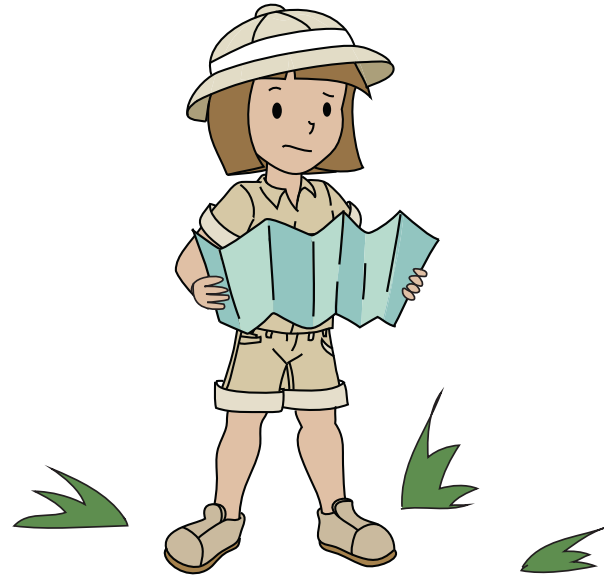


[HTTP:PHET.COLORADO.EDU](http://phet.colorado.edu)

**AMANDA MCGARRY & PHET TEAM**

NCTM ANNUAL CONFERENCE  
APRIL 8, 2017

# Actively Engage Students in Content and Practices with Interactive Simulations



## Goals

What are interactive simulations?

How can I use sims in my classroom?

What does a sim-based lesson look like?

What new sims can I look forward to?

What are  
sims?

Interactive simulations...

Are engaging

Are dynamic

Are intuitive

Link representations

Connect to the real world

What are  
sims?



130+ sims for Physics, Chemistry,  
Math, Biology, Earth Science

K-12 and college

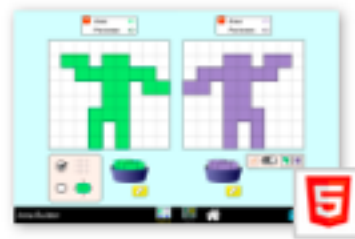
Grant-funded



Translated into 78 languages

Can be run offline

What are  
sims?



