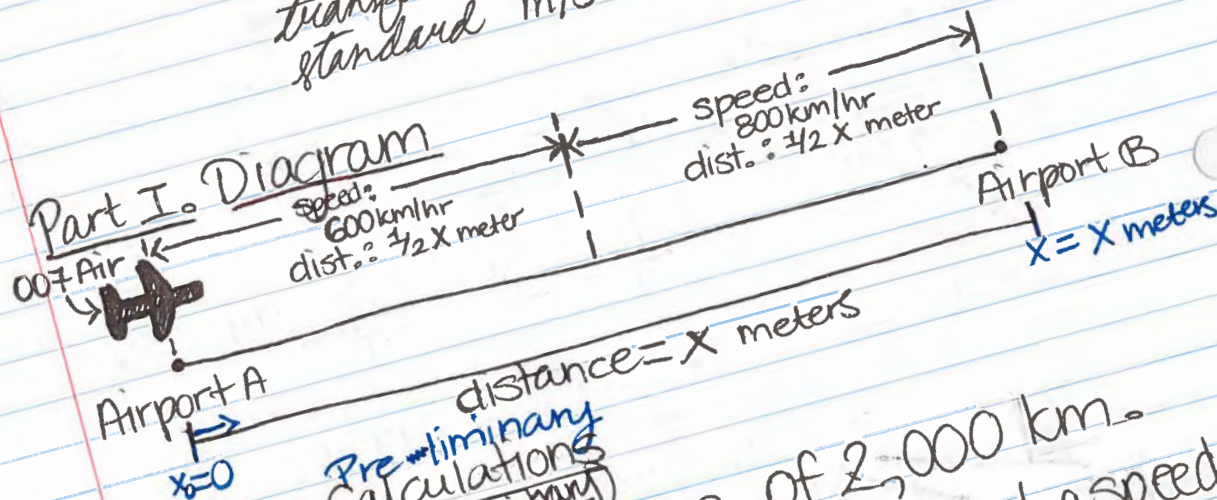
Clearly identify and explain any conceptual errors you made while working on the problem alone, as well as any mechanical errors. Reflect on what you learned and what you completed in class.

## 4-step procedure

1 design

2 approach

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  $\frac{600 \text{ km}}{\text{hr}}$   
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 =  $\frac{800 \text{ km}}{\text{hr}}$   
 $1,000 \text{ km} \left( \frac{1 \text{ hr}}{800 \text{ km}} \right) = \boxed{1.25 \text{ hrs}}$

calculation error

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

25 pages!

Part II: Preliminary Calculations

Assume a distance of 2,000 km.

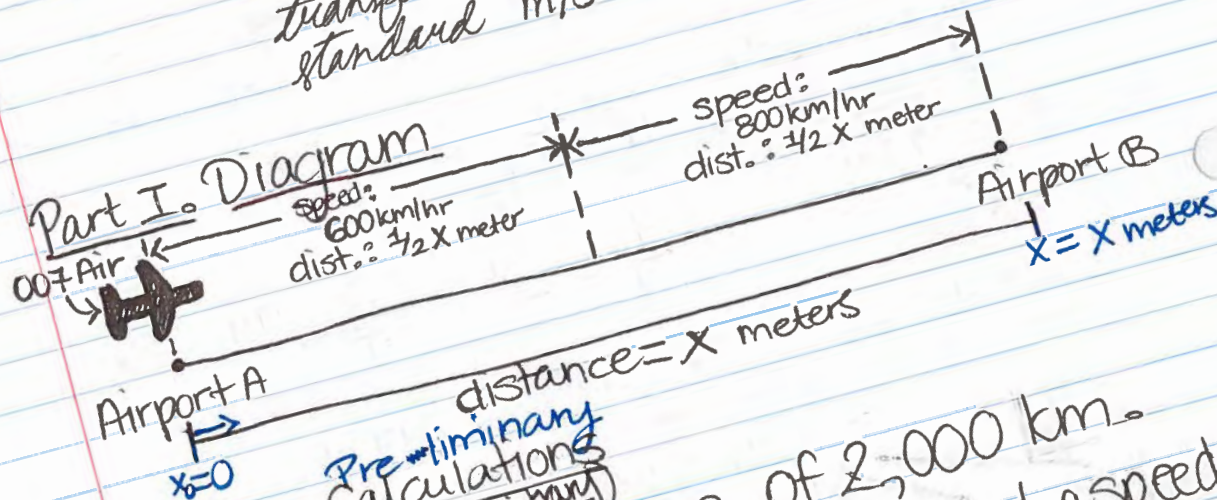
7,000 km, 007 Air flies at a speed of  $1 \frac{2}{3}$  hrs

HF speed = 800 km/h

calculation error

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



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

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

calculation error

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

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

**“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 ripple 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**

**1 design**

**2 approach**

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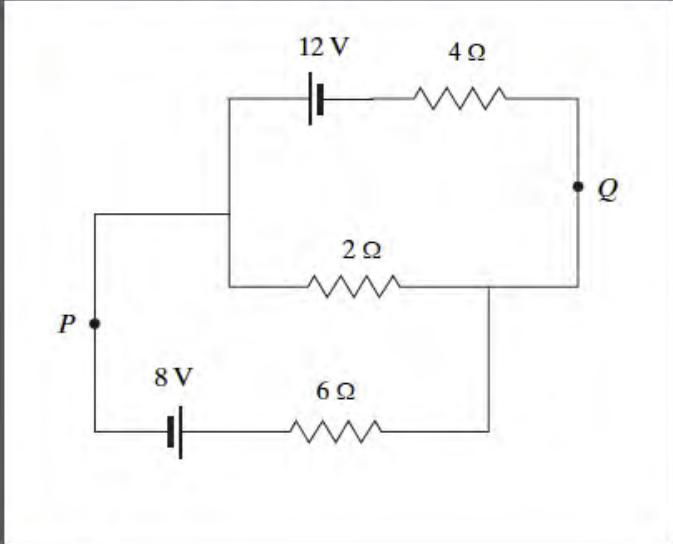
## session 500941

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)



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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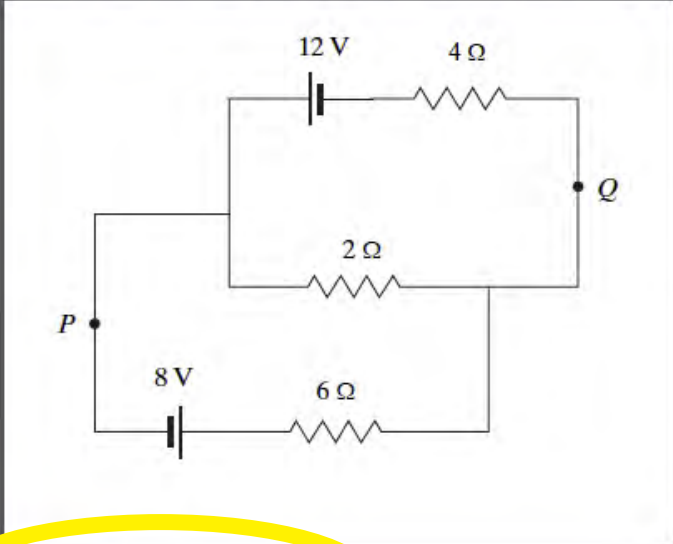
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9 V Submit response

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1 design

2 approach

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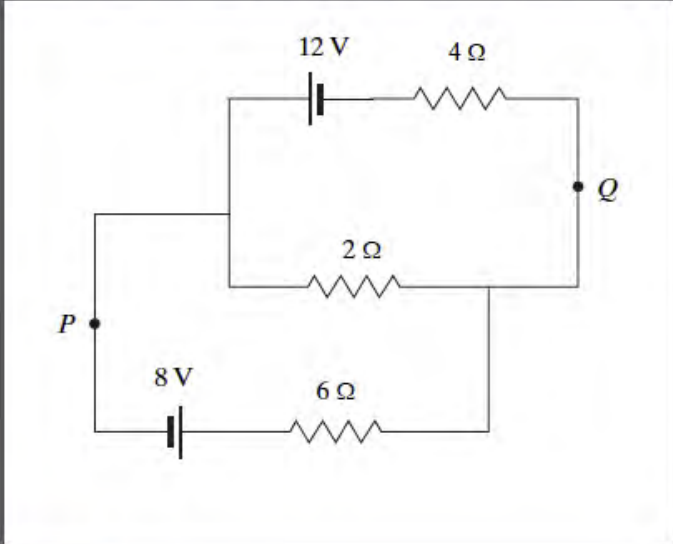
## session 500941

