

# PhET Interactive Simulations: Engaging students and supporting learning

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<https://tinyurl.com/PhET-NFW-Oct2018>

# Goals

**Become familiar** with PhET:

When, how, and why might you use a PhET sim?

**Explore** different ways to use simulations in teaching

**Use research** findings around simulations to guide that use in class

**Look forward** at the frontier of simulations in education

# PhET Overview

## PhET Interactive Simulations

140+ simulations & 1600+ sim-based lessons

Physics, Chemistry, Math, Earth Science, Biology

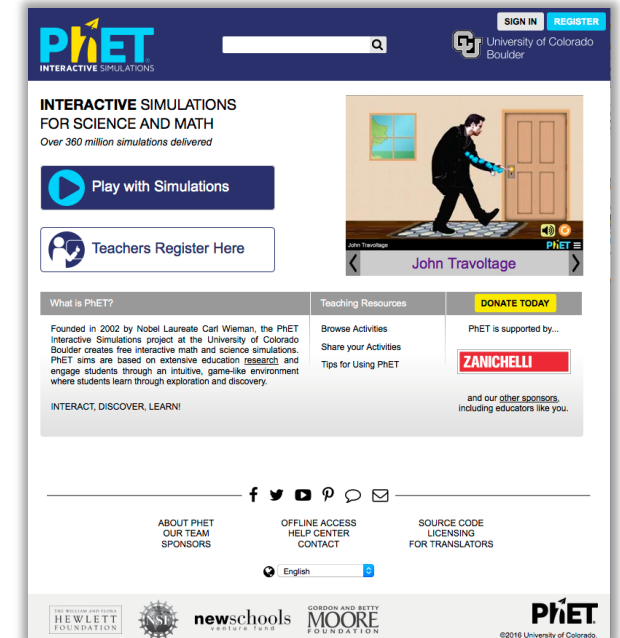
Research-based and user-tested

K-12 and College

Open education resources (free)

Java, Flash, and HTML

Run online or offline

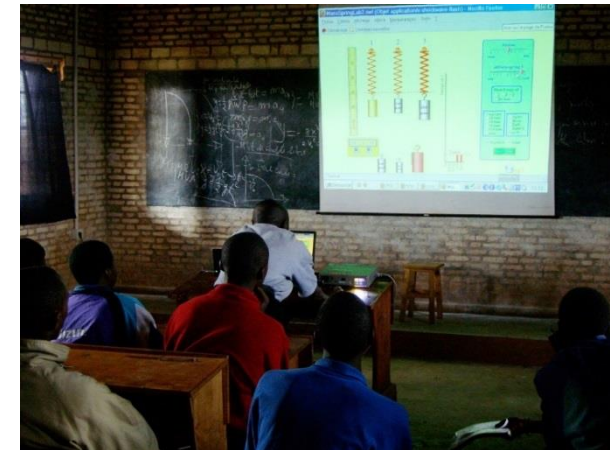
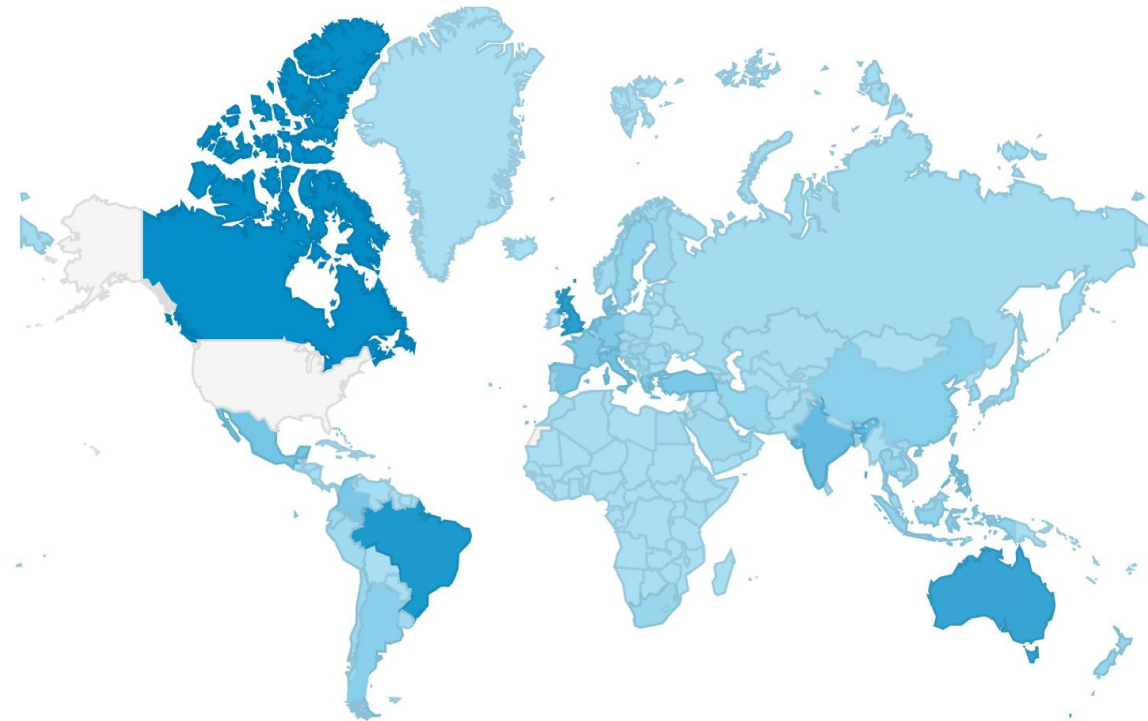


The screenshot shows the PhET Interactive Simulations website homepage. At the top, there is a navigation bar with the PhET logo, a search bar, and links for 'SIGN IN' and 'REGISTER'. Below the navigation bar, the main heading reads 'INTERACTIVE SIMULATIONS FOR SCIENCE AND MATH' with the subtext 'Over 360 million simulations delivered'. A prominent blue button with a play icon says 'Play with Simulations'. Below this is a 'Teachers Register Here' button. To the right, there is a featured simulation thumbnail showing a person walking through a doorway, with the name 'John Travoltage' below it. The page is divided into several sections: 'What is PhET?' with a brief history, 'Teaching Resources' with links to 'Browse Activities', 'Share your Activities', and 'Tips for Using PhET', and a 'DONATE TODAY' section featuring the 'ZANICHELLI' logo. At the bottom, there are social media icons, a footer with links for 'ABOUT PHET', 'OFFLINE ACCESS', and 'SOURCE CODE', and logos for sponsors like 'HEWLETT FOUNDATION', 'newschools', 'GORDON AND BETTY MOORE FOUNDATION', and 'PhET'.