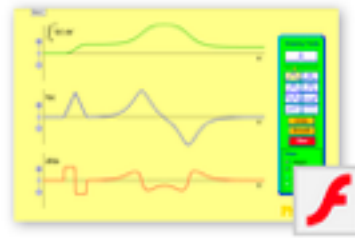
Area Builder



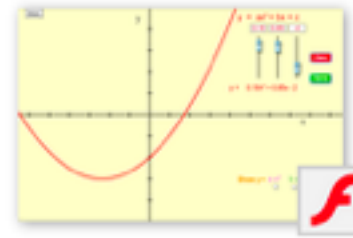
Arithmetic



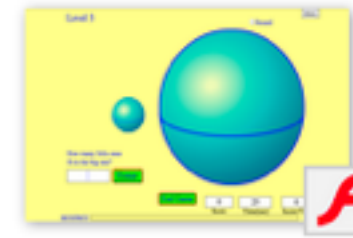
Build a Fraction



Calculus Grapher



Equation Grapher



Estimation



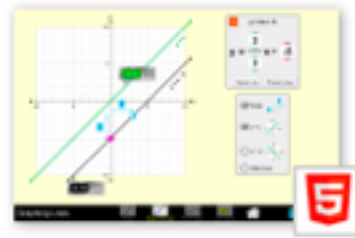
Fraction Matcher



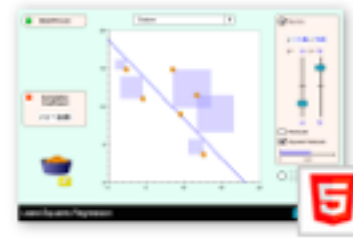
Fractions Intro



Function Builder



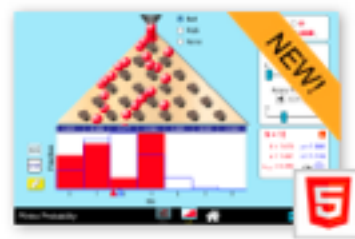
Graphing Lines



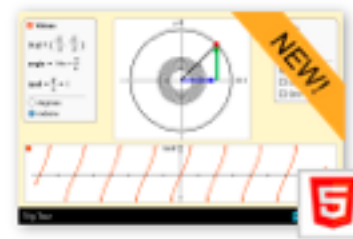
Least-Squares  
Regression



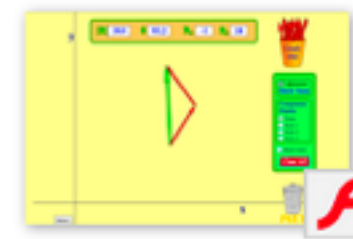
Make a Ten



Plinko Probability



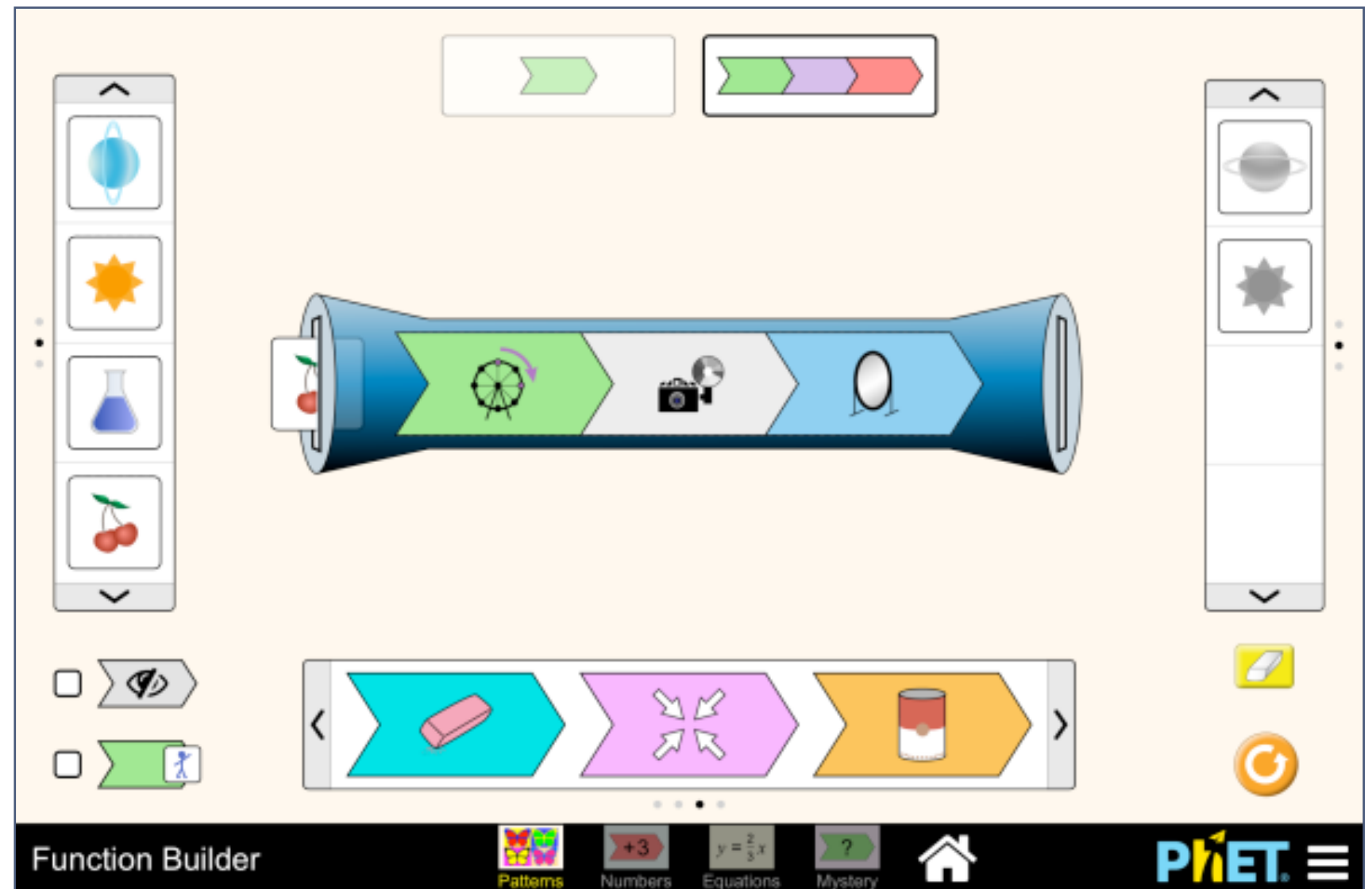
Trig Tour



Vector Addition

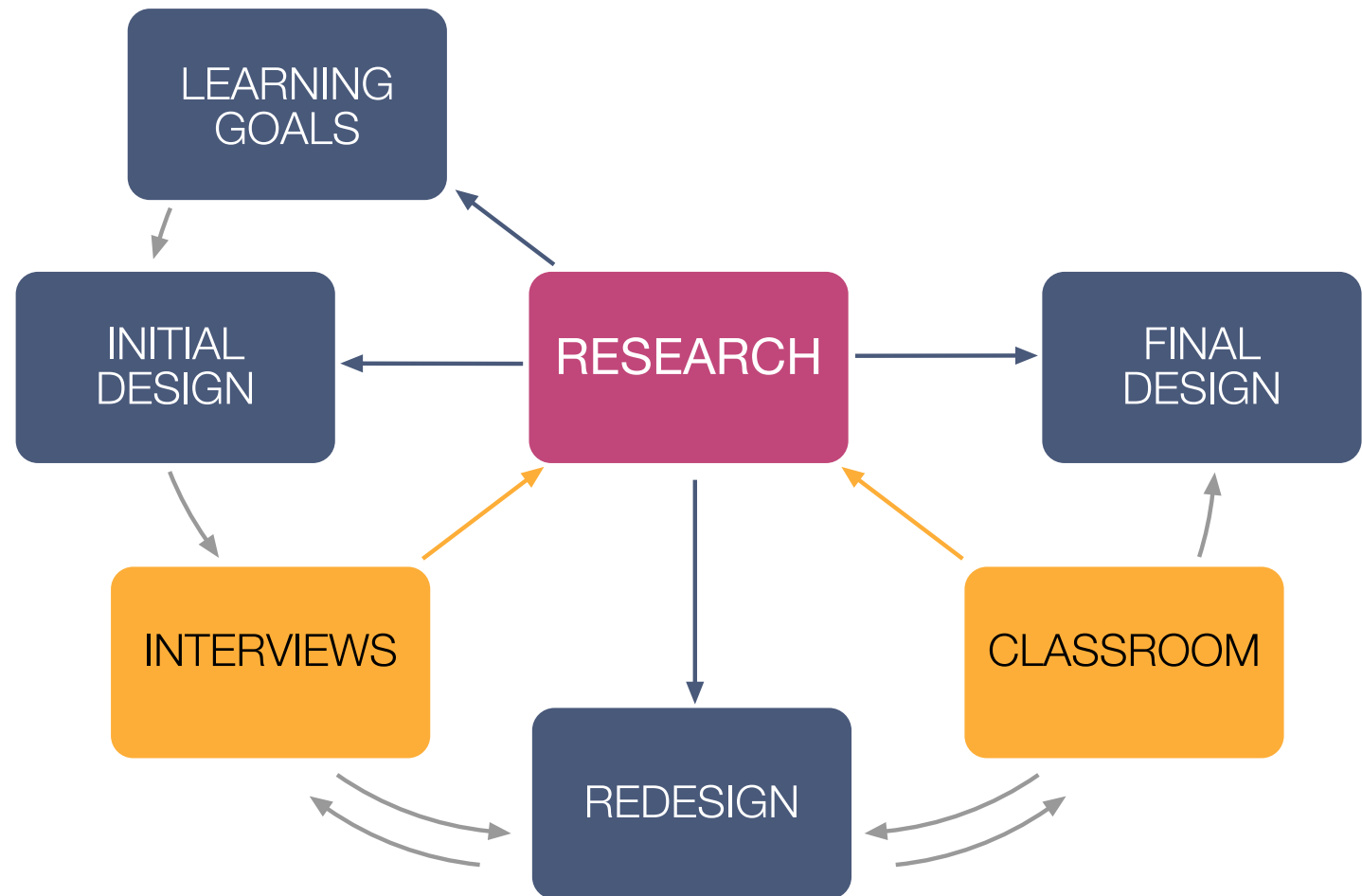
What are  
sims?