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

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Carrier 5:58 PM

## session 500941

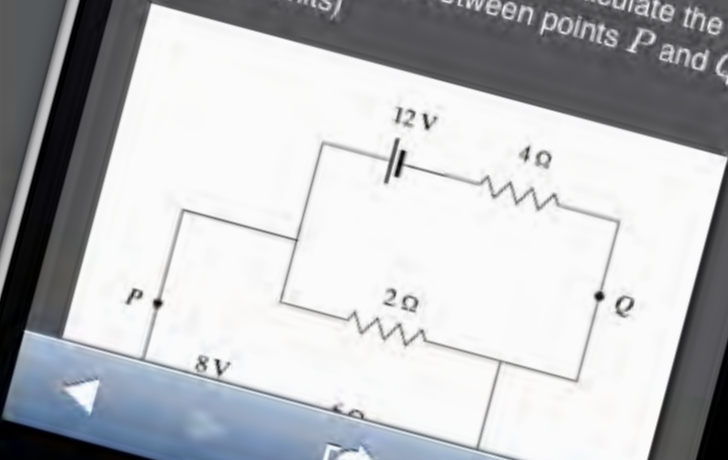
[Logout](#)

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

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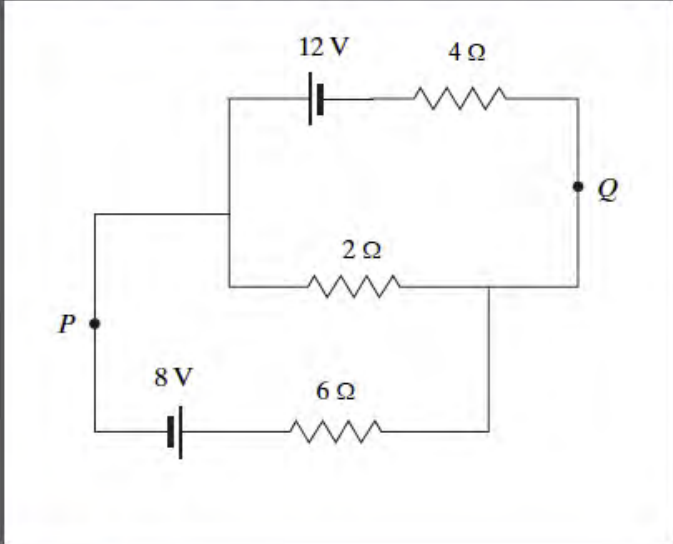
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Jump to 1 2

### 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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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 voltage across the 2 Ω 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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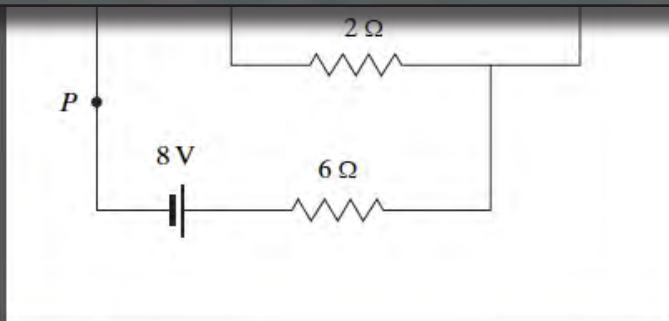
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1/3 questions attempted. 0/4 possible points so far in team round. Score details

1 design

2 approach

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## session 500941

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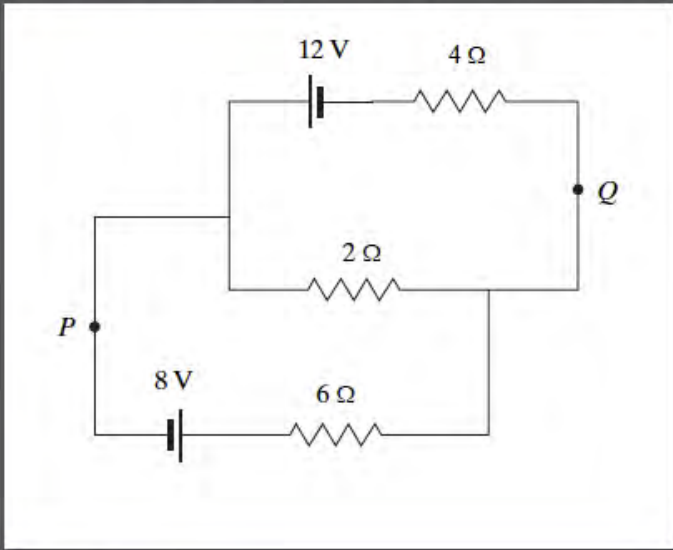
Your team answered Question 3 correctly!

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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## session 500941

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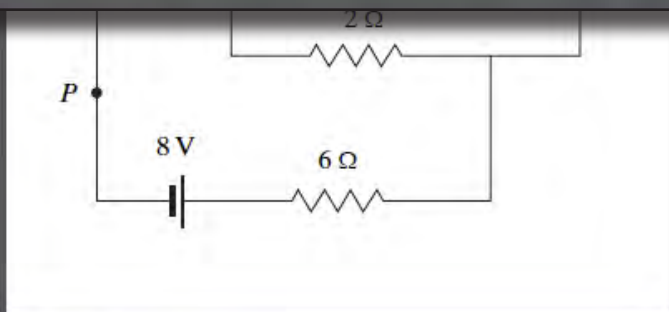
Your team answered Question 3 correctly!

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!



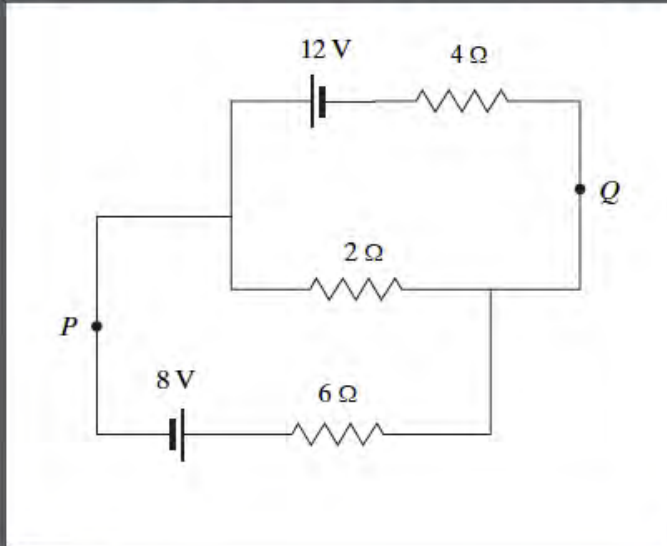
Jump to ▼ 1 2 3



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](#)

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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).

Your team answered Question 3 correctly!



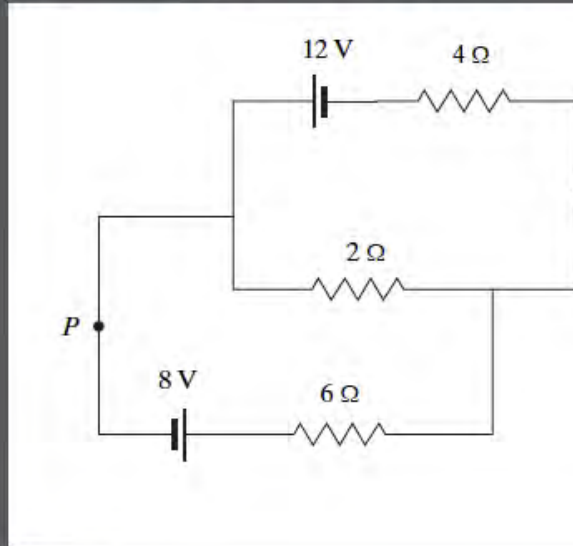
Jump to ▼ 1 2 3



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
<b>Total</b>		<b>2</b>

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

Current seat: A1 [Change seat](#)

