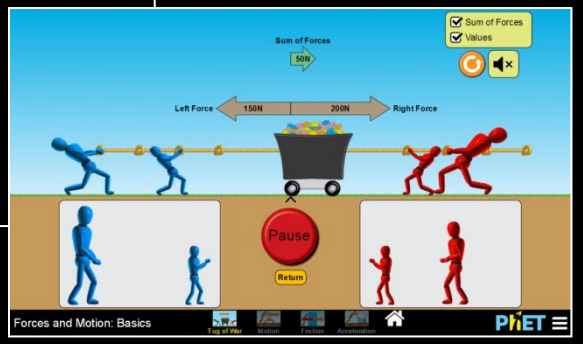
PhET INTERACTIVE SIMULATIONS



PhET Interactive Simulations for Active Learning in STEM

Yuen-ying Carpenter

University of Colorado Boulder

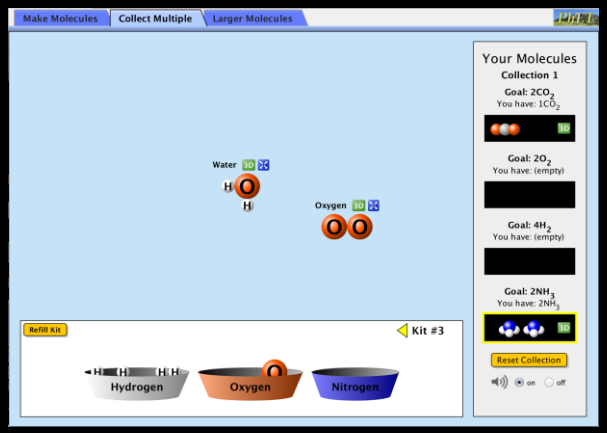
Goals for today

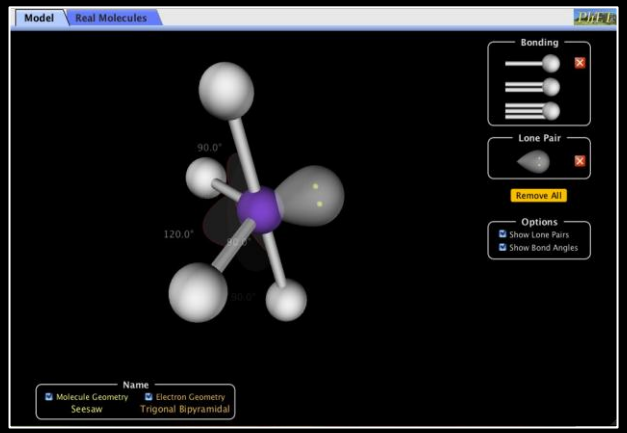
- Describe how certain **simulation features** facilitate student learning and exploration
- Describe the **range of sim uses**, focusing on types of learning goals and facilitation
- Outline **best practices** that leverage sim features in classroom and for the creation of **sim materials and activities**

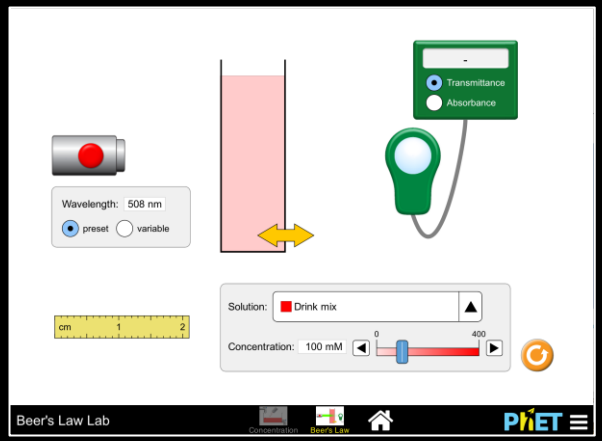
PhET INTERACTIVE SIMULATIONS

What is PhET?

130 free interactive science & math simulations







Elementary → *College*

PhET INTERACTIVE SIMULATIONS

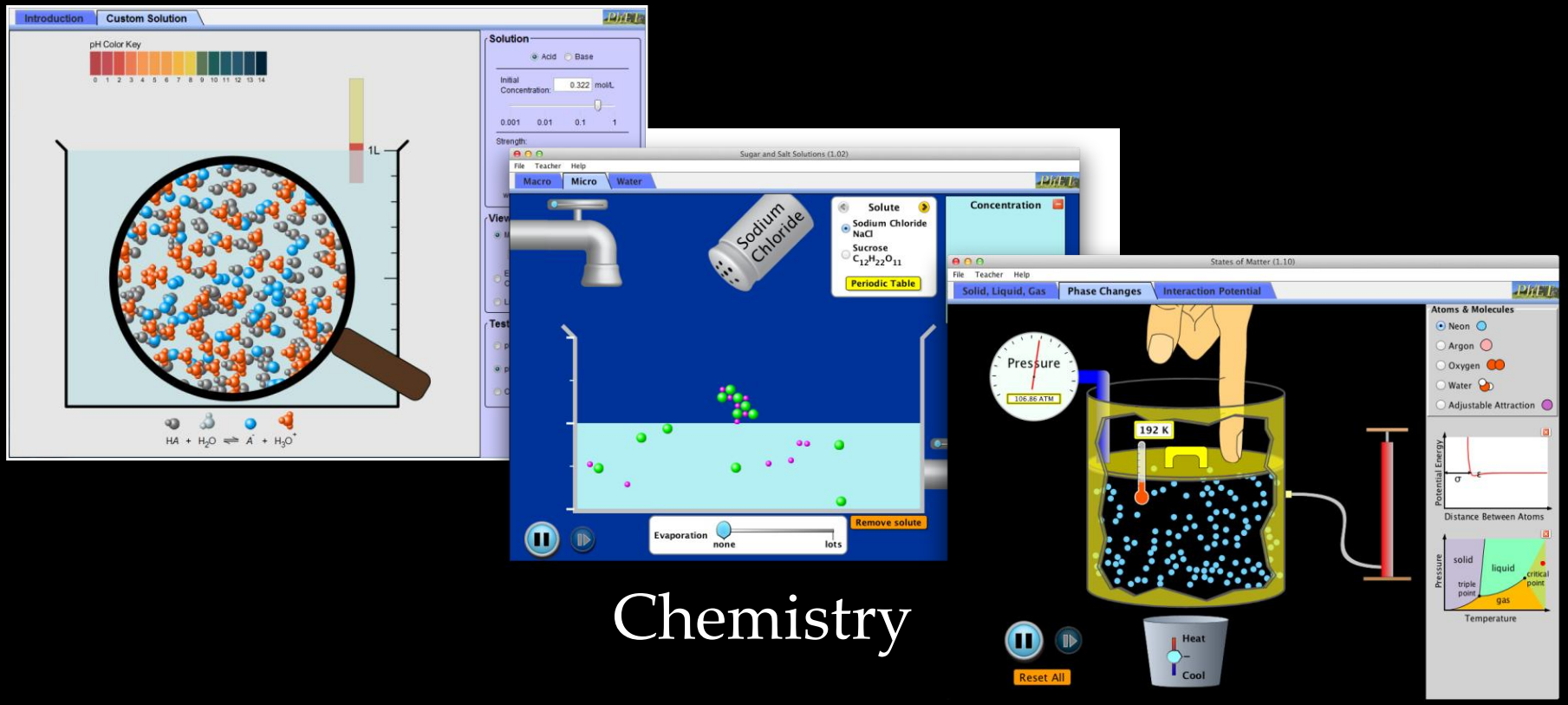
The Evolution of the **PhET Interactive Simulations Project**