## Sim: Function Builder



# What are sims?

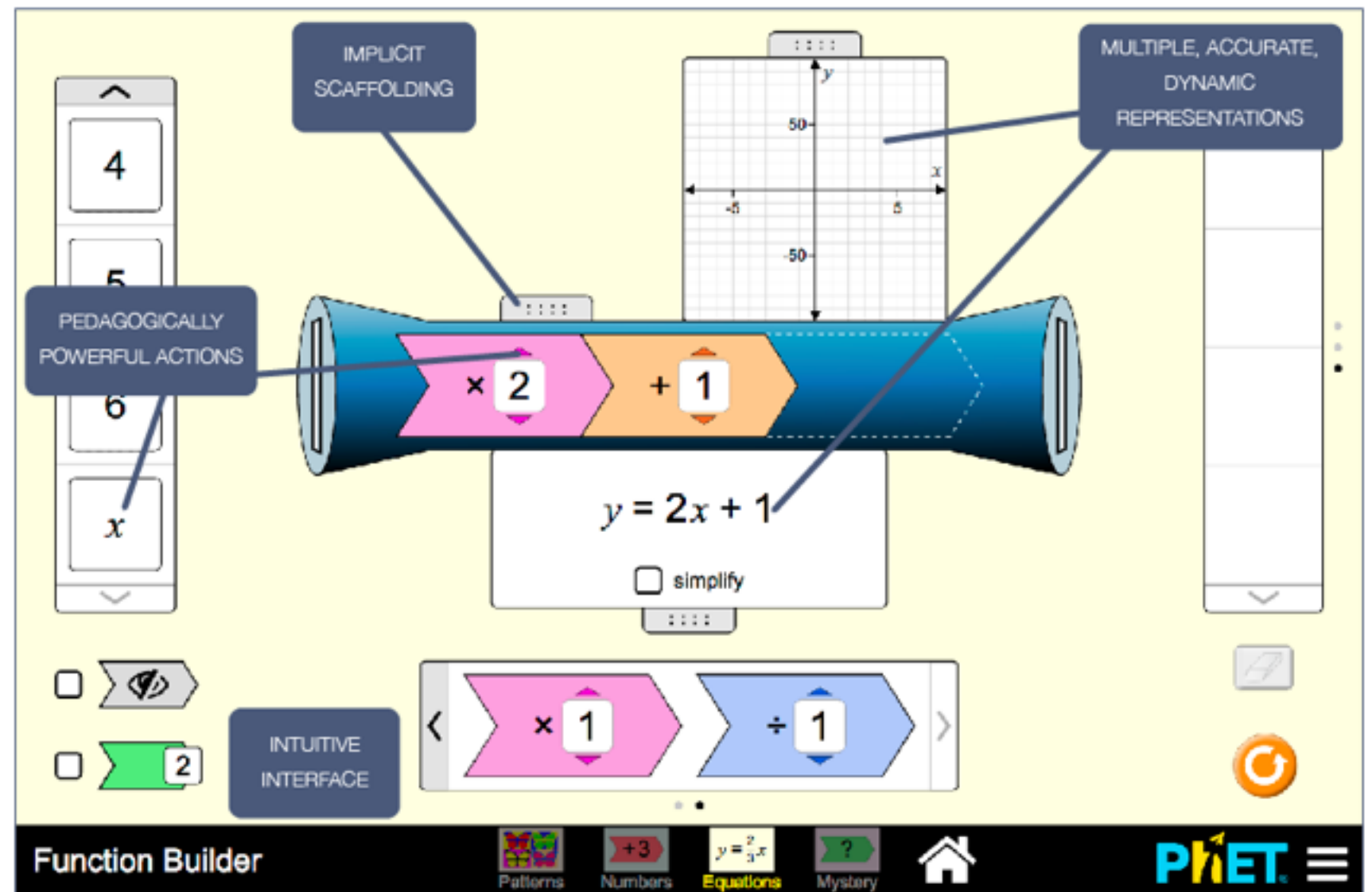
# Research-based design



[http://phet.colorado.edu/publications/phet\\_design\\_process.pdf](http://phet.colorado.edu/publications/phet_design_process.pdf)

What are  
sims?

# Productive Exploration



How can I  
use sims in  
my  
classroom?

## Sim: Expression Exchange



How can I  
use sims in  
my  
classroom?

CCSS.Math.Practice.MP2  
Reason abstractly and  
quantitatively.

CCSS.Math.Content.  
7.NS.A.1.b

## Demonstration

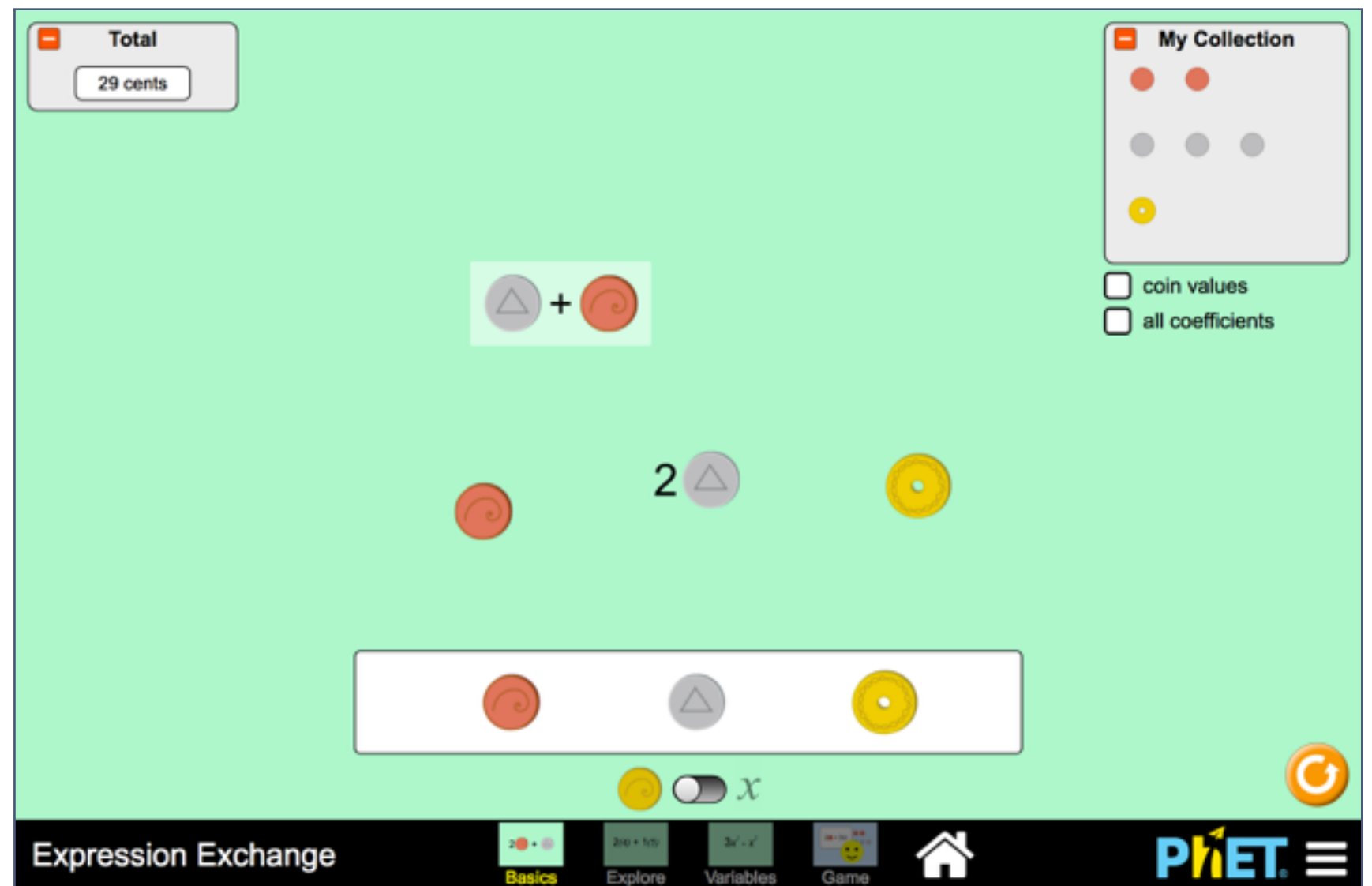
The screenshot shows the PhET Expression Exchange simulation interface. At the top, there are two buttons: "Total" and "My Collection". On the left, a "Values" panel contains three input fields:  $x =$  with a value of 2,  $y =$  with a value of 5, and  $z =$  with a value of 10. Below these is a refresh button. The main area is a light green workspace containing the expressions  $x$  and  $-x$ . At the bottom, a horizontal bar displays a sequence of expressions:  $-x^2$ ,  $-x$ ,  $-y$ , and  $-1$ . To the right of this bar are three checkboxes: "variable values", "all coefficients", and a toggle for  $+ -x \rightarrow -x$ . The bottom of the interface features a navigation bar with icons for "Expression Exchange", "Basics", "Explore", "Variables" (highlighted), "Game", and a home icon, followed by the PhET logo.

