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Can students learn from simulations at home, alone?

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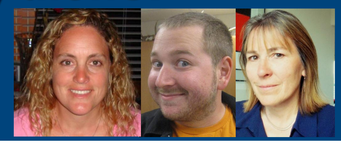


Introduction

- Most previous work on student learning with PhET simulations focuses on **classroom environments** where students work **in groups**, with scaffolding from both worksheets and instructors[1].
- Here we explore the space of when and how students can learn **individually** from PhET Sims.
  - In class wrapped with driving questions
  - At home wrapped with driving questions
  - At home via a Mastering Physics Tutorial[2]
  - At home without wrapping

Individual Use of PhET Sims

PhET Sims are Unique

Research on learning shows that to develop expert problem solving and understanding in science, students must actively build that understanding[3].

- Requires focus and motivation, and feedback on the student's thinking.
- Active-learning instructional methods "…aim to generate, through interactions with peers and instructors, understandings that eventually match those of physicists."[4]
- Interactive sims facilitate those same processes in ways that other teaching methods cannot[5].
  - Representations not available in real world
  - analogies to help students make meaning of and connect across multiple representations and phenomena
  - a high level of interactivity with real-time, dynamic feedback.

Prior work does not take full advantage of this.

PhET Sims are Not Automatically Effective

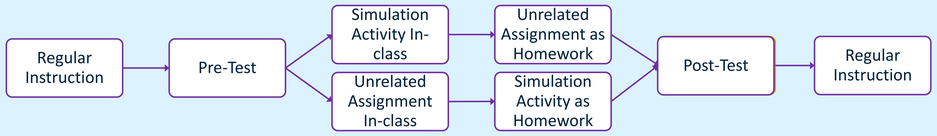
- ***Interview studies***[6] reveal that no guidance or driving questions engage students. Gently guided and heavily guided instruction nudged students into answer making mode
- Chemistry study[7] of ***small groups in recitation*** found Students explored more and attended to their sim interactions more in the light guidance condition and least in the heavy guidance condition.

References

1. see the research section of the PhET website http://phet.colorado.edu/new/research/index.php
2. E. S. Morote and D. E. Pritchard, Am. J. Phys. **77** (2009).
3. J. Bransford, A. Brown, R. Cocking, Eds. *How People Learn: Brain, Mind, Experience, and School* (National Academy Press, Washington, DC, 2000).
4. D. E. Meltzer & R. K. Thornton, Am. J. Phys., **80**, (2012), p 479
5. W. K. Adams, S. Reid, R. LeMaster, S. B. McKagan, K. K. Perkins, M. Dubson and C. E. Wieman. J. Interactive Learning Res., **19**. (2008).
6. W. K. Adams, A. Paulson and C. E. Wieman, AIP Conf. Proc., **1064**, 1 (2008).
7. J. Chamberlain, K. Lancaster, R. Parson and K. K. Perkins, Chem. Educ. Res. & Practice, **15.**
8. Activities, pre/post tests and rubrics can be found at http://www.unco.edu/nhs/physics/faculty/adams/Research/Armstrong_Supplementary.pdf
9. Tips for Using PhET can be found here: http://phet.colorado.edu/en/teaching-resources/tipsForUsingPhet

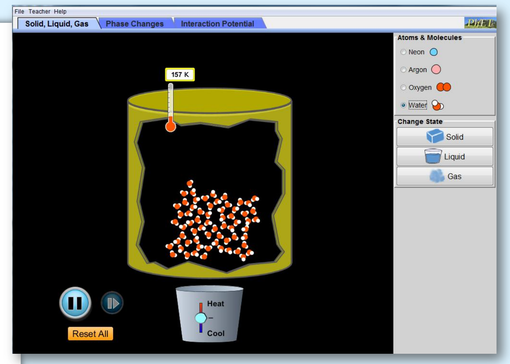
Effective Individual Activities

To determine if PhET wrapped with *Driving Questions* could be engaging and effective learning tools, when used individually, we worked with three periods of a high school physics class. One period used them in class while we observed, and other periods used them at home.



Sample Driving Question Activity

5. Have you heard that solid water, ice, takes up more space than liquid water? If your pipes freeze they split!!! Can you see why that is the case? Draw and label a picture to explain.
6. Do other molecules take up more space as a solid as compared to a liquid? Use words and pictures to explain.
7. How do the temperatures of a solid, liquid and a gas compare? Is it the same for all 4 atoms/molecules? Explain.
8. When you add heat to a container of molecules, what happens to the molecules?
9. Can you get the molecules to stop wiggling? If so, how?



Sample Pre/Post Test Questions

1. What are the differences and similarities between solid, liquid and gas particle motion? Include an illustration of a solid, liquid and a gas.
2. How does temperature relate to the kinetic energy of molecules?
3. Can all substances change into solid, liquid and gas form? Explain.