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

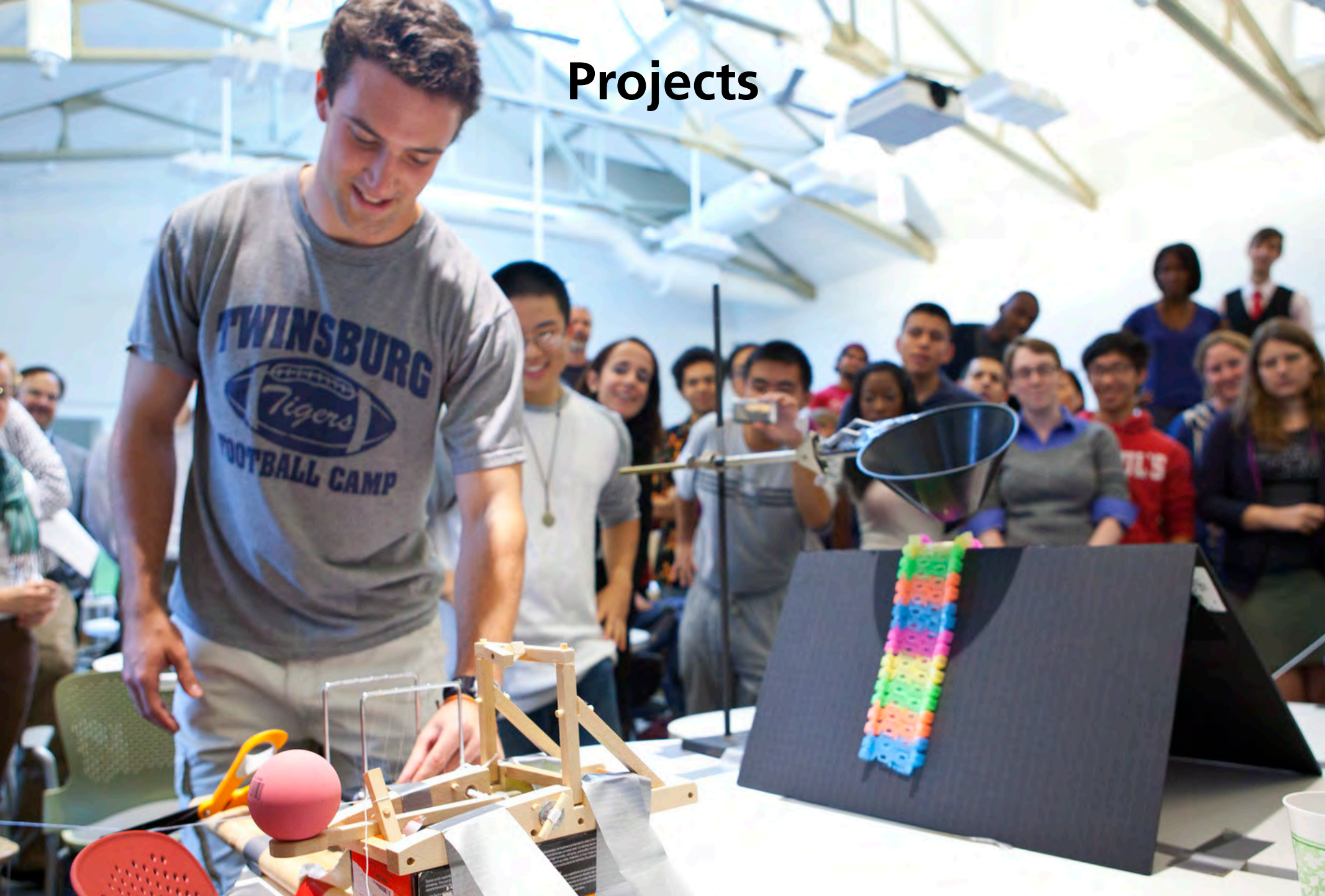
Question	Team Result	Points
1	No response	
2	No response	
3	Correct (on attempt 2)	2
<b>Total</b>		<b>2</b>



**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

---

**Fall**

**Rube Goldberg**

**Mission to Mars**

**Musical Instrument**

---

**Spring**

**Environment**

**Safe cracking**

**Energy**

---

**1 design**

**2 approach**

# 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




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

# Projects



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

# Projects



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

# AP50a FALL 2013

## Project Brief

Week

Week

Week 3

Week 4

Mission to Mars



# **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

## 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 <b>ZERO</b>							
		Below Average			Average	Above average			
	Name	-3	-2	-1	0	1	2	3	
	Me								
	Member 1								
	Member 2								
	Member 3								
	Member 4								

# Assessment

- self-directed learning
- learning goals
- teamwork
- professionalism

1 design

2 approach

# Assessment

- self-directed learning — NB & problem sets
- learning goals
- teamwork
- professionalism

# Assessment

- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork
- professionalism

# Assessment

- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork — project & peer assessment
- professionalism

# Assessment

- self-directed learning — NB & problem sets
- learning goals — RAA & project reports
- teamwork — project & peer assessment
- professionalism — participation, punctuality & ethics

