

# Teaching Physics with PhET simulations: Free, researched, web-based resources

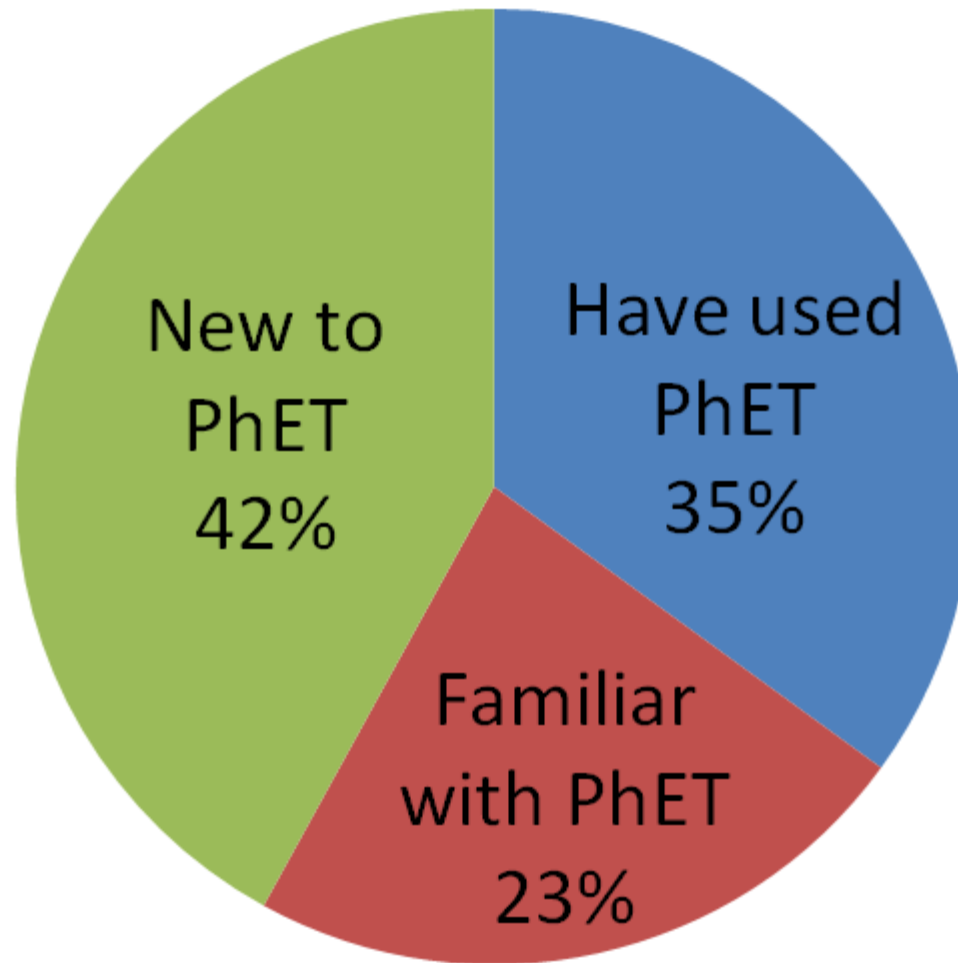
**Kathy Perkins**  
University of Colorado

# The Team

University Faculty, Post-docs,  
K-12 Teachers, Software Developers



# Prior Knowledge

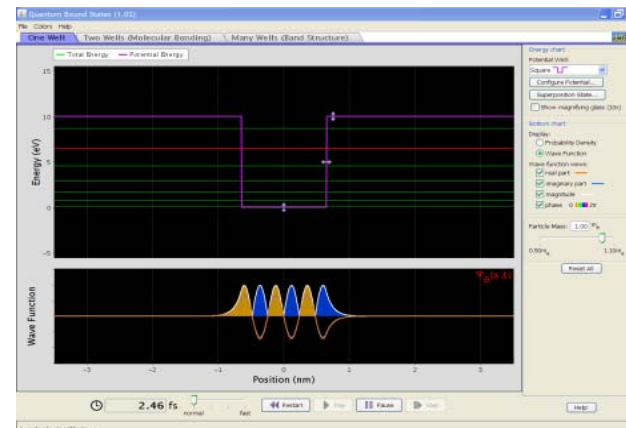
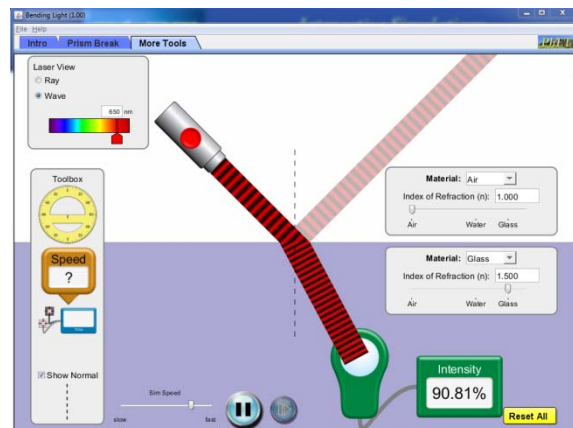
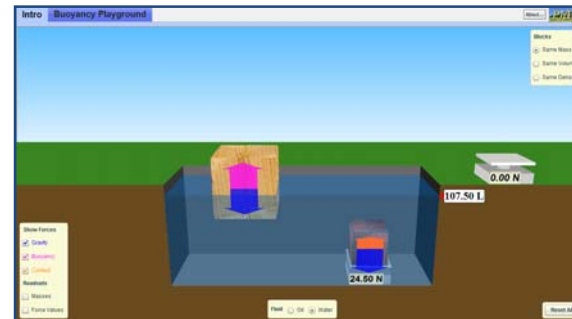
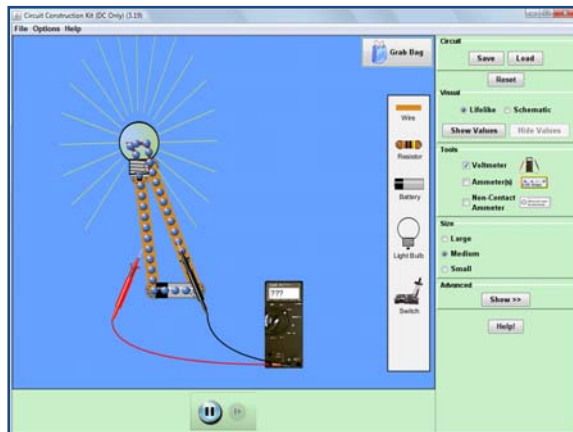


# Workshop Goals

1. Become familiar with PhET:  
When, how, and why might you use a PhET sim?
2. Explore different ways to use them in teaching
3. Use research findings around simulations to guide that use in class.

# What is PhET?

Suite of **127 interactive sims** on science and math!  
Currently Java and Flash → will move to HTML5 (slowly)

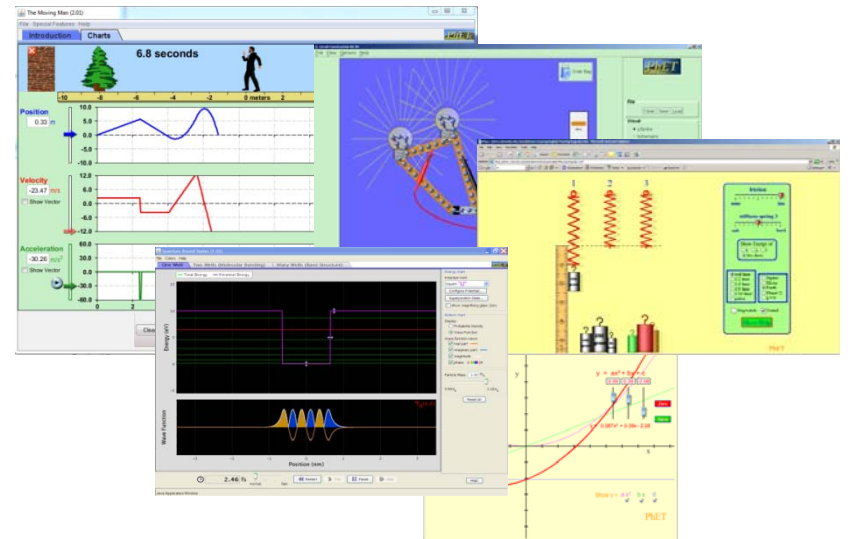


# First thoughts or impressions?

What aspects do you see supporting your students' learning?

**Your thoughts here:**

- **Visualization**
- **Access to conceptual ideas**
- **Fun**
- **Why we use models**
- **How fast to explore and probe ...**
  - **don't forget question**



**Ways to use:**

- **Students find and present and explain the applet**

# Finding PhET



A screenshot of a PhET simulation interface. On the left, a circuit diagram is shown with a battery, a light bulb, and a switch. The text "Circuit Construction Kit (DC Only) &gt;&gt;" is at the bottom left. On the right, there is a control panel with various sliders and buttons. The text "Interactive Science Simulations" is at the top right, followed by "Fun, interactive, research-based simulations of physical phenomena from the PhET project at the University of Colorado." and a "Play with sims... &gt;" button. Below this, logos for ERCSME at King Saud University, National Science Foundation, and The William and Flora Hewlett Foundation are displayed, along with the text "and the O'Donnell Foundation: Using Science to Teach Science".

