

# Next Generation PhET Simulations: New Opportunities for Education Research in Science and Math

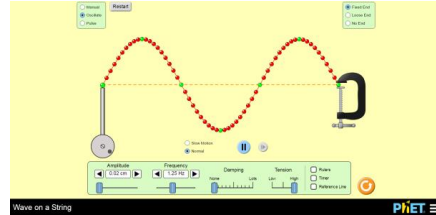
Kathy Perkins

University of Colorado Boulder

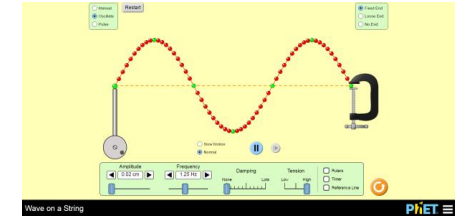
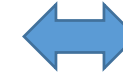
# Brief Introduction to PhET

# Intro to PhET

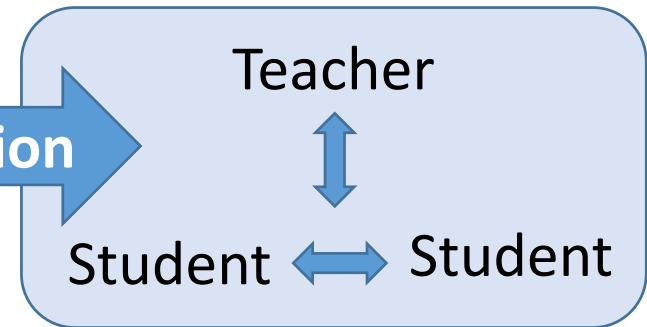
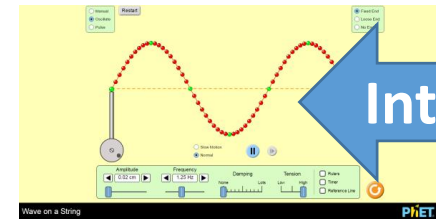
## Product Development



## Research

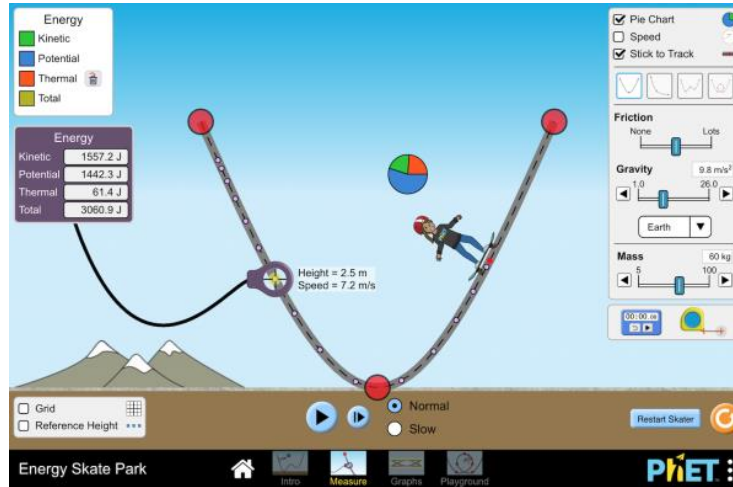


## Classroom



# Intro to PhET

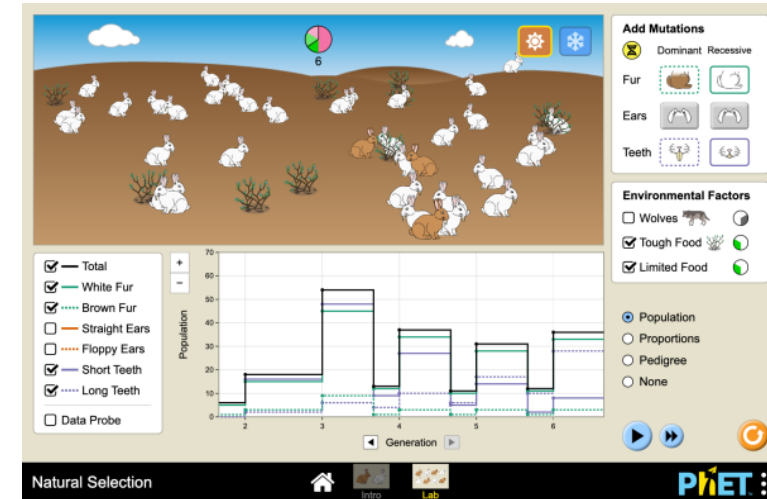
## Examples



The Energy Skate Park simulation shows a skater on a track with various energy values and controls. The Energy panel displays:

Energy	Value
Kinetic	1557.2 J
Potential	1442.3 J
Thermal	61.4 J
Total	3060.9 J

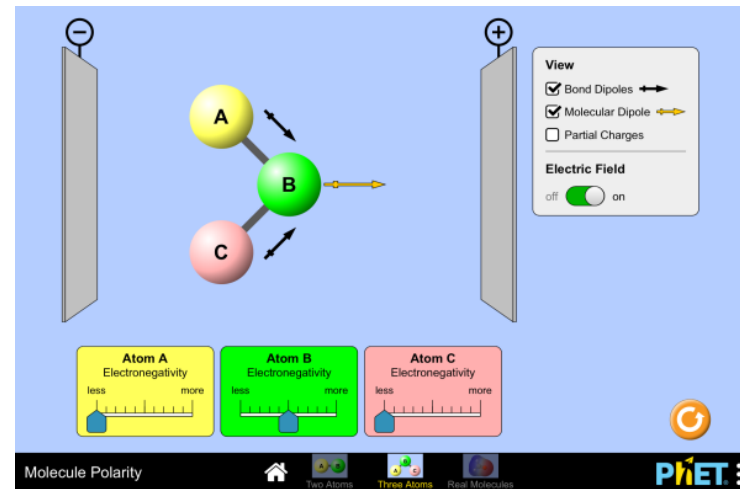
Current state: Height = 2.5 m, Speed = 7.2 m/s. Controls include Friction (None to Lots), Gravity (9.8 m/s<sup>2</sup> to 26.0), Mass (5 kg to 100 kg), and a Pie Chart for energy distribution.



The Natural Selection simulation shows a population of rabbits with various traits and a graph of population over generations. The Add Mutations panel includes:

- Fur:  Dominant,  Recessive
- Ears:  Straight,  Floppy
- Teeth:  Short,  Long

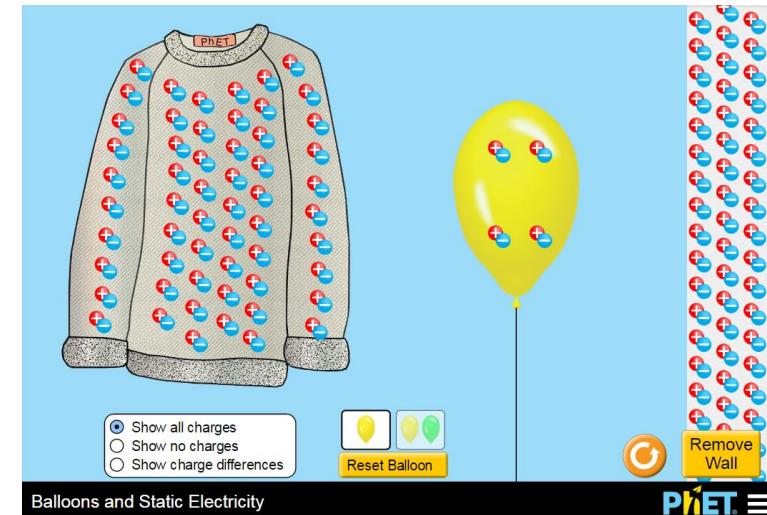
Environmental Factors:  Wolves,  Tough Food,  Limited Food. The graph shows population changes over 6 generations.



The Molecule Polarity simulation shows three atoms (A, B, C) with electronegativity sliders and a view of bond dipoles, molecular dipoles, and partial charges. The View panel includes:

- Bond Dipoles
- Molecular Dipole
- Partial Charges

Electric Field:  on. The electronegativity sliders for Atom A, Atom B, and Atom C are shown.



The Balloons and Static Electricity simulation shows a sweater and a balloon with static charges. The View panel includes:

- Show all charges
- Show no charges
- Show charge differences

Buttons: Reset Balloon, Remove Wall. The sweater and balloon are shown with positive and negative charges.