# PhET Overview

## Global

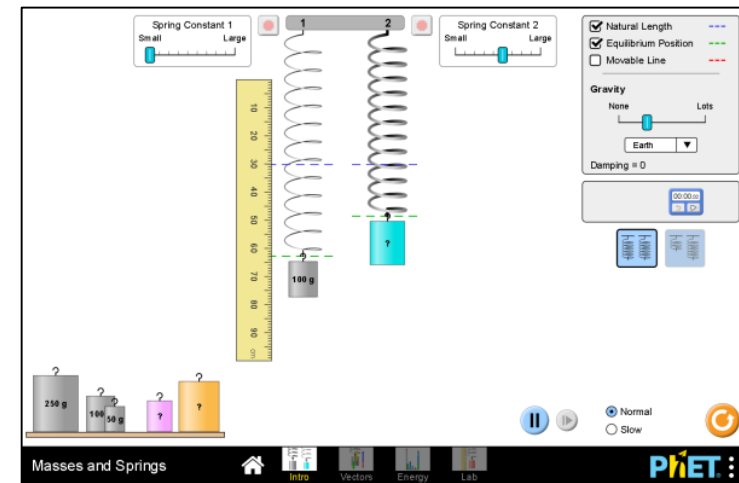
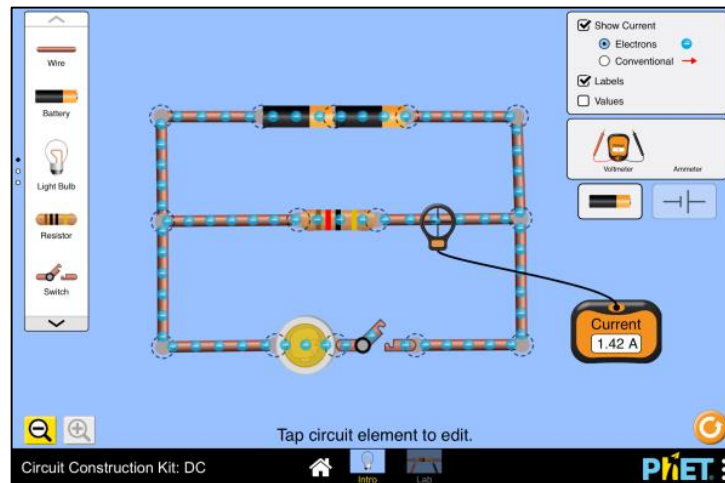
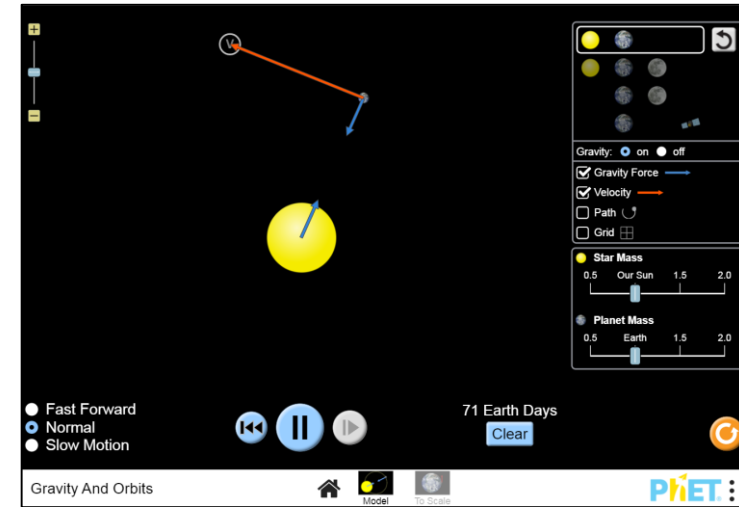
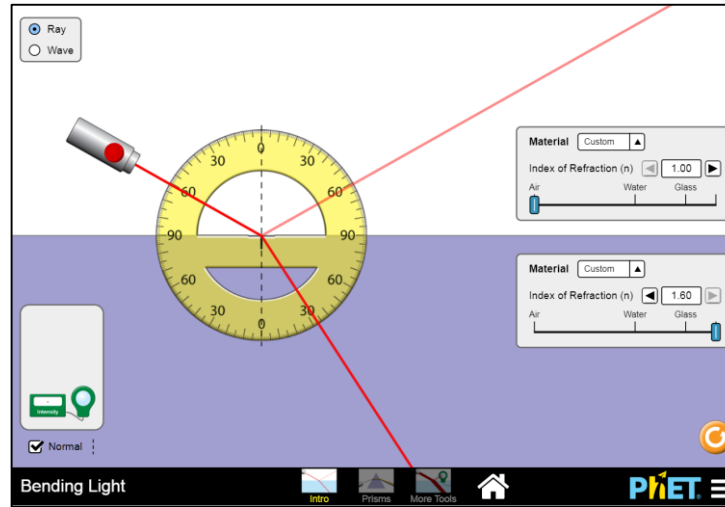
Over 100 million sim runs per year!  
~33% International. In 90 languages.



BURUNDI

# Sim Tour

## Examples



# Sim Design

## Support Multiple Learning Goals

**CONTENT:** Concepts, Models, Representations, Relationships

**PROCESS:** Explore, Question, Design, Predict, Data, Evidence, Reason

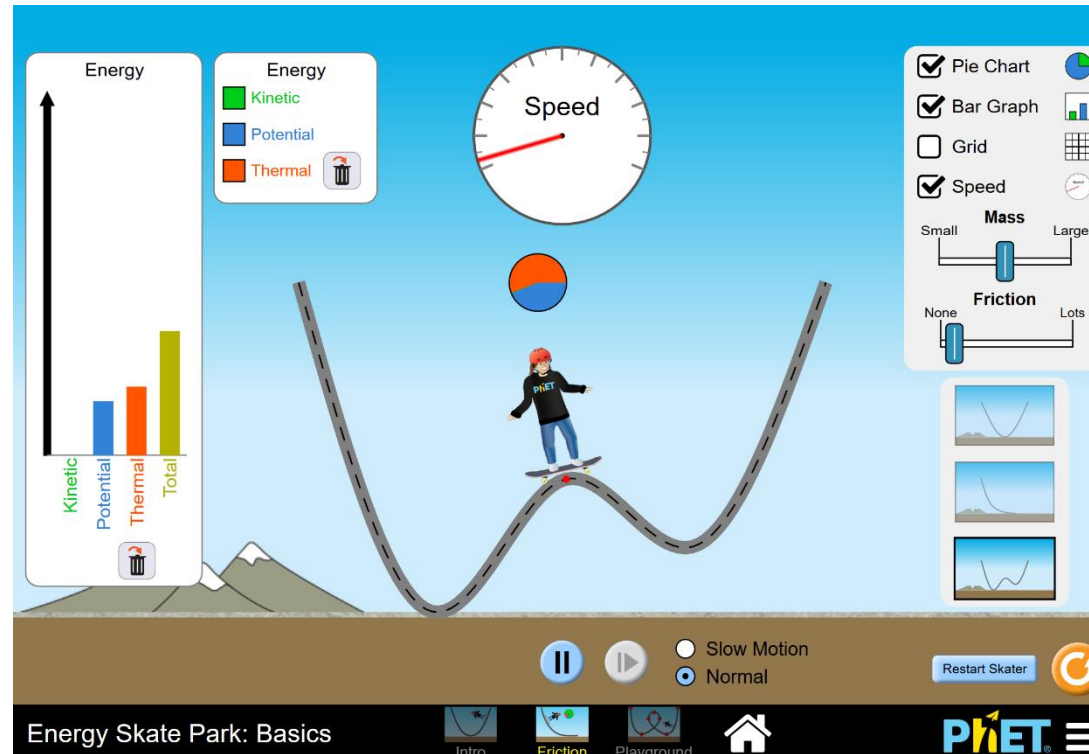
**SOFT SKILLS:** Argumentation, Collaboration, Planning, Reflection