PhET INTERACTIVE SIMULATIONS

Physics

2000 2002 2004 2006 2008 2010 2012

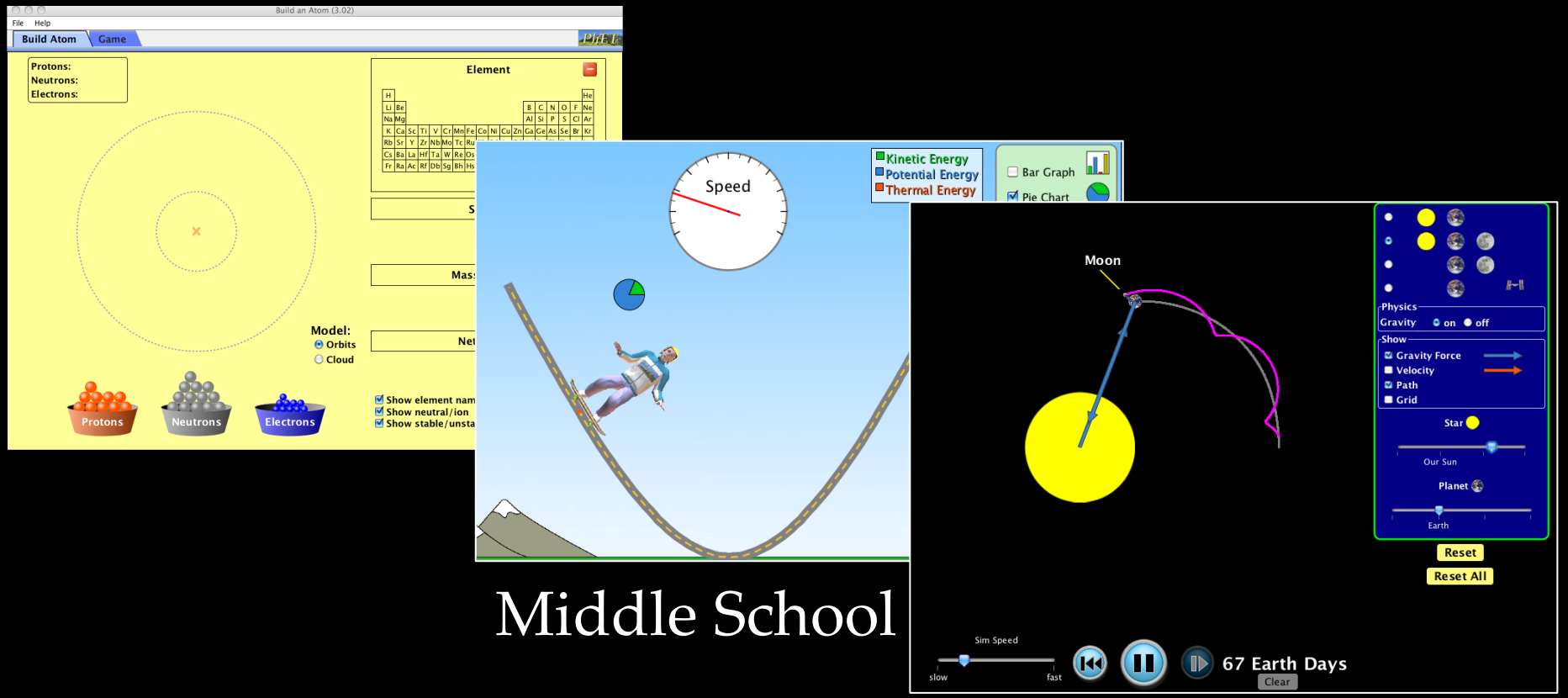
PhET INTERACTIVE SIMULATIONS



Chemistry

2000 2002 2004 2006 2008 2010 2012

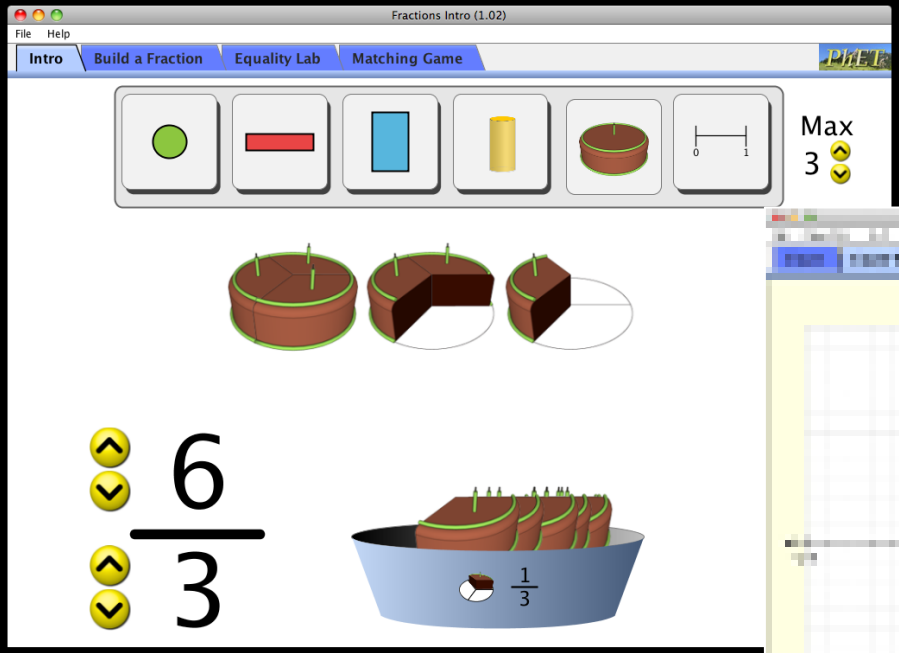
PhET INTERACTIVE SIMULATIONS

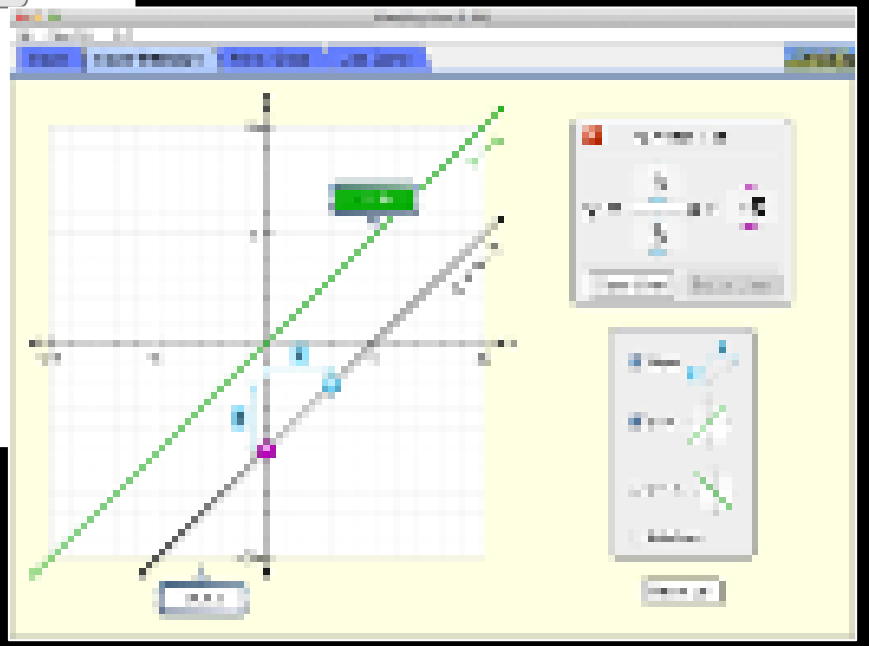


Middle School

2000 2002 2004 2006 2008 2010 2012

PhET INTERACTIVE SIMULATIONS



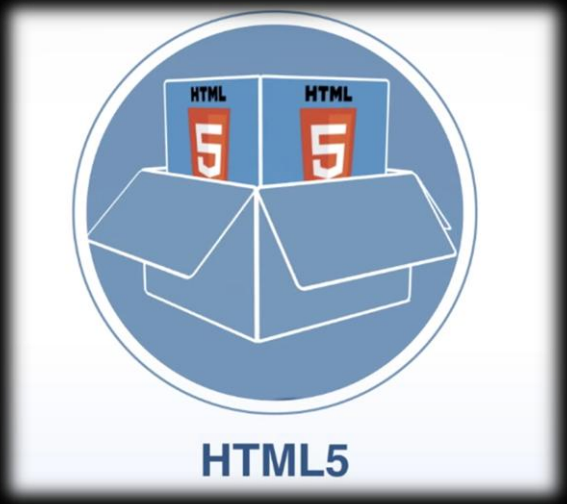


Mathematics

2000 2002 2004 2006 2008 2010 2012

PhET INTERACTIVE SIMULATIONS

Next Generation PhET Sims



=

Inclusive Features: Sonification, Captioning, Haptic Devices

2000 2002 2004 2006 2008 2010 2012