What will happen when we combine  $x$  and  $-x$ ?

How can I  
use sims in  
my  
classroom?

CCSS.Math.Practice.MP1  
Make sense of problems  
and persevere in solving  
them.

## Introductory Exploration

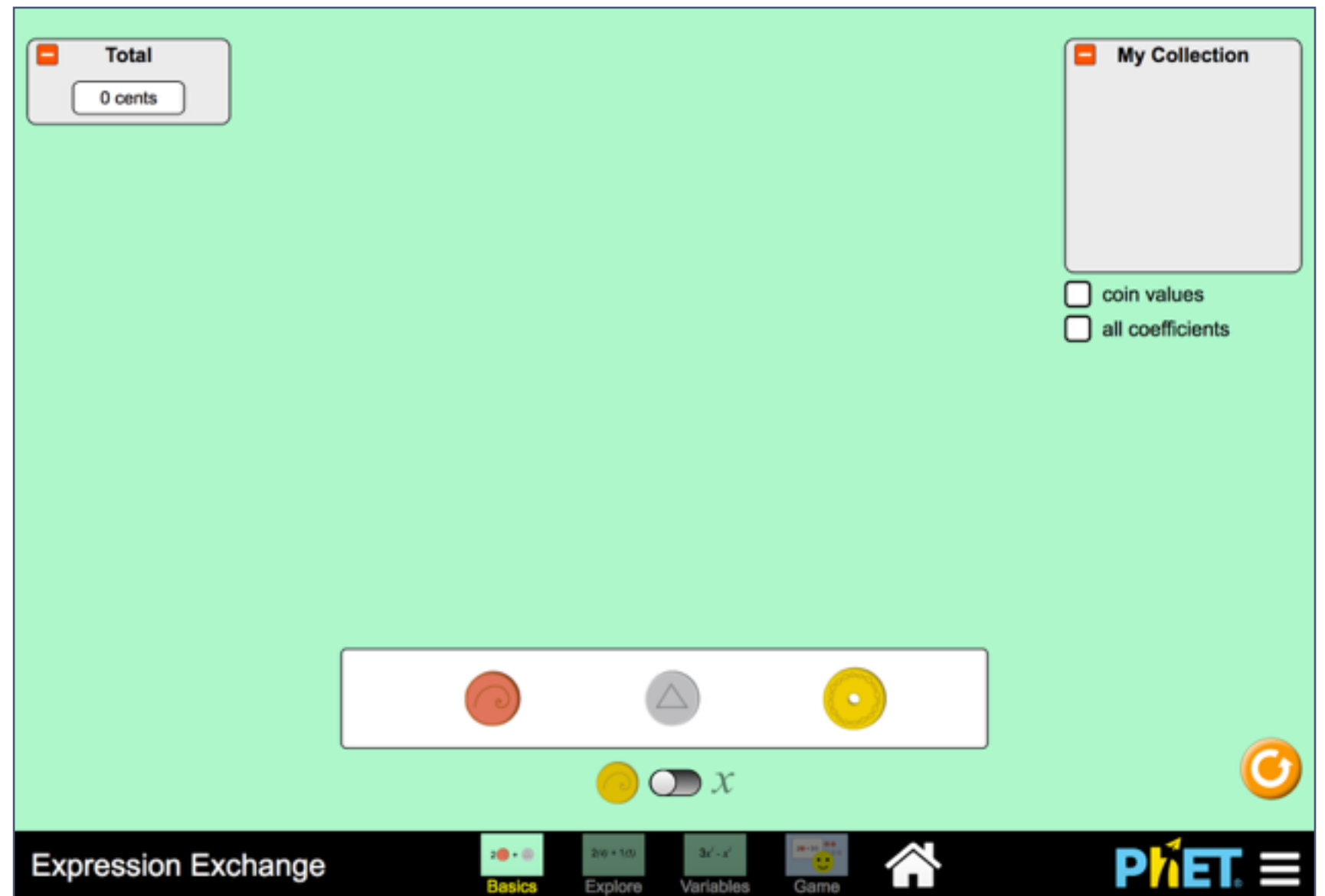


What are the different ways you can combine coins?

How can I  
use sims in  
my  
classroom?

CCSS.Math.Practice.MP8  
Look for and express  
regularity in repeated  
reasoning.

## Guided Exploration



Build an expression that equals 97 cents.

How can I  
use sims in  
my  
classroom?

CCSS.Math.Content.  
6.EE.A.1  
Write and evaluate  
numerical expressions  
involving whole-number  
exponents.

## Clicker Questions

The screenshot shows the PhET Expression Exchange simulation interface. At the top left, there is a 'Total' button with a green plus icon. To its right is a 'My Collection' button with a green plus icon. Below the 'Total' button is a 'Values' panel with a red minus icon. This panel contains three input fields: 'x = 2', 'y = 5', and 'z = 10', each with left and right arrow buttons. Below these is a circular refresh button. In the center of the interface, the mathematical expression  $x^2 + 2x + xy + z$  is displayed. To the right of the expression, there are two checkboxes: 'variable values' and 'all coefficients', both of which are currently unchecked. Below the expression is a horizontal bar with three segments labeled 'x', 'y', and 'z', flanked by left and right arrow buttons. At the bottom of the interface, there is a navigation bar with several icons: a yellow circle, a toggle switch, and the letter 'x'. The bottom of the screen features a black bar with the text 'Expression Exchange' on the left, and a series of icons for 'Basics', 'Explore', 'Variables', 'Game', and a home icon on the right. The PhET logo is also visible in the bottom right corner.