**HARD SKILLS:** Lab techniques, Quantitative problem solving

**AFFECTIVE:** Enjoyable, Understandable, Relevant, Student Agency

# Sim Design

## Implicit Scaffolding



HIGHLY INTERACTIVE

IMMEDIATE DYNAMIC FEEDBACK

REAL WORLD CONNECTIONS

ACCURATE, DYNAMIC VISUAL  
MODELS & REPRESENTATIONS

SHOWS THE INVISIBLE

SCAFFOLDED THROUGH DESIGN

ALLOWS ACTIONS NOT POSSIBLE  
IN THE REAL WORLD

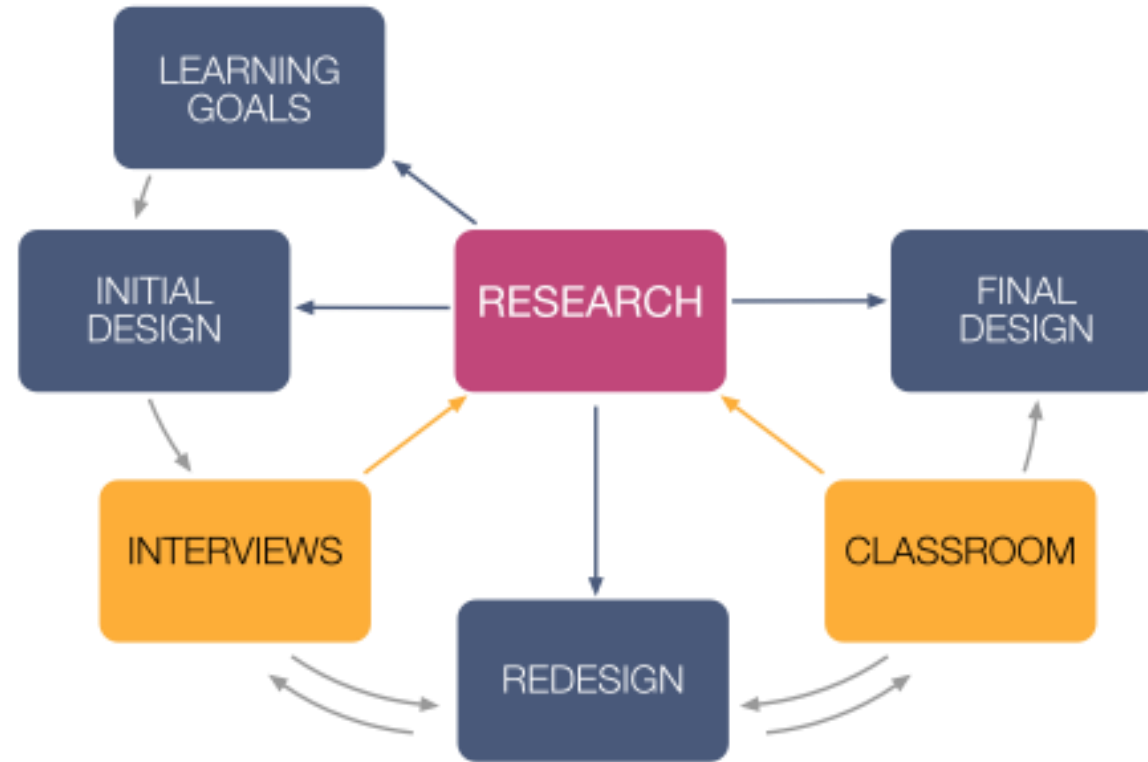
INTUITIVE INTERFACE

*Adams et al. (2008a), J. Interactive Learning Research*

*Adams et al. (2008b), J. Interactive Learning Research*

# Sim Design

## Design Process





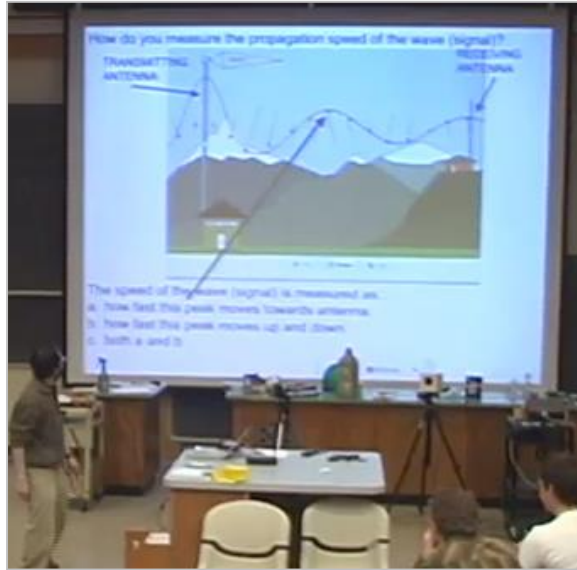
Sim-based  
Learning

How might you use these sims in  
your learning environment?

# Sim-based Learning

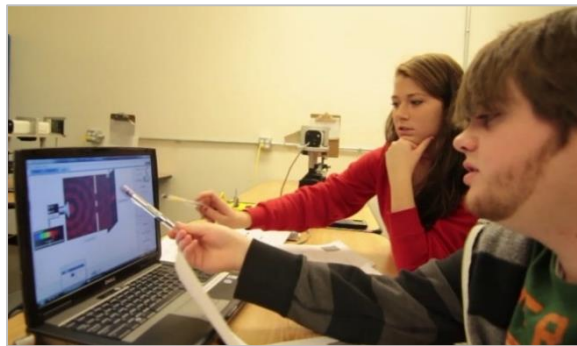
## Versatile tool for teaching and learning

Interactive Lecture



Lecture Tutorial

Activity/Lab



First, students make predictions and then investigate with the sim.

To answer the following questions, you should use the [PhET photoelectric effect simulation](#).

7. (1 pt) Suppose you set up the experiment so that the plate is ejecting electrons. Predict which of the following changes to the experiment could increase the maximum initial kinetic energy of the ejected electrons. (Select all that apply) Then test your prediction.

- A. Increasing the intensity of the light beam
- B. Decreasing the intensity of the light beam
- C. Increasing the wavelength of light
- D. Decreasing the wavelength of light
- E. Increasing the frequency of light
- F. Decreasing the frequency of light
- G. Increasing the voltage of the battery
- H. Decreasing the voltage of the battery
- I. Replacing the target with a material that has a larger work function
- J. Replacing the target with a material that has a smaller work function

A short essay is used to emphasize the importance of **explaining concepts** in every-day language.

12. (essay) Explain what the phrase -'the work function for sodium' - means in a way that would make sense to a non-science person.

Finally, using the simulation's "mystery metal" feature, students have to **develop their own procedure** for measuring the work function in a real experiment (there are several ways to do this with the sim).

You have a plate of metal, but you have no idea what kind of metal it is. You come up with the brilliant idea of measuring the work function of this metal by using it as the target in a photoelectric effect experiment. You can perform this experiment virtually by selecting "???" as the target in the simulation. What is the work function, in eV, of the mystery metal?

Pre-lab/  
Pre-class/  
Homework

# Sim-based Learning

## **Engaging Students in Lecture**

Lecture Demonstration / Visualization

Coupled with Concept Tests and Peer Instruction

Interactive Lecture Demos

Interactive Discussion with Predictions

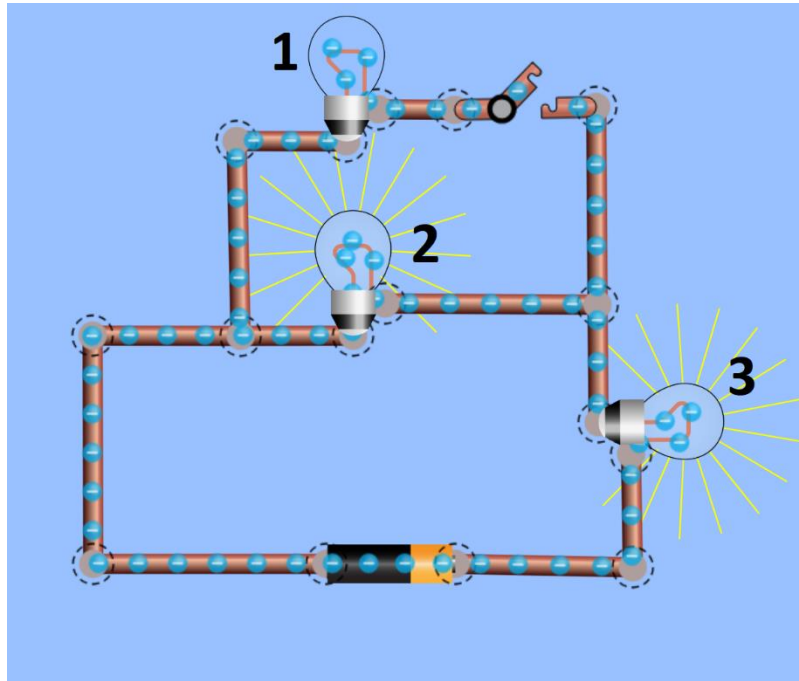
Whole Class Inquiry (student-suggested experiments)