# Intro to PhET

## Multiple Goals

**Content:** Concepts, Models, Representations, Relationships

**Process:** Explore, Question, Design, Predict, Data, Evidence, Discuss

**Affective:** Enjoyable, Understandable, Relevant, **Student-centered**

**Dissemination:** Flexible, Easy, Free

# Intro to PhET

## PhET Today

Over 158 simulations (85 in HTML5) & 2000+ sim-based lessons

Physics, Chemistry, Math,  
Biology, Earth Science

K-12 and College

Open education resources (free)

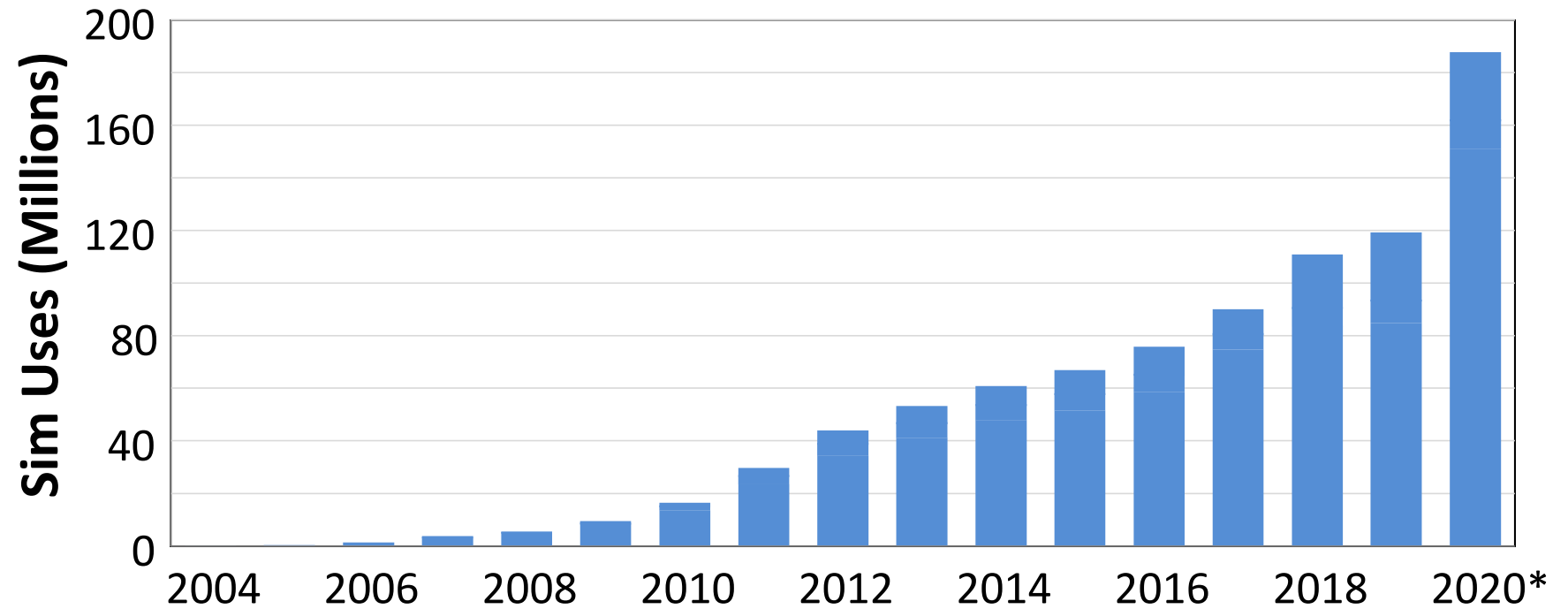
Translated into 90+ languages

Run online or offline

The screenshot shows the PhET website homepage. At the top left is the PhET logo (University of Colorado Boulder). Navigation links include SIMULATIONS, TEACHING, RESEARCH, ACCESSIBILITY, and DONATE. A search icon and user profile icon are on the right. The main hero section features a background image of a student in a red hoodie using a laptop. Text reads "Interactive Simulations for Science and Math" with a "PLAY WITH A SIM" button. Below this, a statistic states "658 million simulations delivered". A horizontal row of five colored circles represents subject categories: PHYSICS (pink), CHEMISTRY (light blue), MATH (yellow), EARTH SCIENCE (light green), and BIOLOGY (purple). The bottom section is titled "Teaching Resources, Activities, and Community" and includes a small text block: "Teachers have access to simulation-specific tips and video primers, resources for teaching with simulations, and activities shared by our".