Or download!  
(~300 MB)

Join us on [f](#) | Follow us on [t](#) | Read our blog | Subscribe to our newsletter

How to Run Simulations	For Teachers	About	PhET is supported by...
<ul style="list-style-type: none"><li>On Line</li><li>Full Installation</li><li>One at a Time</li><li>Troubleshooting</li><li>FAQs</li></ul>	<ul style="list-style-type: none"><li>Browse Activities</li><li>Contribute Activities</li><li>Workshops / Materials</li><li>Translate simulations</li><li>Translate the website</li></ul>	<ul style="list-style-type: none"><li>What's New?</li><li>About PhET</li><li>Contact Us</li><li>Donate</li></ul>	<p>The Mortenson Family Foundation</p> <p>and our <a href="#">other sponsors</a>, including educators like you.</p>

English | العربية | 正體中文 | Dansk | Galego | ગુજરાતી | Ελληνικά | Magyar | 한국어 | كوردی | Македонски | فارسی | Português do Brasil | Српски | Tiếng Việt

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<http://phet.colorado.edu>



# Making PhET Accessible

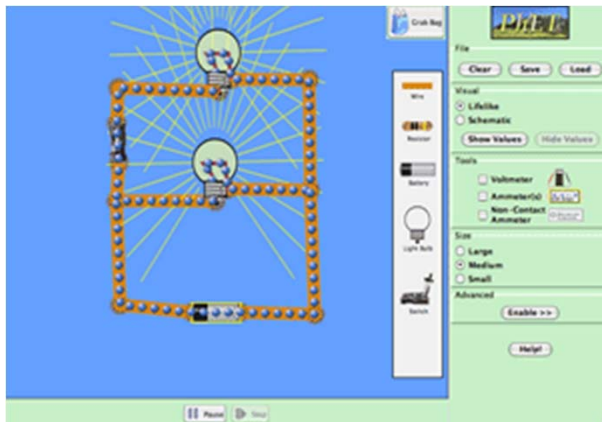
- **Open-use License:** Creative Commons – Attribution
- Easy to translate for World-wide Use:
  - Over 3000 translations in 74 languages
- Over 45 million sims run per year, and growing



# Made for easy use

- Flexibility for you to
  - ✓ Pick and choose which sims to use
  - ✓ Customize use ...  
to your environment and your learning goal
  - ✓ Search database of activities (>800 by PhET or Teacher-users)

## Circuit Construction Kit



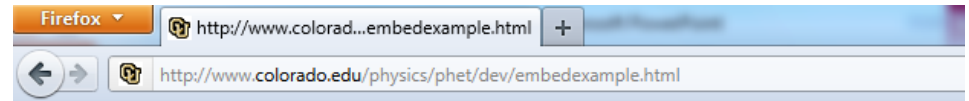
## CCK in grade school:

“Make the light bulb light”

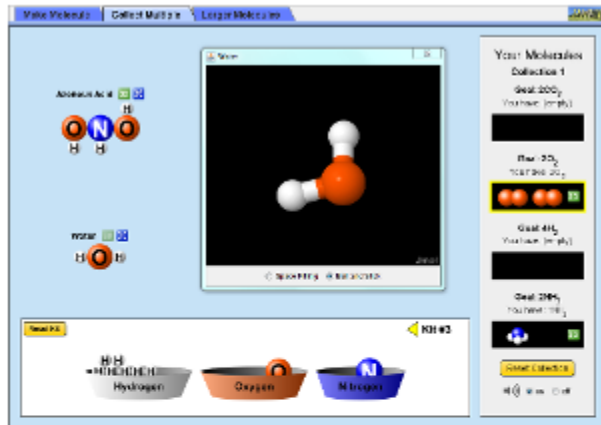
## CCK in college:

“Explain why the light dims when you turn the heater on”

# Embed Sims in Your Page



## Build a Molecule



Download

4,844 kB

Run Now!

Embed

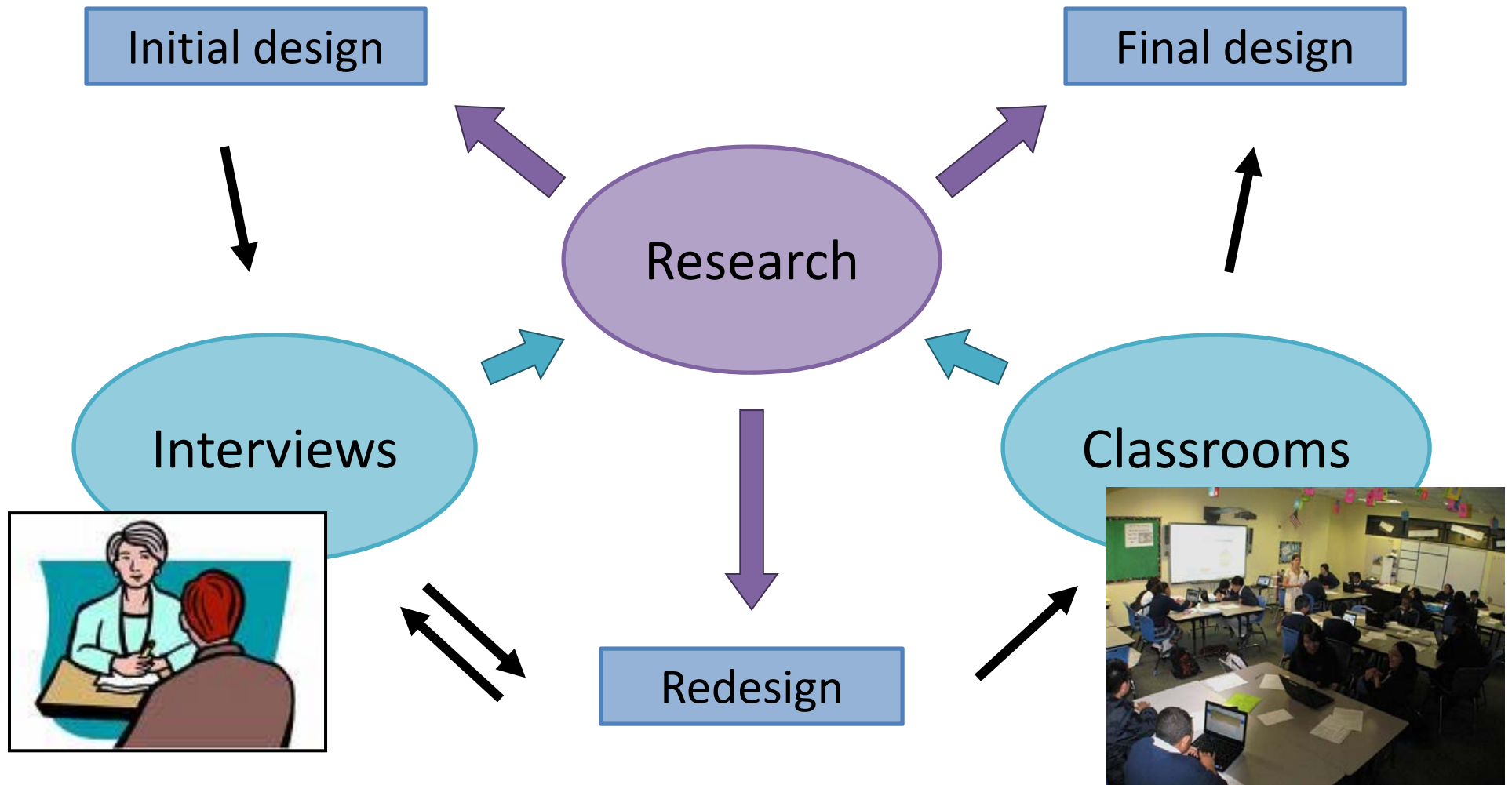
Version: 1.01 ([change log](#))

