New tools for undergraduate education in physics: the Physics Education Technology (PhET) Project

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Introduction

The Physics Education Technology Project (PhET) has developed a suite of more than 50 free, downloadable simulations that span the content of introductory physics, as well as simulations on more advanced physics and chemistry topics. These research-based simulations are designed to promote student understanding and interest in science and to provide introductory physics, as well as simulations on more advanced physics and chemistry topics. We present the research design and the evaluation of these simulations in undergraduate physics. More available at http://phet.colorado.edu

Goals for Students

• engage in exploring and understanding physics
• see how much of everyday life is governed by physics principles
• develop accurate visual and conceptual models of underlying principles through exploration and inquiry
• build bridges between conceptual physics and abstract concepts or between different forms of representation
• see physics as accessible and understandable

Design Features

• Engaging & Interactive Approach: More supportive of student learning than traditional, passive, instructor- and text-centered environments.
• Dynamic Feedback: Emphasize causal relations by linking ideas temporally and graphically.
• Constructivist Approach: Students learn by building on their prior understanding through a series of scaffolding exercises.

Design Philosophy

• Workspace for Play: Simulations create a self-consistent world for the students to learn about key features of a system by engaging them in systematic play and investigation.
• Visual Models: Observable features of physics (e.g., microscopic models) are made explicit to encourage students to observe otherwise invisible features of a system.
• Productive Constraints: By simplifying the systems in simulations, students are encouraged to focus on physically relevant features rather than accidental conditions.

PhET Simulation

Connect to real world through real data

• Radii vectors move through space and respond to your changes

Field vectors set in all directions

Select the arrows to represent Force on Electric Field (green)

Switch between displaying the radiating field or static field

Receiver electron responds to radio wave

Change views to field

P-N Junctions and LEDs

Instruction on conductivity. When will electrons conduct?

2003 – static visuals and words

2004 – Conductivity and Semiconductors Simulation

Students were asked what happens when you combine P-N type semi-conductors together

Hook up battery, what happens?

a) electrons flow clockwise
b) electrons do not flow
c) electrons flow counterclockwise

Reverse battery, what happens?

a) electrons flow clockwise
b) electrons do not flow
c) electrons flow counterclockwise

Correct static picks/x: 74%
sim: 86%

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Conductivity

N-type

Conductivity

P-type

Attitude Towards Sims

Algebra-based introductory physics laboratory

One lab utilized a sim, while the remaining 8 did not.

Students found the lab with sim more useful and more enjoyable than the other labs

Usefulness of Labs

Sim used in Lab

Sim not used in Lab

Enjoyment of Labs

Sim used in Lab

Sim not used in Lab

Detailed Study of a Sim

Circuit Construction Kit (CCK)

CCK in Lecture

• Can CCK help students understand concepts?
• Calculus-based, second semester intro physics course (E&M)
• Directly test sim-use: traditional lecture, demo lecture, sim, talk only

DC Circuit Questions

For a traditional DC circuits lab, CCK was used in lieu of real equipment in 4 sections (N=99)

Real equipment (TRAD) was used in 6 sections (N=132)

At end of lab, all students participated in a challenge building circuits using real equipment and writing results

Note: Nearly all students had no formal experience with real circuits prior to challenge

Conceptual Understanding on Final Exam

Student achievement on three conceptual circuits questions on final exam (q1, q2, q3); "null" remaining 26 questions on final.

The mean for all 3 questions is 0.593 for CCK and 0.476 for TRAD groups (p<0.001).

Circuit Construction Time

Mean time for students to build a circuit with real equipment and write about it

"No Lab" was a control group; students in another course without a lab

CCK was faster at building circuit and writing about it (p<0.01)

References and Acknowledgements


Conclusions

• Sims can be productive tools for learning
• Under the right conditions, simulations can be successfully used in lieu of real equipment
• Results suggest conventional wisdom may not be correct—that experience with real equipment is NOT essential for conceptual development and laboratory practices
• For more info, go to http://phet.colorado.edu

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