# Intro to PhET

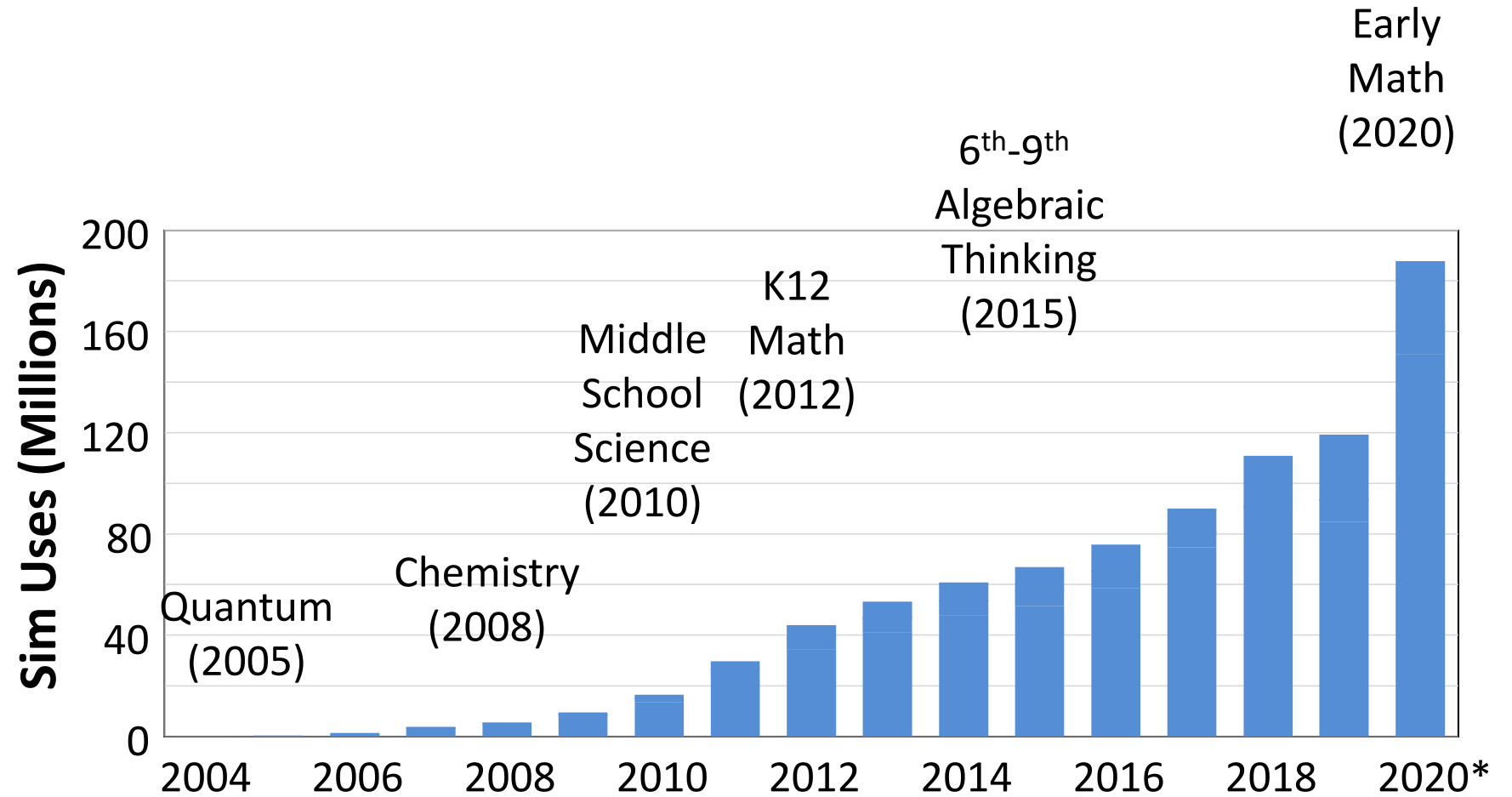
## Over 200 Million Uses/Year



*\*Estimated projection for 9/20-12/20*

# Intro to PhET

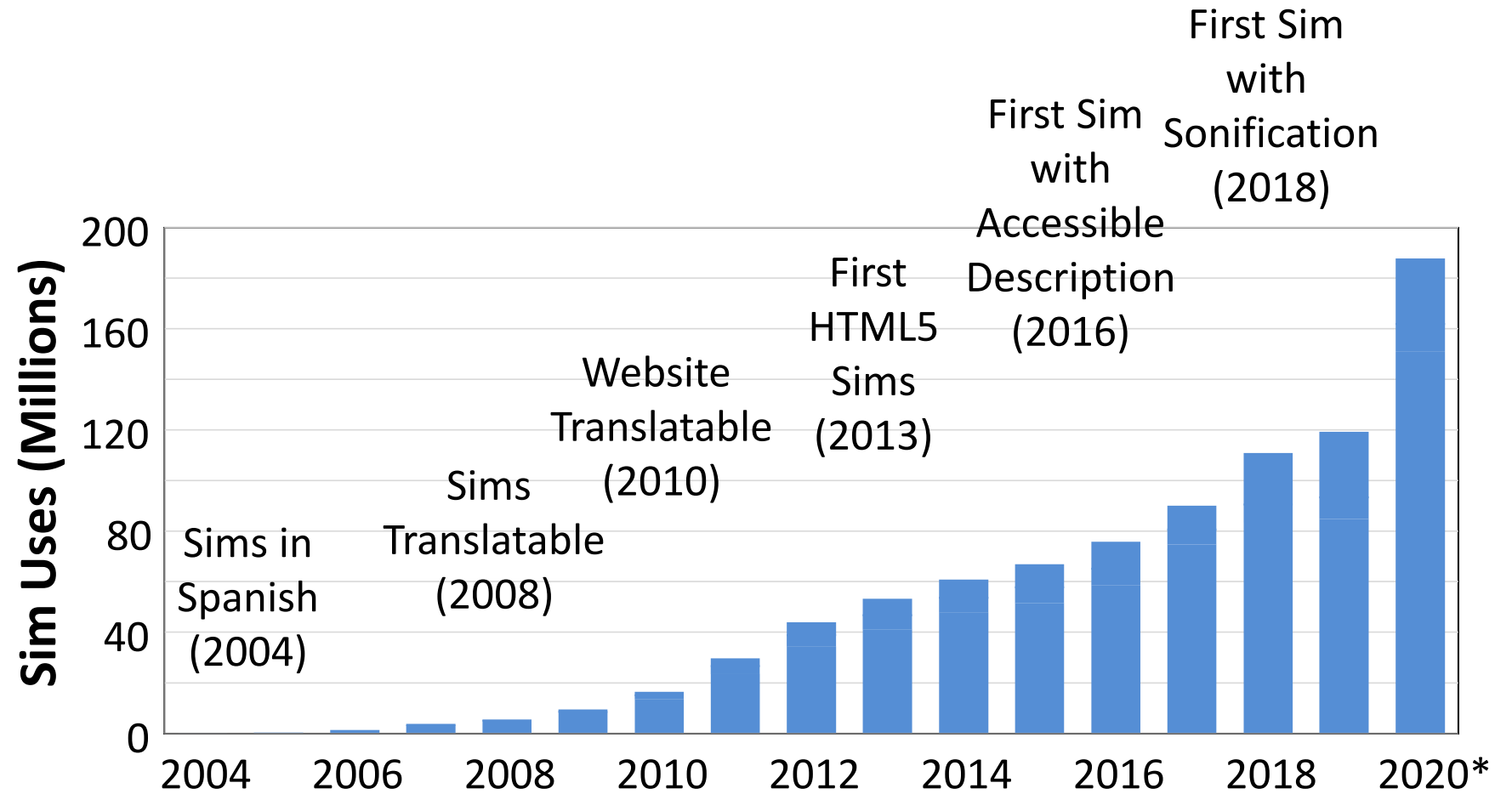
## Content Expansion





# Intro to PhET

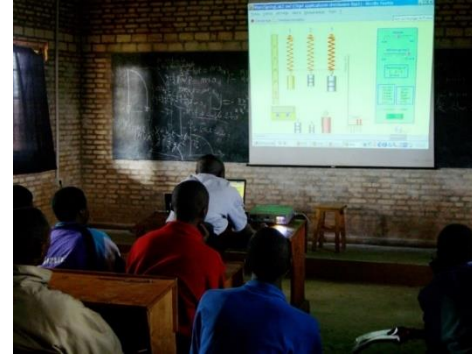
## Technology Advancement



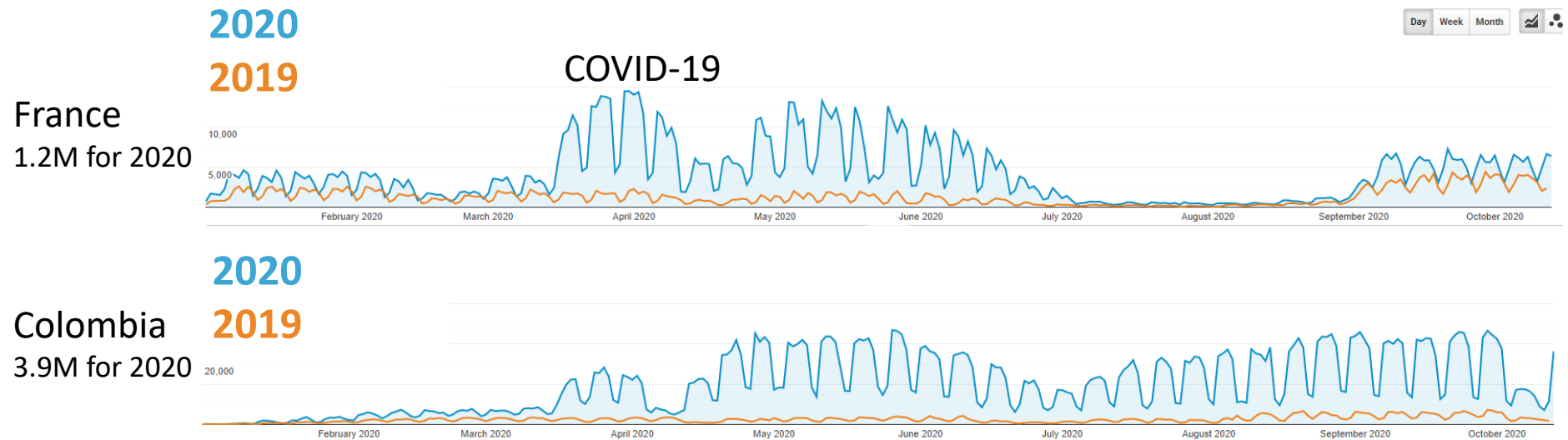
# Intro to PhET

## Global

~50% International. In 90 languages.



