Engaging Students and Supporting Learning with PhET Interactive Simulations

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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**

- Experimentation
- Evidence
- Reasoning
- Analysis
- Inquiry
- Test
- Designing Experiments

- Data
- Interpretation
- Predict
- Representations
- Uncertainty
- Explanation
- Assumptions
- Mechanism
- Models

- Limits
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 (Physics Education Technology)
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
Activity #1: Explore a Sim!

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.

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.

What science practices do you see students engaging in?

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

<table>
<thead>
<tr>
<th>Topic</th>
<th>% of Utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Arrangement (Pre-Sim Use)</td>
<td>6%</td>
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<tr>
<td>Chemistry Concept - polarity</td>
<td>62%</td>
</tr>
<tr>
<td>Instructor-Student - polarity</td>
<td>2%</td>
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<tr>
<td>School - homework, lab</td>
<td>10%</td>
</tr>
<tr>
<td>Off-topic</td>
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### Evidence of new classroom norms

<table>
<thead>
<tr>
<th>Sim Lessons</th>
<th>Non-Sim Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploring new mathematical ideas</td>
<td>Practicing standard procedures</td>
</tr>
<tr>
<td>Inventing strategies</td>
<td>Recalling facts</td>
</tr>
<tr>
<td>Sharing own ideas</td>
<td>Appealing to rules</td>
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</tbody>
</table>

Flexible

Pre-Lab

Activity/Lab

Lecture

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

- **Intuitive Interface**
- **Implicit Scaffolding**
- **Pedagogically Powerful Actions**
- **Multiple, Accurate, Dynamic Representations**
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
Sim-based Learning

- PhET Sim
- Activity Design
- Teacher Facilitation
Teaching with PhET Sims

More Teacher Control

Lectures

Interactive Lecture Demonstrations
(see resources)

Concept Questions
(see resources)

Activities & Labs

More Student Control
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
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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.
Top Tip #1:

Start with an “open explore” question.

- Play with this simulation and develop your own ideas.
- Record a few discoveries you make.
Top Tip #2:

Use challenge prompts rather than direct specific instruction.
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.
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Rewrite as: **Challenge Prompt:**
Challenge Prompts

Before: **Direct Instruction**

- Set the cannon 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
### Translations

#### Translated Sims

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### 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**

- Desktop/Laptop Computer
- Chromebook
- iPad

[PhET App Store](https://phet.colorado.edu) [Google Play](https://play.google.com/store/apps)
Q&A
Q&A and Thank you!

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