Engaging Students and Supporting Learning with PhET Interactive Simulations

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PhET™ INTERACTIVE SIMULATIONS

Objectives

By the end of this session, you will be able to:

- Find and use PhET simulations and lessons for your course
- Describe the PhET design philosophy
- Explain when, where, how and why you might use interactive simulations in teaching
- Write effective sim-based interactive engagement questions and activities

Have you used PhET simulations?

Your experience is a resource for others:

Discuss: Share the…

- course (intro, modern, stat mech, etc)
- context (lecture, lab, homework, etc)
- simulation

Science is…

Science is…

Curiosity

Data

Limits

Experimentation

Interpretation

Evidence

Predict

Representations

Reasoning

Analysis

Uncertainty

Explanation

Mechanism

Inquiry

Test

Assumptions

Designing Experiments

Models

The Challenge

Science learning is often far from practice.

In lab:
Directed
Procedures

In class:
Content
Knowledge

Goal: To make physics learning more:

- **ENGAGING**: Interact & discover key ideas
- **RELEVANT**: Connect to everyday life
- **ACCESSIBLE**: Intuitive and understandable
- **EFFECTIVE**: Use STEM practices and develop understanding
- **PERSONALIZED**: Student agency

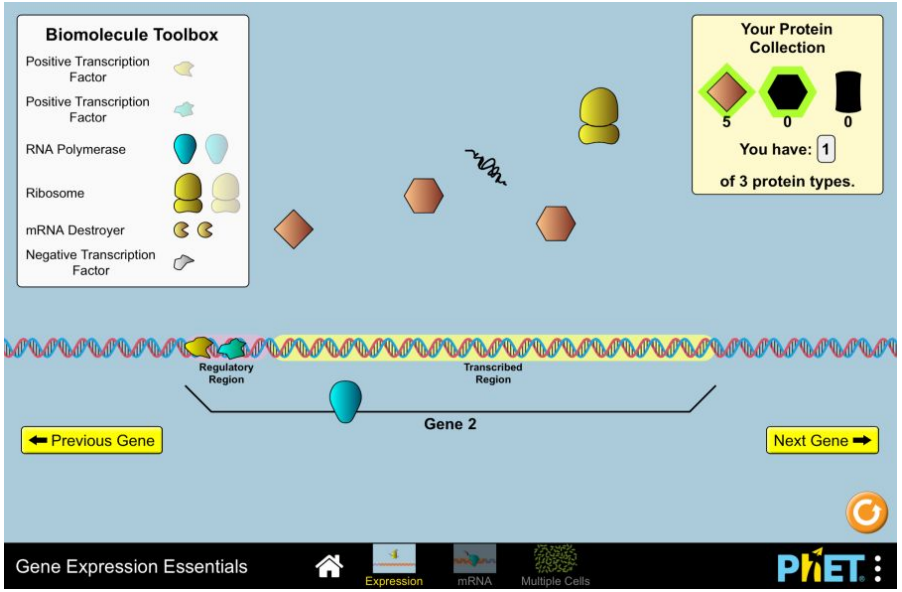
Make **learning physics** more like **doing physics.**

A Brief History of PhET Interactive Simulations

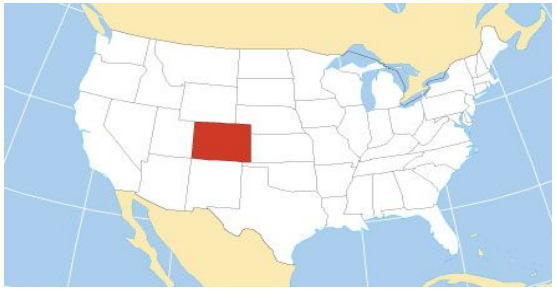
To learn science and mathematics

2001 Nobel Prize in Physics

Founded by Carl Wieman in 2002
PhET (**Ph**ysics **E**ducation **T**echnology)



A Brief History of PhET Interactive Simulations



Physics Education Research Group

Simulation Development

Product Development

Research

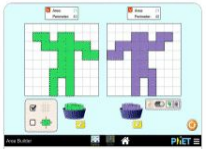
Integration

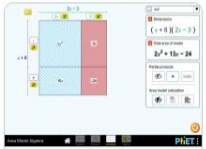
Teacher

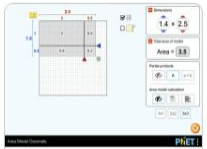
Student Student

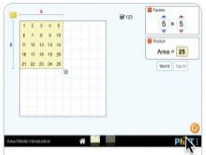
Today: Over 190 simulations - all free

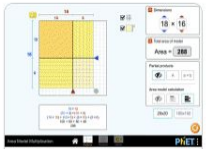

Acid-Base Solutions


Area Builder

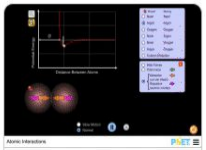

Area Model Algebra


Area Model Decimals

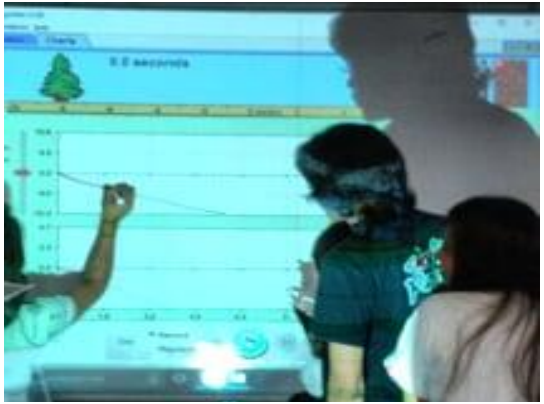

Area Model Introduction


Area Model Multiplication


Arithmetic

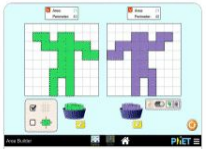

Atomic Interactions

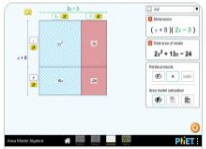

Balancing Act



Activity #1: Explore a Sim!


Acid-Base Solutions


Area Builder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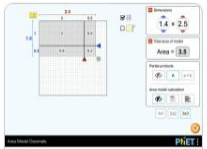
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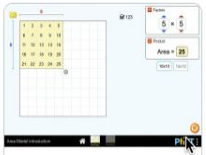
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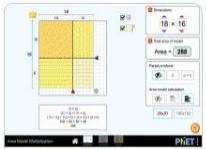
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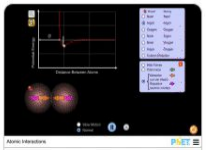

Atomic Interactions


Balancing Act

Discuss:

What are your favorite features?

Benefits of Using PhET Simulations

INTERACTIVE VISUALIZATION: Foster visual, dynamic learning of scientific concepts.

COGNITION: Aids learning through scaffolding, reducing cognitive load.