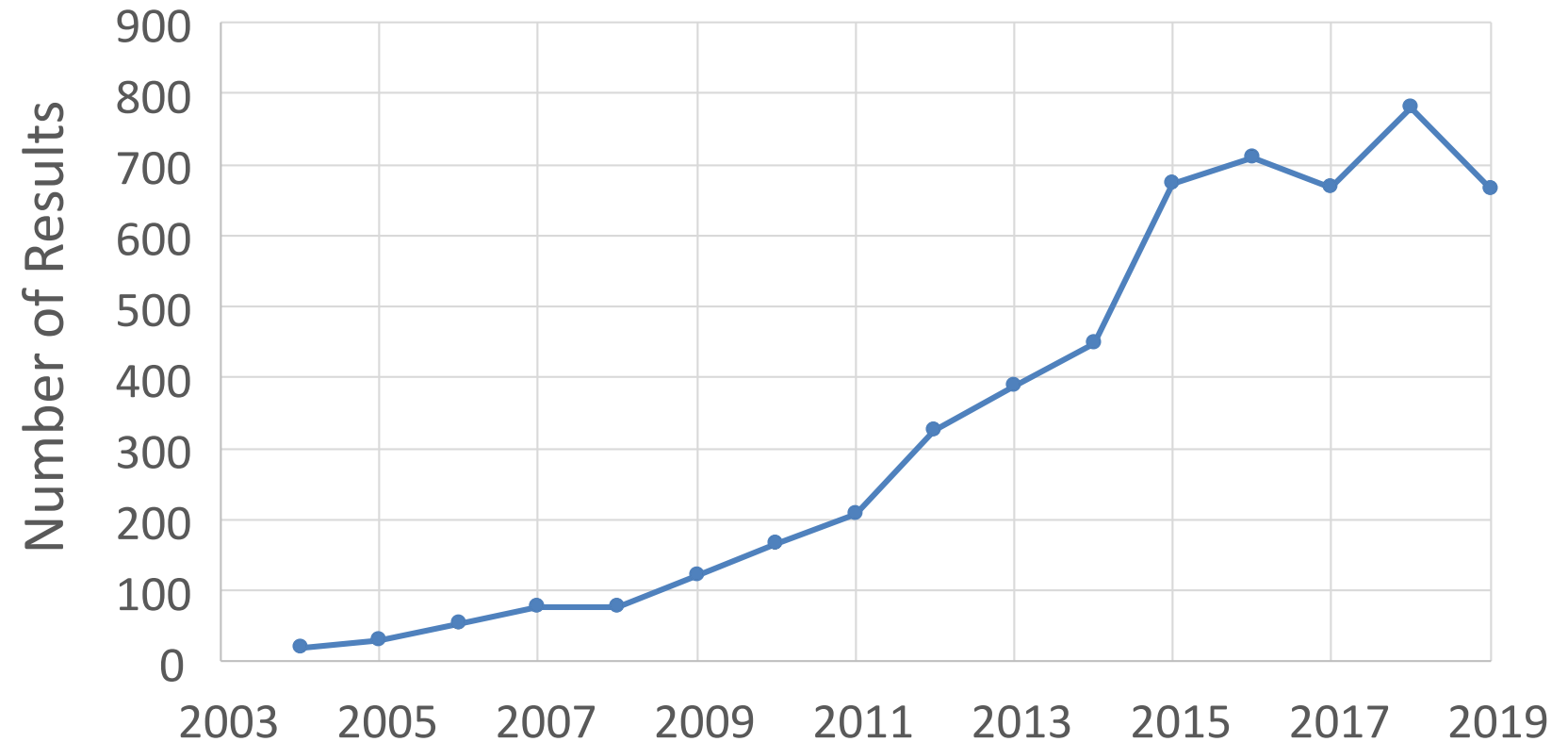
BURUNDI



# Intro to PhET

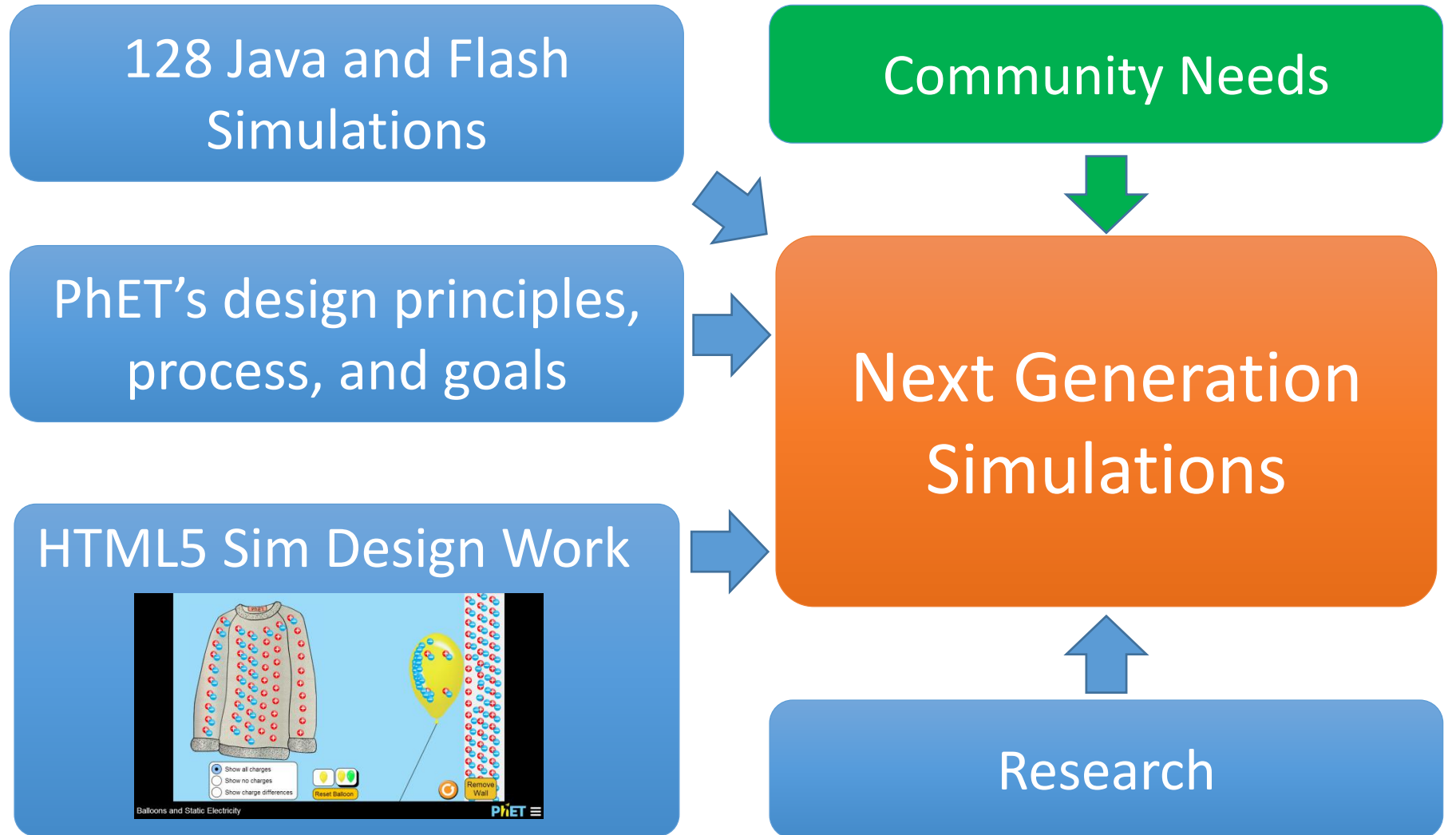
## Research on PhET sims

Google Scholar Search: "PhET Simulation Education"



# Next Generation PhET Sims

# Next Gen PhET Sims



# Next Gen PhET Sims

## **Community Stakeholders**

Educators

Learning Designers

Assessment Professionals

Researchers: DBER and Learning Sciences

Inclusive Design / Accessibility Experts

Education Technology Companies

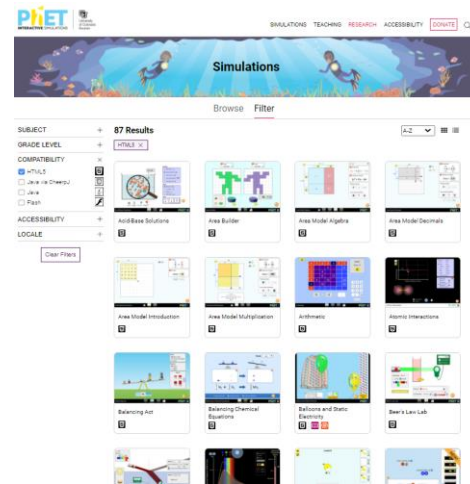
2014 Stakeholders' Meeting: Envisioning Next-Gen PhET Sims

# Next Gen PhET Sims



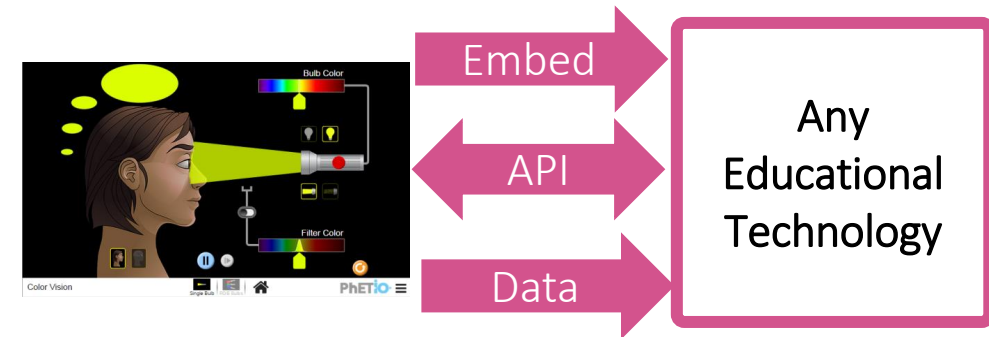
All devices (HTML5)  
Translatable  
Embeddable  
Highly Accessible (in progress)

(87sims)



Customizable  
Interoperable  
Backend Data Collection

(~20 sims, but growing)

