

PhET simulations provide interactive learning tools

January 26 2012, By Ellen Ferrante



Students use the PhET Wave Interference simulation in their introductory physics lab at University of Colorado Boulder. Credit: Final Hour Films

(PhysOrg.com) -- What causes a balloon to stick to a sweater? How do microwaves heat coffee? How is electricity generated from a bar magnet?

The physical world poses a number of questions. The PhET Interactive Simulations project at the University of Colorado Boulder helps students discover the answers and go beyond, while improving their scientific literacy.

The PhET project, founded by [Nobel Laureate](#) Carl Wieman and funded by the National Science Foundation (NSF) and others, provides free,

interactive, research-based simulations of [physical phenomena](#) for elementary through university students. NSF's Directorate for Education and Human Resources (EHR) provides primary support through its Transforming Undergraduate Education in Science, Technology, Engineering and Mathematics program (and its predecessor the Course, Curriculum and Laboratory Improvement Program) and the Discovery Research K-12 program.

The simulations are presented as individual exploratory environments rather than courses, so each computer simulation can be integrated into various classroom activities. They're also readily accessible--with a simple "click," these simulations, written in Java and Flash, open up an engaging science playground.

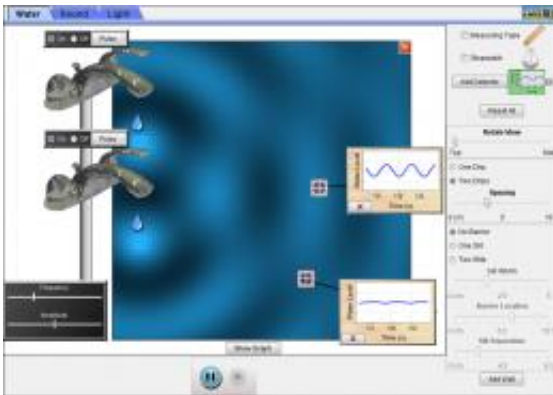
"PhET allows students to simulate experiments," said Zeke Kossover, a 2011-2012 NSF Einstein Fellow and a high school [physics teacher](#). "This allows them to do experiments with equipment that might not normally be available to them. It lets students play around in a physics sandbox where they can't break anything and they can try everything. It also can let them do experiments in such a way that they can explore just the idea being tested without having too many real world complications going on at once."

Don Millard, program director in EHR's Division of Undergraduate Education, said "PhET gives students the ability to put a context around formulas and theories, etc., and helps students to explore 'what if' questions that arise in science."

PhET simulations are developed using extensive research to help make the simulations as effective as possible. Katherine Perkins, director of PhET, explained that PhET simulations draw from and are aligned with published research in a variety of disciplines, including cognitive science, multimedia and computer interface design, and general and

discipline-based education research.

"In addition, we conduct a series of individual interviews on every simulation to examine whether the simulation is engaging students in scientist-like exploration, whether the interface is intuitive, whether students are correctly interpreting the representations and feedback provided by the simulation to advance their understanding, and whether students are able to achieve the learning goals of the simulation through their interaction and investigation," said Perkins. "Finally, we conduct observations and research in classroom environments."



In the PhET Wave Interference Simulation, students can experiment with making waves using a faucet, an audio speaker and a laser. Credit: PhET Interactive Simulations, University of Colorado

PhET's learning tools and simple design have caught on around the world. PhET simulations have been used over 60 million times, and are available in 65 languages with 22 full website translations.

PhET in action

"I use PhET in three ways," said Kossover. "In the first way, the students are given a playground to explore a topic. In the second way, I give the students a structured lab and tell them what to do. This is relatively rare. The third way is I find an applet that is very similar to an activity we did in class. Students who were absent can repeat the activity. Students that had more questions can poke around and explore on their own time. Students who were confused or made some sort of mistake can redo the work at home."

Ultimately, PhET can help students develop skills to use beyond the classroom and create their own new innovations. "Students are able to get fundamentals and apply them to create new products," said Millard. "Interactive simulations, such as PhET, allow students to integrate knowledge to help better identify problems we might be facing, and use this knowledge to develop innovative solutions."

A Mini-lesson using a PhET simulation on waves

Many PhET simulations help students make mental models of things that are too small to see.

In the Wave Interference Simulation, students can experiment with making waves using a faucet, an audio speaker and a laser. Students can control the frequency and amplitude of each of the waves (for light, the amplitude and the wavelength) as well as control other variables.



A screenshot of the PhET Build an Atom simulation. Credit: PhET Interactive Simulations, University of Colorado

Kossover gives a mini-lesson on waves using the audio speaker/sound-wave model:

After running the Wave Interference Simulation, switch to the "Sound" tab, and then press the green "plus" on the upper right corner of the wave simulation to enlarge the simulation. Then, on the middle right side of the simulation, switch from "Grayscale" to "Particles."

"You can see right away how the motion of the speaker moves particles back and forth and how they collide with other particles and send them moving," said Kossover. "You can increase the frequency and see the speaker vibrate more times per second. You can raise the amplitude and see the distance moved by the speaker get larger and the particles become more compressed with fewer particles in between the compressed spots."

A user can also add a second speaker to the simulation.

"Then, you can see that there are some parts where the particles move more and some places where the particles move less, showing

constructive and destructive interference," said Kossover.

"While the visualization factor itself is great, the students' ability to adjust the frequency and the amplitude makes it easier for them to get a feel for what's happening in such a way that they can make a mental model of what's happening," said Kossover. "Imagine how challenging it is to explain this model to students in another way."

"Understanding waves is part of most state physics standards but learning more about waves and sound is a hook that helps students, especially if they are musicians or listen to music," said Kossover.

"It helps students understand that much of their everyday lives has hidden beauty and complexity that can be described by physics models. The scientific process of making mental models of how the world works and using them to make predictions about the world are the first steps to becoming a scientist or at least thinking like one. The PhET simulations help [students](#) make these mental models and see scientific principles in action."

PhET selected as a 2011 Tech Award laureate

Last September, PhET was selected as a 2011 Tech Award laureate, and the recipient of the Microsoft Education Tech Award \$50,000 cash prize. The Tech Award is a signature program of The Tech Museum in San Jose, Calif. that recognizes and honors technical solutions that benefit humanity and address crucial issues in our world today. PhET was selected as one of 15 laureates, out of over 600 nominations representing 54 countries. Watch PhET's Tech Award Laureate video to learn more.

More information: phet.colorado.edu/

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