Embed an image that will launch the simulation when clicked

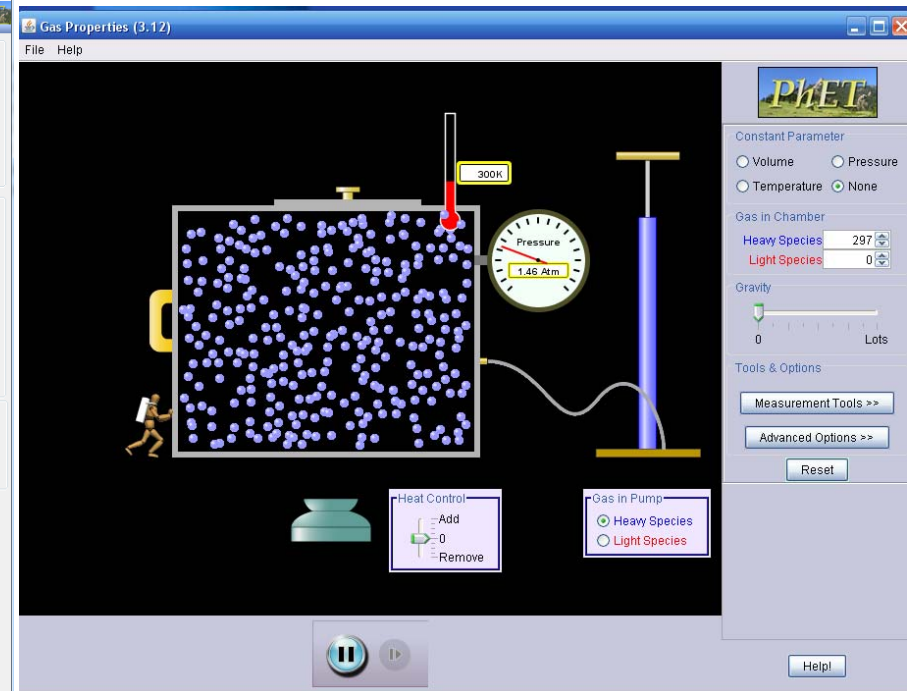
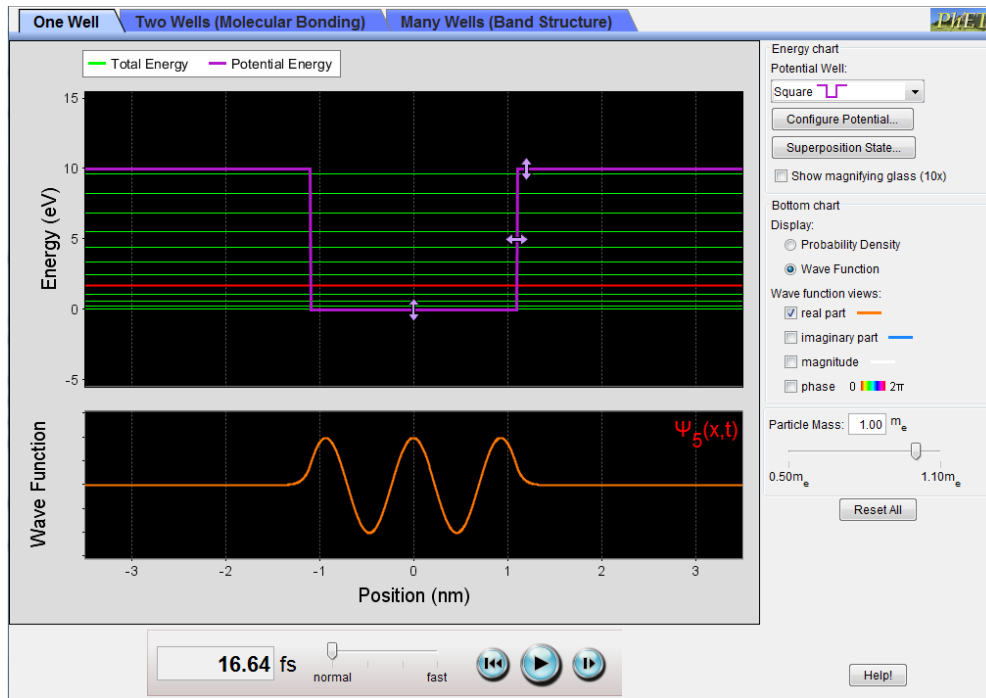
```
80px; left: 50px; top: 65px; "><tr><td style="text-align: center; color: #000; font-size: 24px; font-family: Arial, sans-serif; ">Click to Run</td></tr></table></a></div>
```

Use this HTML code to display a screenshot with the words "Click to Run".

# PhET Design Process

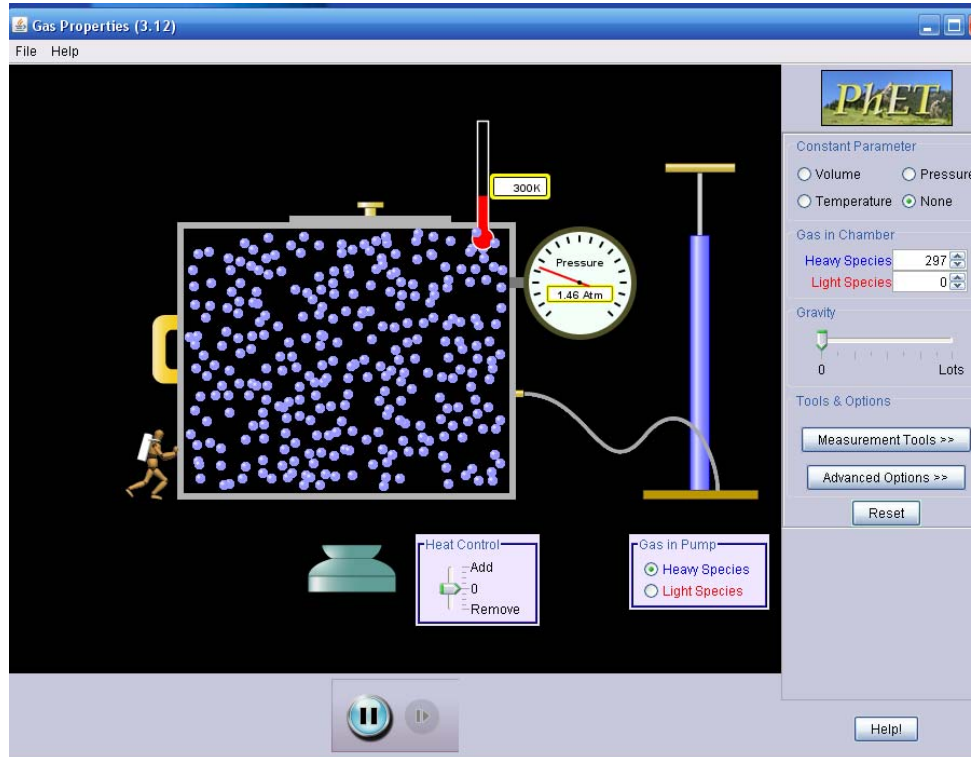


# From survey: Use in lecture – Lecture Demo



# Use in lecture - Visualization

## Common expert visualization



## Comparison Study

**No sim group:** 30 min lecture

**Sim group:** 30 min lecture  
with 5 min of sim demo

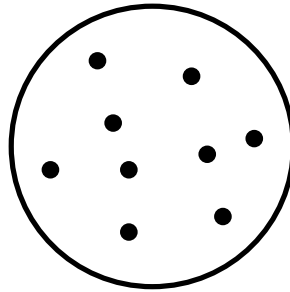
## Work by PhET Collaborator:

Jack Barbera (UNC)

Jessica R. VandenPlas (NAU)

# Assessment Question\*

Helium gas at 20°C  
and 3 atm pressure

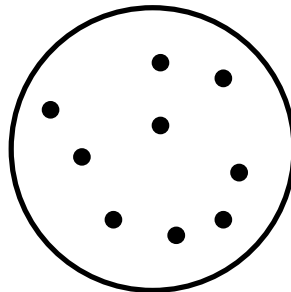


\*Nurrenbern/Pickering  
Question with  
Sanger Question  
Modifications

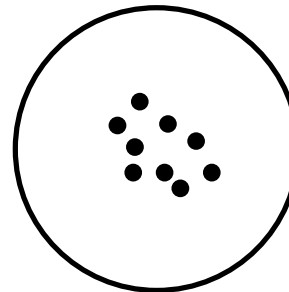
If lower temp to  
-20°C, what would  
Helium gas  
look like?

(note boiling point  
is around  
-270°C at 3 atm)