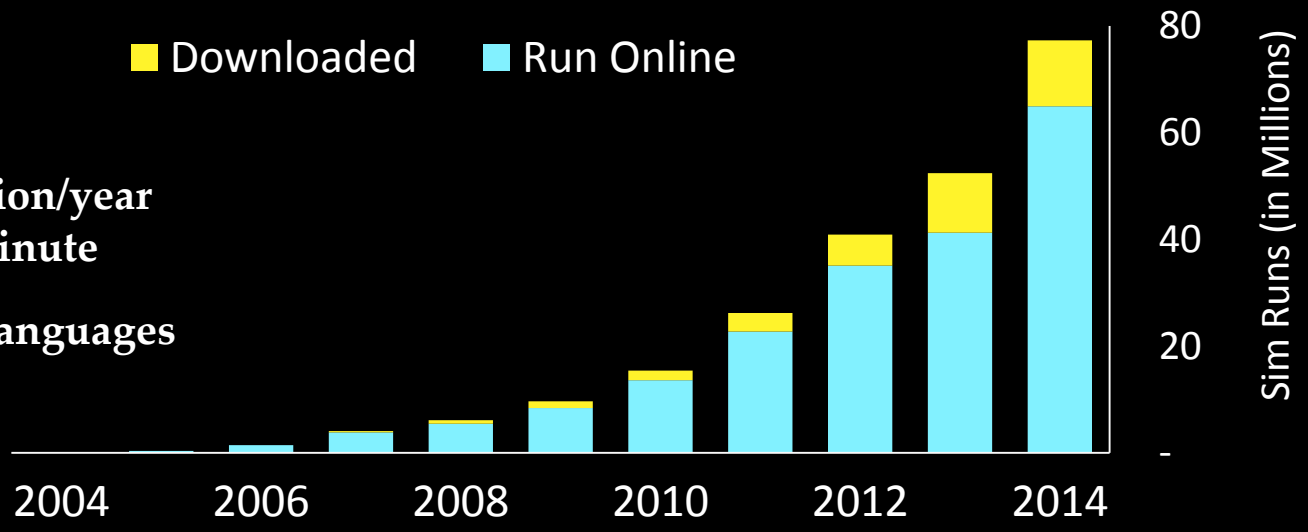
PhET INTERACTIVE SIMULATIONS

Who uses PhET?

- Teachers and students worldwide
  - Designed and researched to support productive inquiry-based learning

Currently 75 million/year
> 100 uses/minute

Translated in 77 languages



PhET INTERACTIVE SIMULATIONS

Our goals

PhET Accessibility Goals

- Freely available (online/offline)
- Flexible for use across diverse environments

PhET Pedagogical Goals:

Support students to…

- Engage in scientific exploration
- Take ownership of the learning experience
- Develop conceptual understanding
- Make connections to everyday life
- View science as accessible and enjoyable

