

Research-Based Design Features of Web-based Simulations

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Funded by NSF and the Kavli Operating Institute



Introduction

Through extensive interviews with students, we have developed guidelines for creating simulations which are easy to use, inviting, encourage exploration by the student and promote development of student understanding of physics.

The Physics Education Technology (PhET) Project¹ focuses on the development of elaborate Java- and Flash-based animated simulations that help students develop visual and conceptual models of physical phenomena. We have researched and characterized elements of effective simulation layouts, representational models, user help and guiding questions. We incorporate these elements into the design for future PhET simulations and they should prove useful for developing simulations in general. This poster will present these design principles and the research base of clinical interviews used to derive them.

Research Methodology

- Interviews
 - Think-aloud style
 - Either no guidance or limited to one or two conceptual questions.
 - 30 to 60 minutes per simulation
 - 4-6 interviews per version of simulation
- Homework
- Pre-Class Assignments
 - Simulation use vs. Reading
 - Helps identify level of simulation sophistication.
- Lecture Demonstrations
 - Clicker Questions

Design Philosophy

- Fun Bridge to Real World
- Research-Based
- Interactive
- Animated
- Engaging
- Promote Student Learning

- Intuitive Controls
 - Click and Drag Interface
 - Grabbable objects
- Representations
 - Start up Settings (manual/not moving, simplest version!)
 - Subtle visual cues important (electron spacing, E-field, nothing without conceptual value)
- Tool Use
 - Limit on useful number of tools (play buttons overlooked)
 - Tabs (placement is crucial)
- Encourage Exploration
 - Legends (some tool labels encourage use, label electrons, photons, molecules etc., but avoid “information overload”.)
 - Little Puzzles (don’t tell the student everything)