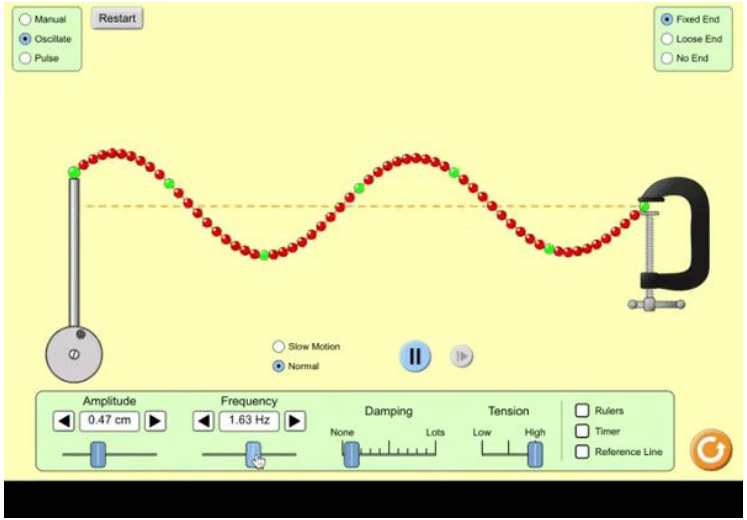
SELF-ASSESSMENT: Provide real time feedback with minimal explicit guidance.

REINFORCEMENT: Support multiple representations, pacing and self-directed learning.

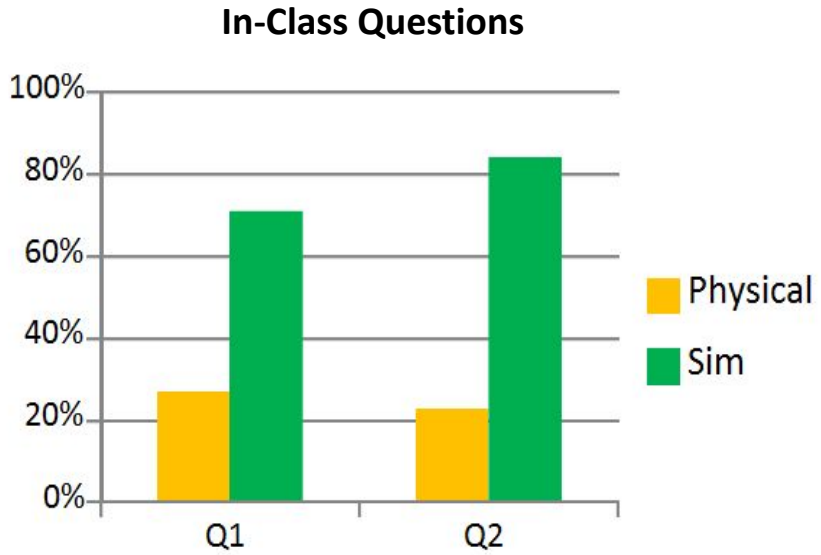
AGENCY: Guides students without feeling guided.

Sims are specifically designed to support students in constructing a robust conceptual understanding of math and science topics through exploration.

Evidence of increased learning

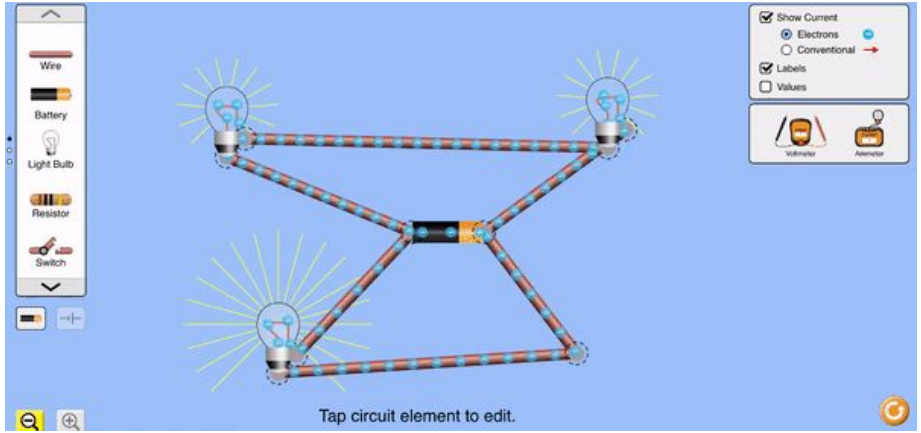


A greater percentage of students answer conceptual questions correctly when a sim is used in demos vs. physical equipment.

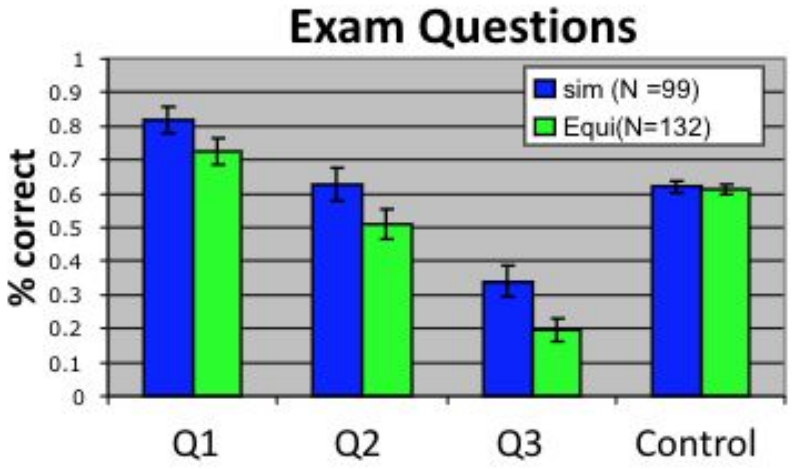


Perkins, K., et al. (2006). *Physics Teacher, 44*(18).