# Assessment

self-directed learning

learning goals

team work

professionalism

# Assessment

Scale: 3–0

self-directed learning

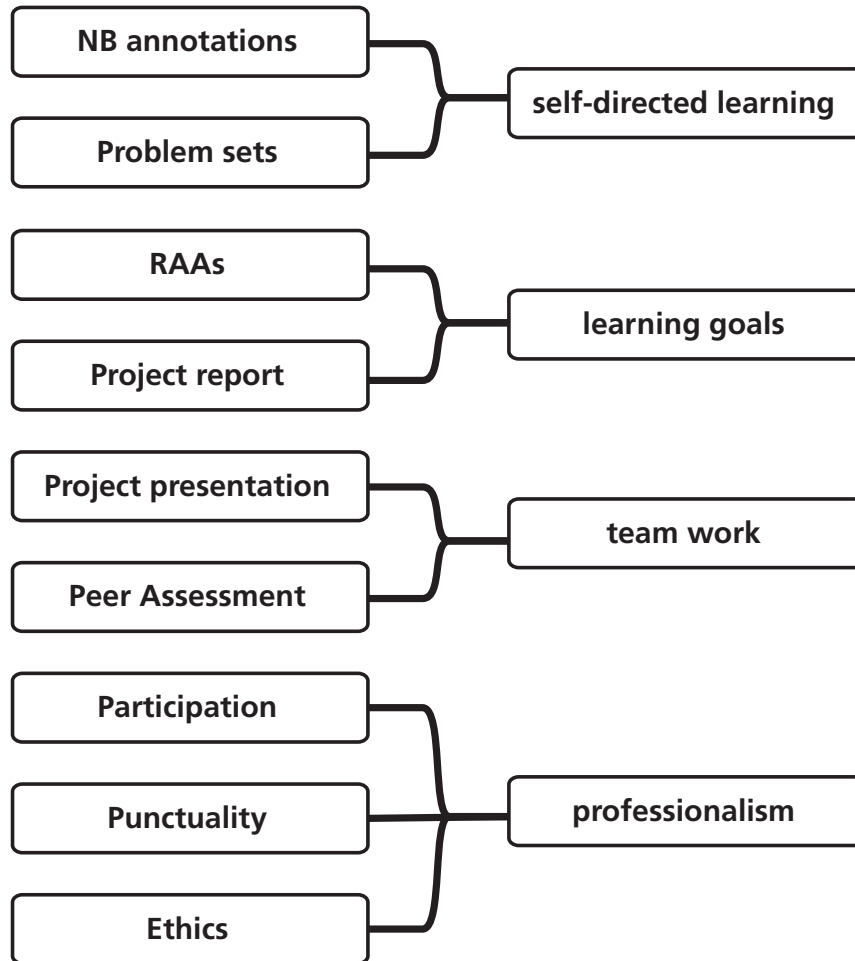
learning goals

team work

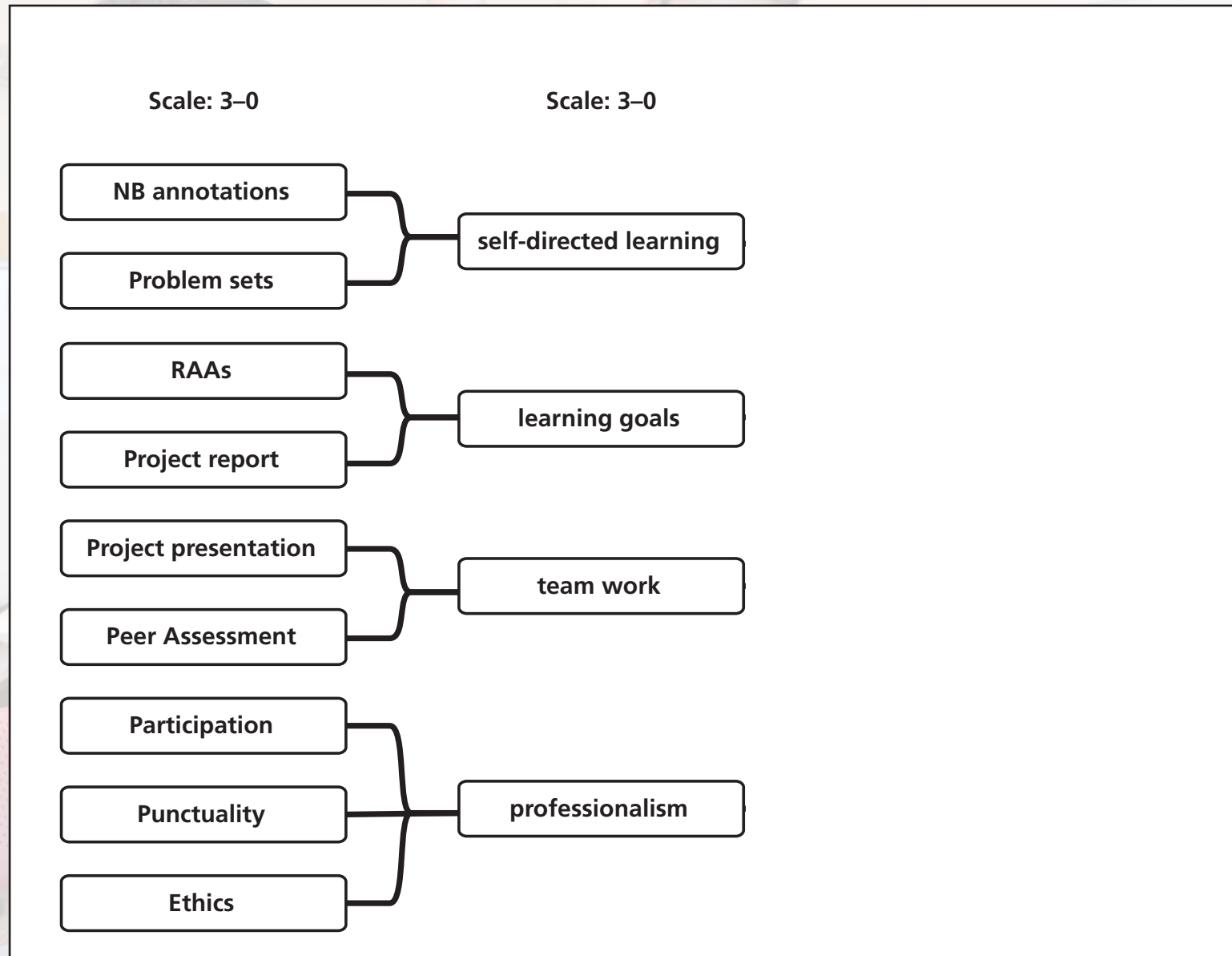
professionalism

# Assessment

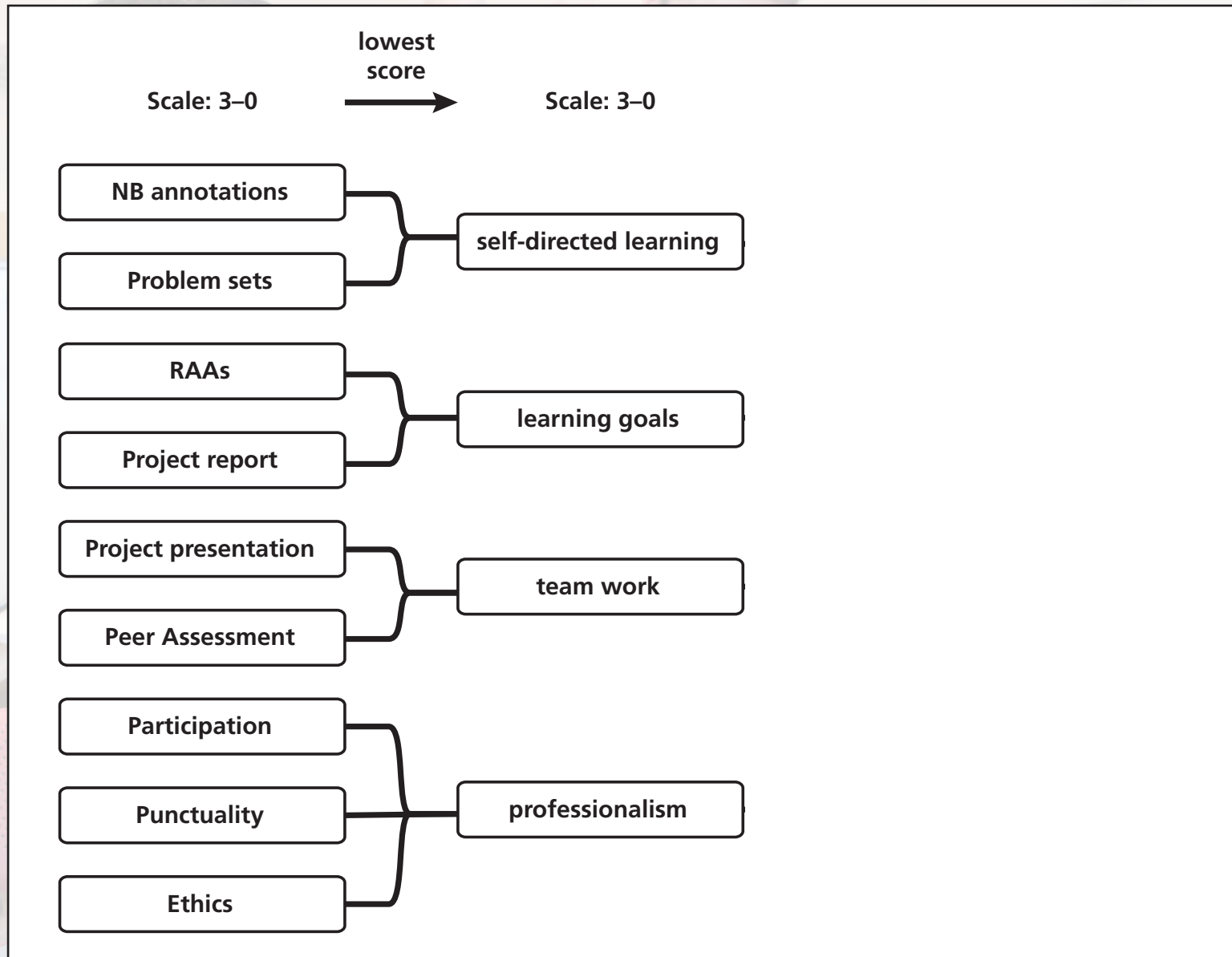
Scale: 3-0



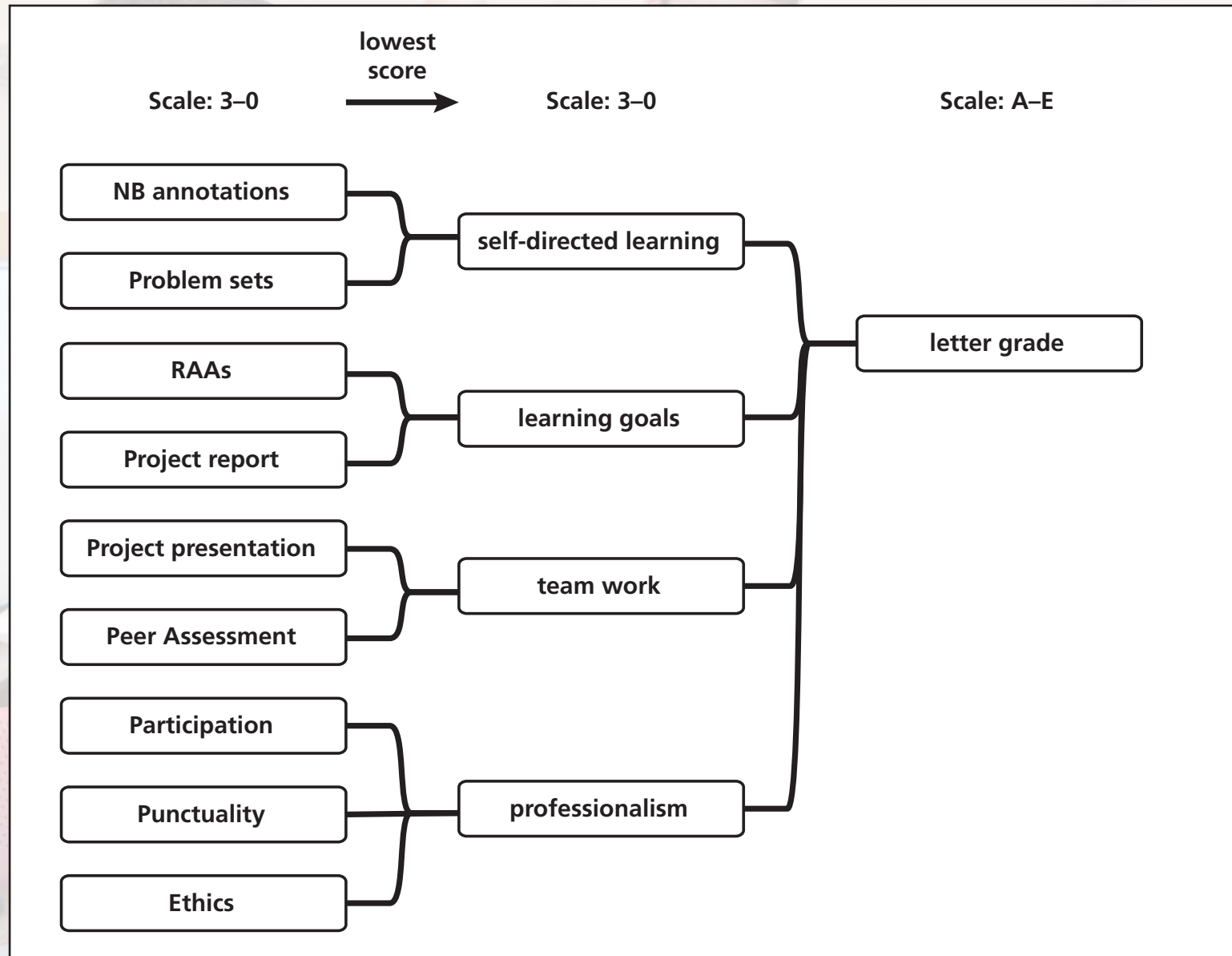
# Assessment



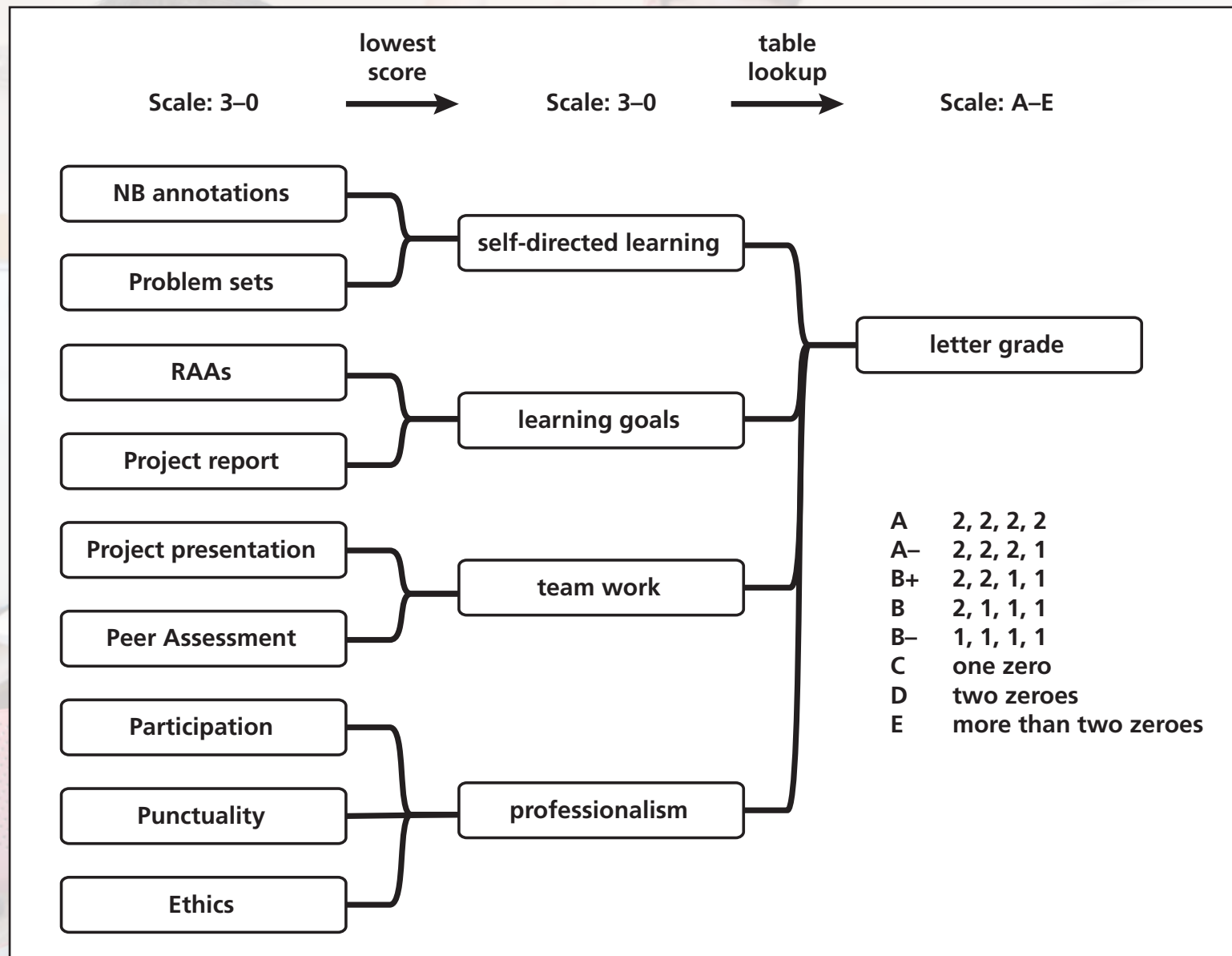