**See Teaching Resources for helpful videos:**

<http://phet.colorado.edu/en/teaching-resources/usingPhetInLecture>

# Sim-based Learning

## Concept Questions

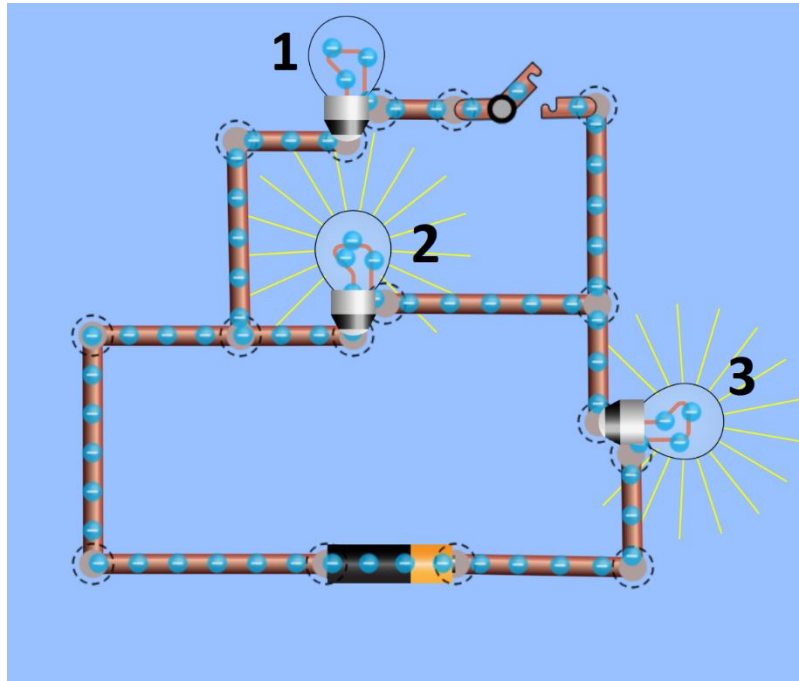


What happens to bulb 3, when the switch is closed

- A) Bulb 3 gets brighter
- B) Bulb 3 gets dimmer.
- C) Remains the same.

# Sim-based Learning

## Concept Questions

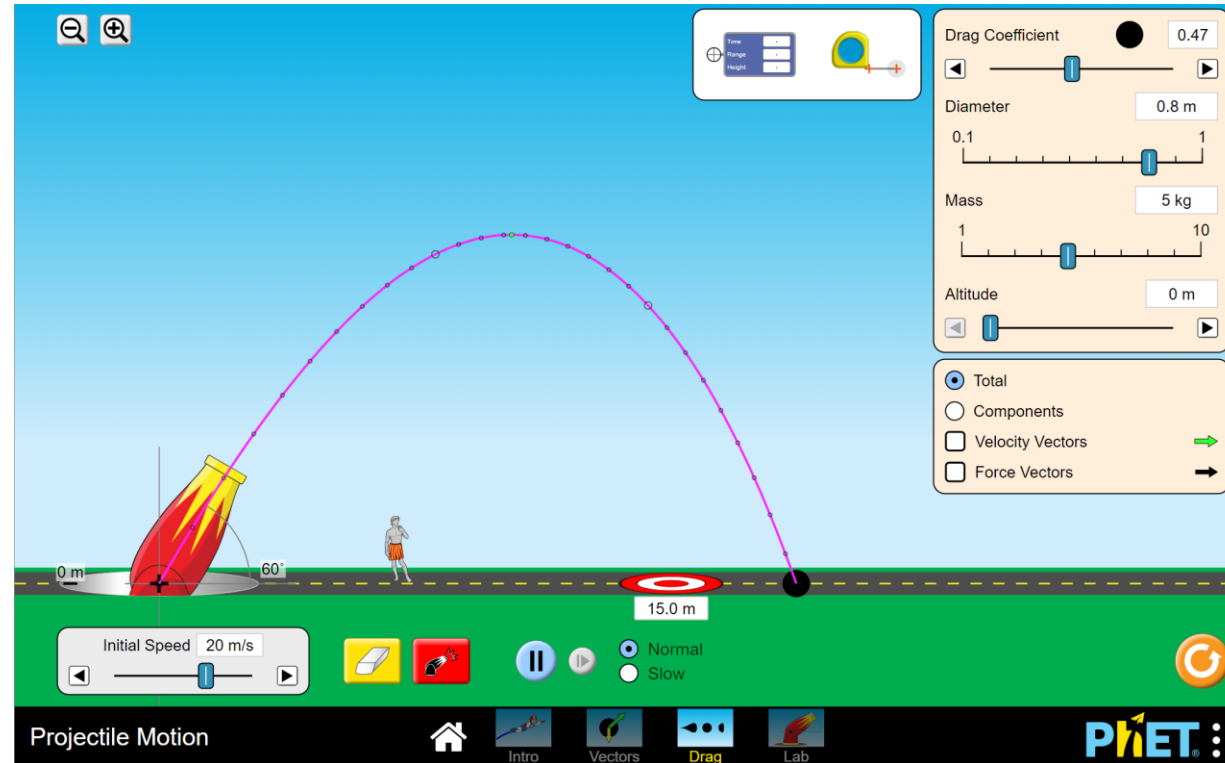


Rank the brightness of the bulbs when the switch is closed

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

# Sim-based Learning

## Whole Class Inquiry



What parameters could I change to increase the range without changing the initial speed of the projectile?

A look  
inside the  
classroom

## Concept test & Follow-up discussion

Is there a force of friction acting on my laptop which is sitting stationary on a level table?

- A) Yes
- B) No
- C) Not sure



A look  
inside the  
classroom

## Follow-up discussion





# Sim-based Learning

## Instructor versus Student Control



Opportunity for students to engage in and think about exploration, experimentation, design, evidence