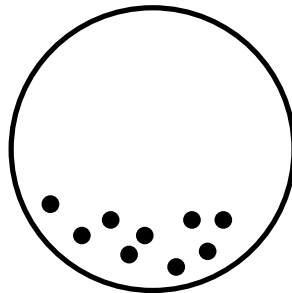
**A**



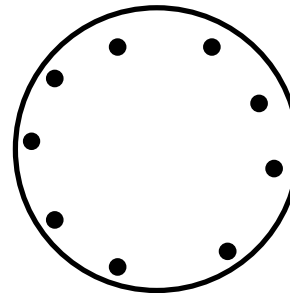
**B**



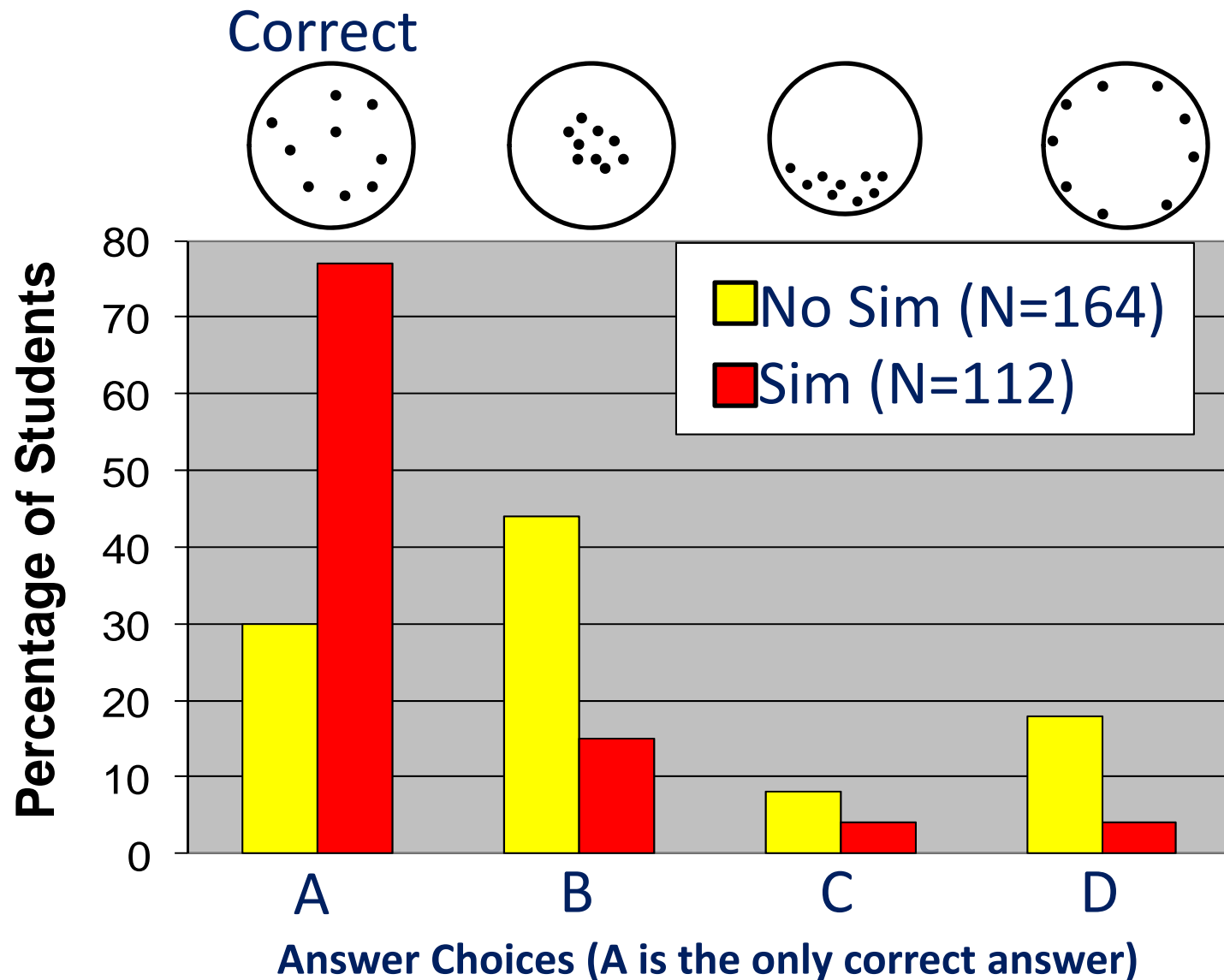
**C**



**D**



# Sim effective for students



# Use in lecture

Use in lecture:

- Lecture Demonstration

Going beyond:

- Coupled with Clicker Question
- Interactive Discussion with Predications
- Interactive Lecture Demos (see Thornton and Sokoloff)

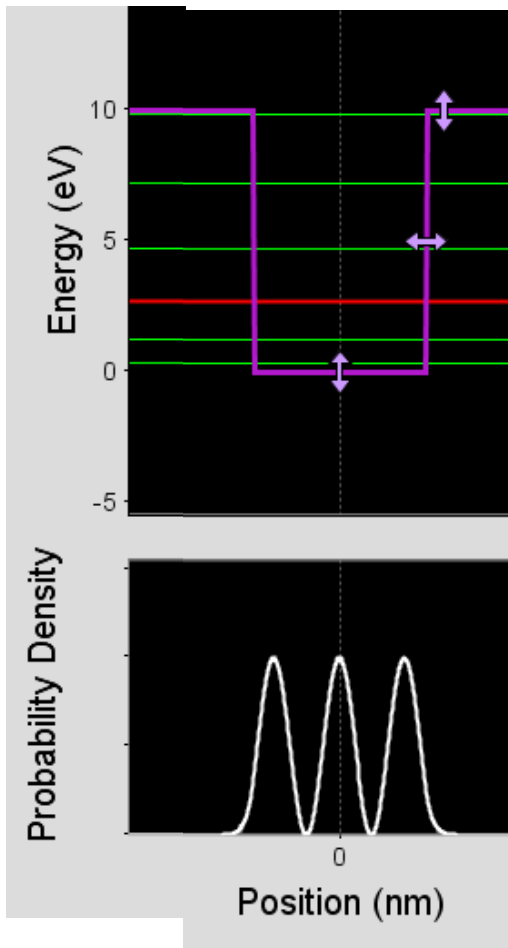
Here is a helpful video:

<http://www.youtube.com/watch?v=x7nJHxH1J58>

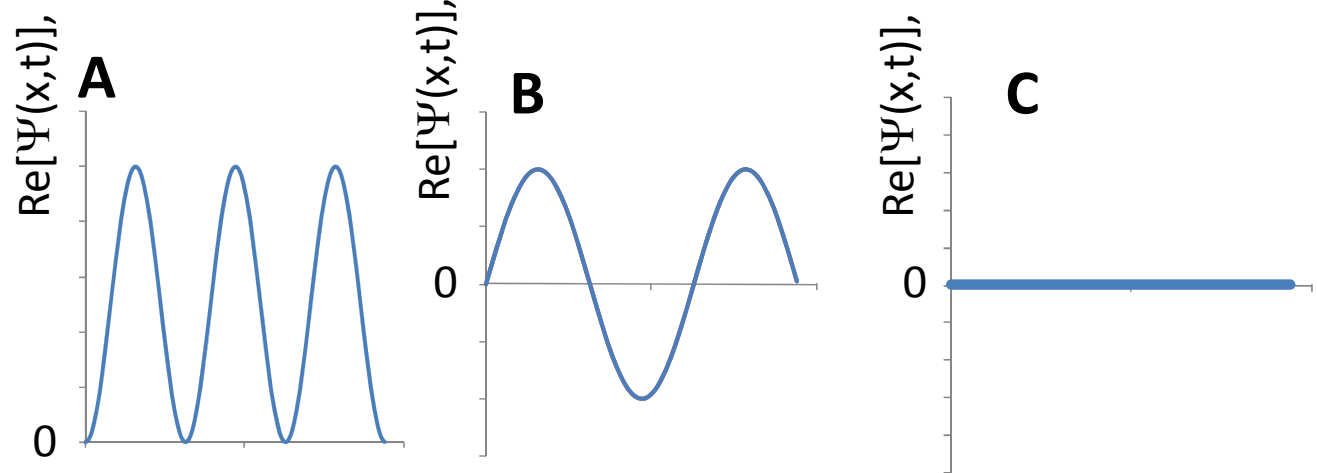


# Interactive Lecture: Concept tests

## Probability Density for $n=3$



Which of the following are possible graphs of the **real-part** of the wave-function,  $\text{Re}[\Psi(x,t)]$ , at some time  $t$ ?



- D. A and B are both possible**
- E. B and C are both possible**

# Exploring floating and sinking

The simulation interface includes the following elements:

- Block Settings:** Radio buttons for "My Block" (selected) and "Material". Sliders for "Mass" (3.00 kg) and "Volume" (3.00 L). A "Material" dropdown menu is set to "Aluminum".
- Fluid Density:** A slider at the bottom labeled "Fluid Density" with options: Air, Gasoline, Olive Oil, Water, Honey. The current value is 1.00 kg/L.
- 3D View:** A tank containing two blocks, A and B, and a scale. Block A is partially submerged in a fluid. Block B is fully submerged. The scale shows 0.00 N. A volume readout on the right indicates 106.00 L.
- Force Readouts:** A scale on the right shows 0.00 N.
- Force Settings:** A "Show Forces" panel with checkboxes for Gravity (checked), Buoyancy (checked), and Contact (unchecked).
- Other UI:** A "Blocks" panel with radio buttons for "One" and "Two" (selected).

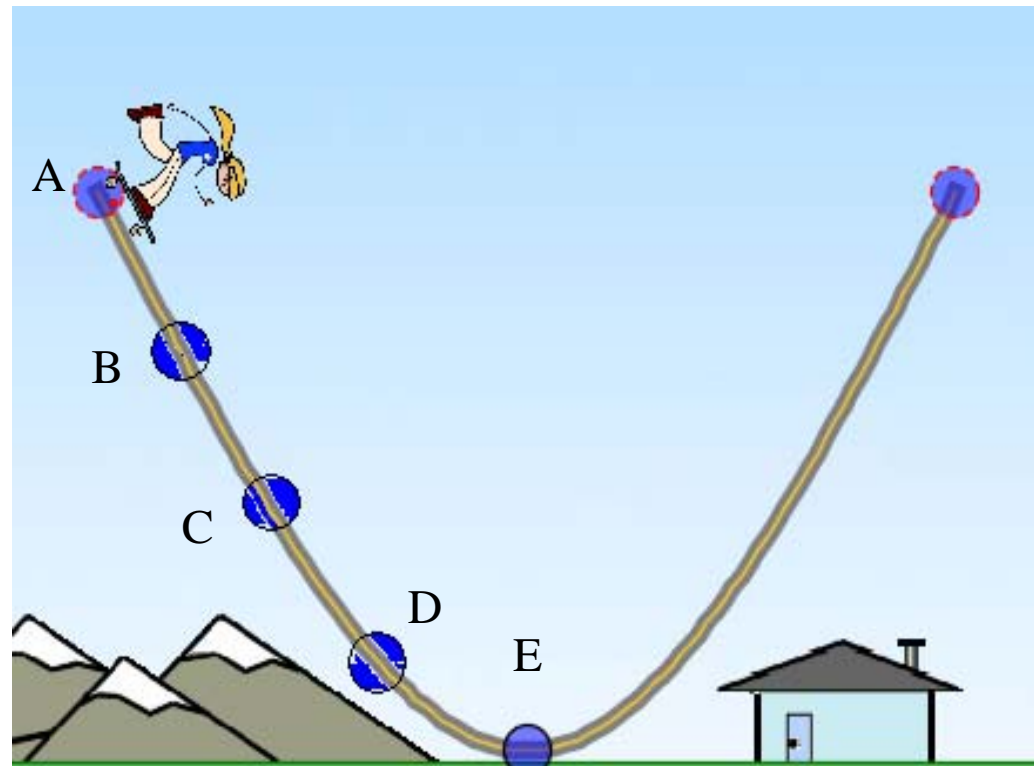
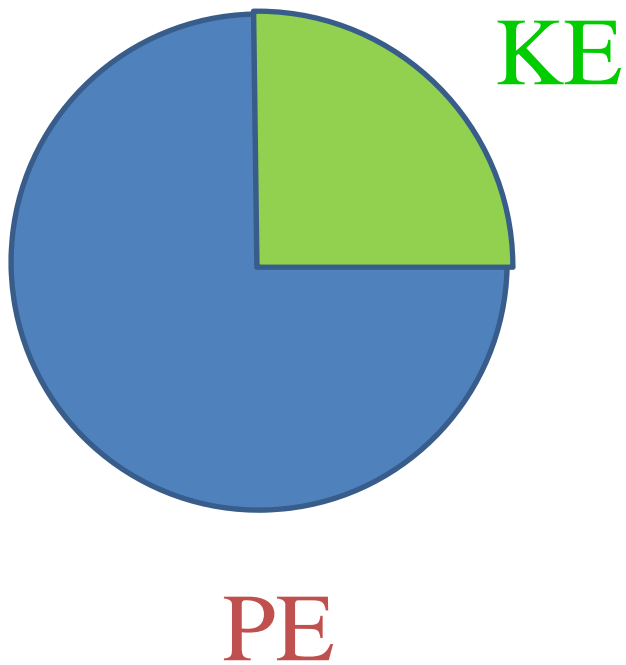
What change would make these blocks float?