# Assessment



# Assessment



# Assessment





# 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.”**

**1 design**

**2 approach**

**3 results**

# Ownership

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

# Ownership

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

**3 hours and they don't *leave*!**

# 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

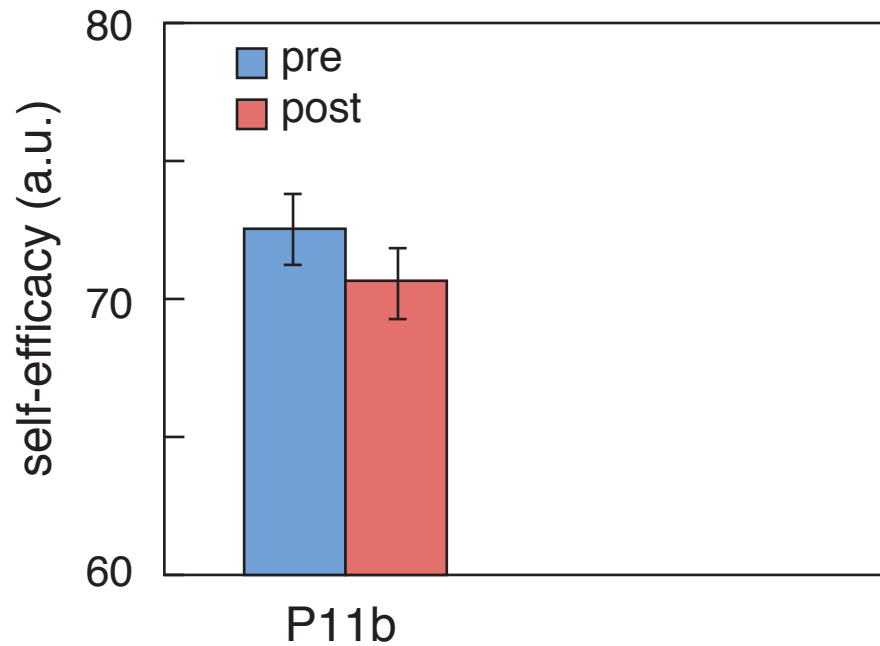
**(students' belief in their ability to succeed)**