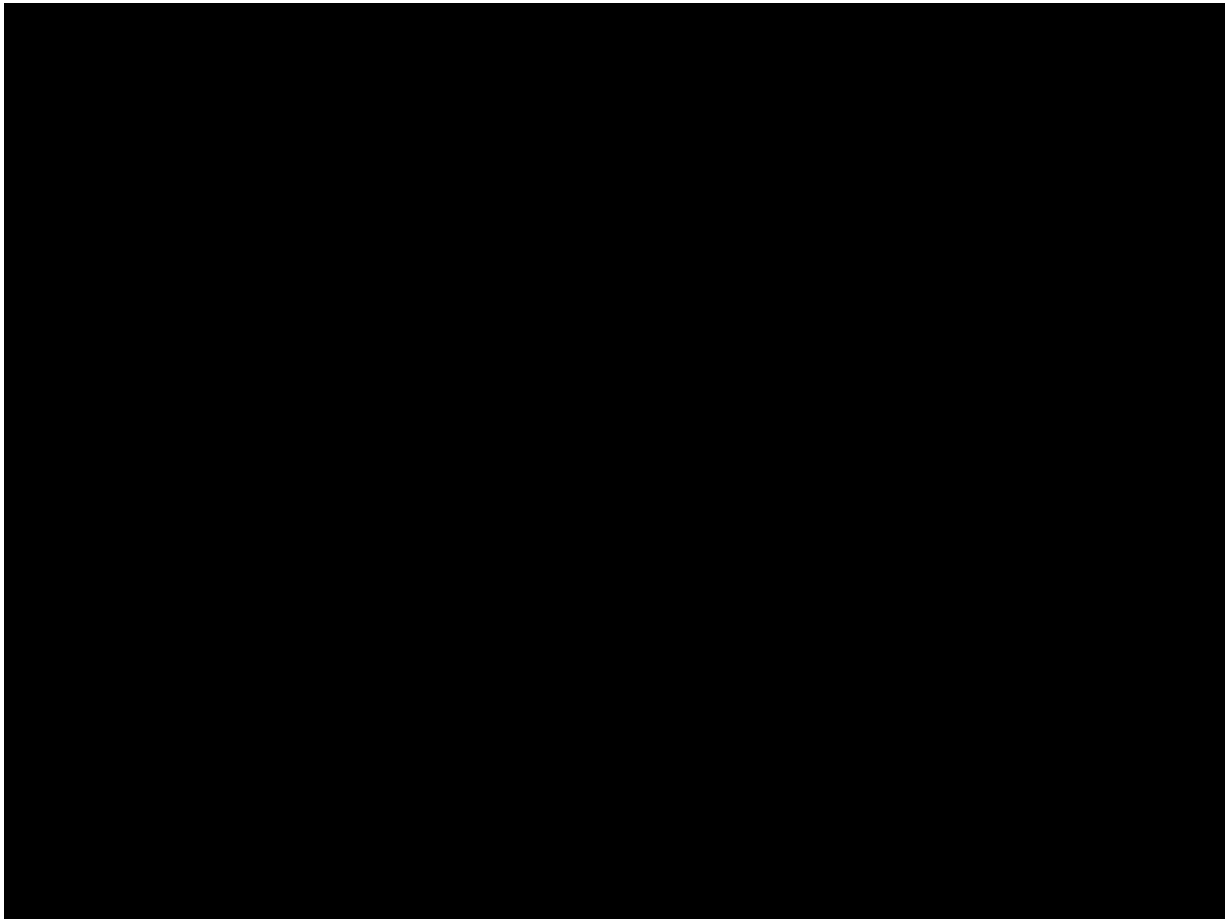
Evidence of increased learning



A greater percentage of students answer conceptual questions correctly when they do experiments with sim, followed by real equipment, compared with only using physical equipment.



Finkelstein, N., et al. (2005). *Physical Review Special Topics-Physics Education Research, 1*(1), 010103.



Discuss:

What science practices do you see students engaging in?

Moore et al. Chemistry Education Research and Practice, 14(3), 257-268, 2013.

Evidence of increased engagement

The power of 10 min of free exploration:
Molecular Polarity

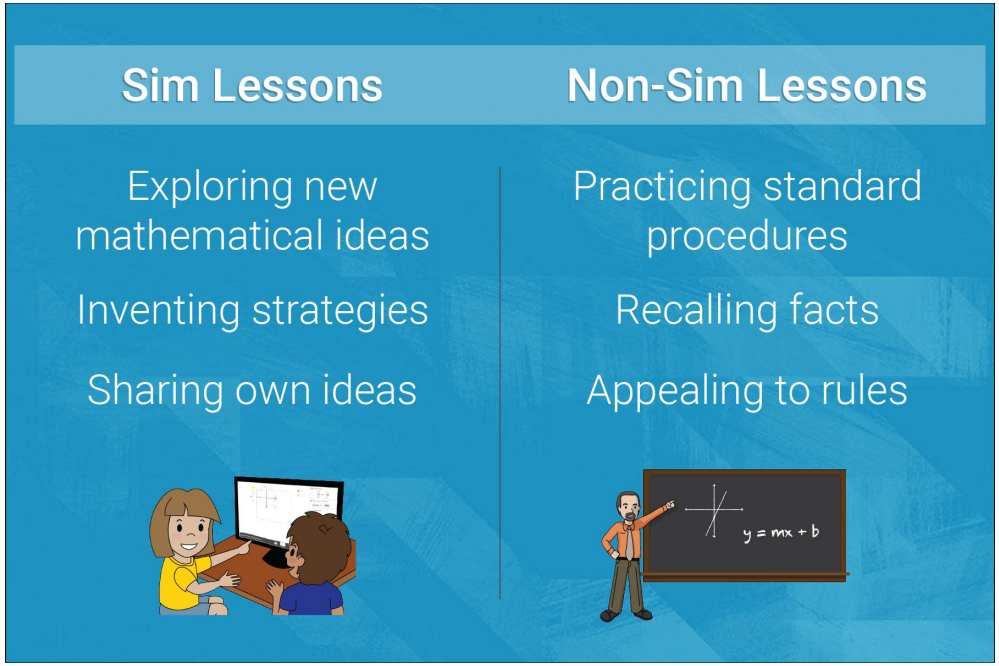
Analysis of 80 students working in groups:

- Explore 80% of all sim features across 3 screens
- Majority of talk about polarity

Topic	% of Utterances
Group Arrangement (Pre-Sim Use)	6%
Chemistry Concept - polarity	62%
Instructor-Student - polarity	2%
School - homework, lab	10%
Off-topic	20%

Moore et al. (2013). *Chemistry Education Research and Practice*, *14*(3), 257-268, 2013.

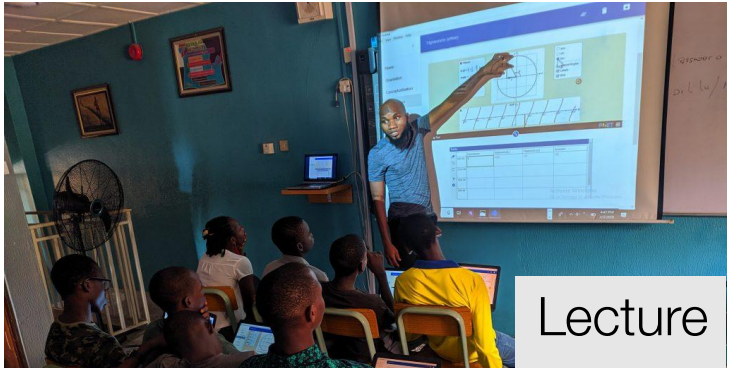
Evidence of new classroom norms



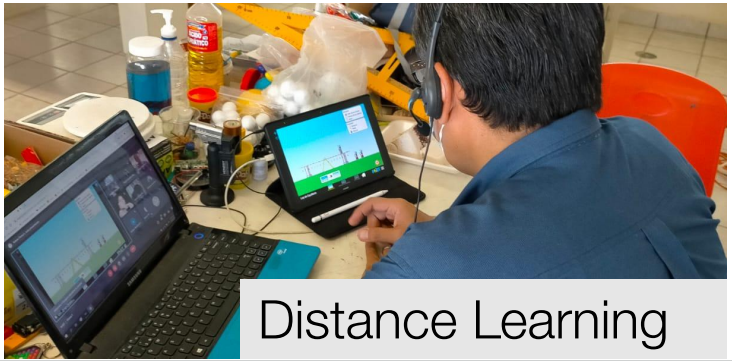
Atabas, S. et al. (2020). A tale of two sets of norms: Comparing opportunities for student agency in mathematics lessons with and without interactive simulations. *The Journal of Mathematical Behavior, 58*, 100761.