# Science Learning

Science learning often far from science practice

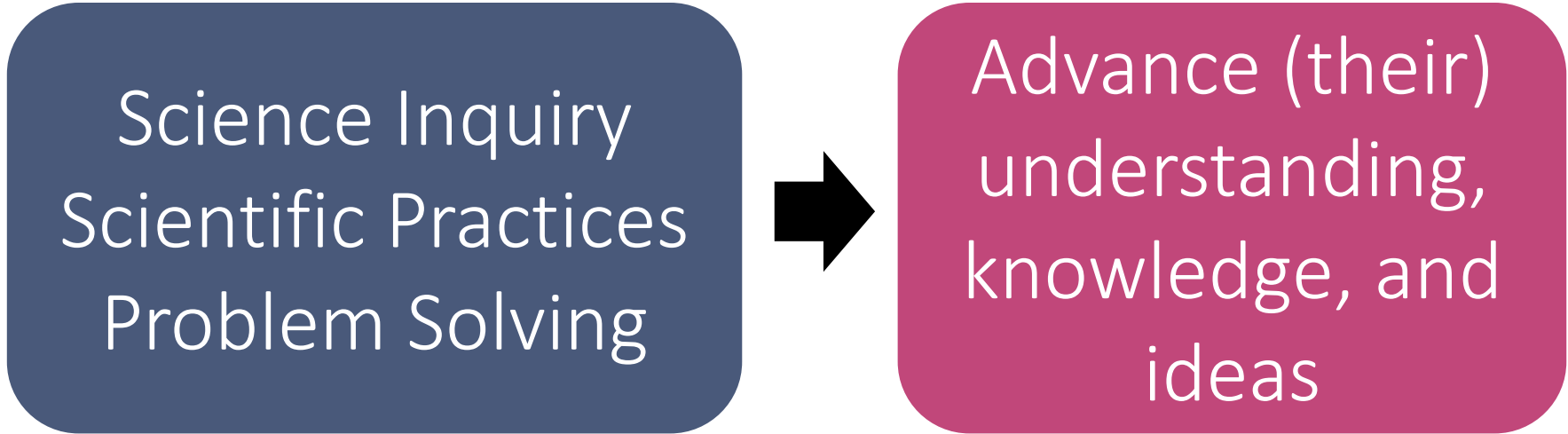
In lab:  
Specific  
Procedures

In class:  
Content  
Knowledge

# The Challenge

## Learning science through science inquiry

Science Inquiry  
Scientific Practices  
Problem Solving

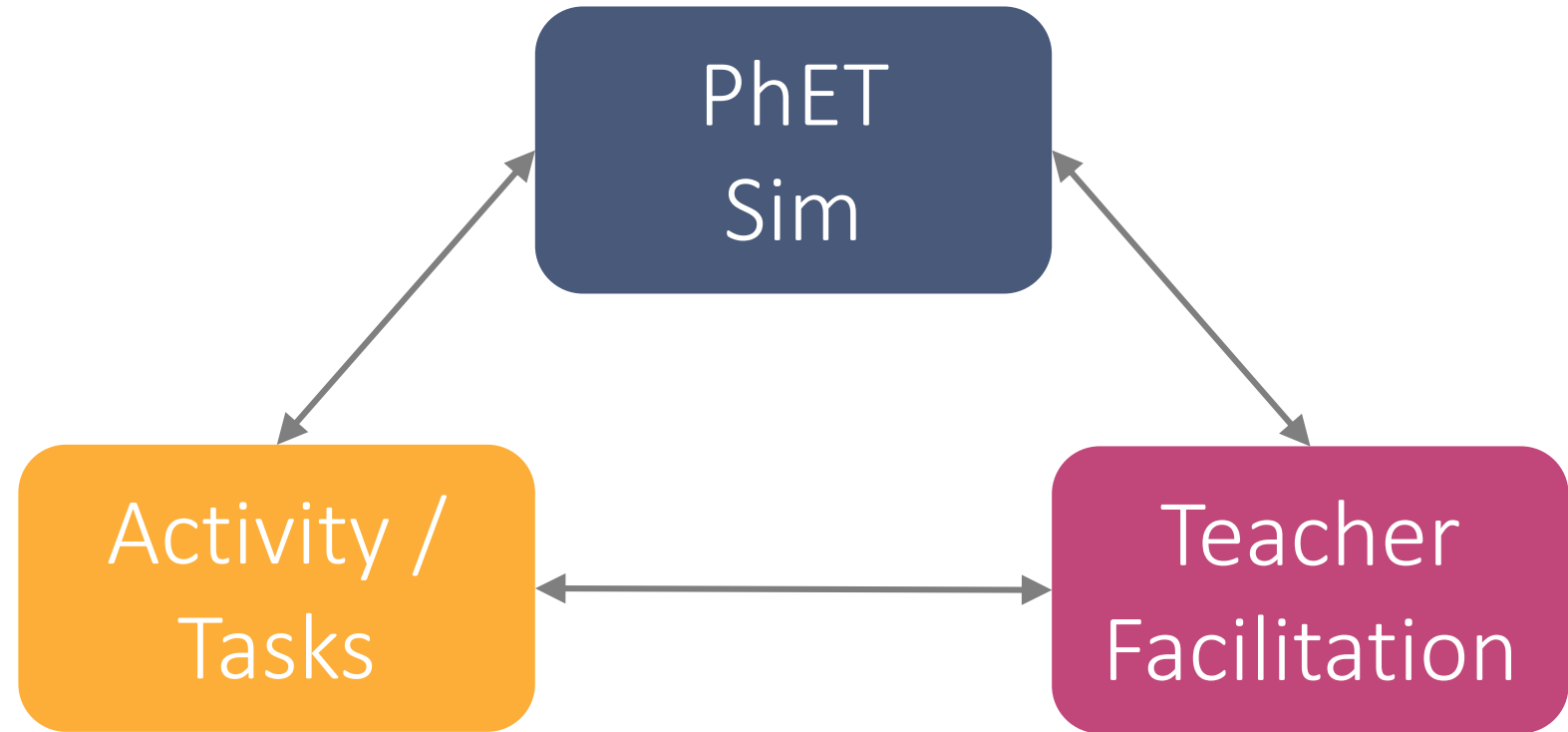


Advance (their)  
understanding,  
knowledge, and  
ideas



Sim-based Learning

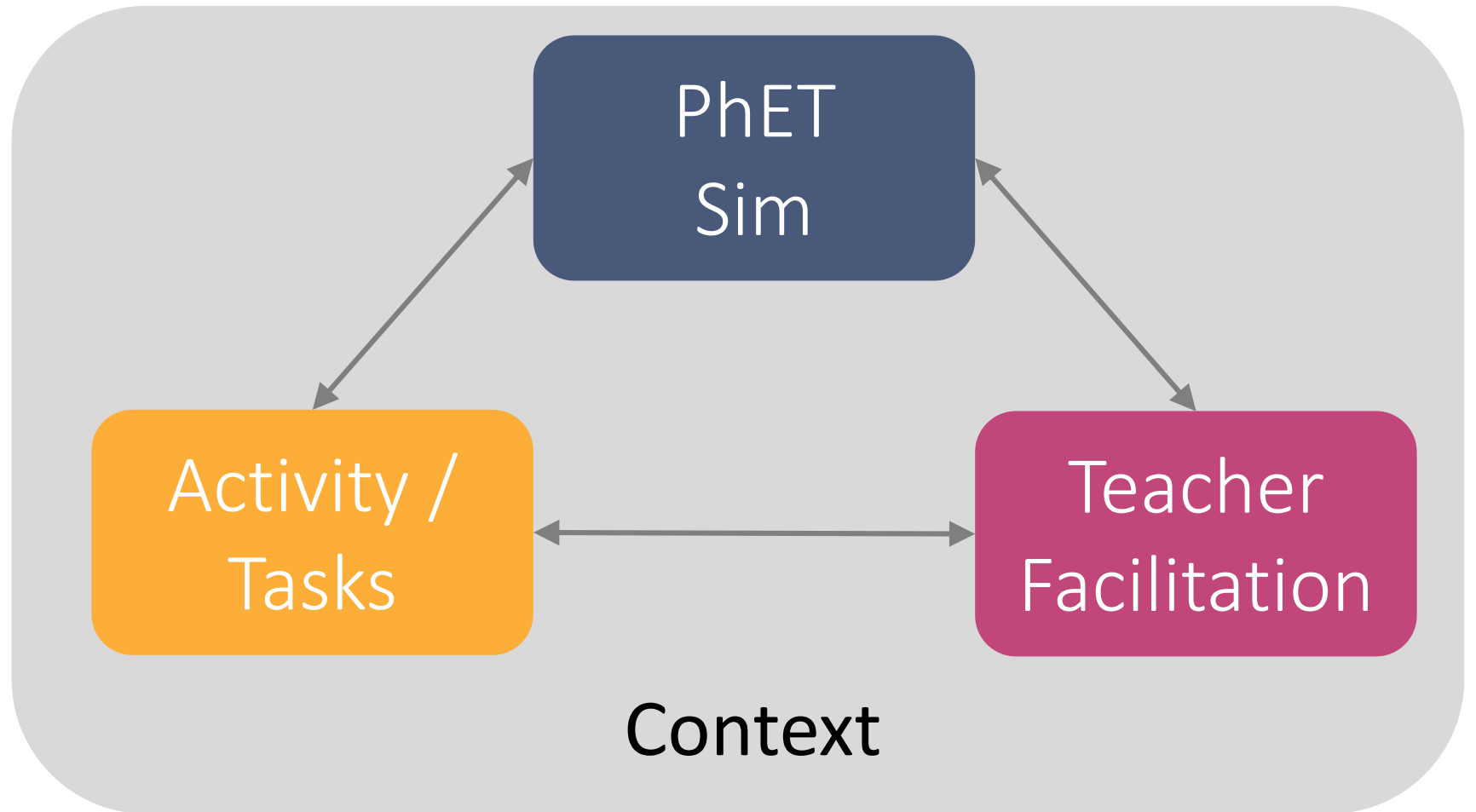
## Creating Sim-based Learning Environments