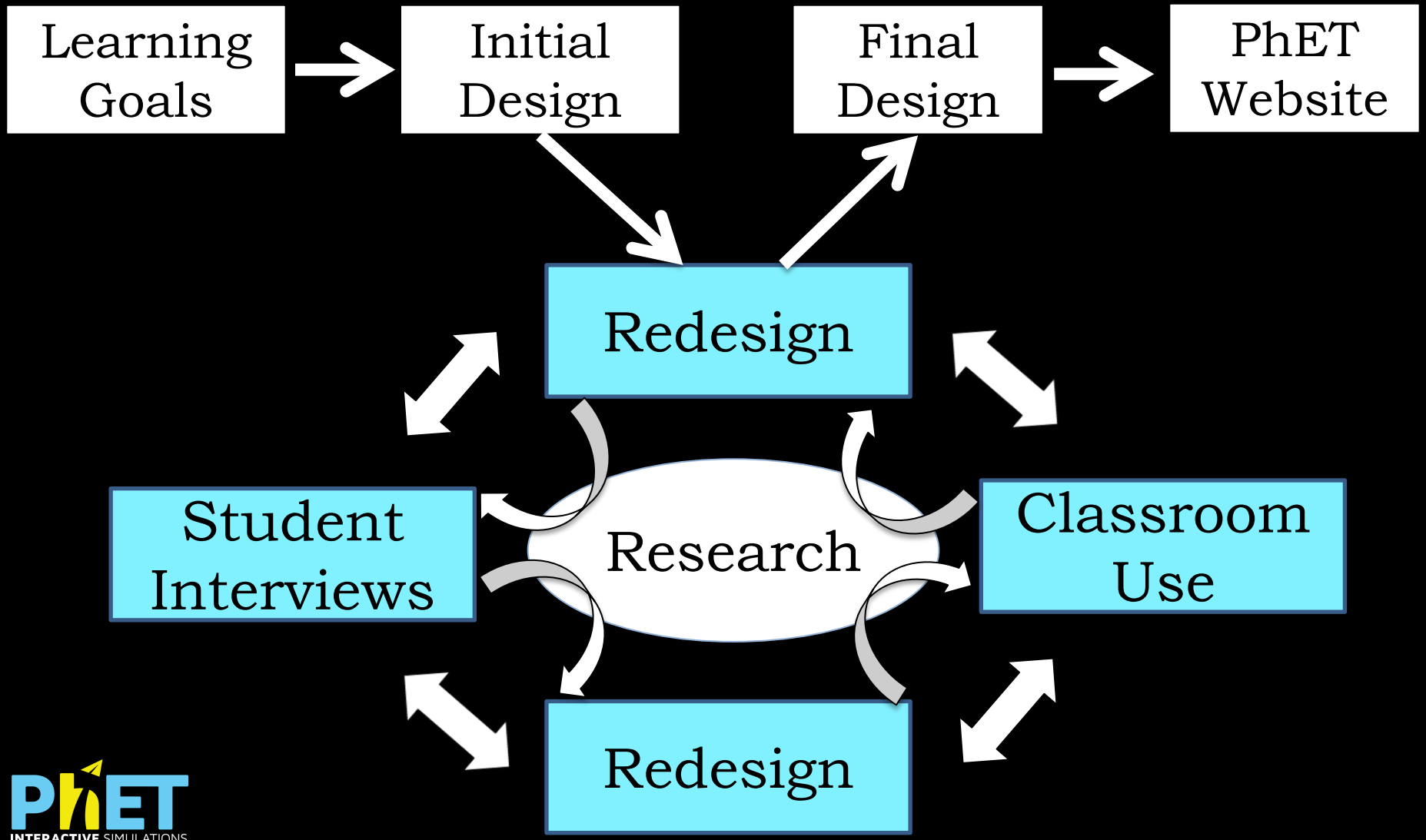
} Enable More Student Centered Pedagogies

PhET INTERACTIVE SIMULATIONS

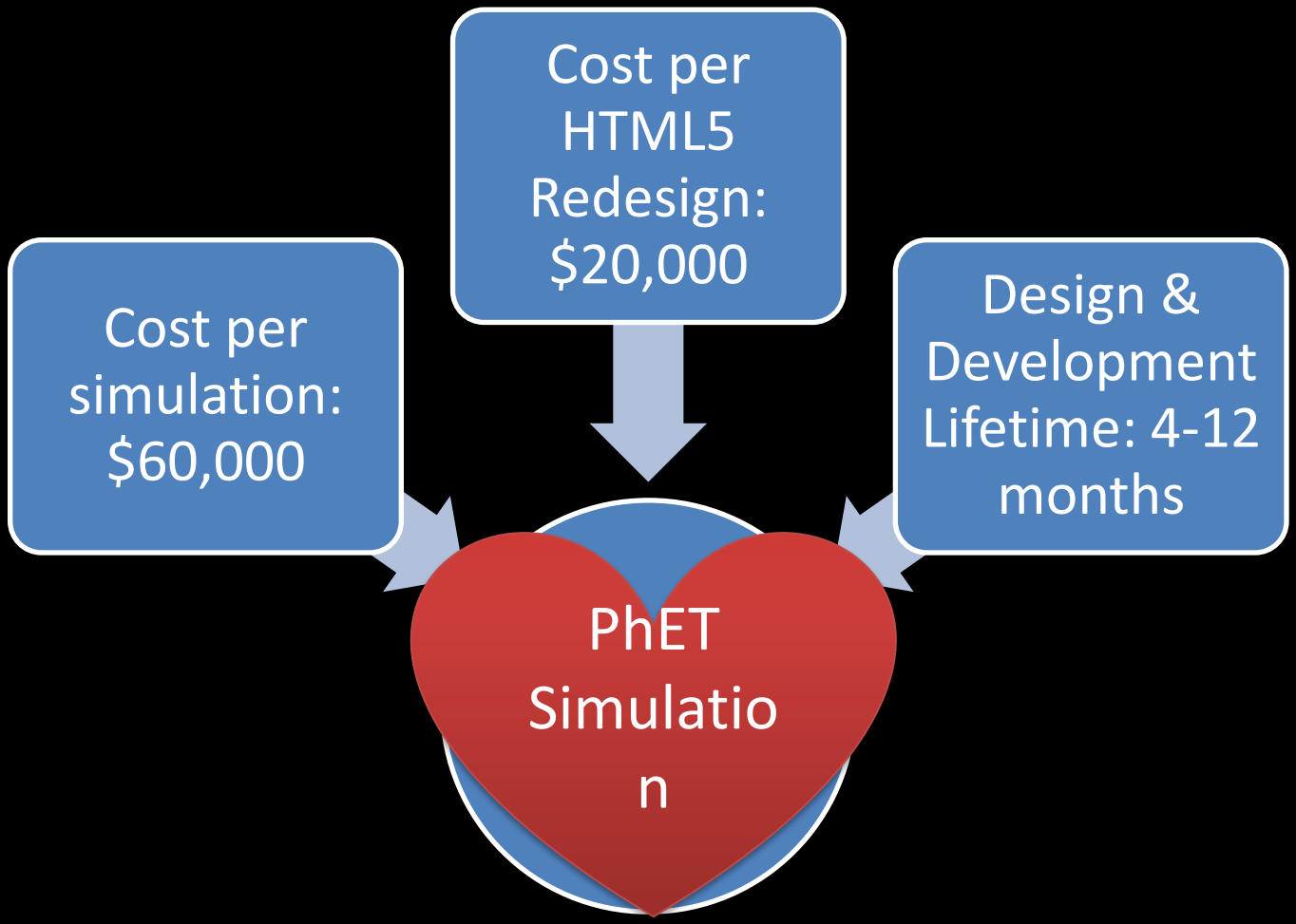
Time to explore!