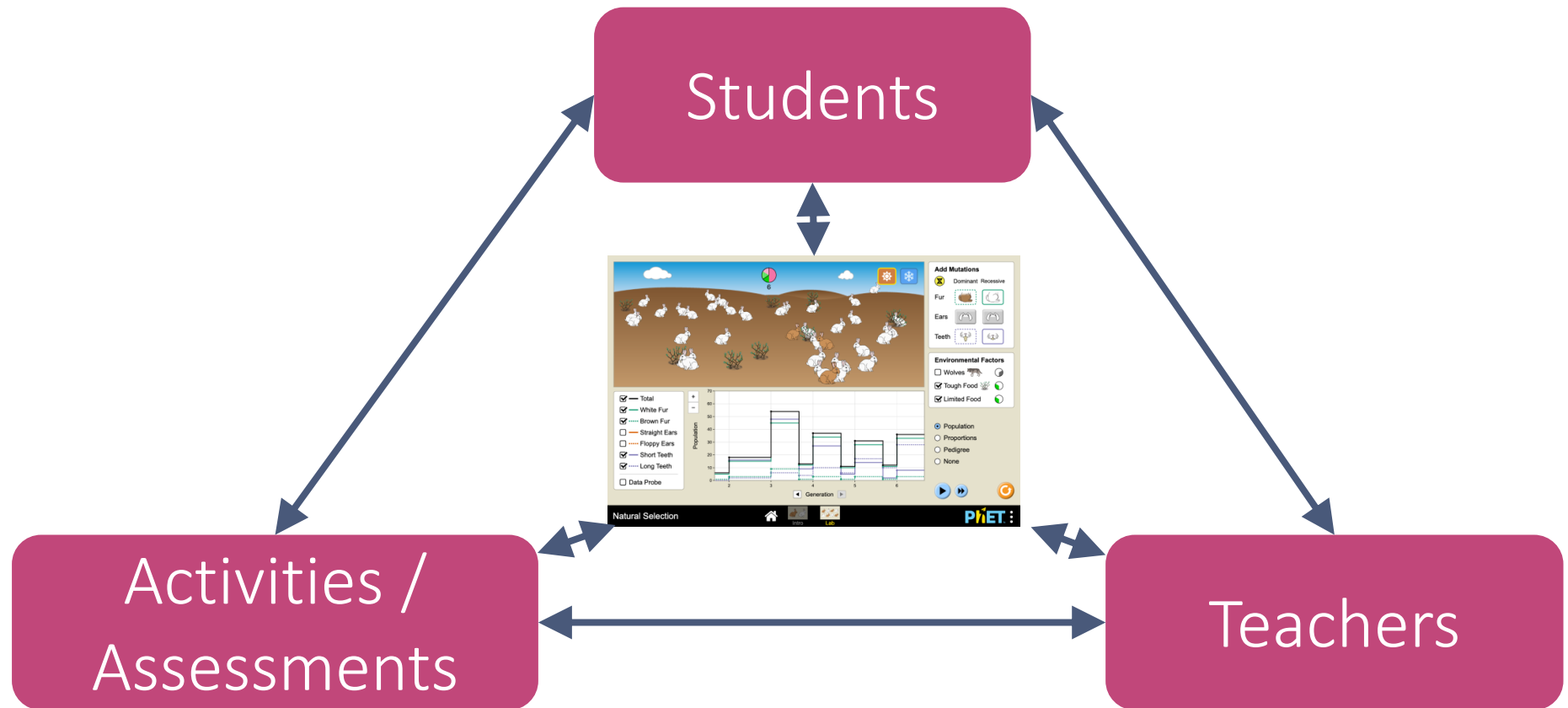


<https://phet-io.colorado.edu>

# Next Gen PhET Sims

## New Learning and Research Opportunities

New Structures, Roles, Activities, Feedback, Measures





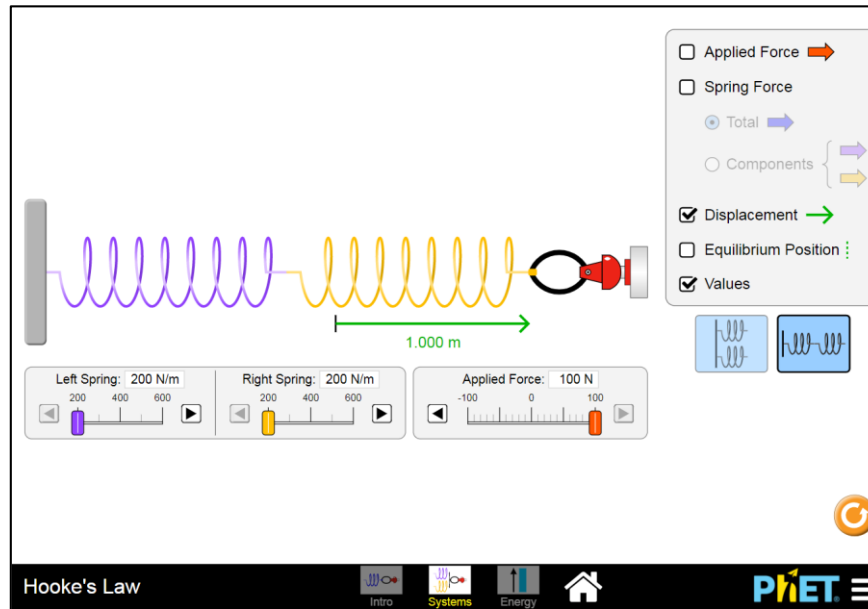
# Sim-based learning



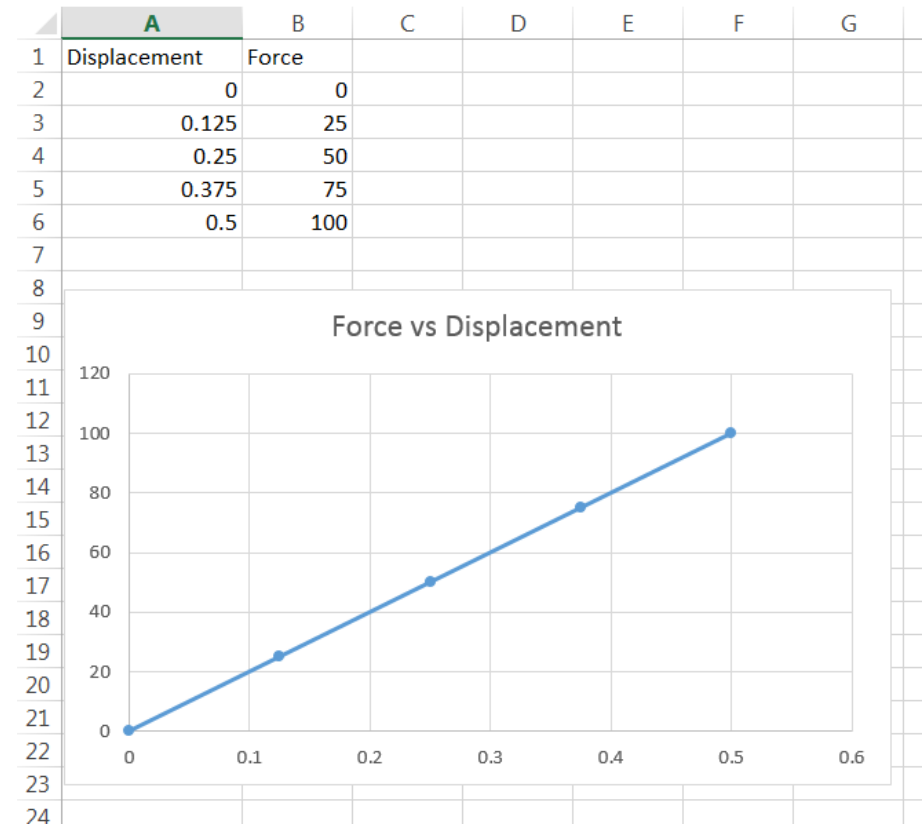
Andy Gavrin  
IUPUI

## Sim-based Lab: Process + Content Goals

### Sim: Hooke's Law



### Spreadsheet



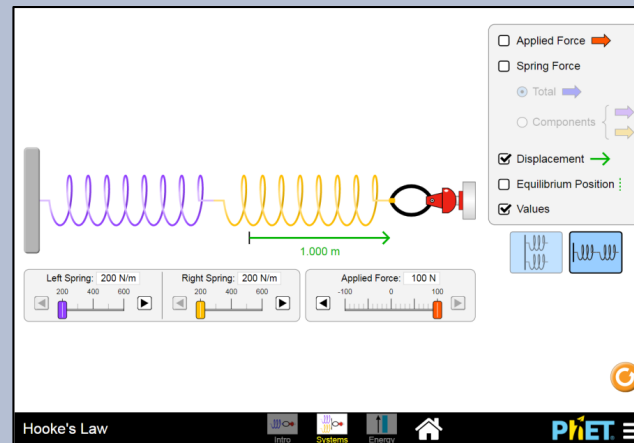
# Sim-based learning



Andy Gavrin  
IUPUI

## Online Sim-based Lab:

### Sim: Hooke's Law (PhET-iO)



Customize the Sim  
Design Instructional Wrapper  
Follow Student Actions  
Provide Adaptive Feedback  
Assess on Process and Content

Learning Platform

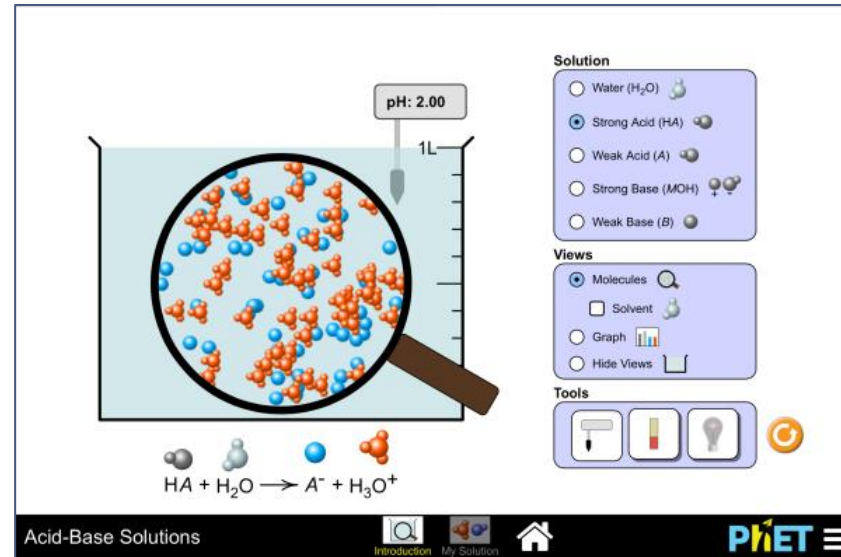
# Research Examples

# Sim-based Learning



Julia Chamberlain

## Research on Activity Design: Guidance



### Context

College Chem 1 Lab Sections

3 Activities:

Different Levels of Guidance

Logged Event Stream of User Interactions

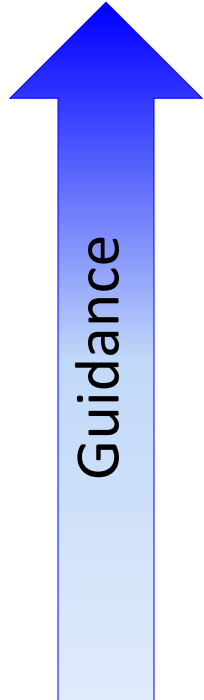
Chamberlain, J. M. *et al.* How guidance affects student engagement with an interactive simulation. *Chem. Educ. Res. Pract.* **15**, 628–638 (2014).