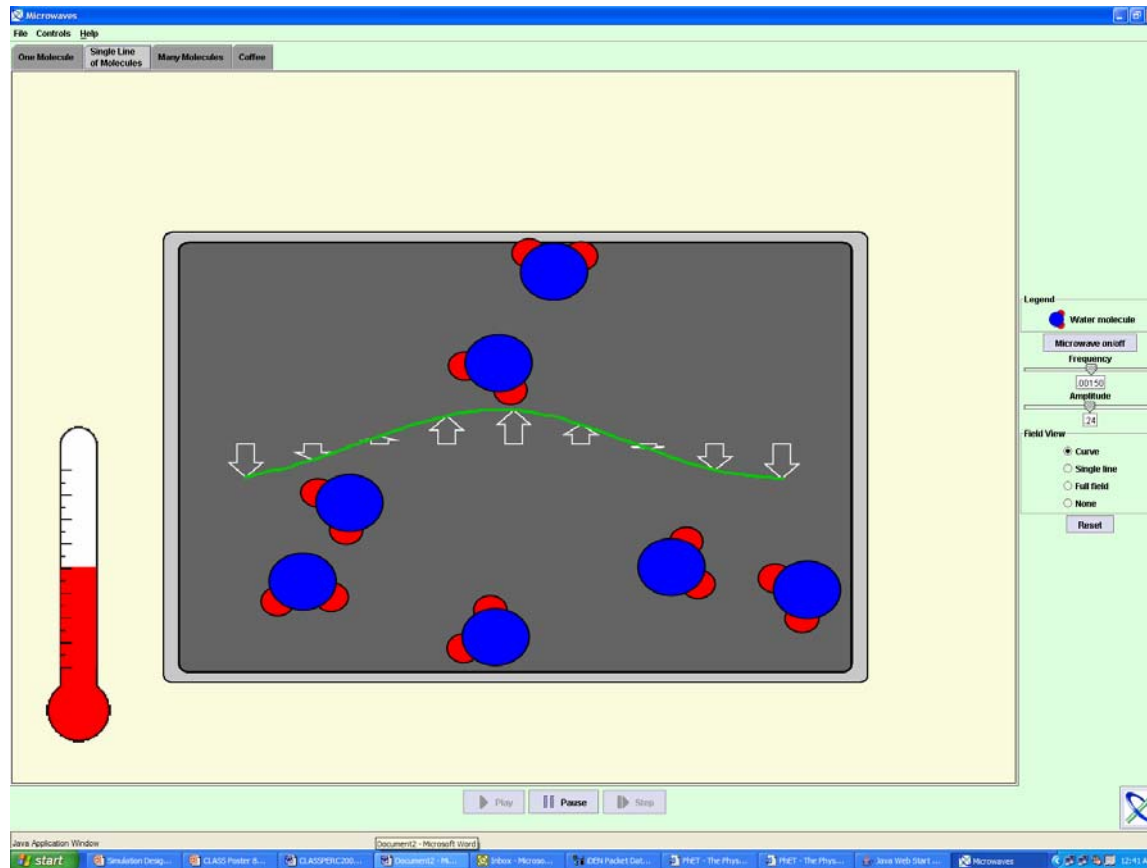
Interface Design- Research Conclusions

The screenshot displays the 'Radio Waves' simulation interface. The main window features a landscape with a transmitter tower on the left labeled 'KPhET' and a receiver antenna on a hill on the right. A red wave is shown propagating between them, with green arrows indicating the electric field direction. The interface includes a menu bar (File, Help), a PhET logo, and various control panels on the right side. The control panels include:

- Legend:** Electron
- Transmitter Movement:** Manual, Oscillate, Frequency slider, Amplitude slider
- Field Displayed:** Radiated field, Static field
- Display Type:** Curve with Vectors, Curve, Full field, None
- Field Sense:** Force on electron, Electric field, Display strip chart

At the bottom of the window, there are 'Play', 'Pause', and 'Step' buttons. The status bar at the bottom shows 'Java Application Window', 'Java Web Start Cons...', 'Radio Waves', and the time '1:41 PM'.

Microwave oven simulation: design principles work!



- Design features from previous interviews integrated into Microwaves
 - Start up Settings
 - Intuitive control
 - Tab Placement
 - Legend

- Help
 - Best if the simulations are designed totally intuitive.
 - Minimal Reading
 - *Student's rarely read.*
 - Inviting straight forward text
 - Minimal Guidance
 - *Found that help (both from instructor or onscreen), if not done properly, severely limits students' natural curiosity thus exploration.*
 - Unobtrusive
 - *Place help so that it can be seen; however, all fo the simulation should still be accessible.*

C:\Program Files\PhETnew\simulations\stringwave\stringWave.swf - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address C:\Program Files\PhETnew\simulations\stringwave\stringWave.swf

Links Survey Page WebMail UNC CU UNC Physics CU Physics CU class rolls KSCO 97.3 Boulder SideStep Web Cam University of Colorado at Boulder

0.5 tension

damping low high

Ruler
 Timer

Hide Help

Mega Help

draggable rule

10 cm 20 30 40 50 60 70 80 90 cm

Wiggle me!

Manual
 Oscillate

reset

Fixed End
 Loose End
 No End

pause/play

00:00:00

reset start/pause

draggable reference line

draggable timer

start Java Web Start 1.4.2... Screenshotsaug04.d... Microsoft PowerPoint... Noah P. - Microsoft O... DEN Packet Data Ser... PhET - The Physics E... C:\Program Files\PhE...

Basic Help (appears only upon request)
Normally all that is needed.

PhET Waves on a String

The image shows the PhET Waves on a String simulation interface. At the top, there are three sliders for amplitude (set to 50), frequency (set to 55), and damping (set to 0.5). To the right is a tension slider and a ruler. Below the sliders are checkboxes for 'Ruler' and 'Timer', both checked, and a 'Mega Help' button. The main simulation area shows a string with beads connected by an invisible string, oscillating in a wave pattern. A dashed red line represents the equilibrium position. On the left, there is a manual oscillator handle. At the bottom, there are mode selection buttons for 'Manual' and 'Oscillate', a 'reset' button, and a 'pause/play' button. A timer is also present, showing '00:00:00' with 'reset' and 'start/pause' buttons. The right end of the string is fixed to a wall.

Adjust the **amplitude** and **frequency** of the oscillator.

Adjust the string **damping**.

Adjust the string **tension**.

Check to show the ruler and timer.

The ruler is draggable. You can move it with the mouse.

In **Manual** mode, wiggle the end of the string with the mouse to create waves.

In **Oscillate** mode, the oscillator wiggles the string for you.

The beads are connected by an invisible string.

Choose the right end to be **fixed, loose, or open** (fixed is shown here).