- http://phet.colorado.edu

Development Cycle



PhET INTERACTIVE SIMULATIONS



PhET INTERACTIVE SIMULATIONS

Research-Based Design

- Extensive design feedback on each sim

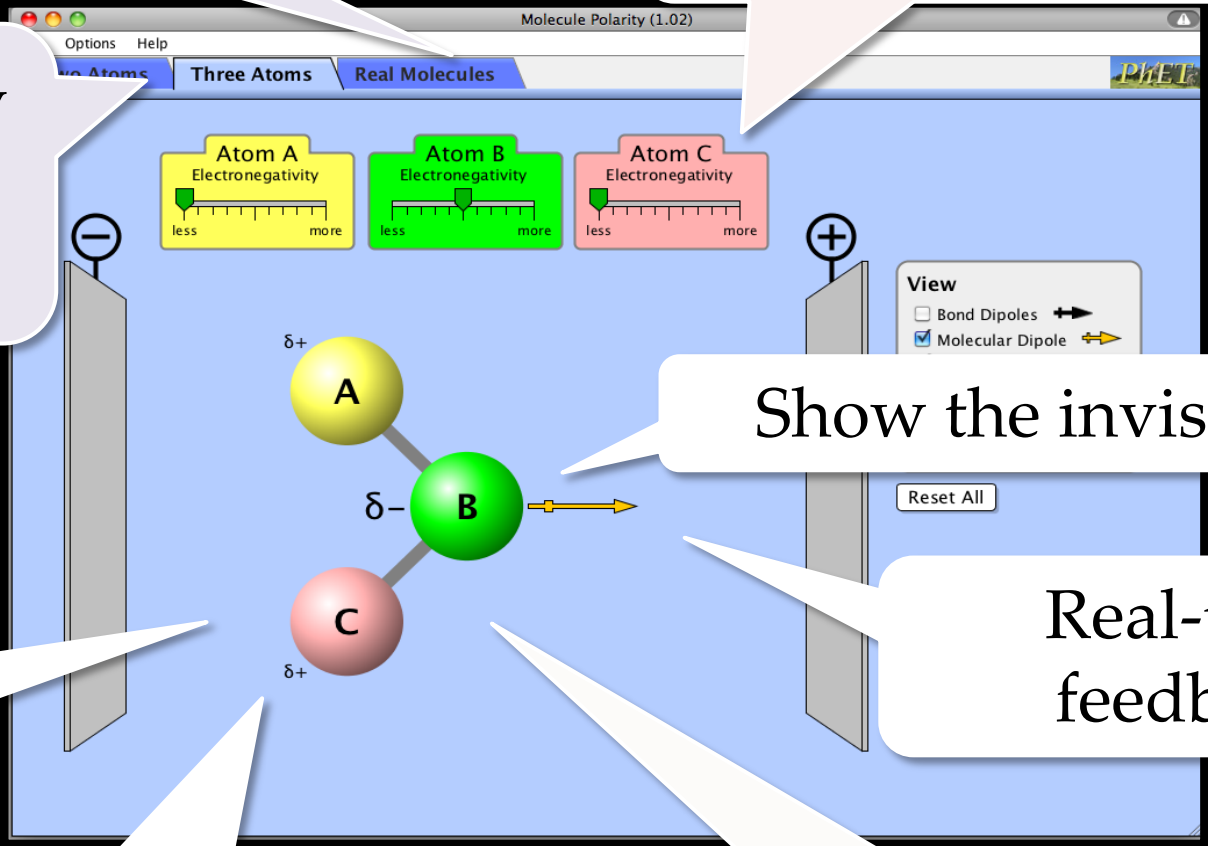
- Research over many sims shows what works
  - *Affordances* What actions are cued by the design?
  - *Constraints* What limitations focus or frame attention?