What is the total value of this expression?

What  
does a  
sim-based  
lesson  
look like?

## Sim: Build an Atom

The simulation interface for 'Build an Atom' displays a central model of a Helium atom. The nucleus is labeled 'Helium' and contains two protons (red) and two neutrons (gray). Two electrons (blue) are positioned on the inner dashed orbit. A legend in the top-left corner identifies the particles: Protons (red dot), Neutrons (gray dot), and Electrons (blue dot). Below the atom model are three bins labeled 'Protons', 'Neutrons', and 'Electrons', each containing several corresponding particles. To the right of the atom model, a 'Model:' section offers two options: 'Orbits' (selected with a blue dot) and 'Cloud' (represented by a white circle). Further right, three panels provide additional information: 'Element' shows a periodic table with Helium (He) highlighted; 'Net Charge' features a scale from -2 to +2 with a current value of 0; and 'Mass Number' shows a balance scale with a current value of 4. Below these panels, a 'Show' section includes checkboxes for 'Element Name' (checked), 'Neutral/Ion' (checked), and 'Stable/Unstable' (unchecked). A circular refresh button is located to the right of the checkboxes. The bottom of the interface features a black bar with the title 'Build an Atom' and navigation icons for 'Atom', 'Symbol', 'Game', a home icon, and the PhET logo.

Protons: ●●  
Neutrons: ●●  
Electrons: ●●

Neutral Atom

Helium

Model:  
● Orbits  
○ Cloud

Protons Neutrons Electrons

Element

Net Charge

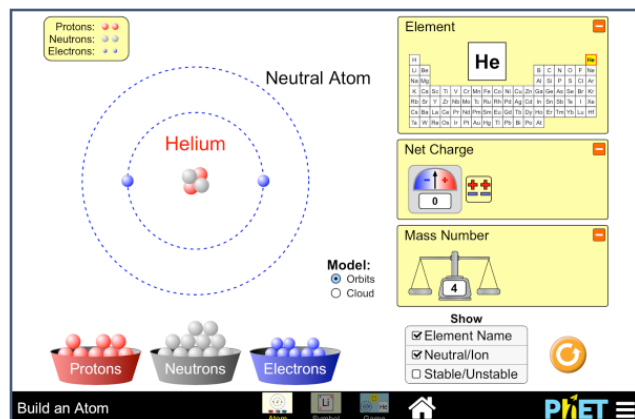
Mass Number

Show  
☒ Element Name  
☒ Neutral/Ion  
☐ Stable/Unstable

Build an Atom

Atom Symbol Game Home PhET

What  
does a  
sim-based  
lesson  
look like?



Teacher facilitation strategies

Make learning objectives explicit and  
meaningful

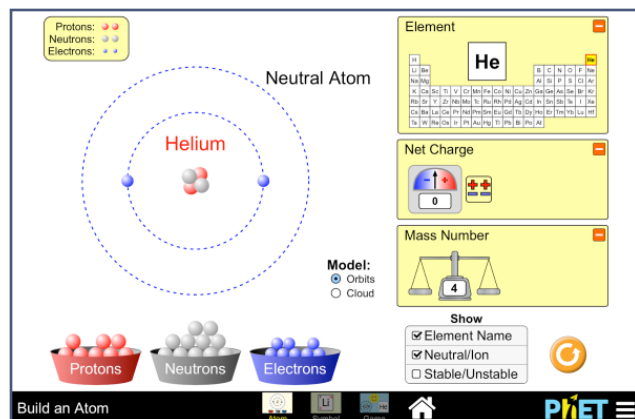
Start with open play

Avoid explicit instruction

Monitor and measure student learning

Reflect and refine facilitation techniques

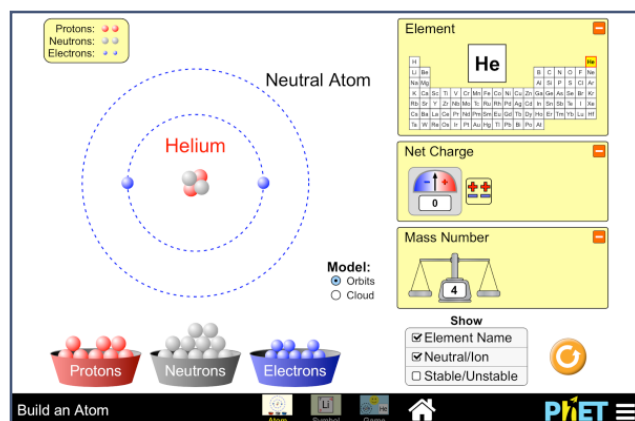
What  
does a  
sim-based  
lesson  
look like?



# Lesson: Atomic Addition

| Overview                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Prerequisite Skills:</b> <ul style="list-style-type: none"> <li>Identify integers as positive and negative numbers.</li> <li>Graph integers on a number line.</li> <li>Understand absolute value as the distance a number is from zero on a numberline.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Learning Goals:</b> <ul style="list-style-type: none"> <li>Identify additive inverses (zero pairs).</li> <li>Model addition of integers using protons and electrons, and extend this to a number line.</li> <li>Create a rule for adding integers.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <b>Common Core Standards:</b> <p><a href="#">CCSS.Math.Content.7.NS.A.1.a</a> Describe situations in which opposite quantities combine to make 0.</p> <p><a href="#">CCSS.Math.Content.7.NS.A.1.b</a> Understand <math>p + q</math> as the number located a distance <math> q </math> from <math>p</math>, in the positive or negative direction depending on whether <math>q</math> is positive or negative. Show that a number and its opposite have a sum of 0 (are additive inverses). Interpret sums of rational numbers by describing real-world contexts.</p> <p><a href="#">CCSS.Math.Content.7.NS.A.1.d</a> Apply properties of operations as strategies to add and subtract rational numbers.</p> <b>Mathematical Practices:</b> <ol style="list-style-type: none"> <li>1. Make sense of problems and persevere in solving them</li> <li>2. Reason abstractly and quantitatively</li> <li>4. Model with mathematics.</li> <li>5. Use appropriate tools strategically</li> </ol> <b>Florida Science Standards:</b> <p><a href="#">SC.912.P.8.4</a>: Explore the scientific theory of atoms (also known as atomic theory) by describing the structure of atoms in terms of protons, neutrons and electrons, and differentiate among these particles in terms of their mass, electrical charges and locations within the atom.</p> |
| <b>Materials:</b> <ul style="list-style-type: none"> <li>PhET <i>Build an Atom</i> simulation:</li> <li><a href="http://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html">http://phet.colorado.edu/sims/html/build-an-atom/latest/build-an-atom_en.html</a></li> <li>Computers/tablets for each student or pair of students</li> <li>Atomic Addition Activity Sheet (1 per student)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Estimated Time:</b><br>Approximately 45 minutes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