Flexible

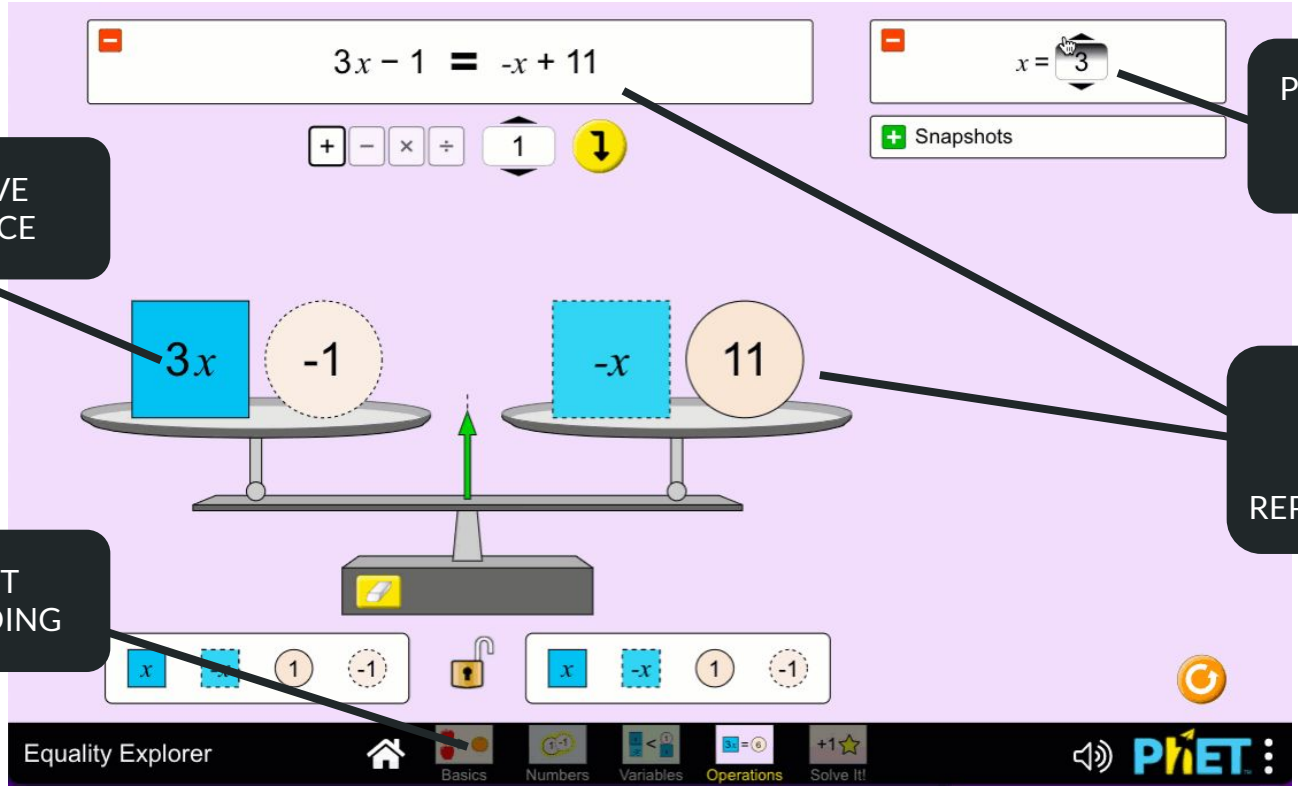

Pre-Lab


Lecture


Activity/Lab


Distance Learning

Sim Design: Open, flexible tools. Adaptable to your class.



INTUITIVE INTERFACE

PEDAGOGICALLY POWERFUL ACTIONS

MULTIPLE, ACCURATE, DYNAMIC REPRESENTATIONS

IMPLICIT SCAFFOLDING

Sim Design: Supports multiple learning goals.

CONTENT: Concepts, Models, Representations, Relationships

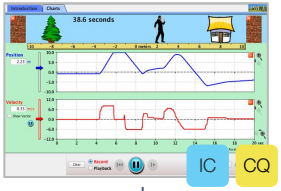
PROCESS: Explore, Question, Design, Predict, Data, Evidence, Reason

SOFT SKILLS: Argumentation, Collaboration, Planning, Reflection
HARD SKILLS: Lab techniques, Quantitative problem solving

AFFECTIVE: Enjoyable, Understandable, Relevant, Student Agency

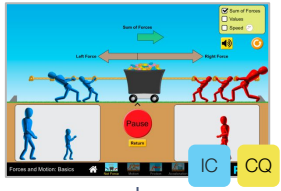
Integrating PhET in Introductory Physics