PhET INTERACTIVE SIMULATIONS

Real-world connections

Highly interactive, Game-like

Implicitly scaffold inquiry



Show the invisible

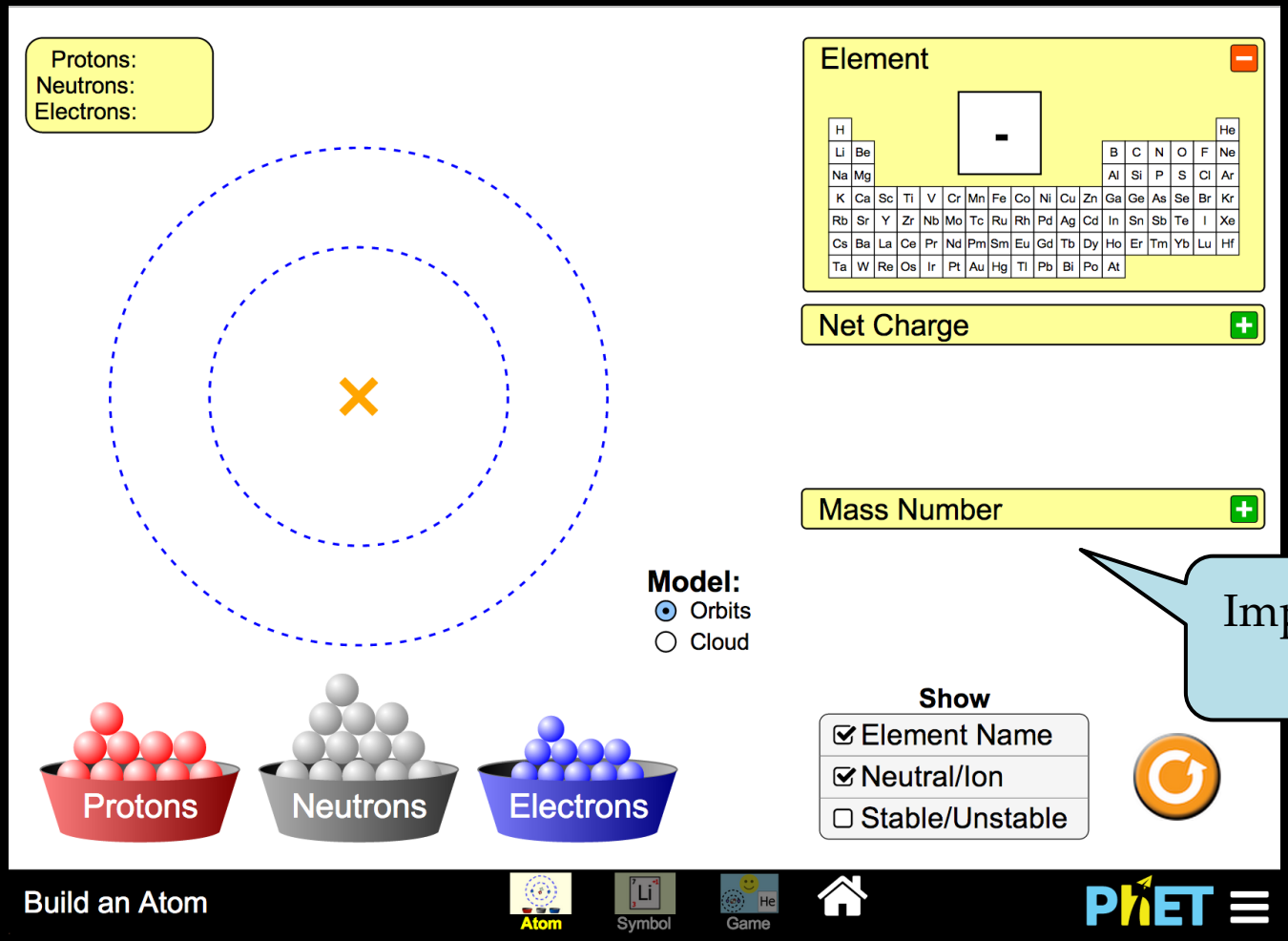
Intuitive interface

Real-time feedback

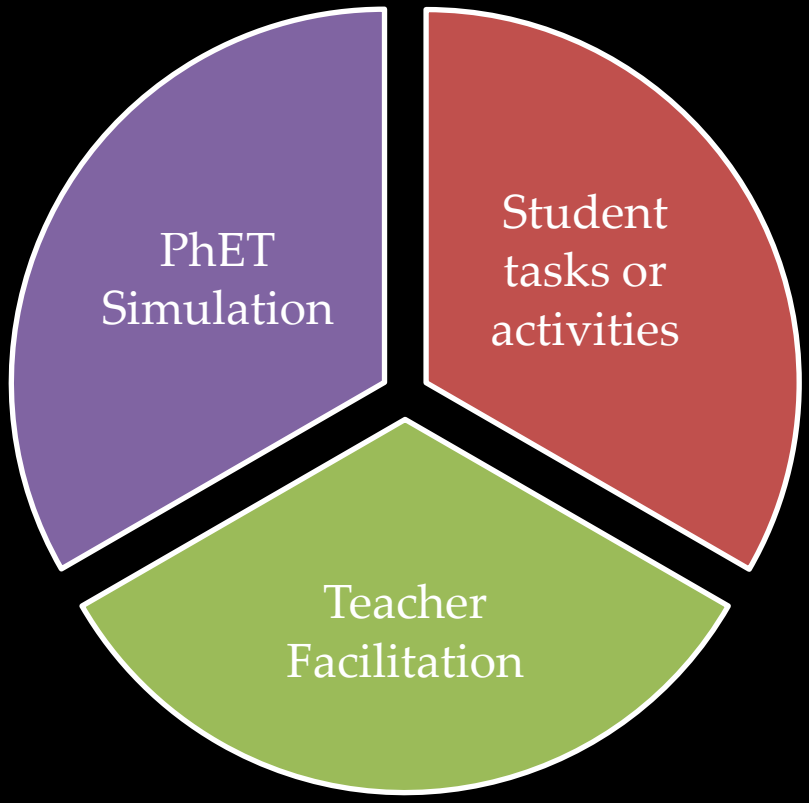
Multiple representations

Allow difficult or impossible actions

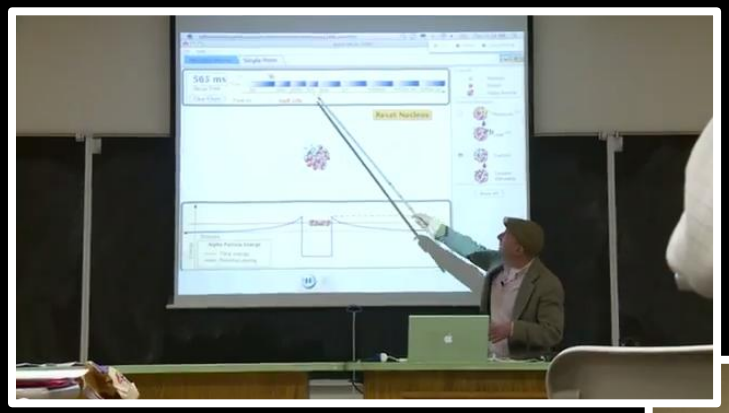
PhET INTERACTIVE SIMULATIONS


Protons:
Neutrons:
Electrons:
Element
Net Charge
Mass Number
Model:
Orbits
Cloud
Protons
Neutrons
Electrons
Show
Element Name
Neutral/Ion
Stable/Unstable
Implicitly scaffold inquiry
Build an Atom
Atom
Symbol
Game

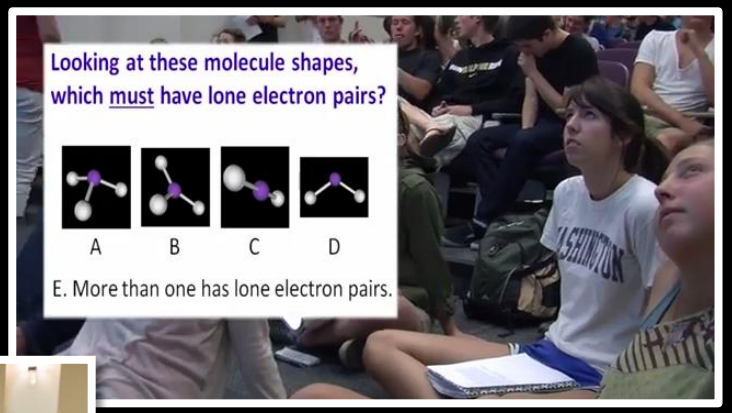
PhET sims don't exist in isolation



Classroom Contexts



Lecture Demo



Clickers

Guided-Inquiry Activity

PhET INTERACTIVE SIMULATIONS

Learning Contexts

e.g. Lecture or lab demos
+ discussion
+ clicker Qs

Group / individual work

e.g.
- In-class guided-inquiry
- Recitation / Tutorial
- Lab or pre-lab activities
- Homework