Use the **Reset** and **Stop/Pause** buttons to control the timer. The timer is draggable. You can move it with the mouse.

The dashed line is draggable. You can move it with the mouse.

Choose **Manual** or **Oscillate** mode. Click **Reset** to set the string to its initial state.

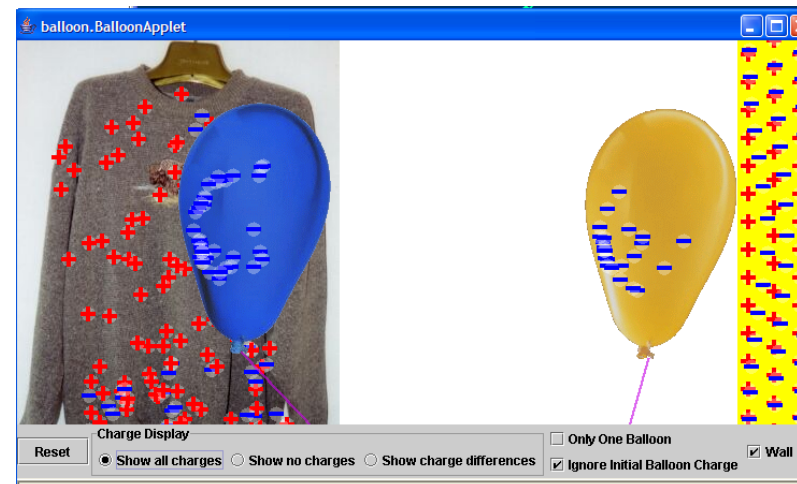
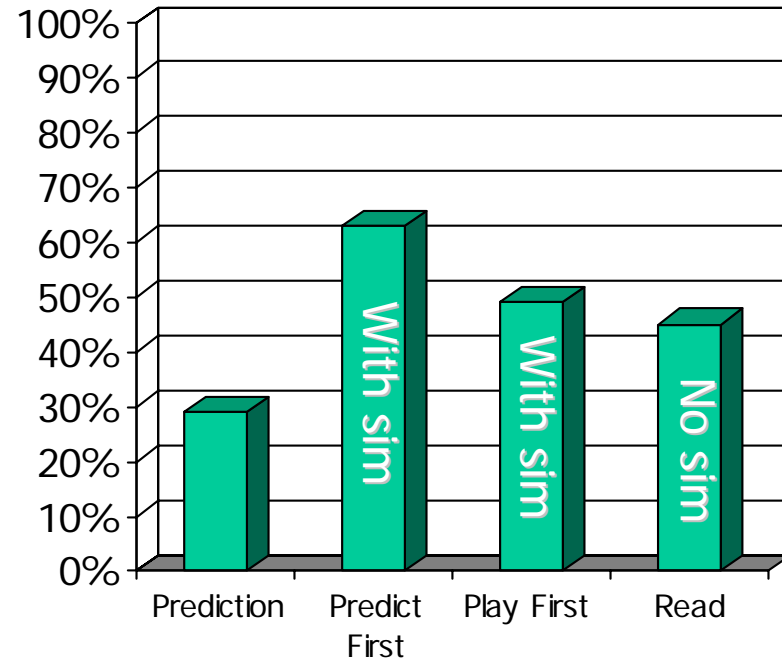
Use **Pause/Play** to freeze the motion. Clicking **Manual, Oscillate, or Reset** will unpause.

Mega Help (appears if requested after basic help)

Full manual. Does not explain concepts.

Guidance – Research Conclusions

- Some simulations are effective with a single question (*Understanding of concepts gained before instruction with only prediction question as guidance.*)
- Others require instruction or more carefully designed guidance. (*Not gain understanding of concepts before instruction. After instruction and written homework, students gain conceptual understanding with simulations.*)



Conclusion

Computer simulations are quickly becoming accepted as effective educational tools. We also feel that simulations can be highly effective learning tools; however only if carefully designed, researched and implemented. Interface design is crucial. If the students are not engaged, the simulations can not be effective. We are carefully studying our simulations through interviews, use as homework, lecture demonstrations, pre-lecture assignments and replacement for lab equipment¹ to be sure that each simulation is engaging and encourages learning. In this poster we have outlined the design features we have found effective in creating engaging, interactive computer simulations.

1. See Posters EA20 and EA22 PERC Poster CP-IP05