Moving Man

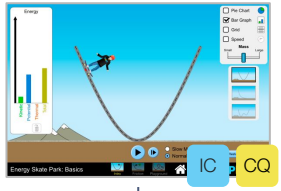


Projectile Motion

Forces and Motion: Basics



Energy Skate Park



Ladybug Revolution

Intro to Motion

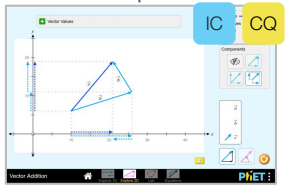
2D Kinematics

Newton's Laws

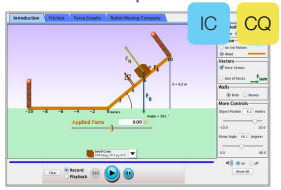
Work, Energy, Momentum

Circular Motion

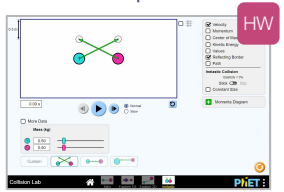
Calculus Grapher



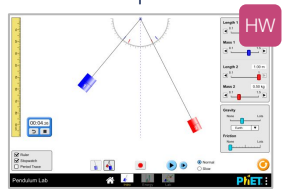
Vector Addition



Ramp: Forces and Motion



Collision Lab



Pendulum Lab

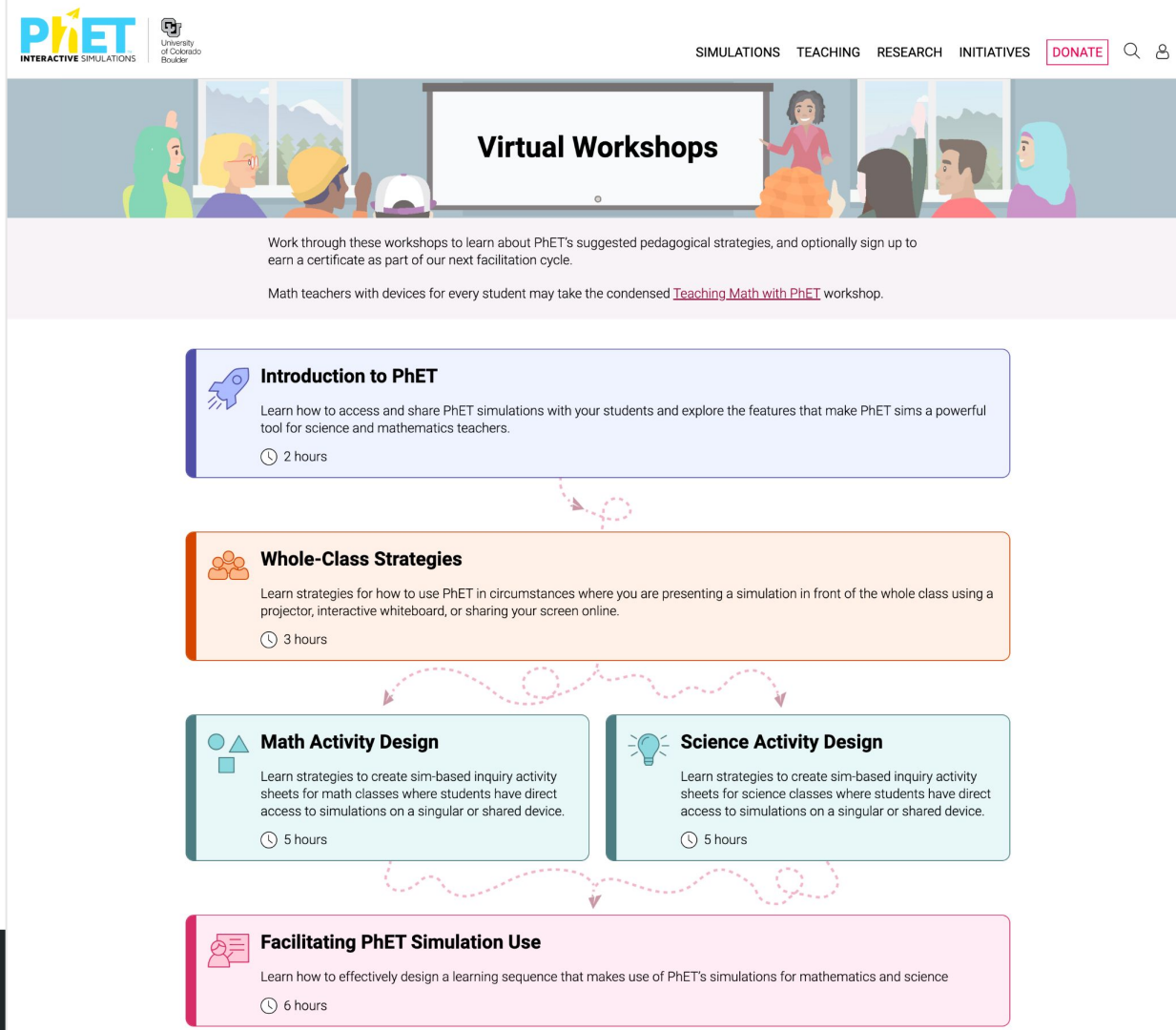
CQ Clicker Questions

IC In Class Activity

HW Homework

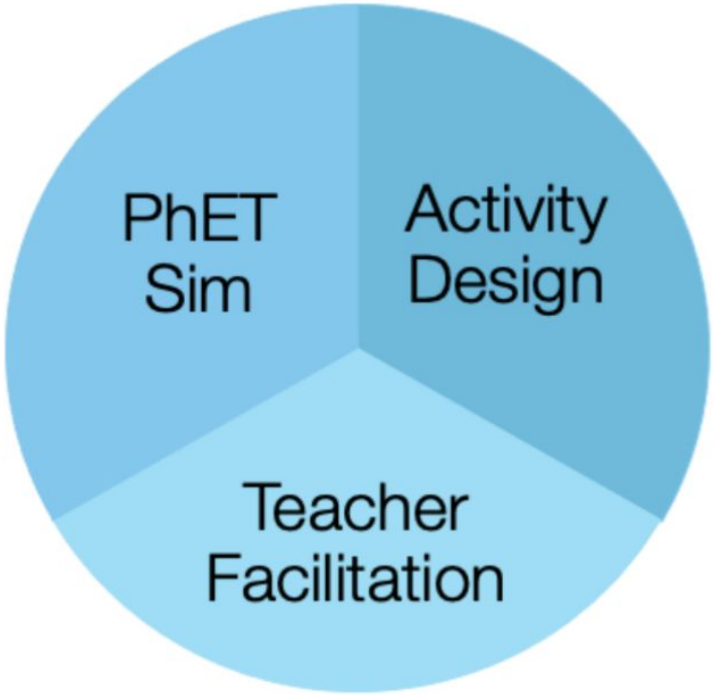
Sims + Effective Pedagogies

- Whole-Class Inquiry
- Interactive Lecture Demonstrations
- Concept Questions w/Peer Instruction
- Challenge Prompts



PhET

Sim-based Learning

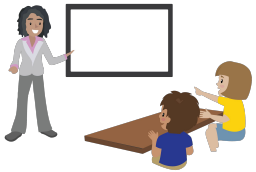


Teaching with PhET Sims

More Teacher Control

More Student Control

Lectures

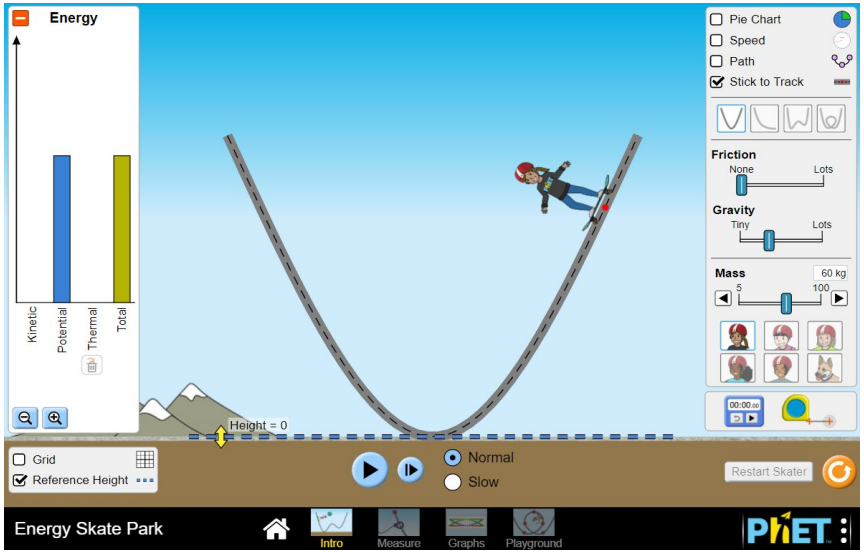


Interactive Lecture Demonstrations (see resources)

Concept Questions (see resources)

Activities & Labs

Whole Class: Concept Question w/Peer Instruction

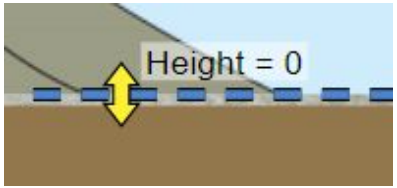


I move the reference height for zero of Potential Energy up to the **starting point** of the Skateboarder (skateboarder still starts from rest).