PhET INTERACTIVE SIMULATIONS

Guiding Questions for Sim Use

Based on how you use the sim…

1. What do students think they should be doing?

2. Are you leveraging the sim design for…

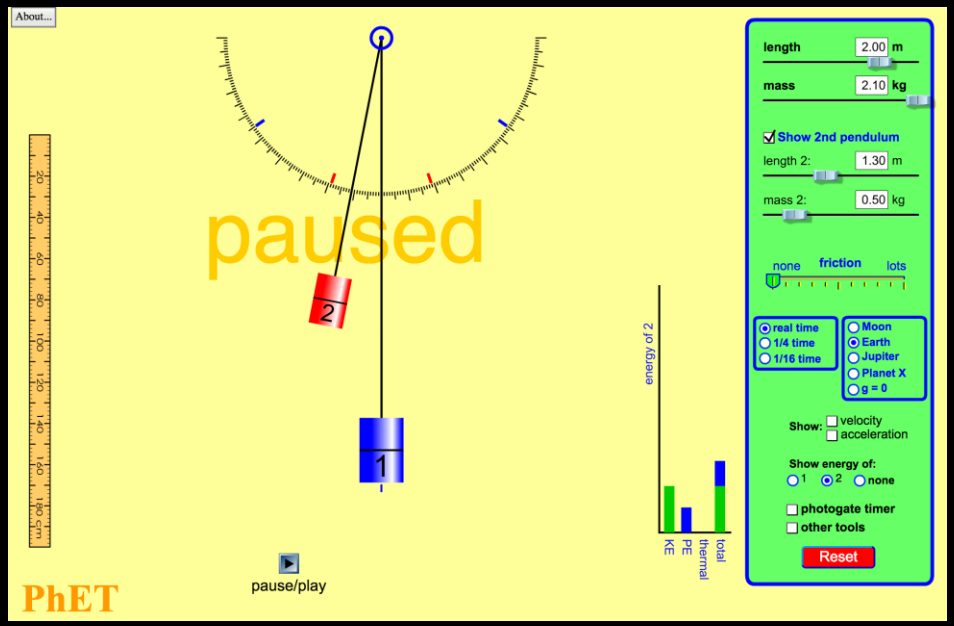
Student learning
Concepts
Practices

Student motivation
Interest
Ownership
Sense of progress

PhET INTERACTIVE SIMULATIONS

Goals

- 2-3 focused learning goals per activity
- Consider whether those goals target practices/skills or concepts (or both!)



Framing

Instructor-led

- Open-ended guiding question or an initial prediction
- Basic orientation to the relevant sim features
  - what are we looking at
  - what can we alter

Student-led

- Allow for 5-10 min of open exploration
  - Student ownership
  - Orients students towards exploration and sense-making

PhET INTERACTIVE SIMULATIONS

Guidance

Student-led

C LENSES

C lenses (this designation does not appear on the lenses) can be used with the 500C, 500C/M, 500EL, 500EL/M, 2000FC, and 2000FC/M (see also the Instruction Manual for the 2000FC/M).

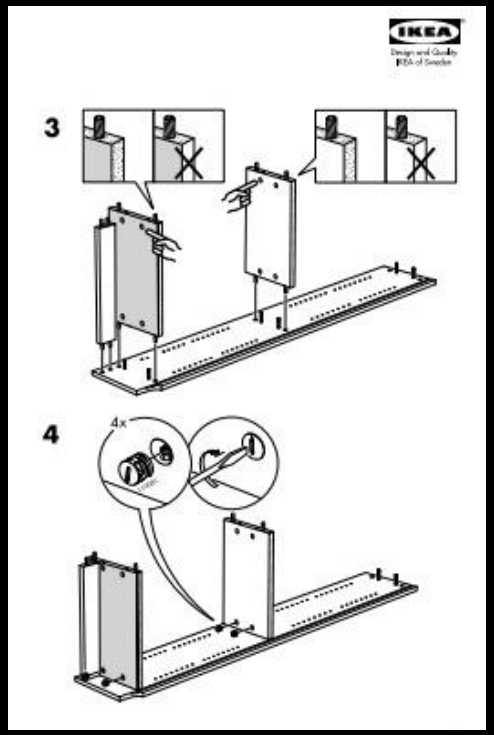
They all feature a built-in Synchro-Compur leaf shutter, an automatic diaphragm, an exposure value scale, automatic depth-of-field indicators, M and X flash synchronization at all speeds, and a self-timer V. The C lenses attach to the camera via a bayonet mount.

Diaphragm (Fig. 62)

The aperture ring (13) and shutter speed ring (14) are cross-coupled. Both rings are operated with the grip ring (15). For independent setting of the aperture or shutter speed, press the cross-coupling release (4) to the rear and rotate the ring until the desired value is opposite the central index (12). The lens is normally focused wide open. The diaphragm automatically closes down to the working f/stop at the moment of exposure. Press the depth-of-field preview catch (5) to check out the available depth of field. This will stop the lens down to the working aperture. The diaphragm is reopened to the maximum aperture by turning the aperture ring (13) to the maximum aperture or tripping the shutter (with a detached film magazine) and winding the camera.

Shutter speeds (Figs 63—64)

The shutter speed ring (14) has three different scales with white (black on chrome finish lenses), green, and red numerals. Only the white (black) numerals and B can be set opposite the central index (12).



PhET Computer Simulation Activity: Isotopes and Atomic Mass

10. Lithium (Li) has only two stable isotopes. Use the simulation to determine the following.
    a. Atomic mass of lithium-6 = _____ amu
    b. Atomic mass of lithium-7 = _____ amu
    c. Complete the following table using the simulation:

	Number of $^{6}_{3}Li$ atoms	Number of $^{7}_{3}Li$ atoms	% composition of $^{6}_{3}Li$ in sample	% composition of $^{7}_{3}Li$ in sample	Average atomic mass of sample (amu)
Sample 1	3	2			
Sample 2	6	4			

    c. What do you notice if you compare the average atomic mass of the two samples? Explain.

    d. Is the average atomic mass you just determined closer to the mass of lithium-6 or lithium-7? Explain.

11. Without the simulation, write out a method to calculate the average atomic mass of a mixture of lithium-6 and lithium-7 atoms if you were given the **number of atoms** of each.

12. Without the simulation, write out a method to calculate the average atomic mass of a mixture of lithium-6 and lithium-7 atoms if you were given the **percent composition** of the mixture.