Distributed Scaffolding

# Sim-based Learning

## Creating Sim-based Learning Environments



# Sim-based Learning

## Strategies for designing sim-based activities

Start with open play

Avoid explicit instruction

Leverage affordances of the sim

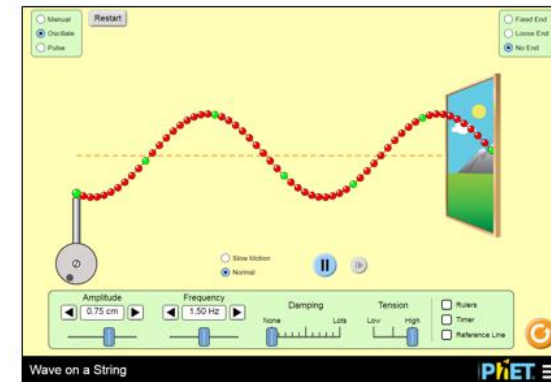
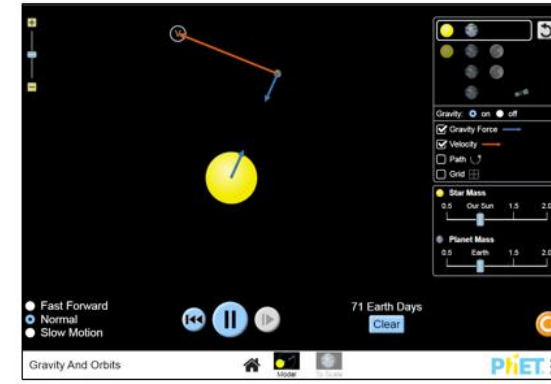
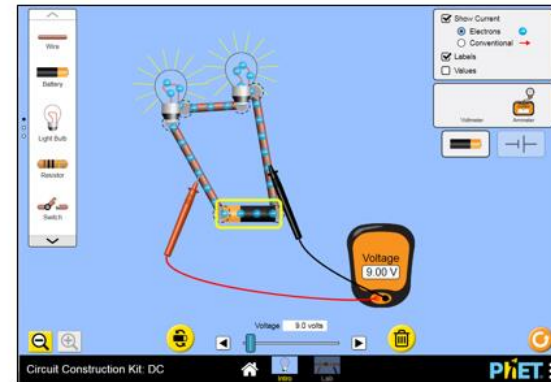
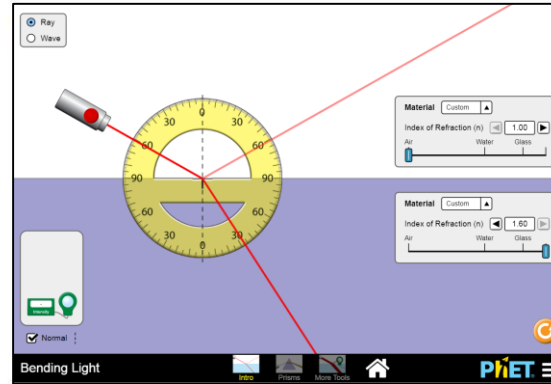
Use open, investigative questions and **challenge prompts**

(How are all the ways you could...?)

More at: <https://phet.colorado.edu/en/teaching-resources/tipsForUsingPhet>

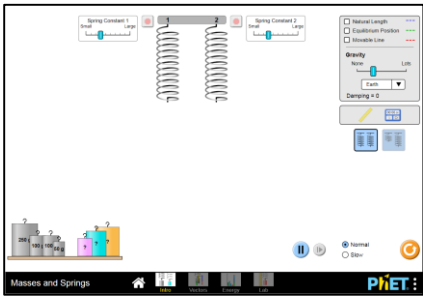
# Mini design task

Pick one sim and write a challenge prompt





# Example Activity



## Masses and Springs

5-10 minutes of play – No instructions.

**Challenge 1:** Using data from the sim, make a graph that shows whether or not the springs obey Hooke's Law.

**Challenge 2:** What are the masses of the mystery weights?

**Challenge 3:** Determine the spring constant in two different ways: with your graph from (1) and with the stopwatch.


# Sim-based Learning

# Activity Design and Facilitation Resources

Video Series

**Video Series: Facilitating PhET Activities in K12 Classrooms**

A video series that discusses key things to consider when preparing to use and then facilitating activities with PhET simulations. Focused on K12.



[1] Facilitating Activities in K-12: Preparing for a PhET acti...

Designing PhET Activities for the K12 Classroom

Facilitating Activities with PhET: An Overview

[1] Facilitating Activities in K-12: Preparing for a PhET

Course Alignment Documents

**PIET** INTERACTIVE EDUCATION

Plans for using PhET simulation activities in Loeblein's HS Physics

IC In Class Activity; CQ clicker questions; HW homework; Demo: teacher centered group discussion

**Semester 1**

Unit 1: **Introduction to Motion:**  
Moving Man IC/CQ  
Calculus Grapher HW/CQ

Unit 2: **More on motion and Measurement**  
Vector Addition IC/CQ  
Projectile motion IC/CQ

Unit 3: **Forces and the Laws of Motion Publishing skills: curve fit, drawing, tables**  
Forces and Motion: Two activities IC/CQ  
Ramp- Force and Motion: Two activities IC/CQ  
Maze Game: HW/CQ  
Curve Fitting: HW

Unit 4: **Work, Energy, Momentum and Collisions**  
Energy Skate Park: Four activities IC/CQ  
Masses and Springs: IC/CQ  
Collision: HW

Unit 5: **Circular Motion and Semester Project**  
Pendulum: HW/CQ  
Gravity Force Lab: IC/CQ  
Pendulum: HW

Activity Writing Guide

**Prompts and Tables**

**Prompts to Encourage Targeted Inquiry:**

- Find all the ways to...make a complete circuit.
- What's the largest... molecule you can make?
- How many... collection boxes can you fill in 5 minutes?
- List all the essential items to...make a circuit.
- What are two ways to...get the sleepy dog to move?
- How can you make...the gravity force...bigger?
- Develop a procedure for... comparing the densities of two objects with different mass.

**Effective Table Structures:**

**Cueing Variables:** This structure cues students to make comparisons between variables.

Environment	Selection Factor	Mutation	Bunnies Take Over?	Bunnies Die Out?	Observations
			<input type="checkbox"/> Yes <input type="checkbox"/> No	<input type="checkbox"/> Yes <input type="checkbox"/> No	

**Cueing Cause/Effect Relationships:** This structure cues students to notice important effects of an action within the sim.

Action	Gravity Force
Put star and planet closer together	<input type="checkbox"/> Increases <input type="checkbox"/> Decreases
	<input type="checkbox"/> Increases <input type="checkbox"/> Decreases
	<input type="checkbox"/> Increases <input type="checkbox"/> Decreases

**Cueing Classification:** This structure cues students to classify objects into distinct categories and is useful for organizing cause/effect relationships.