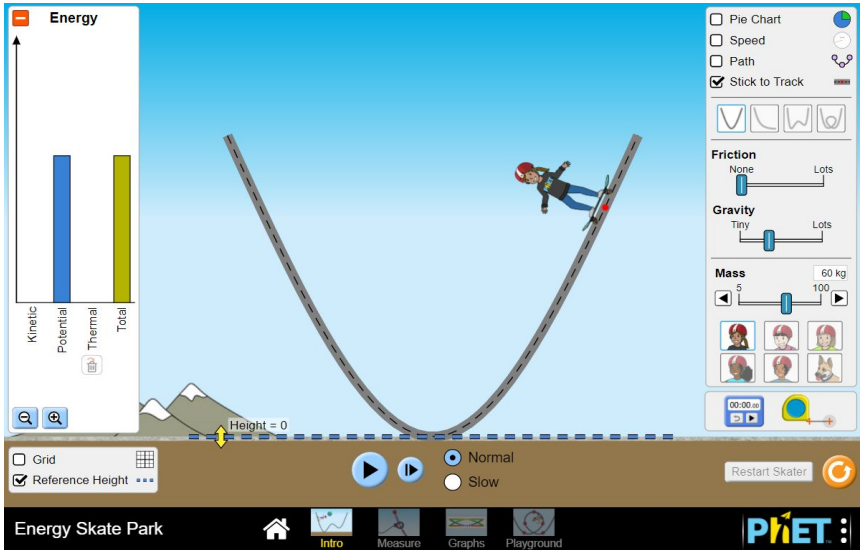
The total energy of the system is now:

A) Zero
B) Positive
C) Negative
D) Depends on the position of the skateboarder

? **Poll**



Whole Class: Concept Question w/Peer Instruction



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The total energy of the system is now:

A) Zero
B) Positive
C) Negative
D) Depends on the position of the skateboarder

?

Discuss: What are some science practices students engage in while considering this question?

Activity #2: Write a Concept Question!

Write 1 or more concept questions for a simulation of your choice.

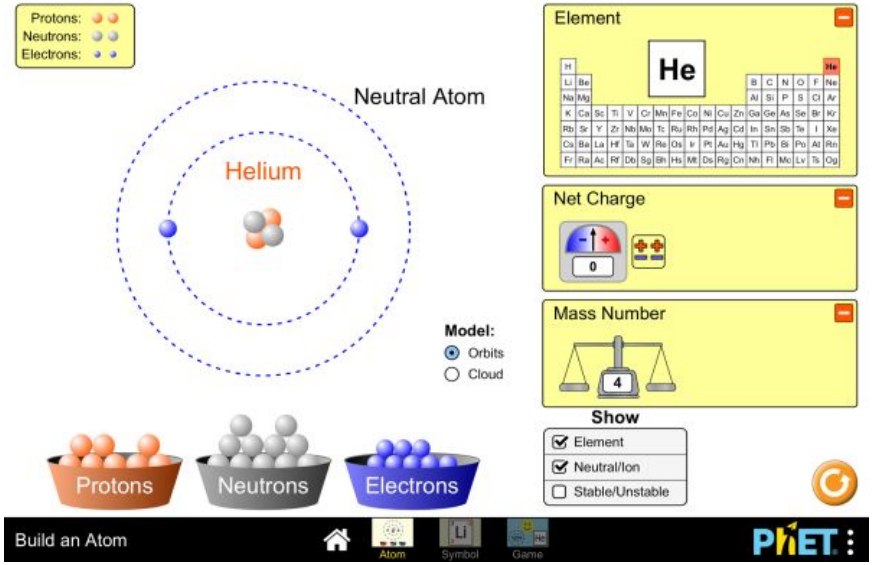
Be prepared to share your concept question.

Small Group/Ind.: Promoting Engaging and Inquiry

Top Tip #1:

Start with an "open explore" question.

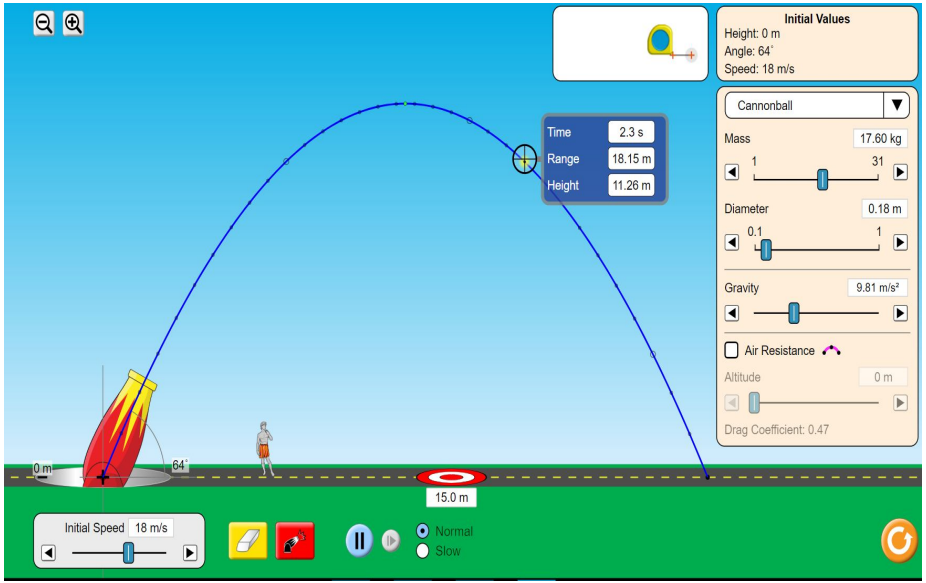
- Play with this simulation and develop your own ideas.
- Record a few discoveries you make.



Small Group/Ind.: Promoting Engaging and Inquiry

Top Tip #2:

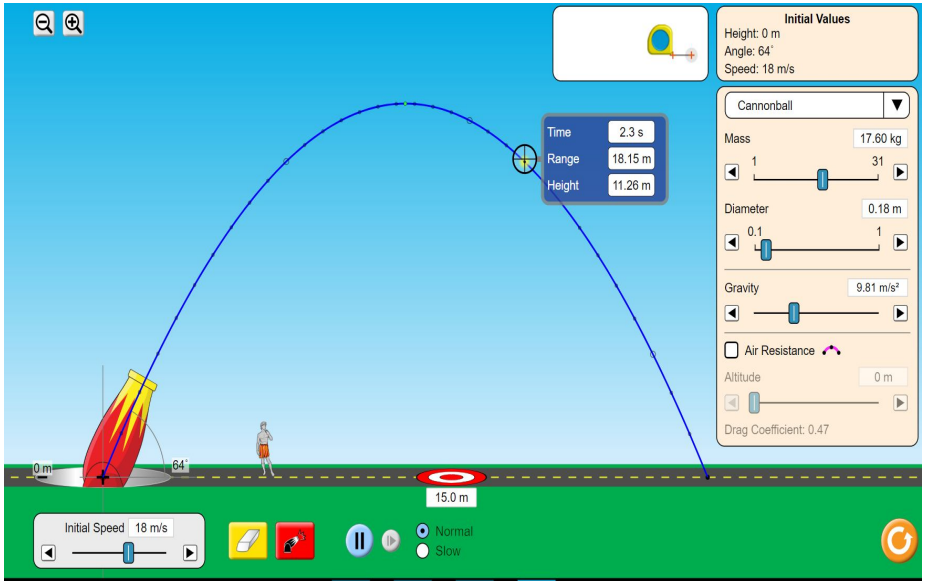
Use challenge prompts rather than direct specific instruction.