Treat student activities as structured guidance not instructions

PhET INTERACTIVE SIMULATIONS

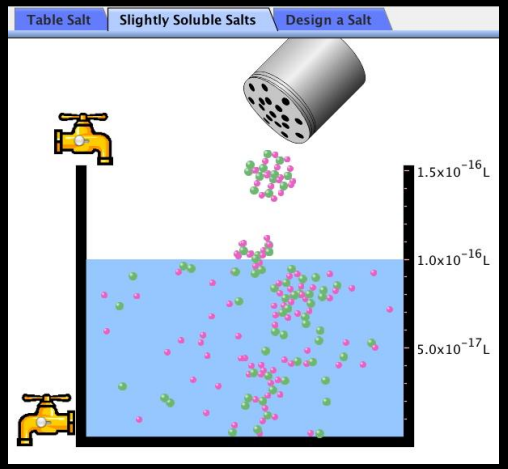
Prompts

Add 100 silver bromide pairs to the water.

How many silver and bromide ions dissolve in the water?

Repeat this for all salts.

Task completion + Answer making



Investigate different salts.

What features do salts have in common, and how do salts differ from each other?

Sense making

PhET INTERACTIVE SIMULATIONS

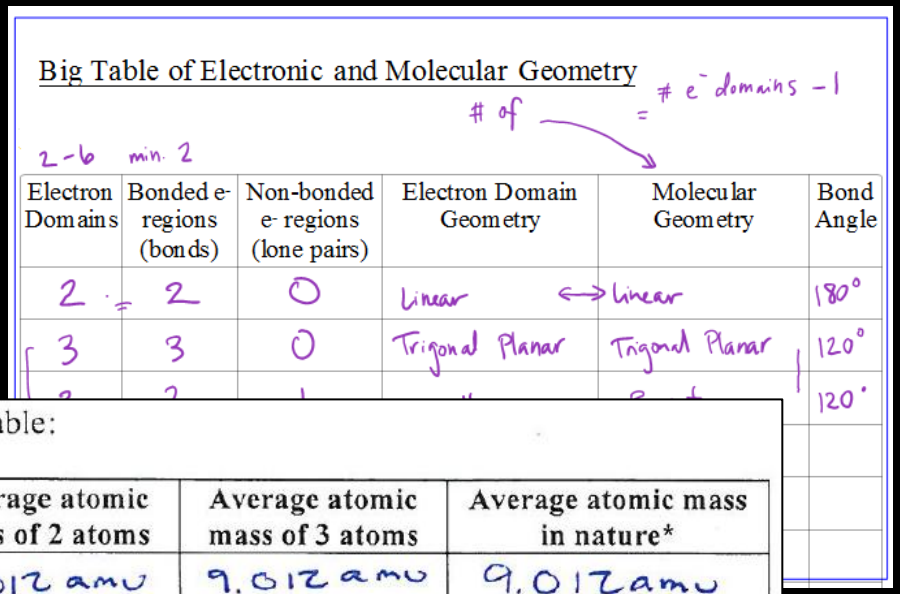
Prompts

1. Use minimal words
2. Focus on sense-making and reasoning (not just on answers)
3. Use sim features and examples
4. Ask students to reason with both words *and* diagrams
5. Help students monitor understanding

PhET INTERACTIVE SIMULATIONS

Tables

- Use tables to cue and organize without need for explicit directions
  - Comparisons
  - Effects of variables
  - Classifications



Big Table of Electronic and Molecular Geometry

of = # e⁻ domains − 1

2–6 min. 2

Electron Domains	Bonded e⁻ regions (bonds)	Non-bonded e⁻ regions (lone pairs)	Electron Domain Geometry	Molecular Geometry	Bond Angle
2	2	0	Linear	Linear	180°
3	3	0	Trigonal Planar	Trigonal Planar	120°
					120°

8. Use the simulation to complete the following table:

Element	Mass of 1 atom	Average atomic mass of 2 atoms	Average atomic mass of 3 atoms	Average atomic mass in nature*
Beryllium (Be)	9.012amu	9.012 amu	9.012 amu	9.012amu
Fluorine (F)	18.998 amu	18.998amu	18.998amu	18.998 amu

* *The average atomic mass in nature can be found in the simulation OR on a periodic table*

9. Why are all the values in each row of the table above the same?

PhET INTERACTIVE SIMULATIONS

Integration & Follow-through

- More consistent, integrated usage encourages students to engage with the sim

Instructor-led

- Screenshots in lecture summaries, clicker Q
- Using the sim to answer student Q

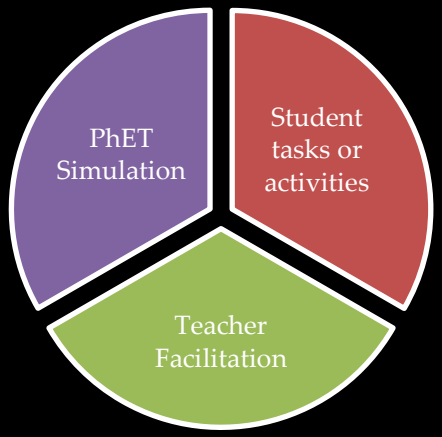
Student-led

- Use available sim examples so that students use the sim for feedback and communication

PhET INTERACTIVE SIMULATIONS

Summary

Goals **Framing** **Guidance** **Integration**

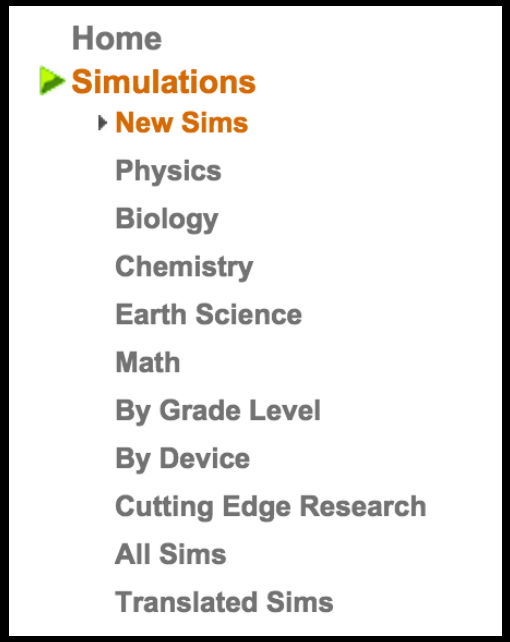


- Facilitation and activity design influence student perceptions with simulations
- Focus on engaging students in sense-making

PhET INTERACTIVE SIMULATIONS

How can I get started?

- Get to know the sims



- Website teaching resources
  - **For Teachers** (videos, strategies, tips, etc.)
  - Activities

PhET INTERACTIVE SIMULATIONS

How to Get Involved

http://phet.colorado.edu

- ✓Donate
- ✓Share activities, clicker questions, or demo materials
- ✓Follow:

PhET INTERACTIVE SIMULATIONS

Acknowledgments

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The William and Flora Hewlett Foundation

King Saud University

O'Donnell Foundation
Devoted to Excellence in Education