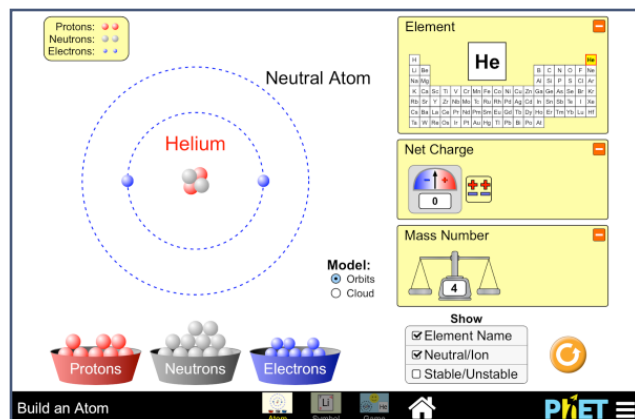
What  
does a  
sim-based  
lesson  
look like?



## Lesson: Atomic Addition

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                                                                                       |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>the net charge of an element for today's lesson.</p> <ul style="list-style-type: none"> <li>• <b>Circulate the room</b> and ask students: <ol style="list-style-type: none"> <li>1. What do you think net charge means?</li> <li>2. What happens to the net charge when you add protons? Neutrons? Electrons?</li> <li>3. What does neutral mean?</li> <li>4. When does the mass number change?</li> <li>5. What could represent positive/negative integers? What could represent zero?</li> <li>6. Why do you think sometimes the net charge is circled?</li> <li>7. What does the arrow indicate with the net charge?</li> </ol> </li> <li>• Ask students to briefly share what they wrote down for #1 on the activity sheet, and discuss any of the questions above.</li> </ul>                                                                                                                                                                                                                                                                                                              | <ul style="list-style-type: none"> <li>• Jot down discoveries as #1 on the activity worksheet.</li> </ul>                                                                                                             |
| <b>Guided Exploration</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | <b>15-20 minutes</b>                                                                                                                                                                                                  |
| <p><i>Teacher will...</i></p> <ul style="list-style-type: none"> <li>• Encourage students to begin working on #2-12 in pairs. Try to give them at least 5 minutes where <b>the teacher is silent</b> before probing/aiding.</li> <li>• <b>Circulate the room</b> to be available for questions and ask probing/pushing questions, such as: <ol style="list-style-type: none"> <li>1. Do the neutrons affect the net charge?</li> <li>2. If you want a negative net charge, do you need more protons or electrons?</li> <li>3. What happens if you only use electrons?</li> <li>4. What happens if you only use protons?</li> <li>5. What happens if you only use neutrons?</li> <li>6. What happens if you make an atom with the same number of protons, neutrons, and electrons?</li> <li>7. Can you make an atom with a net charge of + 3? -4? -5?</li> <li>8. Can you make a Carbon atom/ion with a net charge of -2?</li> <li>9. Can you make a Hydrogen atom with a net charge of + 2?</li> <li>10. Can you make a Neon atom that is neutral or has a net charge of 0?</li> </ol> </li> </ul> | <p><i>Students will...</i></p> <ul style="list-style-type: none"> <li>• Complete #2-12 on the activity sheet.</li> <li>• Respond to teacher questions.</li> <li>• Ask questions or ask for help as needed.</li> </ul> |

What  
does a  
sim-based  
lesson  
look like?



## Activity Guidelines

Start with open play

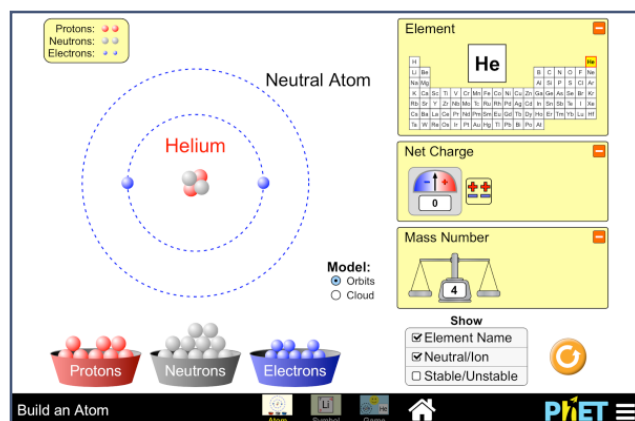
Avoid explicit instruction

Leverage affordances of the sim

Use open, investigative questions and  
challenge prompts

<http://phet.colorado.edu/en/for-teachers/activity-guide>

What  
does a  
sim-based  
lesson  
look like?



## Activity: Atomic Addition

1. **Explore** the Build an Atom simulation for a few minutes, building whatever atoms you choose. Write down 1-3 observations you have about building an atom.

2. Build an atom with a **positive net charge**, then **complete the table** below, and **draw the diagram** of its net charge using + and – symbols for protons and electrons.

|            |  |
|------------|--|
| Protons    |  |
| Electrons  |  |
| Neutrons   |  |
| Net Charge |  |



3. Build a new atom with a **different positive net charge**, then **complete the table** below, and **draw the diagram** of its net charge using + and – symbols for protons and electrons.

|            |  |
|------------|--|
| Protons    |  |
| Electrons  |  |
| Neutrons   |  |
| Net Charge |  |



4. Build an atom with a **negative net charge**, then **complete the table** below, and **draw the diagram** of its net charge using + and – symbols for protons and electrons.

|            |  |
|------------|--|
| Protons    |  |
| Electrons  |  |
| Neutrons   |  |
| Net Charge |  |