Small Group/Ind.: Promoting Engaging and Inquiry

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs distance traveled

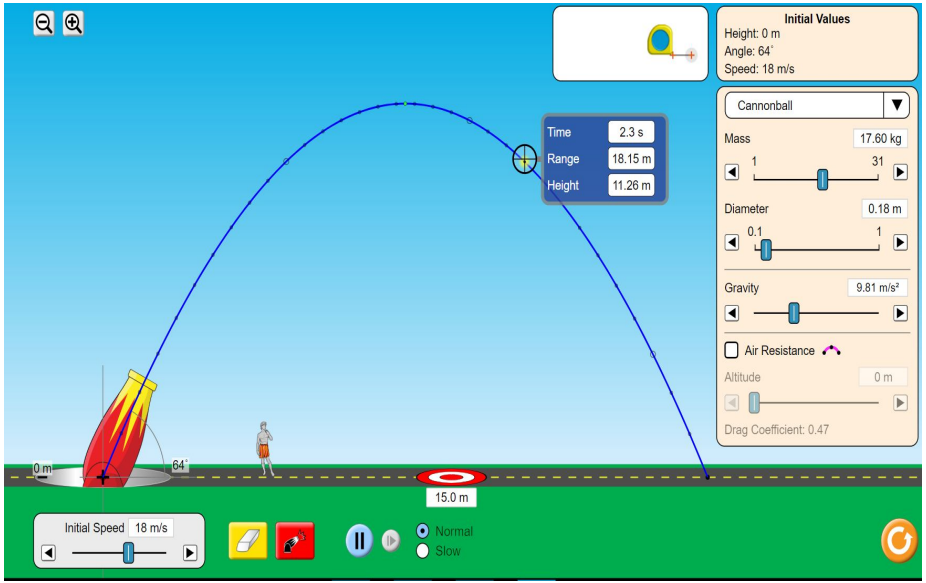


Challenge Prompts

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs. distance traveled.

Rewrite as: **Challenge Prompt:**



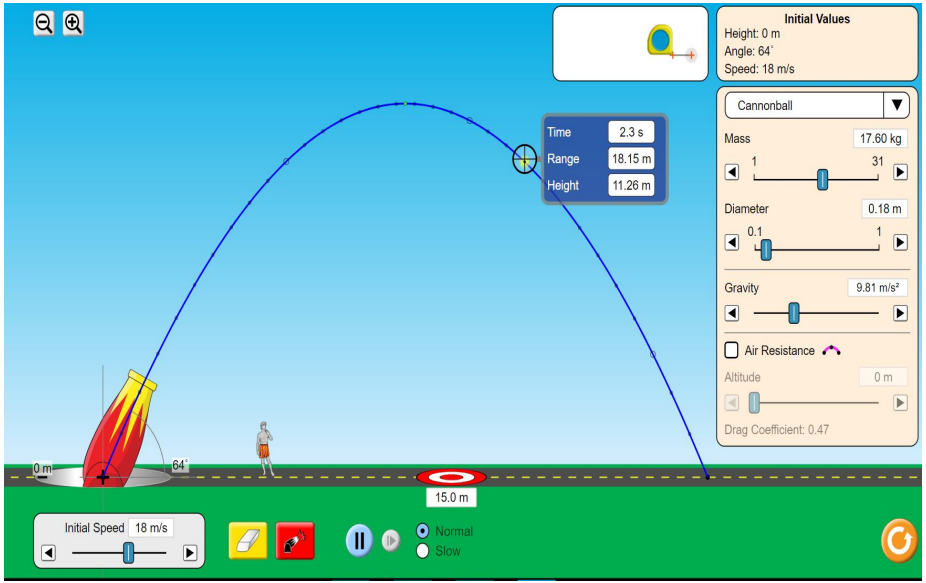
Challenge Prompts

Before: **Direct Instruction**

- Set the canon angle to 45 degrees.
- Measure distance for speeds of 5, 10, 15 m/s.
- Graph launch speed vs distance traveled

Rewrite as: **Challenge Prompt:**

What are all the ways to affect a projectile's horizontal landing distance?



Challenge Prompts

Find all the ways to... increase the force of gravity.

What's the largest... dipole moment you can make?

Create… an atom with a net charge of zero.

How can increase/decrease… the current?

Develop a procedure for... measuring the speed of the wave.

How do you know… if the spring constant is the same?

Activity #3: Challenge Prompts

Write 1 or more challenge prompts for a simulation of your choice.

Be prepared to share one of your challenge prompts

Example Activity

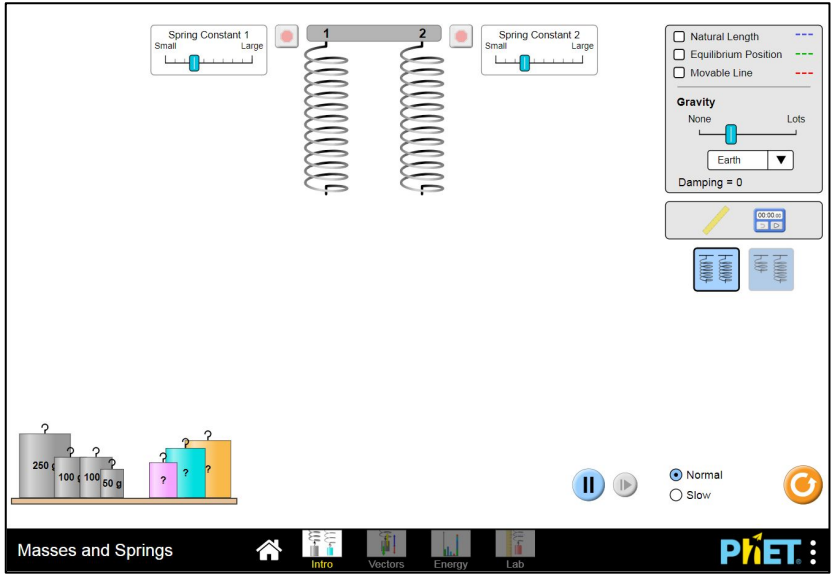
Masses and Springs

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 is the mass of the orange weight?