And why?

(How many strategies can you find!)

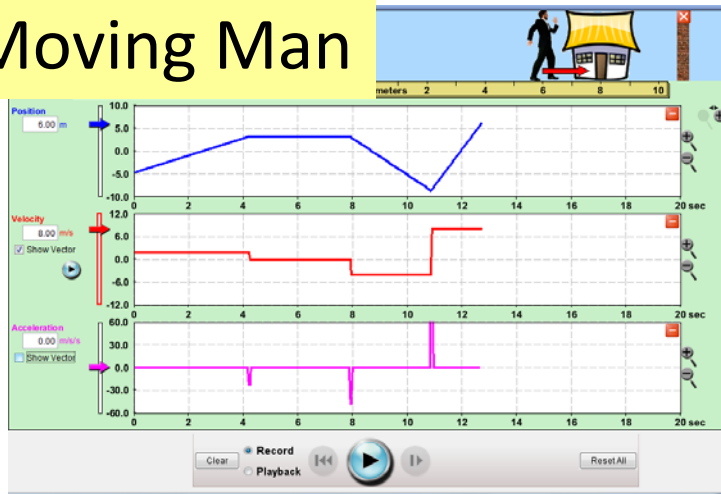
# Interactive lecture: Concept tests

The pie graph shows the energy of the Skater, where could she be on the track?



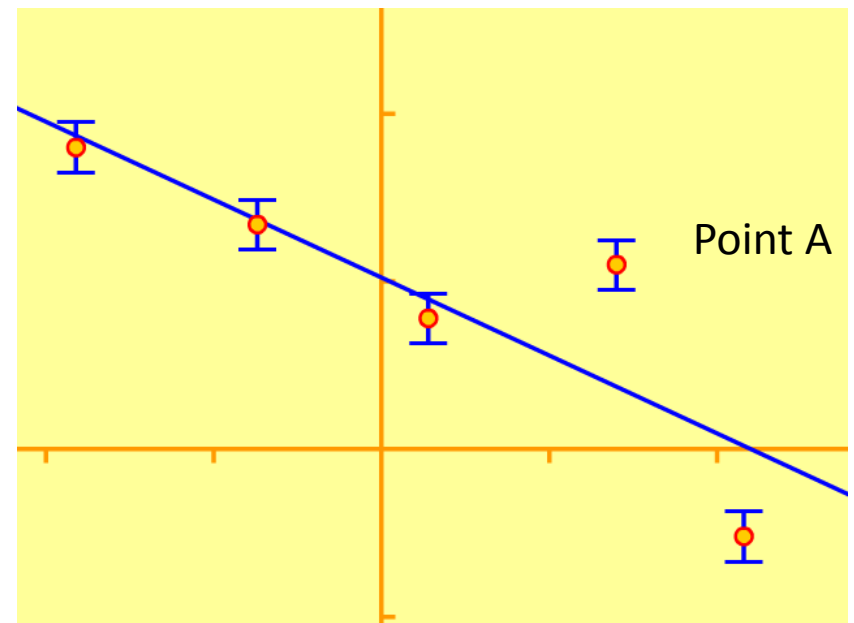
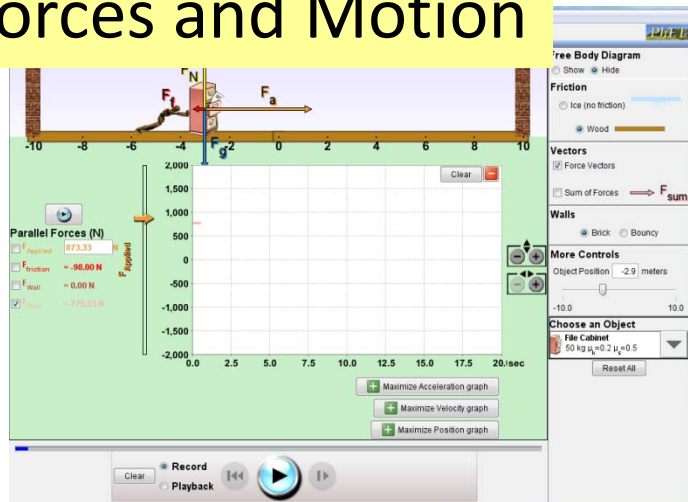
# Interactive Lecture Demo (ILD) mode

## Moving Man



Predict how the best fit line will change if the error bars on data point A increase.  
(Draw your answers)

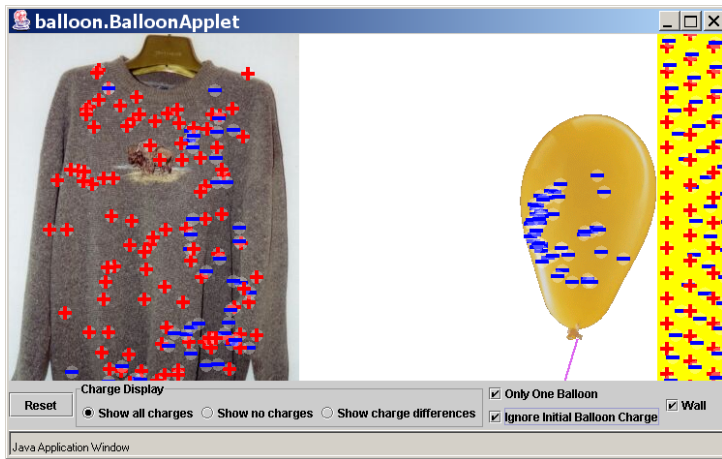
## Forces and Motion



# Use in lecture

## Influence on Learning Environment

### Many More Questions and Class-led Exploration:



- 1) If you rub the sweater on the balloon will electrons transfer the other way?
- 2) Can you polarize something where the protons move?
- 3) Are there any situations in which the '+'s move?
- 4) In an insulator, are the charges stuck?

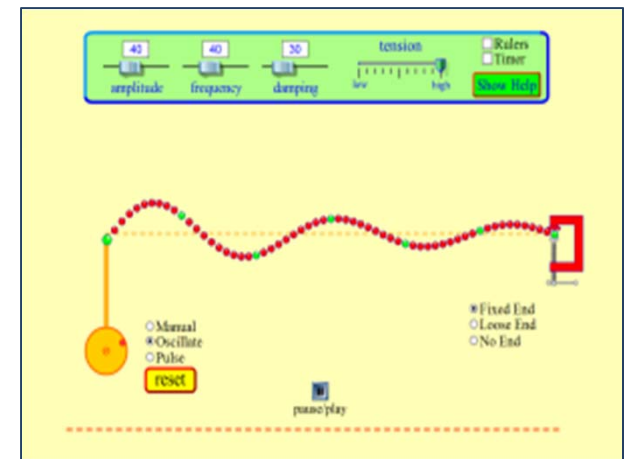
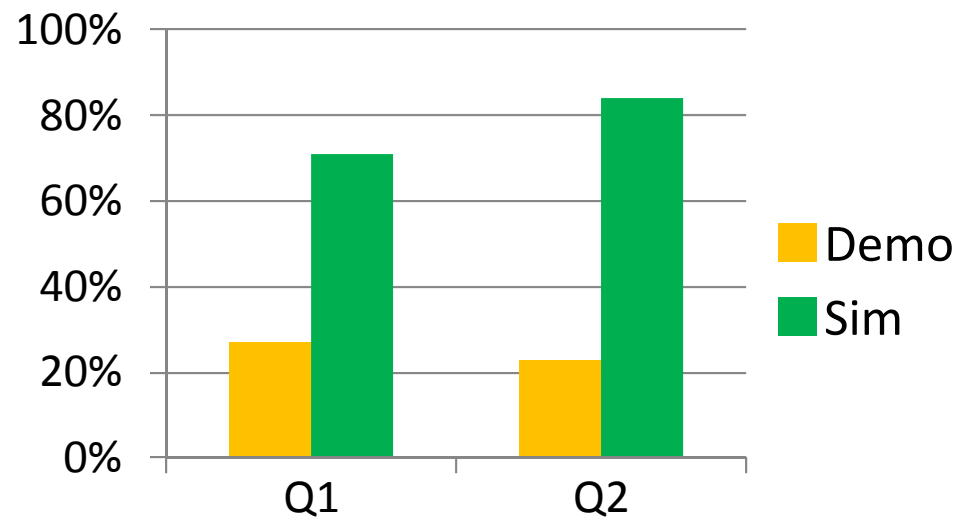
...