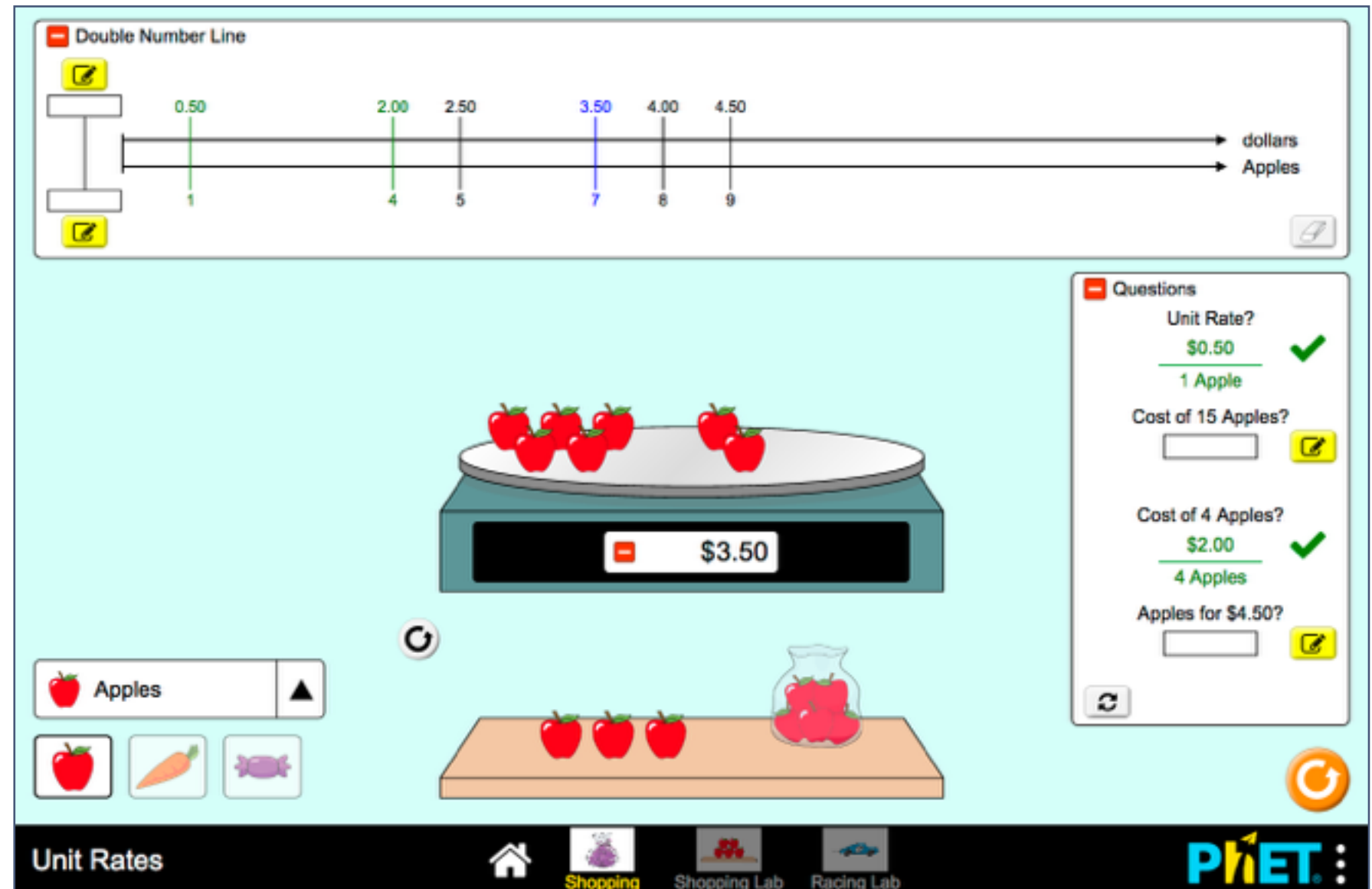
What new  
sims can I  
look  
forward  
to?

# Expression Exchange

The screenshot shows the 'Expression Exchange' simulation interface. The background is a light green color. In the top left, there is a 'Total' panel with a red minus sign icon and a text box containing the number '9'. Below it is a 'Values' panel with a red minus sign icon, two input fields for 'x' (set to 2) and 'y' (set to 5), and a circular refresh button. In the center, a light green box displays the expression  $2x^2 - x^2 + 4x - 3$ . Below this, a horizontal bar contains a scrollable list of terms:  $x^2$ ,  $-x^2$ ,  $y$ , and  $-y$ . On the right side, there is a 'My Collection' panel with a red minus sign icon, showing a list of items: four 'x' terms, three '-1' terms, two ' $x^2$ ' terms, and one ' $-x^2$ ' term. At the bottom right, there are three checkboxes: 'variable values' (unchecked), 'all coefficients' (unchecked), and '+ -x → -x' (checked). An orange circular button with a white 'G' icon is located at the bottom right. The bottom of the interface features a black navigation bar with the text 'Expression Exchange' on the left, a home icon, and four tabs: 'Basics' (with a red dot), 'Explore', 'Variables' (highlighted in yellow), and 'Game'. The PhET logo is on the far right of the navigation bar.

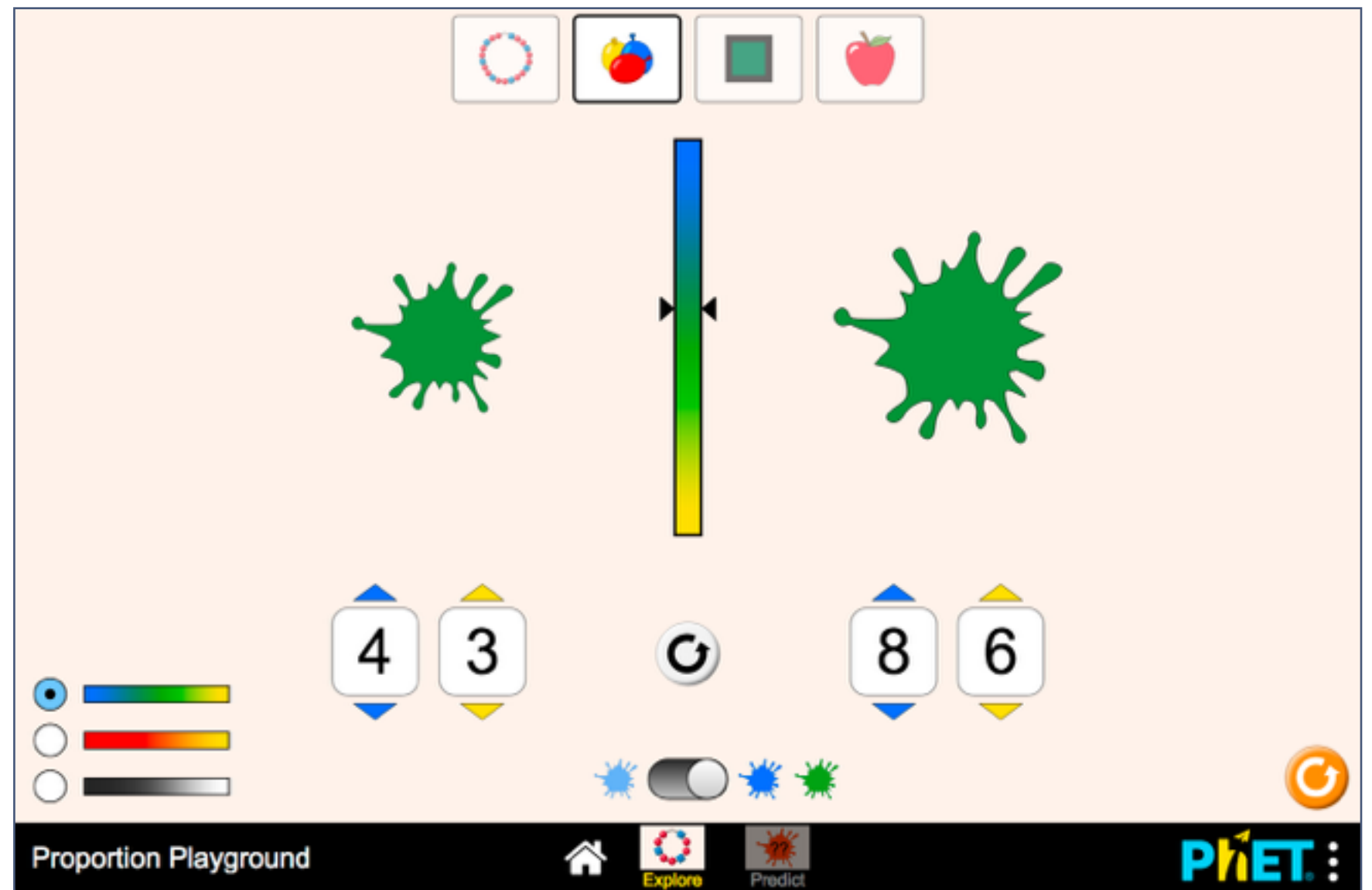
What new  
sims can I  
look  
forward  
to?