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



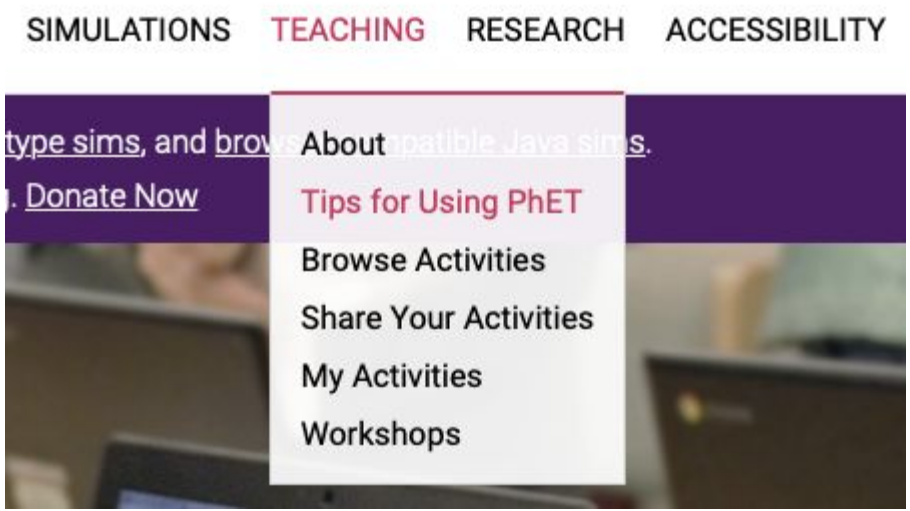
Find Teaching Resources

General tips for using PhET

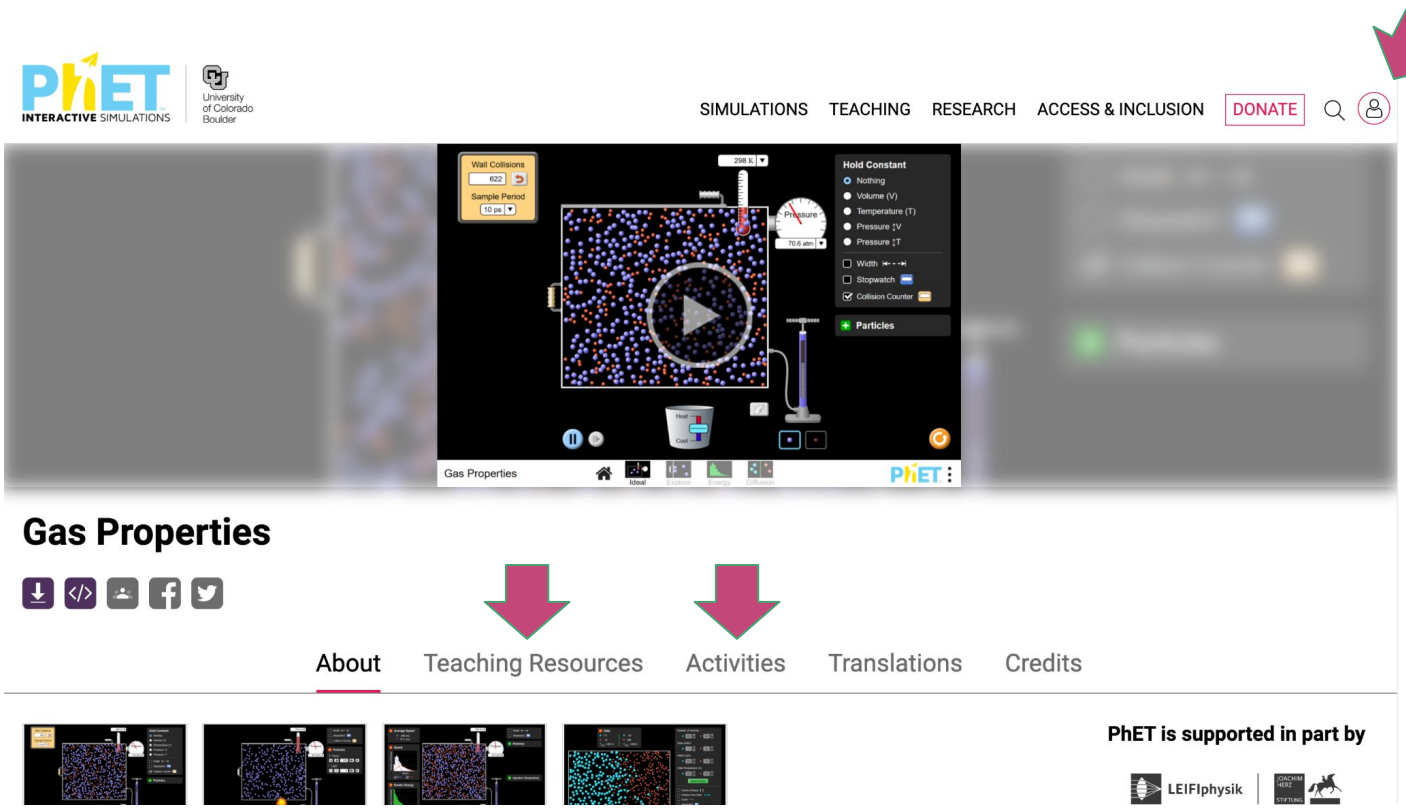
Remote learning tips

Sim-specific resources

- Standards alignment
- Learning goals
- Teacher tips document
- Lessons and activity sheets
- Translated sims



Teacher Resources



Translations

Translated Sims

LANGUAGE	LANGUAGE (TRANSLATED)	NUMBER OF TRANSLATIONS
Afrikaans	Afrikaans	23
Albanian	shqip	171
Amharic	Amharic	90
Arabic	العربية	179
Arabic (Morocco)	العربية (المغرب)	1
Arabic (Saudi Arabia)	العربية (السعودية)	80
Armenian	Armenian	48
Azerbaijani	Azerbaijani	39
Bashkir	Bashkir	1
Basque	Euskara	217
Belarusian	беларускі	111
Bengali	Bengali	5
Bosnian	Bosanski	218
Bulgarian	български	66
Catalan	català	78

Accessibility Features

Accessibility Features

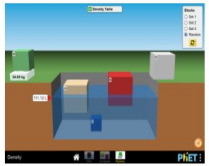
- Alternative Input (e.g., keyboard navigation) ⊞
- Sound and Sonification ⊞
- Interactive Description ⊞
- Interactive Description on Mobile Devices ⊞
- Pan and Zoom ⊞
- Voicing ⊞
- Prototype ⊞

Prototypes

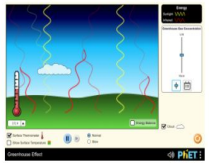
Prototypes are only available in English but will be made translatable once published to the PhET website.

Caution: these simulations are not feature complete or fully tested, so you may find bugs or other issues. OneNote does not support embedding these prototypes.

Circuit Construction Kit: AC



Density



Greenhouse Effect

Offline Access

Offline Access

- **Desktop/Laptop Computer**
- **Chromebook**
- **iPad**

Q&A

Q&A and Thank you!

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