# Use in lecture - Visualization

Common expert visualization - **Wave-on-string simulation**  
**vs. Tygon tube demo**

Follow-up Concept Test:

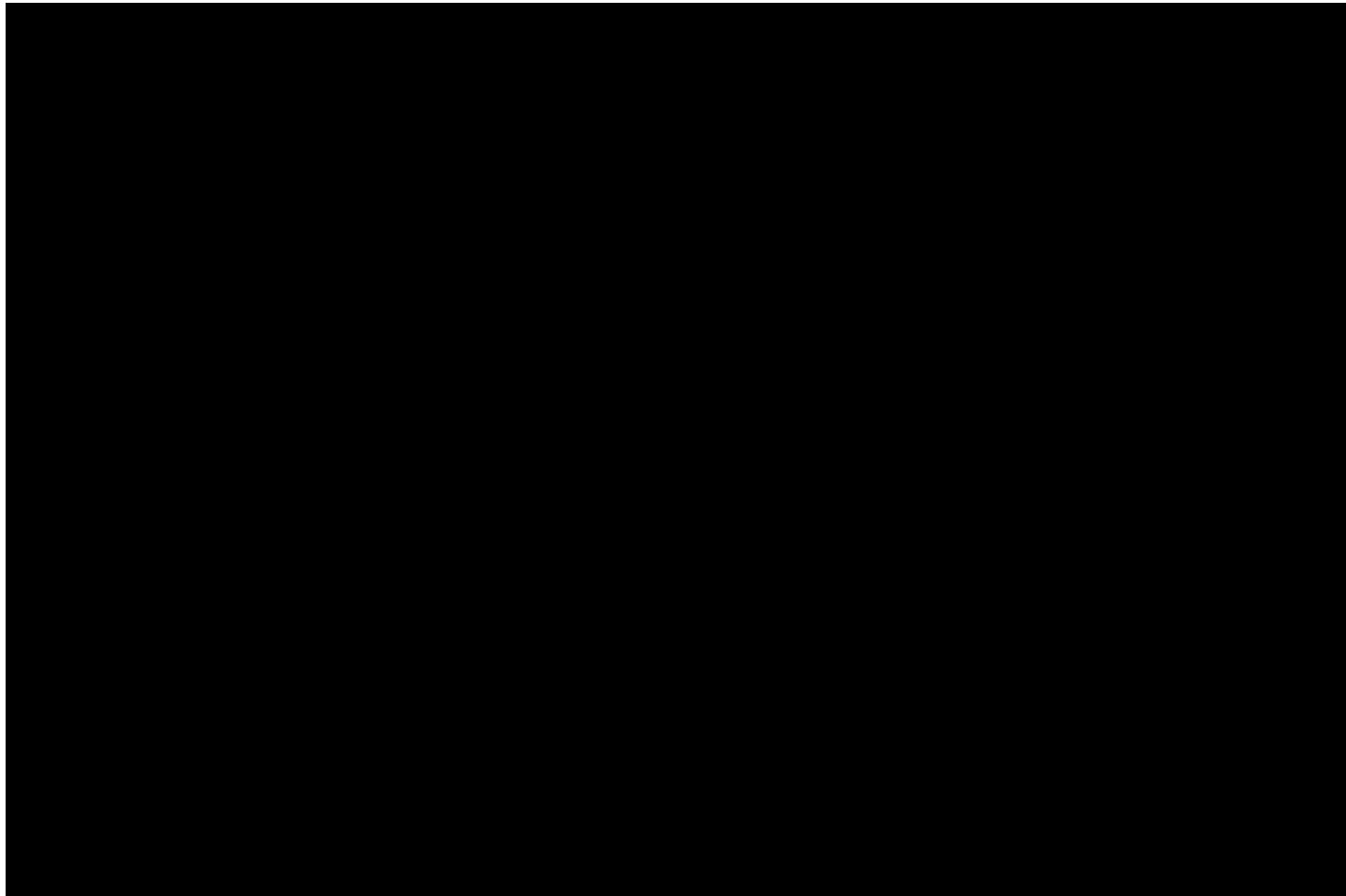
Questions about velocity of different points on the string.



# Instructor vs Student Control



Is sim engaging? Student learning?



Thoughts or Reflections?



# Designed to support inquiry learning

Use accurate, dynamic visual representations

Show the invisible

Provide real-time, animated feedback as students play

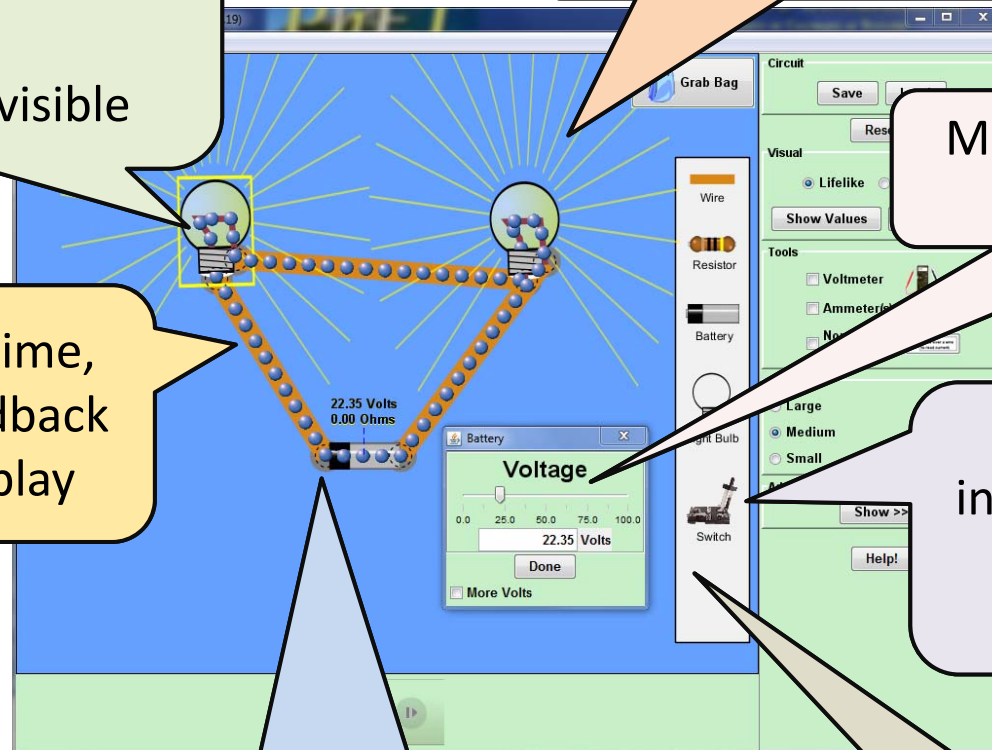
Allow actions that would be difficult or impossible in the real world

Create a game-like environment

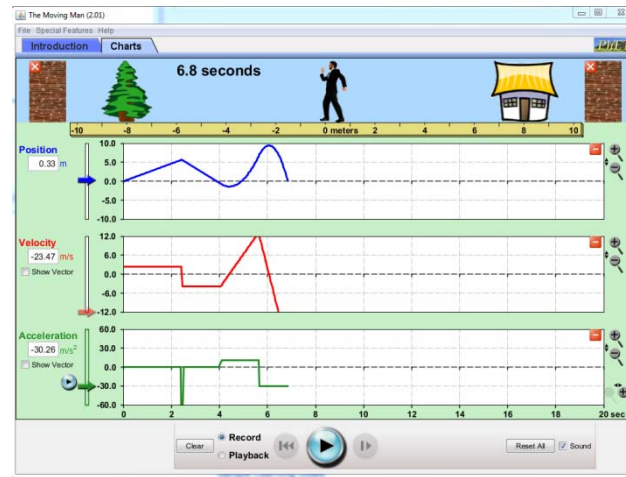
Make simulations highly interactive

Implicitly scaffold inquiry through design of controls and representations

Provide an intuitive interface, usable without instructions



# Ideas for Using Sims beyond in lecture?



- How would YOU use these sims in your class?
- Do they help you address learning goals that are otherwise hard to address?