**1 design**

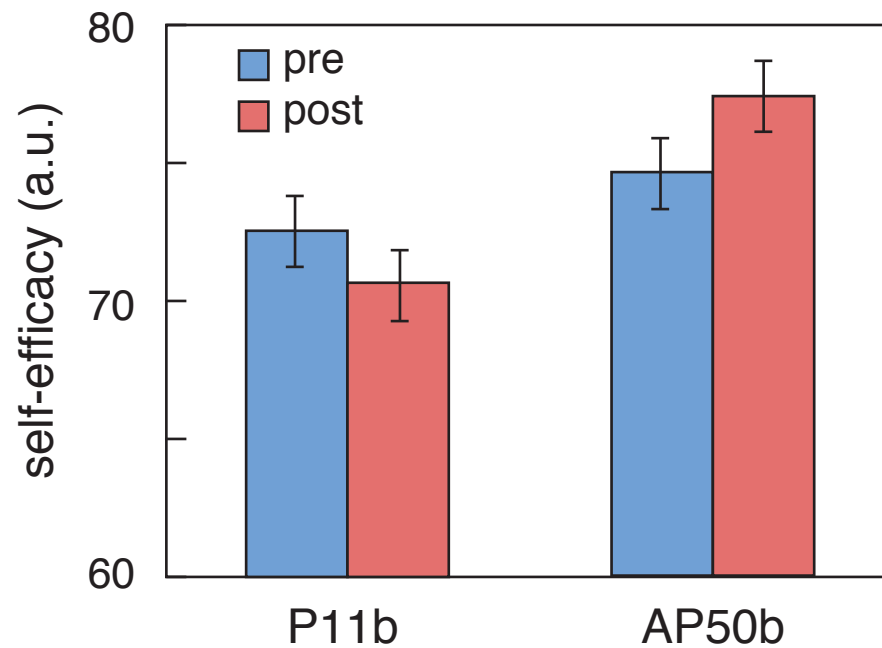
**2 approach**

**3 results**

# Self-efficacy



# Self-efficacy



# Self-directed learning



**1** design

**2** approach

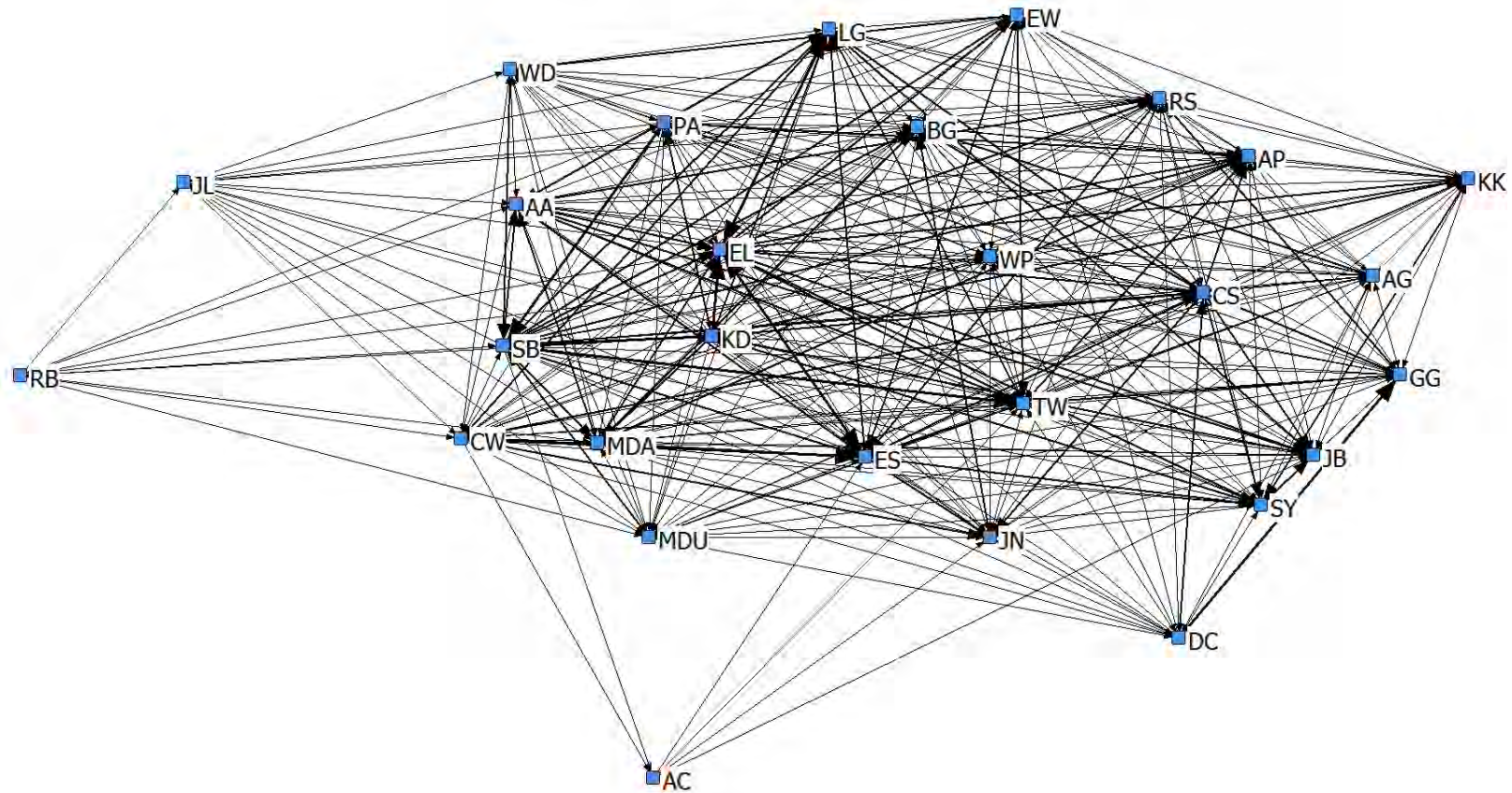
**3** results

# Self-directed learning

**NB data shows:**

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

# Self-directed learning

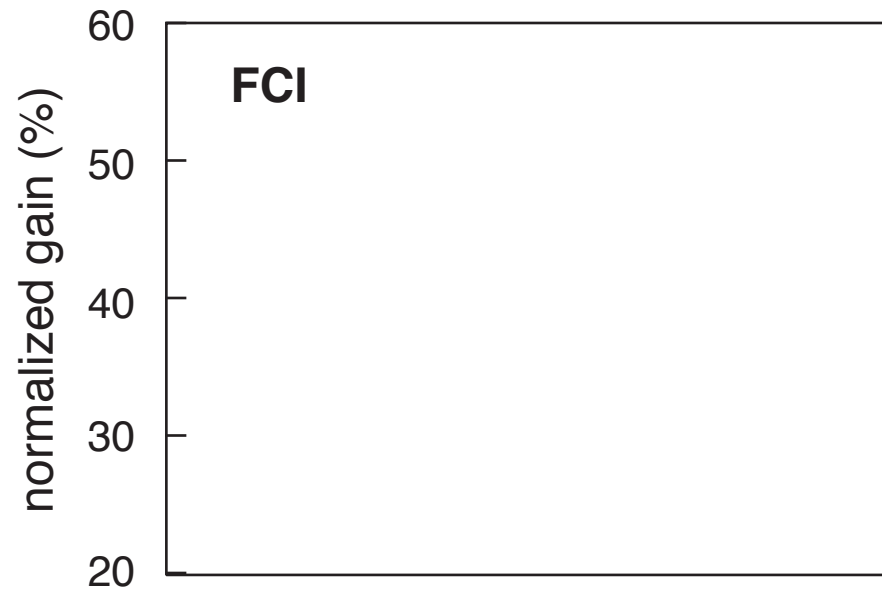


1 design

2 approach

3 results

# Conceptual Mastery

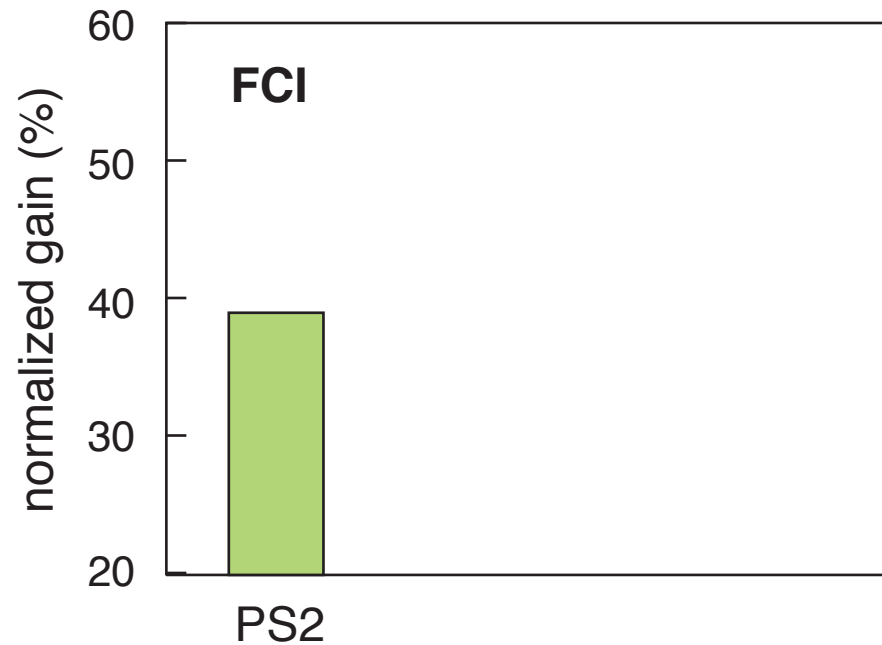


1 design

2 approach

3 results

# Conceptual Mastery

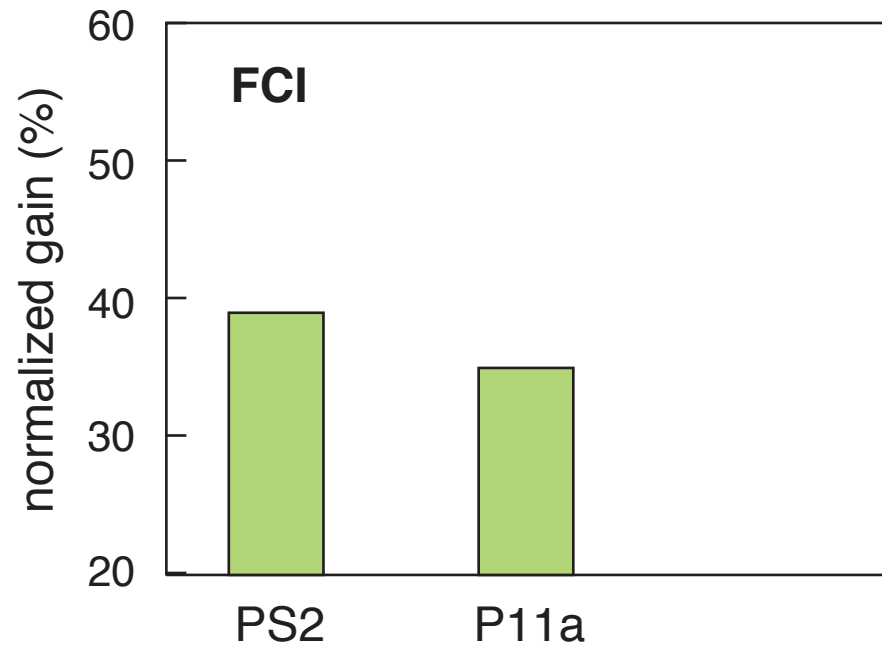


1 design

2 approach

3 results

# Conceptual Mastery

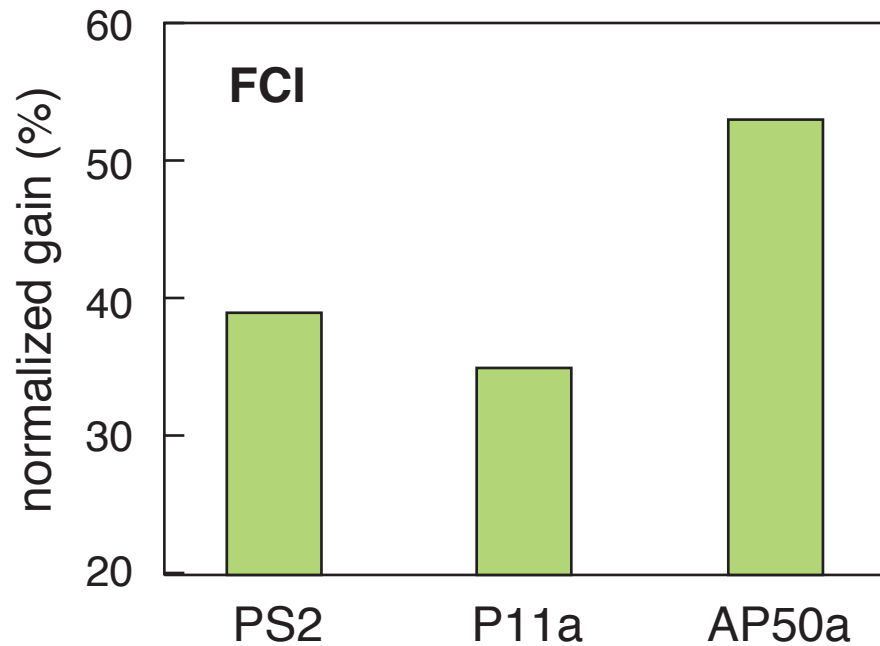


1 design

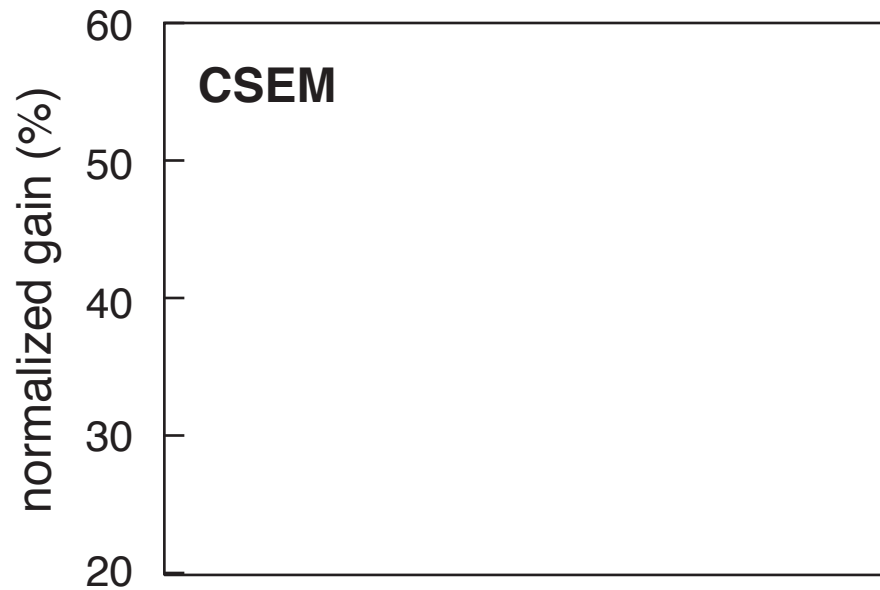
2 approach

3 results

# Conceptual Mastery



# Conceptual Mastery

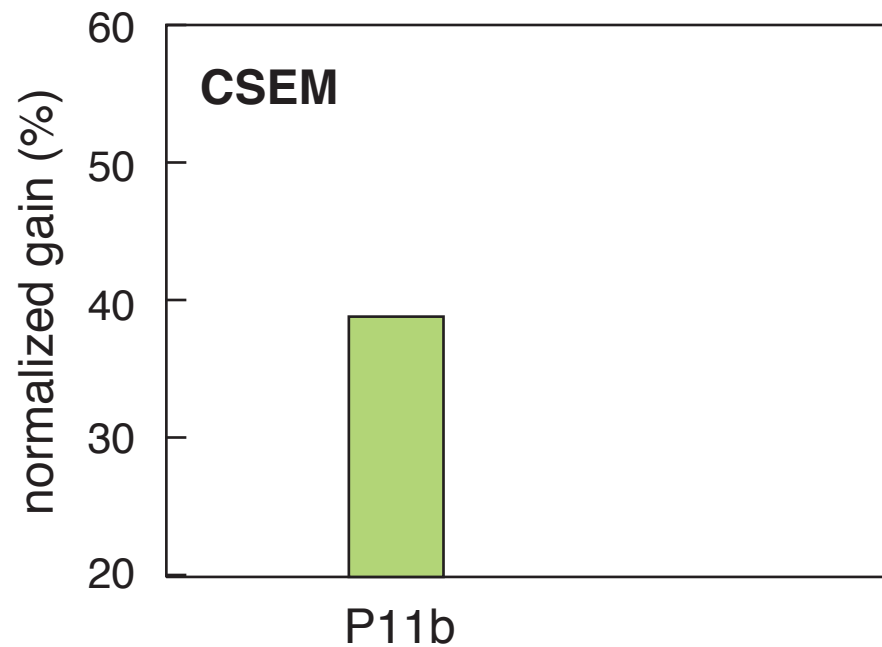


**1** design

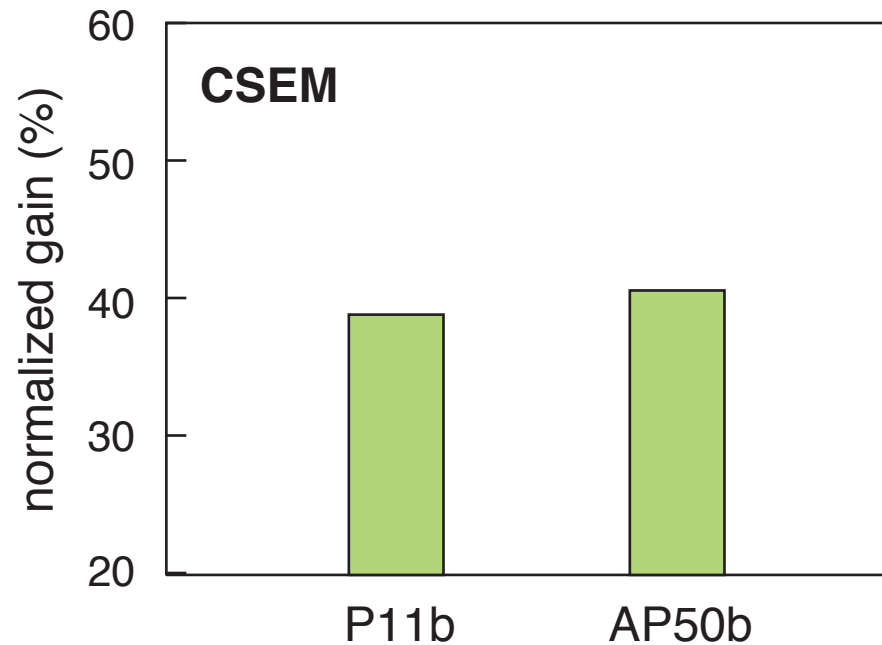
**2** approach

**3** results

# Conceptual Mastery



# 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)**

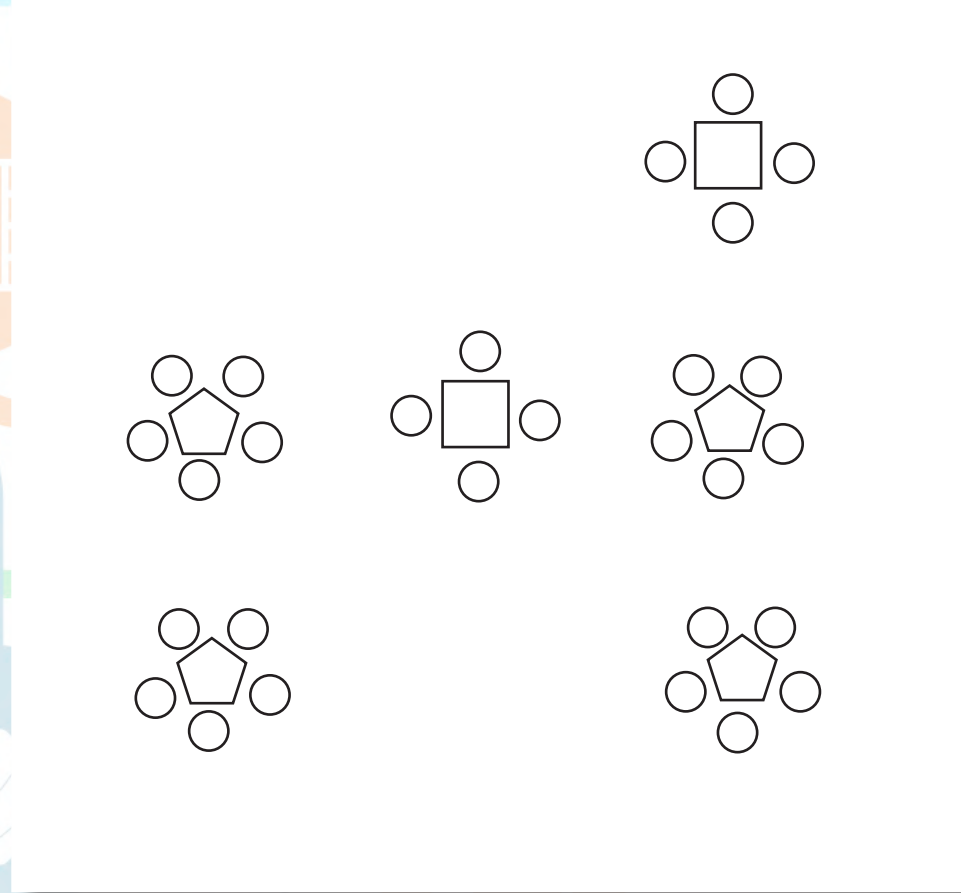
**AP50b students do *twice as well* as Phys11b!**

**1 design**

**2 approach**

**3 results**

# Team skills

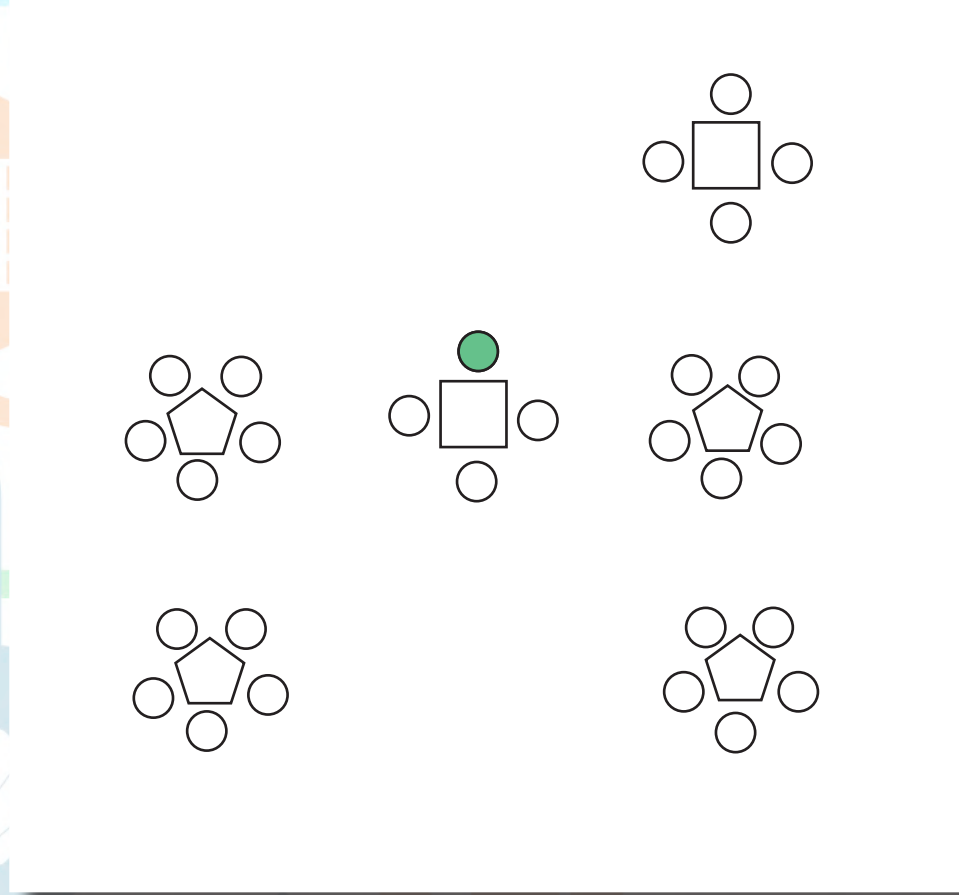