## Unit Rates



What new  
sims can I  
look  
forward  
to?

## Proportion Playground

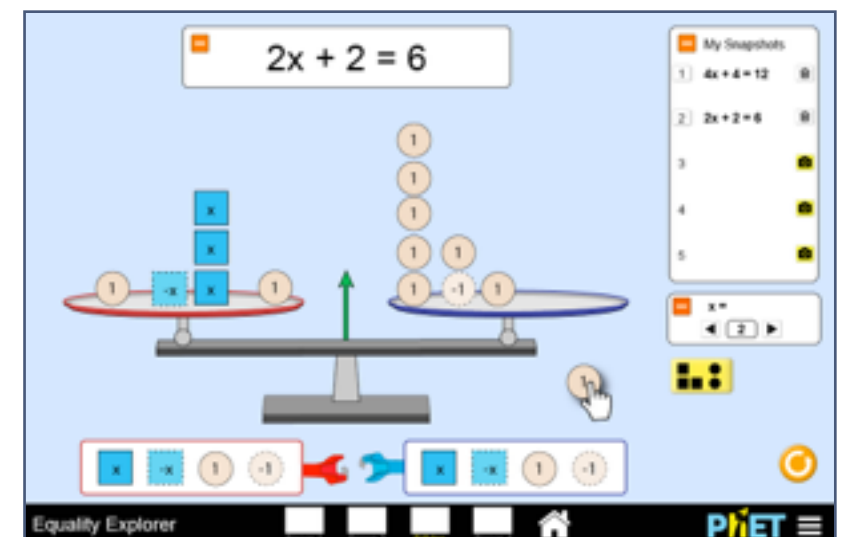
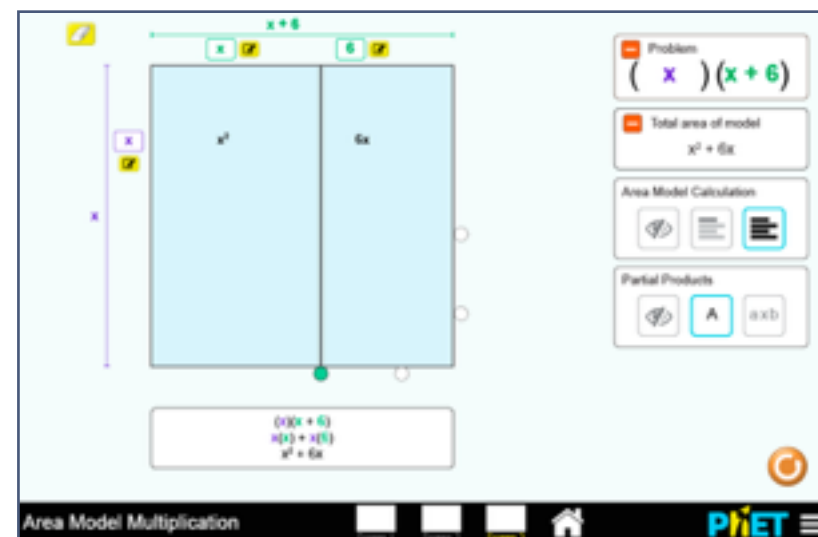


What new  
sims can I  
look  
forward  
to?

Upcoming Sim Topics

Area model multiplication

Equations and inequalities on a balance



Number lines: comparing integers

Number lines: operations with integers

Where do I find sims and resources?

phet.colorado.edu

**SEARCH** for activities and sims by keyword

**BROWSE** sims by topic, grade level, or device

**FIND** sims in 85 languages

**WATCH** a short video for ideas on how to use sim with students

**READ** sim-specific info from the design team

**FIND** an activity to use with sim

★ **Aligned** with research on inquiry-based instruction

**PhET Created** by the PhET team

The screenshot shows the PhET website interface. At the top is the PhET logo and navigation links. A sidebar on the left lists simulation categories like HTML5, Physics, Biology, Chemistry, Earth Science, and Math. The main content area features the 'Fraction Matcher' simulation, which includes a visual representation of fractions and a matching interface. Below the simulation are links for 'ABOUT', 'FOR TEACHERS', and 'Teacher Tips'. A video primer is also visible, with a note to sign in to watch. At the bottom, there is a table of 'Teacher-Submitted Activities' with columns for Title, PhET status, Authors, Level, and Type.

| TITLE                                                                                 | ★ | PhET | AUTHORS          | LEVEL           | TYPE                     |
|---------------------------------------------------------------------------------------|---|------|------------------|-----------------|--------------------------|
| Fraction Matcher Game                                                                 | ★ | PhET | Trish Loeblein   | K-5<br>MS<br>HS | HW<br>Lab                |
| Exploring Equivalence with Rational Numbers: Part 2 Extending to Mixed Numbers        | ★ |      | Michael Matassa  | MS<br>K-5       | Lab<br>Guided<br>Discuss |
| Exploring Equivalence with Rational Numbers: Part 1 Fractions less than or equal to 1 | ★ |      | Michael Matassa  | K-5<br>MS       | Guided<br>Lab<br>Discuss |
| How do PhET simulations fit in my middle school program?                              |   | PhET | Sarah Borenstein | MS              | Other                    |
| Alignment of PhET sims with NGSS                                                      |   | PhET | Trish Loeblein   | HS              | Other                    |
| MS and HS TEK to Sim Alignment                                                        |   |      | Elyse Zimmer     | MS<br>HS        | Other                    |

Thank you!

amanda.mcgarry@colorado.edu  
@McGarryMath