GO TO ACTIVITIES DATABASE

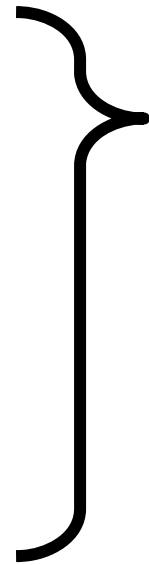


# Use of PhET sims

Lecture/classroom

Lab and Recitation

Homework



Opportunity for  
student scientist-like  
exploration

But, no silver bullet:  
**Context and Activity**  
**critical**

# Research: Activity Design Matters



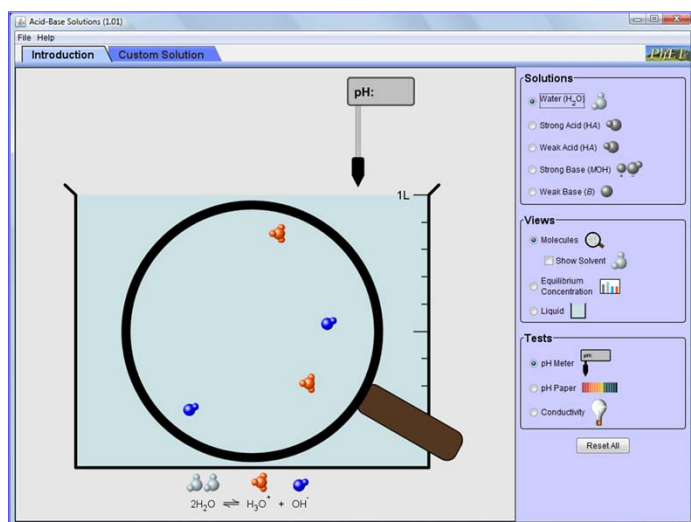
## Acid and Base Solutions

The screenshot shows the PhET simulation window titled "Acid-Base Solutions (1.01)". The interface includes a menu bar with "File" and "Help", and two tabs: "Introduction" and "Custom Solution". The main area features a 1L beaker containing a light blue liquid. A magnifying glass is positioned over the liquid, showing a detailed view of water molecules (two white spheres and one red sphere) and their dissociation into hydronium ions (three white spheres and one red sphere with a positive charge) and hydroxide ions (one white sphere and one red sphere with a negative charge). A "pH:" label with a downward arrow points to the liquid level. Below the beaker, the chemical equation  $2\text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{OH}^-$  is displayed with corresponding molecular models. On the right side, there are three control panels: "Solutions" with radio buttons for Water (H<sub>2</sub>O), Strong Acid (HA), Weak Acid (HA), Strong Base (MOH), and Weak Base (B); "Views" with radio buttons for Molecules, Equilibrium Concentration, and Liquid, and a checkbox for "Show Solvent"; and "Tests" with radio buttons for pH Meter, pH Paper, and Conductivity. A "Reset All" button is located at the bottom of the right panel.

# Activity Design Matters



## Open Exploratory Question



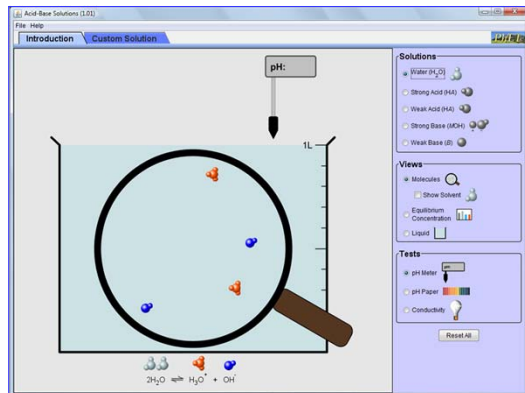
Use the sim to explore all the things that affect **pH**.

Discuss your ideas with a partner, and use the space below to record your ideas using words, pictures, and graphs.

# Activity Design Matters



## Explicit Directions



- Use the “Equilibrium Concentration” view to record the concentrations of [HA], [A-], and [H<sub>3</sub>O+] in the table below.
- Dip the pH meter into solution and record pH in the table below.
- Move the “Initial Concentration” slider to the right to 0.050 M and repeat steps 8 and 9. Complete the table for each strong acid concentration listed.

### **+** Strong Acids

Initial Acid Concentration (mol/L)	[HA] (mol/L)	[A-] (mol/L)	[H <sub>3</sub> O+] (mol/L)	pH
0.005 M				
0.050 M				
0.100 M				
1.00 M				

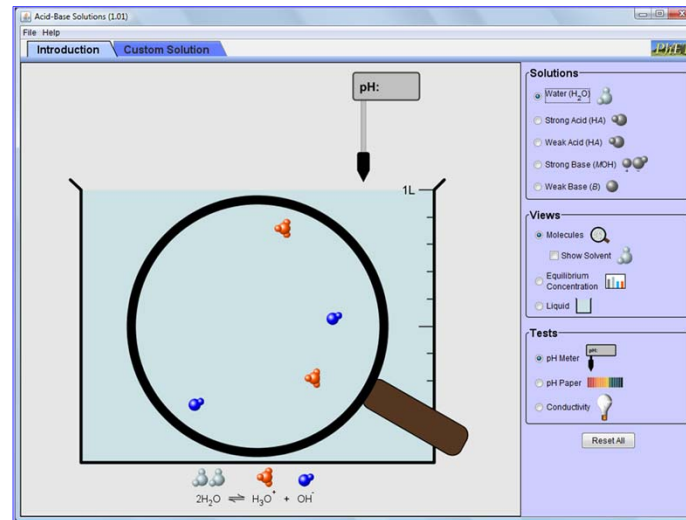
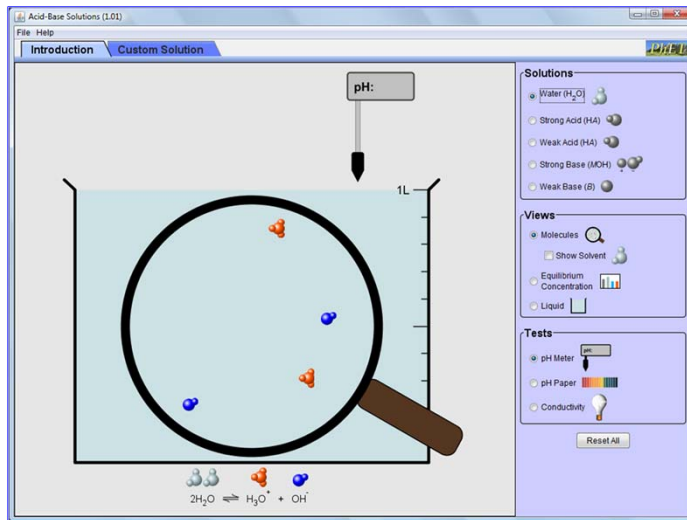
# Reflections?



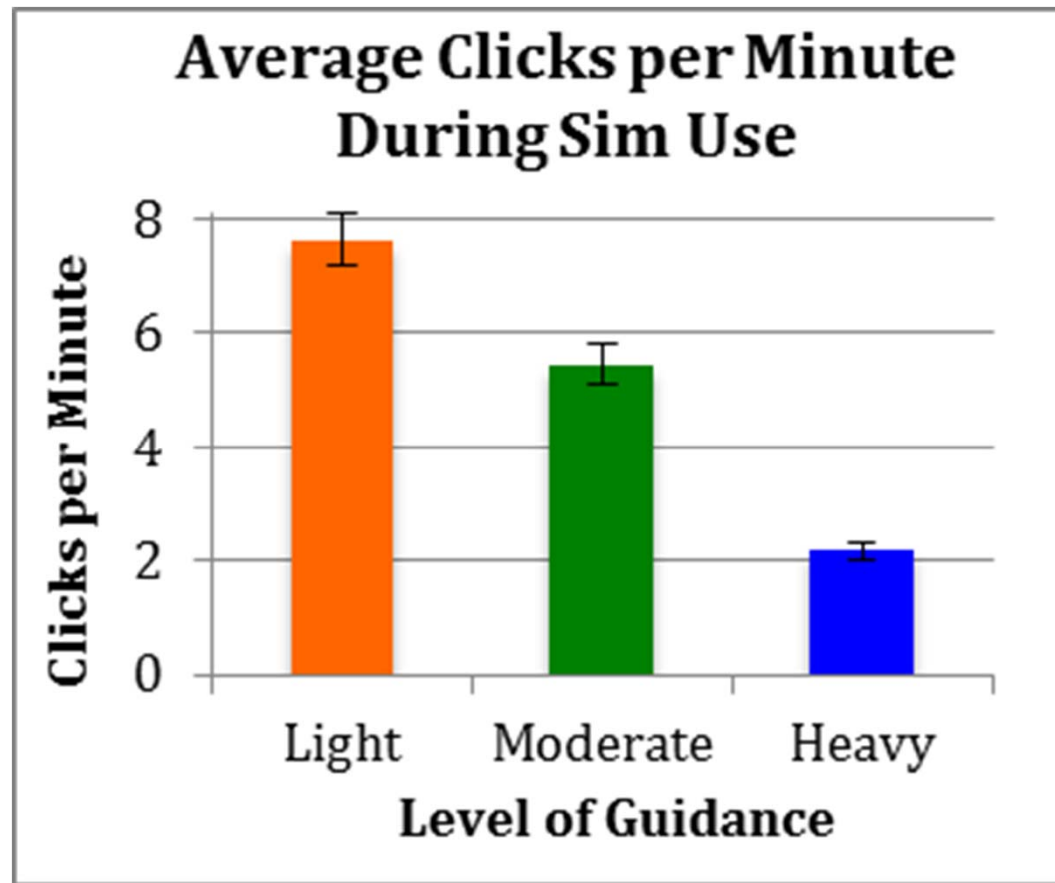
Open  
Exploratory  
Question

vs.