**1** design

**2** approach

**3** results

# Team skills



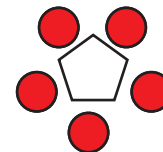
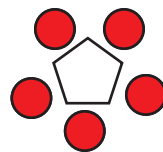
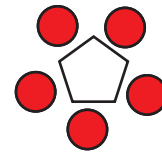
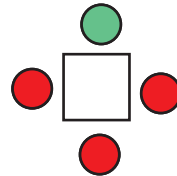
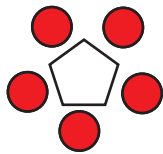
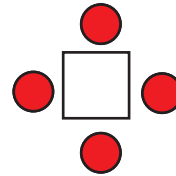
**1** design

**2** approach

**3** results

# Team skills

individual: 4%



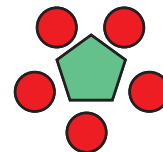
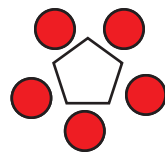
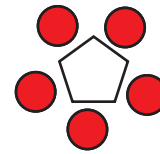
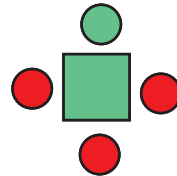
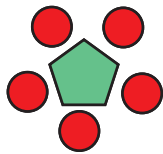
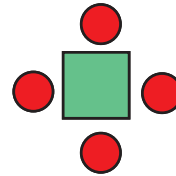
**1** design

**2** approach

**3** results

# Team skills

individual: 4%



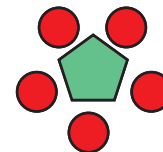
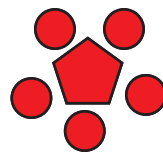
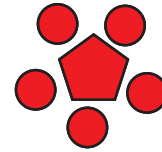
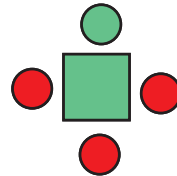
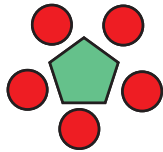
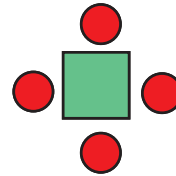
1 design

2 approach

3 results

# Team skills

individual: 4%  
team: 64%



1 design

2 approach

3 results



**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 whiteboards and other equipment.

***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 photograph of four students in a laboratory or workshop setting. A female student with glasses is using a pipette to transfer liquid into a small container within a wooden box. Another female student is smiling and looking on. 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 wooden box contains various components, including a circuit board with many small electronic components and a blue bowl. The background shows a whiteboard and other lab equipment.

**“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 workshop. A woman with glasses is using a soldering iron on a circuit board inside a wooden box. Two other students, a woman and a man, are looking on and smiling. The box has a decorative pattern of red and yellow dots.

## **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 in the box appears to be a circuit board with various components and wires.

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**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. They are all smiling and looking at the project. The background shows a classroom or lab setting with whiteboards and other equipment.

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**1** design

**2** approach

**3** results

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**1** design

**2** approach

**3** results