# Sim-based Learning



Julia Chamberlain

## Activity Design: Impact of guidance



### Heavy

In the “Solutions” section of the control panel, select “Strong Acid.” Record the equation.

### Moderate

Use the “Introduction” tab to compare **strong** and **weak** acid solutions. Describe all the ways that the solutions are similar and different.

### Light

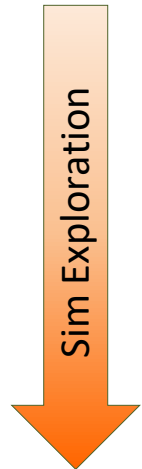
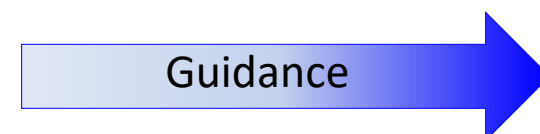
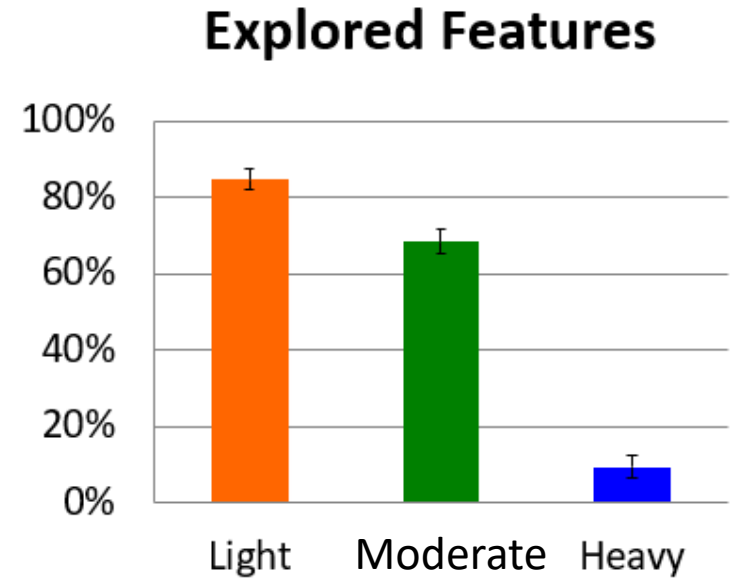
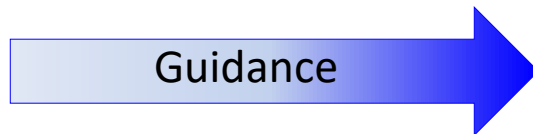
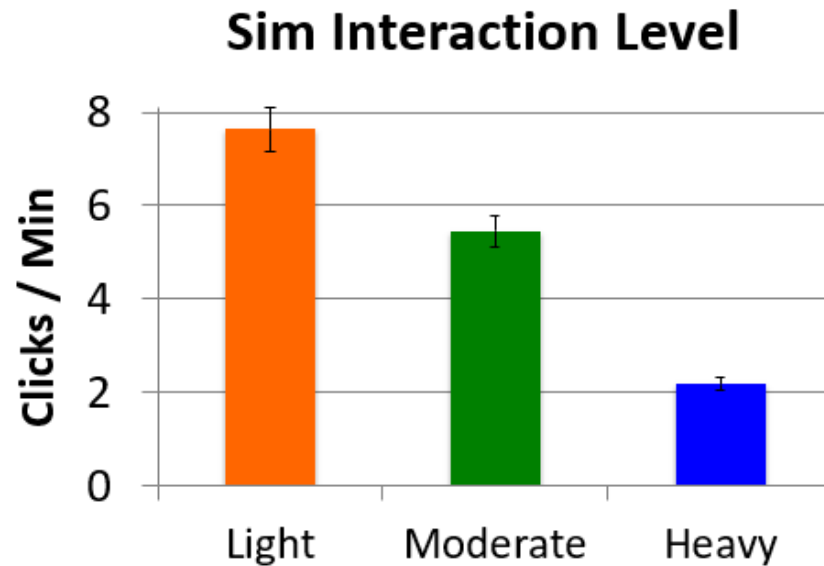
Explore the sim. Make sure to investigate all of the factors that affect the pH of a solution.

# Sim-based Learning



Julia Chamberlain

## Activity Design: Impact of guidance

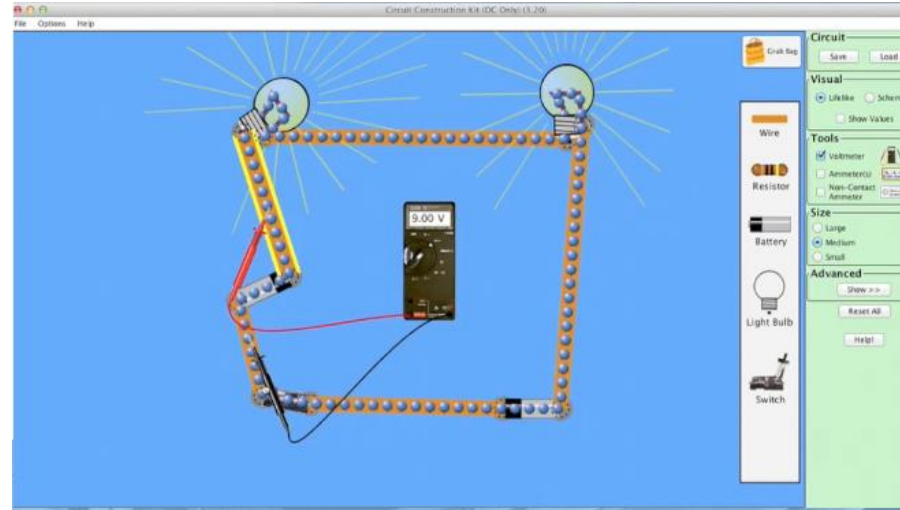


# Learning Analytics



Ido Roll

## Research on Guidance/Scaffolding & Learning



### Context

100 1<sup>st</sup> year college students  
Introductory Physics Courses

2 Conditions:

Different Levels of Scaffolding

Logged Event Stream of User Interactions  
(100 hours of data, ~130,000 actions)

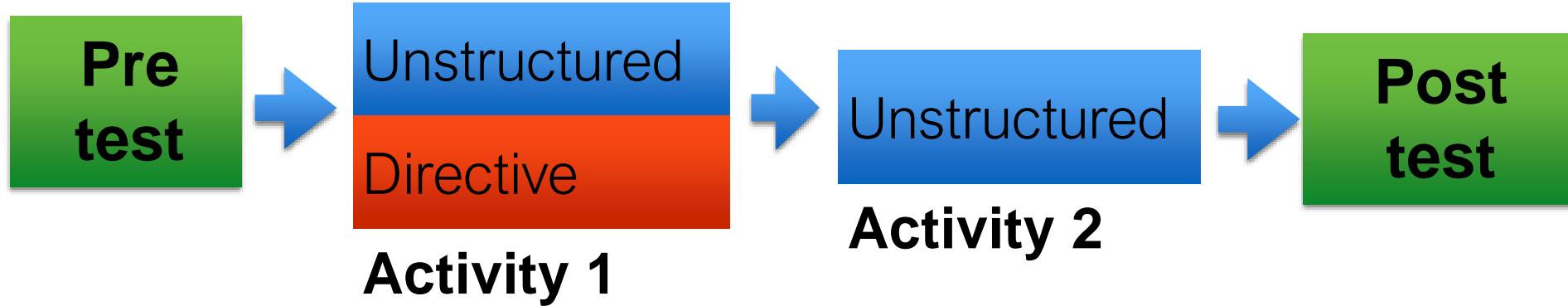
Roll, I. *et al.* Understanding the impact of guiding inquiry: The relationship between directive support, student attributes, and transfer of knowledge, attitudes, and behaviours in inquiry learning. *Instructional Science* **46**, 77–104 (2018).

# Learning Analytics



Ido Roll

## Procedure




### Unstructured

Use the DC Circuit PhET simulation to explore how voltage, current, and the brightness of light bulbs depend on the number and arrangement of light bulbs in a circuit.

### Structured

**PART 1:**  
**One Light Bulb**

1. Drag and drop one light bulb and one battery in the work area. Drag and drop wires to connect the battery to the light bulb. Once the circuit is completed, the bulb should light and you should see the flow of charge from positive to negative end of the battery through the circuit. This is circuit 1.



Circuit 1: One bulb

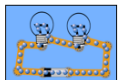
Voltage	Bulb	Battery
Current		
Brightness of Bulb		.....

2. Use a voltmeter (check the box next to voltmeter on the right side of the display) to measure the voltage across the bulb and the battery. Use the **non-contact ammeter** to measure the current in the wires. Describe the brightness of the bulb.

Voltage	Bulb	Battery
Current		
Brightness of Bulb		.....