Explicit  
Directions



# A closer analysis

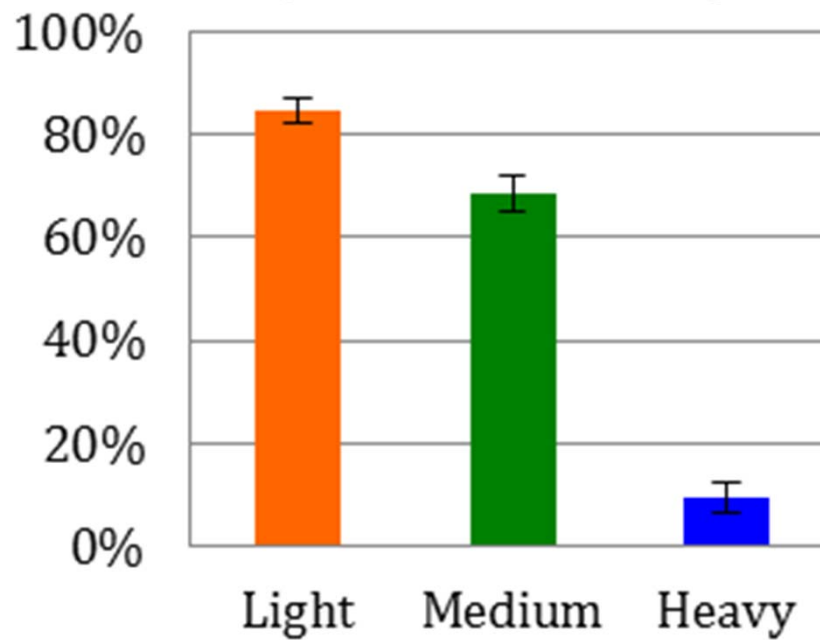




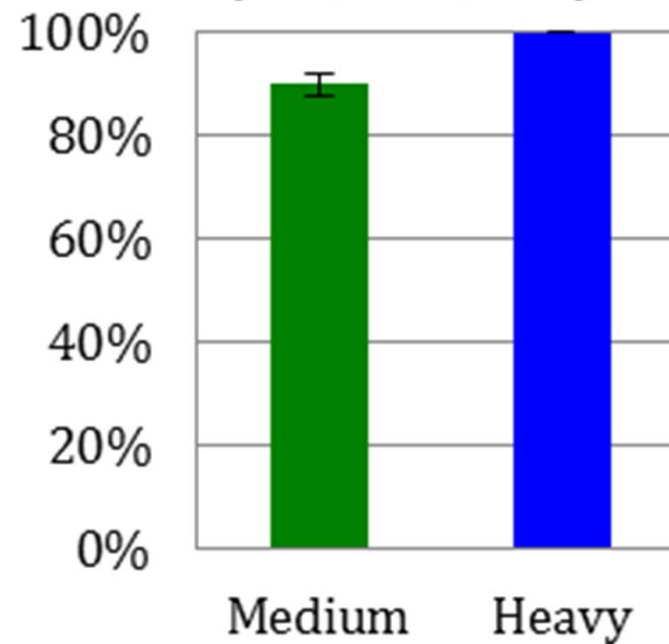
# A closer analysis



**Explored Features**  
(L=19, M=13, H=11)



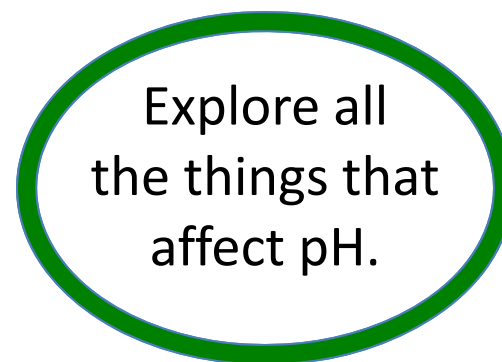
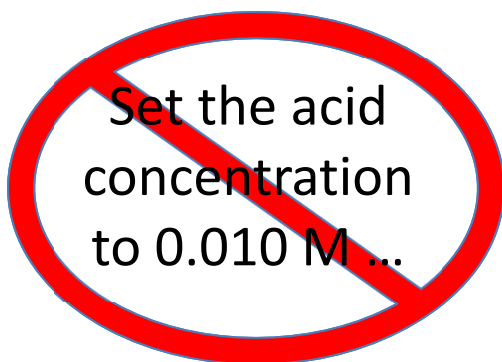
**Prompted Features**  
(L=0, M=6, H=8)



# Tips for Productive Inquiry

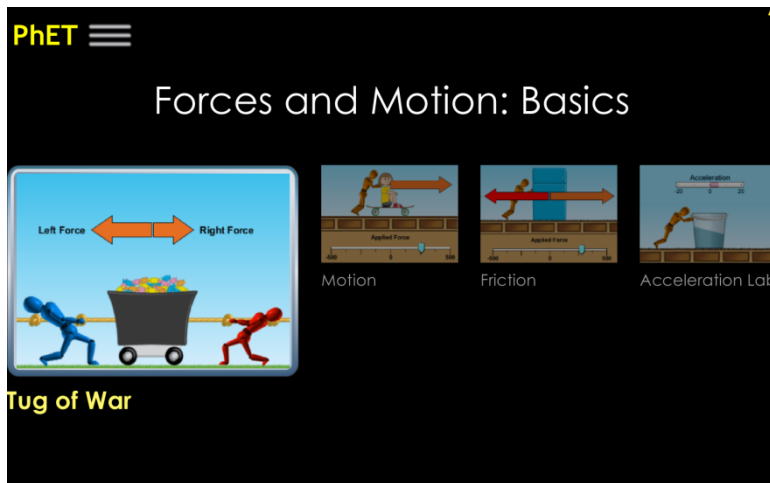


- Start with 5-10 minute open play
  - Establish student ownership of the sim
- Minimize or eliminate “sim-specific directions”
- Use open, investigative questions

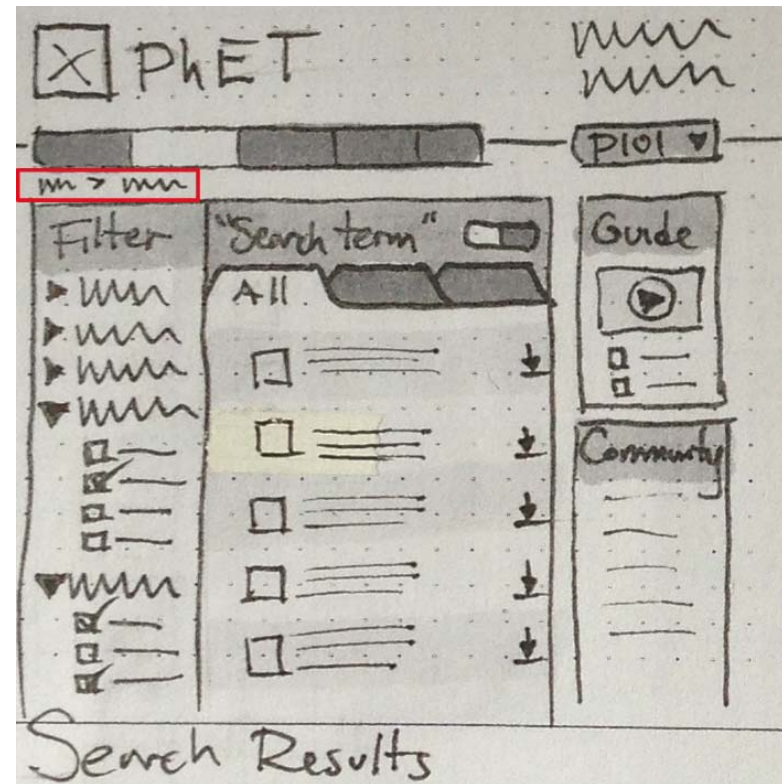


# What's next for PhET?

## HTML5/Touch/iPad



“Teach with PhET” site  
(coming fall 2013?)



# Stay in touch with social media

## A Big 'Thank-You' to Sandor

Thursday  
Mar 10  
2011

by PhET Team  
posted in  
[General](#),  
[Translations](#)



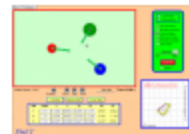
We want to give a 'shout-out' to Sandor Nagy from Budapest, Hungary. Sandor translated every simulation—all 101 of them—AND the website into Hungarian for us. He's also helped us improve our sims, by not only finding issues but also suggesting improvements. Thanks Sandor!



[1 Comment](#) | [Add a Comment](#)



### PhET Interactive Simulations



#### New Collision Lab Sim

[phet.colorado.edu](http://phet.colorado.edu)

Learn about collisions by playing air hockey! Set up your own experiments: vary the number of discs, masses and initial conditions. Is momentum conserved? Is kinetic energy conserved? Vary the elasticity and see what happens.

February 25 at 2:19pm · Like · Comment · Share

6 people like this.



**Meredith Wesolowski** I wanted to thank you all for providing these excellent simulations to the broader public. I use them regularly as part of lecture with my honors general chemistry students at U. Delaware. Students have even mentioned how much they like them on my course evaluations! :)

February 27 at 12:50pm · Like

Write a comment...

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# How can you contribute?

**For Teachers** > **Submit an Activity**

**Send us your ideas  
for new sims!**

**Report  
bugs**

Email: [phethelp@colorado.edu](mailto:phethelp@colorado.edu)

# How can PhET be *free*?

(a \$8 million resource)



NSF

THE WILLIAM AND FLORA HEWLETT FOUNDATION

Hewlett Foundation

The O'Donnell Foundation



Collaborative agreement  
with King Saud University



University of Colorado



Carl Wieman and  
Sarah Gilbert



- Suite of interactive simulations (>125)
- Physics, chemistry, math  
Expanding into biology, earth science
- Research-based and user-tested
- **Free!** Online or downloadable (~300 MB)
- Easy to use and incorporate in class

<http://phet.colorado.edu>