Good Conductors	Weak Conductors	Insulators

How can you tell something is a good conductor of electricity in the sim? How can you tell something is a weak conductor of electricity in the sim? How can you tell something is an insulator of electricity in the sim?

Facilitation Guide

**PIET** INTERACTIVE EDUCATION

Facilitation Strategies for Inquiry-based, In-class Activities using PhET Simulations <http://phet.colorado.edu>

Here we describe effective strategies for facilitation of activities using PhET simulations (sims) in elementary and middle school classrooms. These strategies are derived from observations of teachers using a range of PhET sims in a classroom setting. These strategies are not meant to be strict "step-by-step" directions, nor do they include all possible effective strategies. Rather, these strategies can be adapted to the particulars of different grades, teacher preferences, and classroom environments.

Overall, this collection of strategies aims to support inquiry-based learning. Through the use of PhET sims, students explore new ideas, take ownership of their own learning, and cultivate positive attitudes toward science.

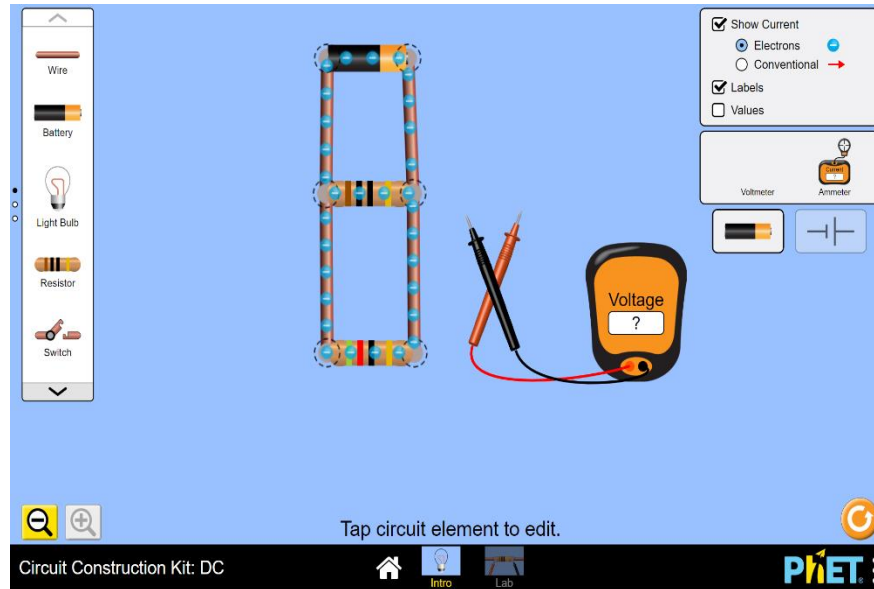
**Outline:**

1. **Goals for Teachers:** Describes what teachers can achieve through implementation of these strategies.
2. **Facilitation Objectives and Strategies:** Introduces 6 objectives of sim-based activity facilitation and suggests specific facilitation strategies.
3. **Monitoring and Measuring Student Learning:** Discusses strategies for monitoring understanding throughout sim use, and the optional use of written assessments.
4. **Example of Activity Facilitation Sequence:** Demonstrates facilitation strategies and sequencing within an example lesson.
5. **Preparation:** Provides a summary of important preparation steps, including creating the lesson, preparing the classroom, and preparing to teach.
6. **Teacher reflection:** Suggests approaches for reflecting on teaching and learning, including a rubric for characterizing lesson qualities.

<https://phet.colorado.edu/en/teaching-resources>

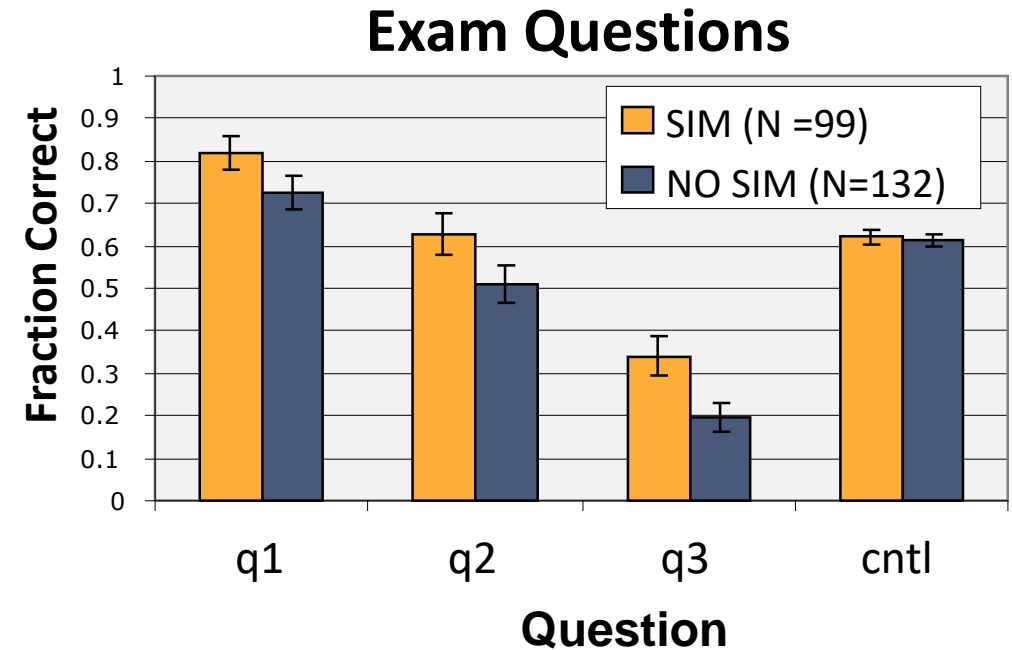
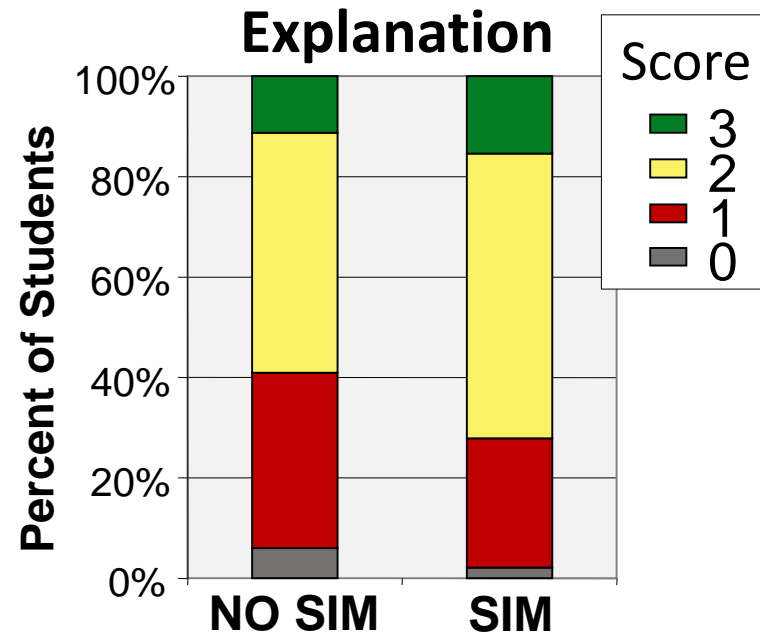
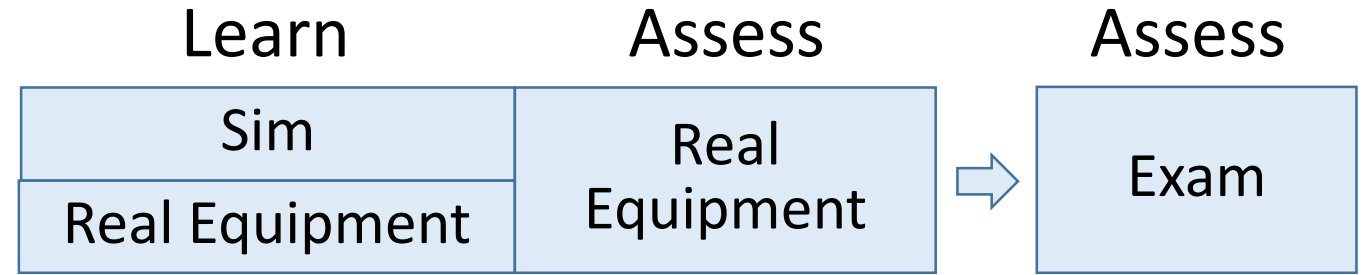
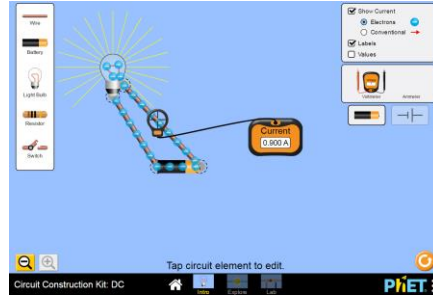
# Sim-based Learning