**PART 2:**  
**Light Bulbs in a Row**

3. Set up another circuit with one battery and two light bulbs (everything is in one single loop). This is circuit 2.



Circuit 2: Two bulbs in a row

4. Use the voltmeter and the non-contact ammeter to measure the values listed below. Describe the brightness of the bulbs.

Voltage	Bulb 1	Bulb 2	Battery
Current			
Brightness of Bulb			.....

5. What happens to the brightness of the bulbs as you add more bulbs in series?

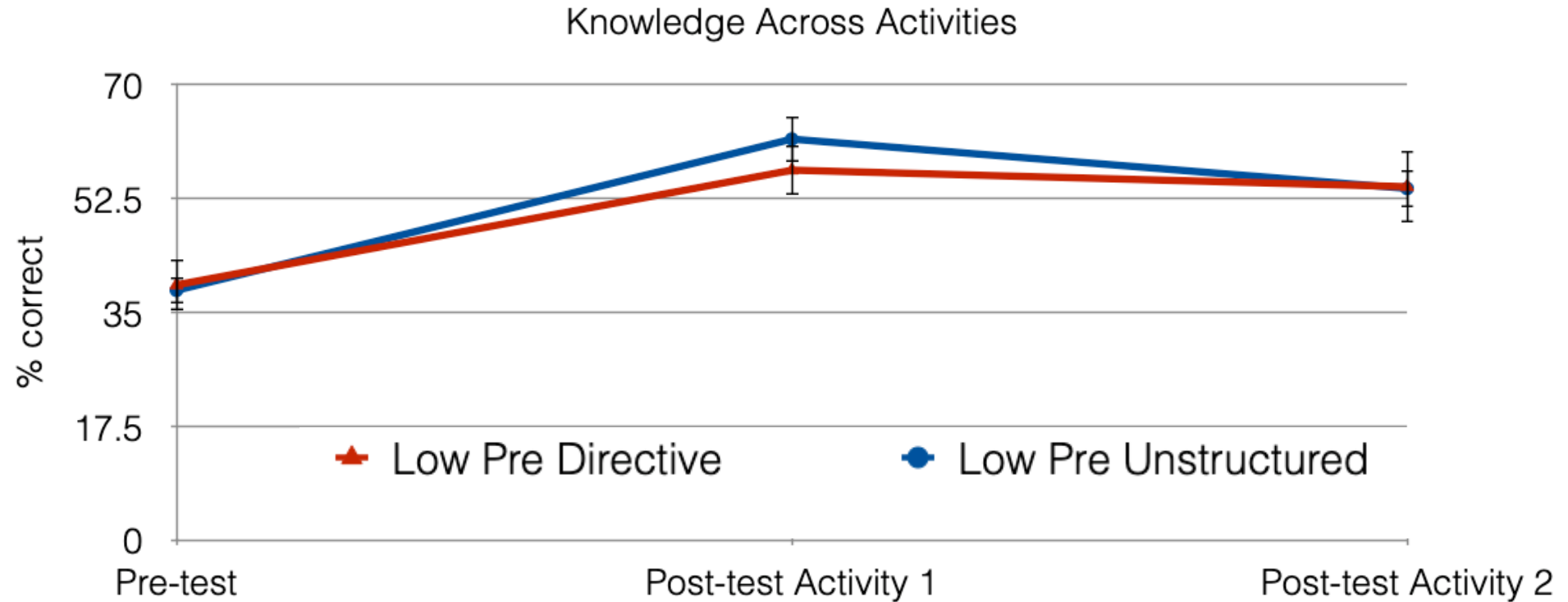


# Learning Analytics



Ido Roll

## Impact on Learning (Low Pre-test Learners)



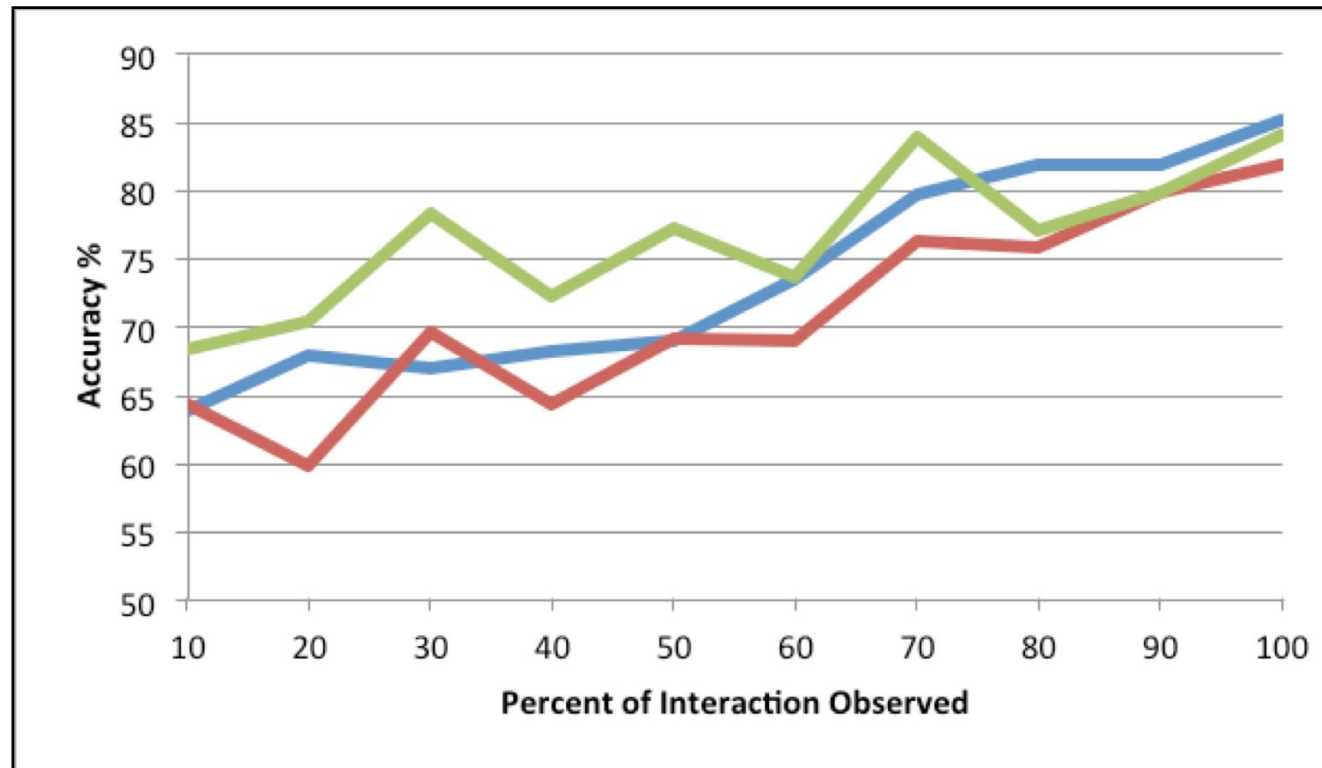
# Learning Analytics



Ido Roll

## Predicting Learning from Sim Interactions

Able to predict learning from log files after about 5 minutes (25% of the interaction).