	Pre	Post	<g>	*d*
Static electricity				
In class	60.6(5.9)	76.1(3.6)	0.39	0.70
At home	62.1(4.4)	77.0(2.4)	0.39	0.81
Faraday induction				
In class	3.2(1.3)	60.9(5.6)	0.60	2.8
At home	2.8(1.6)	56.9(6.3)	0.56	2.4
Nature of matter				
In class	56.1(4.0)	70.6(3.7)	0.33	0.89
At home	48.5(3.8)	68.2(3.9)	0.38	1.1

( ) = Standard Error, <g> = normalized learning gain, *d* = effect size - Cohen's *d*

Completers: To measure the effect of the sim activity, only students who completed 30% or more of the activity were retained.
Inter-rater Reliability: ZA and another HS teacher both scored the pre/posttests[8]. 96% agreement before and 100% after discussion.

Results

PhET Sims indeed appear to be unique in that they provide affordances and constraints that allow for interactive engagement level learning gains with individual use.

✓ Students in class were actively engaged with the sims
✓ Learning gains in class were between 33 – 61%

✓ Learning gains at home were equivalent, providing some evidence that students were also engaged at home.

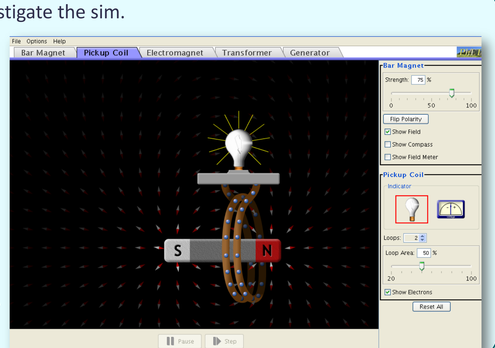
Why was Faraday Induction different?

- Students had little prior knowledge: room to grow and motivation to investigate the sim.
- Sim is very well scaffolded as seen in student interviews.

Pre-Test Responses

What do you have to do to make a light bulb light using a magnet? Use words and pictures in your explanation.

"I didn't know you could use a magnet to light a light bulb!"
"You need to put a positive magnet on the plug area and a negative magnet so the + & - attract and light the light bulb."
"Rub it on the end of a light bulb."
"Touch the magnet to the bulb to create a positive charge."
"You have to get electrons from the magnet to go into the light bulb."
"Take the magnet and put it to the end of a light bulb. The force of the magnet triggers the electrons in the metal of the light bulb and creates electric current."
"Put opposite ends of the magnets to the bulb and hopefully it will light up. Genesis 1:3 "Let there be light.""



Ineffective Individual Activities

Heavy Guidance at Home

Mastering Physics PhET Projectile Motion Tutorial:

- Heavy cognitive load – text heavy, involved problems.
- Explicit instructions on how to use the simulation.
- Explicitly drives "answer making mode"

Learning Goal:

To understand how the trajectory of an object depends on its initial velocity, and to understand how air resistance affects the trajectory.

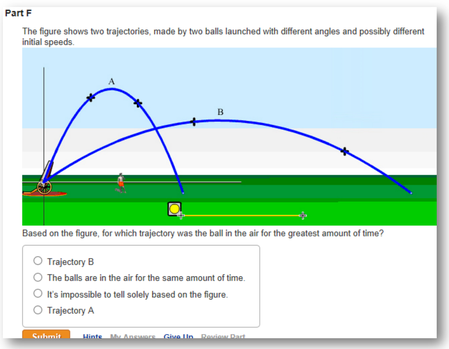
For this problem, use the PhET simulation *Projectile Motion*. This simulation allows you to fire an object from a cannon, see its trajectory, and measure its range and hang time (the amount of time in the air).

Start the simulation. Press **Fire** to launch an object. You can choose the object by clicking on one of the objects in the scroll-down menu at top right (a cannonball is not among the choices). To adjust the cannon barrel's angle, click and drag on it or type in a numerical value (in degrees). You can also adjust the speed, mass, and diameter of the object by typing in values. Clicking **Air Resistance** displays settings for (1) the drag coefficient and (2) the altitude (which controls the air density). For this tutorial, we will use an altitude of zero (sea level) and let the drag coefficient be automatically set

Reading Quiz before class (n=102):
84% of students completed Tutorial. Average score: 86%

Part F asked during following class:
31% initially correct,
30% correct after discussion.
62% chose Option B.

80% correct on the exam one week later.



At Home Without Wrapping - Light/No Guidance

Students told during class about a particularly applicable sim and how it will help them with the material. Screen shot and link provided in online PowerPoint slides.

Poll 1 week later:
5% worked through sim, 5 % looked at it, 29% thought about it but did not open, 57% forgot to look, 5% never intended to look.

Conclusion

- We have demonstrated that when working individually, both in class and at home, students will engage in exploring PhET sims via their own questioning.
- However, this type of interaction only occurs with proper scaffolding[9] to provide motivation and initial questions for students to investigate.