## Compare and Contrast



# Sim-based Learning

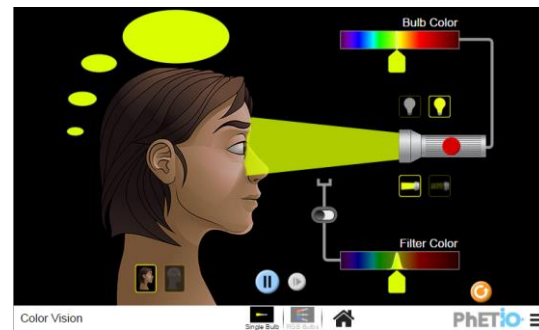
## Impact on learning



# Frontiers: PhET-iO

## PhET-iO Simulations

Customizable and Interoperable with Back-end data



Embed

API

Data

Any Educational  
Technology

<https://phet-io.colorado.edu>

# Frontiers: PhET-iO

## PhET-iO Simulations

Customizable and Interoperable with Back-end data

**NOTES**  
Take notes on the experiment here

**Simulation**

Wavelength:

Solution:  $\text{CuSO}_4$ : Copper sulfate

Concentration: 100 mM

Absorbance: 0.07

Light Absorbance Lab PhET-iO

**RECORD DATA**

**Data Table**

Trial	Wavelength	Width (cm)	Concentration (mM)	Absorbance	Restore Trial	Add to Graph	Delete
1	●	1.00	100.00	0.04		<input type="checkbox"/>	
2	●	1.27	100.00	0.05		<input type="checkbox"/>	
3	●	1.48	100.00	0.05		<input type="checkbox"/>	
4	●	2.00	100.00	0.07		<input type="checkbox"/>	

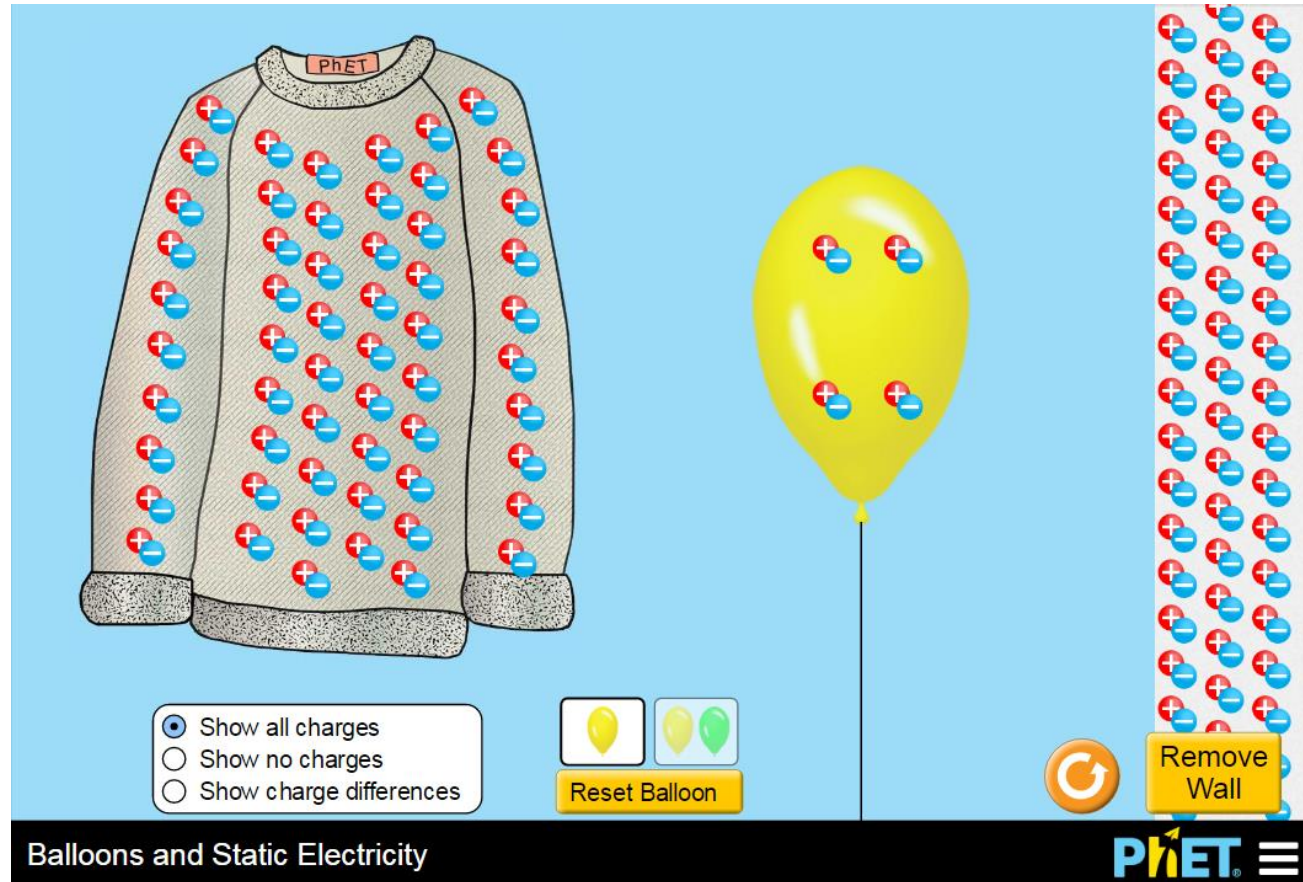
# Frontiers: Accessibility



Emily Moore



## PhET Sims for Students with Disabilities



<https://phet.colorado.edu/en/accessibility>

# Funders





# Deep Dive

Planning use across course

Writing clicker questions and activities

Applying strategies

# Invitation

FIND PHET

<https://phet.colorado.edu>

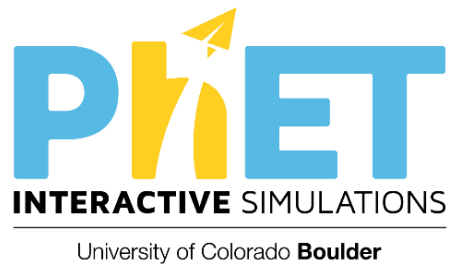
USE SIMS

In lecture, lab, homework

CONTRIBUTE

Lessons

Register at <https://phet.colorado.edu>



SEND IDEAS

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