3 different models of backend data signatures

# Learning Analytics



Ido Roll

## What did productive students do?

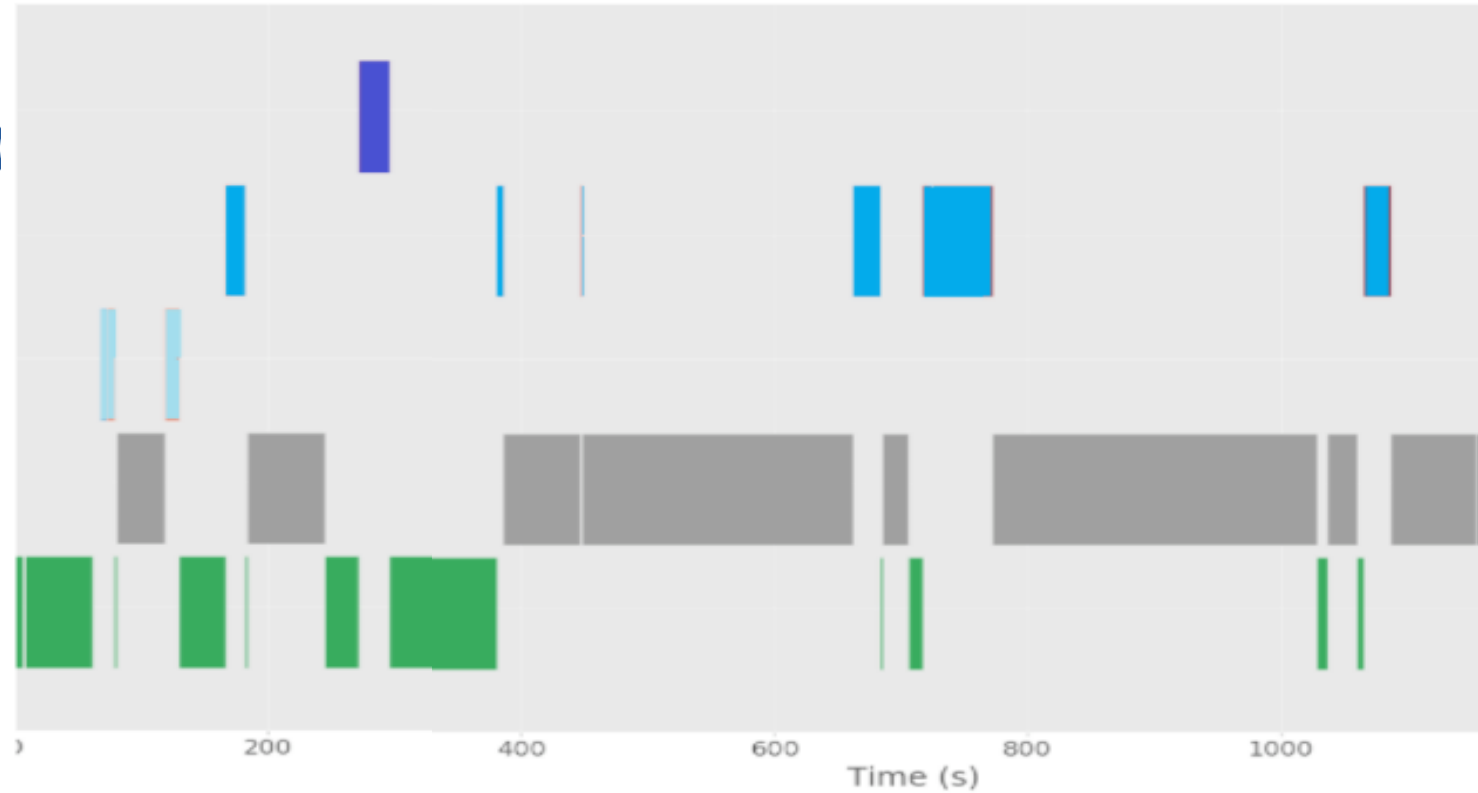
Test a circuit w/  
many resistors ( $T_m$ )

Test a circuit w/  
2 resistors ( $T_2$ )

Test a circuit w/  
1 resistor

Pause

Construct



# Learning Analytics



Ido Roll

## What did productive students do?

Unproductive learners
P C T <sub>m</sub> C T <sub>m</sub> C
C P C T <sub>2</sub> C
P C P C T <sub>m</sub> C
T <sub>m</sub> C P C
T <sub>2</sub> C T <sub>2</sub> C

- T<sub>m</sub> appears a lot.
- Pauses only before and after Construct.

Productive learners
P T <sub>2</sub> P C
C T <sub>2</sub> P T <sub>2</sub> P
P T <sub>2</sub> P
T <sub>2</sub> P T <sub>2</sub> P C
C P T <sub>2</sub>

- T<sub>2</sub> appears often, followed by a pause
- ...and iterate

# Assessment



Shima Salehi  
Wieman Group  
Stanford

# Assessing Knowledge and Practices

The screenshot shows the PhET 'Black Box Study' simulation interface. At the top center, a dropdown menu is set to 'Warm-up'. Below it, the text 'What circuit is in the black box?' is displayed above a central black square containing a white question mark. Two wires with red dashed circles at their ends extend from the left and right sides of the black box. On the left side, a vertical toolbar contains icons for a battery, a wire, a light bulb, and a resistor. On the right side, there is a 'Show Electrons' checkbox, a panel with 'Voltage' and 'Current' meters, and three buttons: 'Explore', 'Test', and 'Reveal'. A 'Reveal' button with an eye icon is also present. At the bottom, a navigation bar includes the text 'Circuit Construction Kit: Black Box Study', icons for 'Explore', 'Black Box', and 'Home', and the PhET logo with a hamburger menu icon.

# Assessment

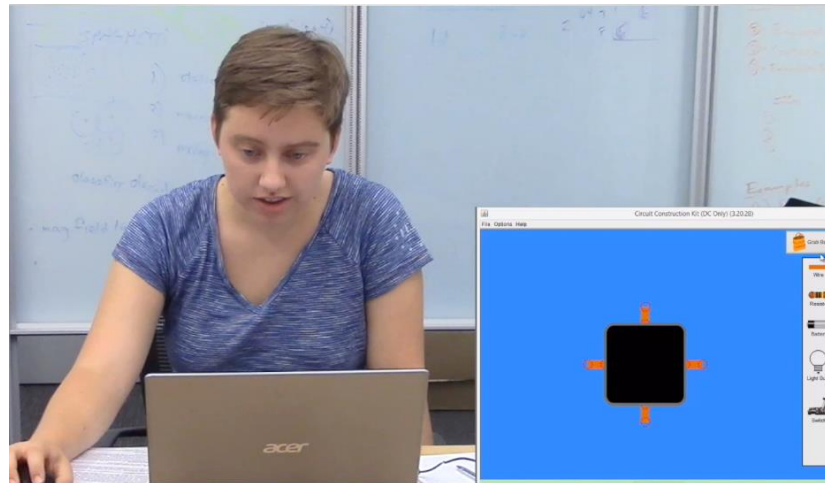


Shima Salehi  
Wieman Group  
Stanford

# Interviews

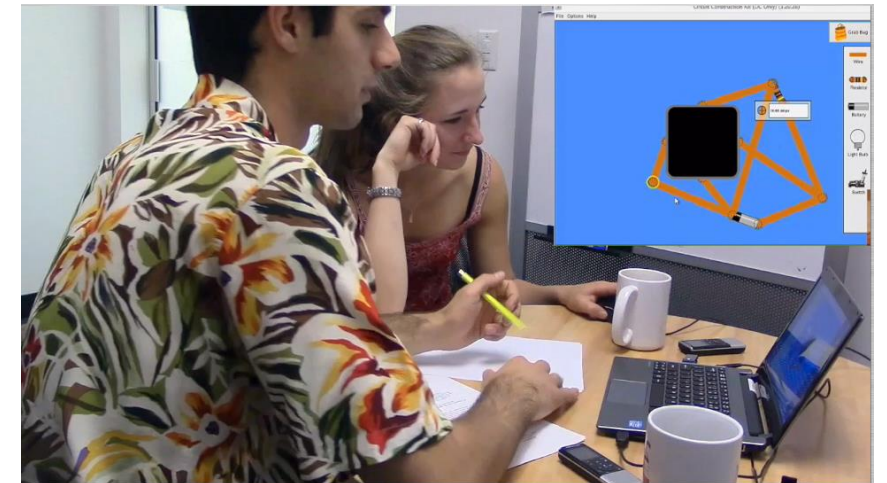
## Ellen

An advanced undergraduate



## Gail and Josh

Introductory E&M students



# Assessment



Shima Salehi  
Wieman Group  
Stanford

## Coding: Distinguishes Novices and Experts

### Experimentation Practices

Problem Decomposition  
Data Collection  
Data Representation  
Data Analysis

### Reflective Practices

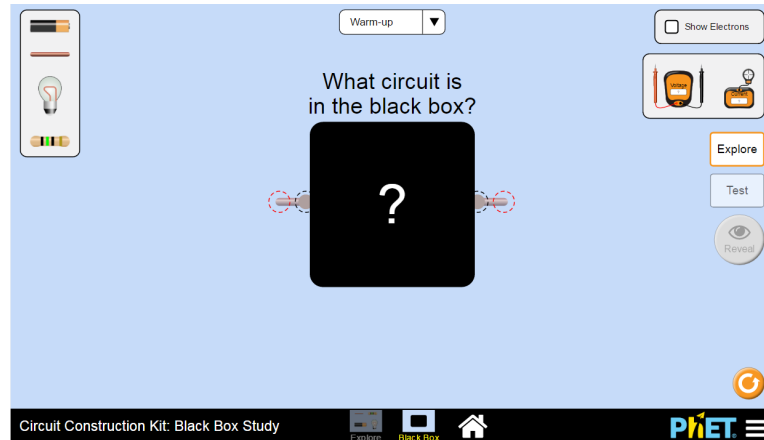
Reflect on Assumptions  
Reflect on Knowledge  
Reflect on Strategy  
Verification

# Assessment




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Wieman Group  
Stanford

# At Scale?



Backend  
Data

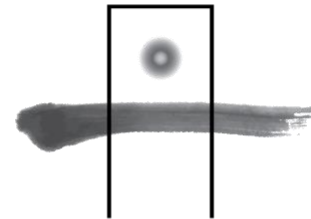
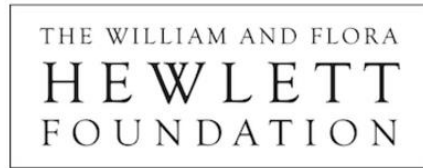


Learning Analytics  
Methods



# Funders

# Thank you!



Yidan Prize  
— 丹 獎



# Invitation

FIND PHET

<https://phet.colorado.edu>

USE SIMS

In lecture, lab, homework

CONTRIBUTE

Lessons

Register at <https://phet.colorado.edu>

SUPPORT

Try the PhET App (\$0.99)

SEND IDEAS

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

CONNECT



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