**PHYS111: Does it make a difference if labs are virtual or hands-on?**

In Fall 2013, Trinity purchased new equipment for hands-on experimentation in PHYS111. Dr. Uzi Awret used these in conjunction with virtual labs (PHET Interactive Simulations, <http://phet.colorado.edu/>). Assessment targeted whether these hands-on pieces of equipment enhanced student learning and retention.

**Description**

At the final exam in Fall 2013, all 22 students in the course answered questions on four different topics from the course (see Appendix). Dr. Awret taught two topics with hands-on experimentation, and two without; all four topics had associated virtual labs.

For each topic there were three questions aimed at students’ perception of their own understanding, the usefulness of virtual labs, and the usefulness of hands-on experimentation. Rating scale was 1-5, with 5 corresponding to strong agreement in understanding and usefulness. For the two topics that lacked hands-on experimentation, Dr. Awret asked students whether they wished there had been a hands-on component. The last question for each topic was a multiple-choice “test” question aimed at assessing student learning.

The same survey was administered in Fall 2014 to 10 students, following an intervention described in the “Follow-up” section below.

**Fall 2013 Results**

Surveys in Fall 2013 showed no compelling evidence that the addition of hands-on experimentation helped student learning (bottom row in Table 1), or student perception of their own learning (top three rows of Table 1). Students valued virtual experiments more than hands-on components for three out of four topics. Few students thought that additional opportunities for hands-on experience would have been useful; out of 22 students, only 3 for energy and 4 out of 22 for ramps indicated strong agreement with the idea that hands-on experiments would have improved their understanding (score of 5).

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Topic: | Circular motion | Projectile motion | Ramps | Energy |
| Student ratings (1-5) | Own learning | 4.2 | 4.0 | 4.1 | 4.3 |
| Virtual experiments | 3.9 | 4.0 | 4.3 | 4.0 |
| Hands-on experiments | 4.2 | 3.6 | 3.8 | 3.7 |
| Test question | Provided answer | 64% | 64% | 64% | 68% |
| Answer correct | 50% | 57% | 86% | 20% |

**Table 1. Fall 2013 survey results.** Grey columns are for topics taught with both virtual labs and hands-on experimental equipment; white columns for topics taught only with virtual labs. For each topic, students rated their own perception of mastering the material (own learning) and the utility of virtual or hands-on experiments, with a 5 corresponding to strong feelings of understanding or utility.

While results from this study are not comprehensive and lack a comparison group who did not receive instruction with hands-on experimentation for circular motion or projectile motion, they are not inconsistent with research in the educational literature that show virtual labs to be as effective as hands-on experimentation (Hawkins and Phelps 2013, 516-523; Corter et al. 2007). Another shortcoming is that the test question for energy differs from the other two, in that it is not a predictor of motion. In spite of this shortcoming, the same questions were used in Fall 2014, to determine whether measures to change laboratory exercises with hands-on experimentation affect learning outcomes and student perceptions.

**Fall 2014 Follow-up and Results**

Educational literature that shows some advantage from hands-on learning cite that (1) hands-on labs allow for unexpected results that make students question their understanding (Ma and Nickerson 2006), and (2) give better opportunities for student interactions that inform the “plan-experiment-analyze” process (Corter et al. 2007). Given these strengths in hands-on experimentation, students will have newly-designed Circular Motion and Projectile Motion hands-on laboratory exercises that include (1) potential for unexpected results, and (2) structure that requires student interaction.

Results from Fall 2014 (Table 2) came from a smaller class, with only 10 surveys administered. A glitch in the survey was that students were not given a hands-on laboratory for Circular Motion, yet the survey assumed that they did. Still, results below do not indicate a strong advantage in understanding or student perception of their own learning for the one topic that involved a hands-on exercise, projectile motion. Both years showed a lack of correlation between student perception of their own learning and the ability to answer a question on the same topic correctly.

An interesting difference in 2014 was that proportionally more students indicated strong preference for hands-on activities. Out of 10 students, 3 strongly agreed that hands-on exercises would have helped their learning on the two topics that lacked hands-on exercises. Because some students do appear to prefer hands-on experimentation strongly, and because the literature suggests that it has advantages, Physics plans to continue using both virtual and hands-on laboratory exercises in the future.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Topic: | Circular motion | Projectile motion | Ramps | Energy |
| Student ratings (1-5) | Own learning | 3.2 | 3.6 | 3.7 | 4.0 |
| Virtual experiments | 3.1 | 3.2 | 3.5 | 3.2 |
| Hands-on experiments | - | 3.3 | 3.8 | 4.0 |
| Test question | Provided answer | 90% | 80% | 80% | 80% |
| Answer correct | 67% | 25% | 88% | 38% |

**Fall 2014 survey results.** Grey columns are for topics taught with both virtual labs and hands-on experimental equipment; white columns for topics taught only with virtual labs. For each topic, students rated their own perception of mastering the material (own learning) and the utility of virtual or hands-on experiments, with a 5 corresponding to strong feelings of understanding or utility.

**REFERENCES**

Corter, James E., Jeffrey V. Nickerson, Sven K. Esche, Constantin Chassapis, Seongah Im, and Jing Ma. 2007. Constructing reality: A study of remote, hands-on, and simulated laboratories. *Acm Transactions on Computer-Human Interaction* 14 (2) (AUG).

Hawkins, Ian, and Amy J. Phelps. 2013. Virtual laboratory vs. traditional laboratory: Which is more effective for teaching electrochemistry? *Chemistry Education Research and Practice* 14 (4): 516-23.

Ma, Jing, and Jeffrey V. Nickerson. 2006. Hands-on, simulated, and remote laboratories: A comparative literature review. *Acm Computing Surveys* 38 (3): 7.

**APPENDIX**

**PHYSICS 111**

**End-of-semester survey**

*Full credit will be given for giving honest and complete answers for all of the questions below.*

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| This semester I learned how to solve problems involving circular motion. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Hands-on experiments with the flying pig were helpful for understanding and gaining intuition about circular motion. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Virtual labs were helpful for understanding and gaining intuition about circular motion. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Answer the following by selecting the best choice, a-d.  A cat sits on a Merry-go-round at a distance of 3 meters from the axis of rotation. How fast would it have to spin for the cat to fly off the Merry-go-round if the coefficient of static friction is 0.2?   1. Fast enough for the centrifugal force to exceed the static friction force. 2. Fast enough for the coefficient of friction to equal the angular velocity. 3. Slow enough not to wake the cat. 4. The cat is not going to fly off no matter the speed of rotation of the Merry-go-round. | | | | | |
|  | | | | | |
| This semester I learned how to solve problems involving ramps. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| The PHET virtual lab about ramps was helpful for my understanding of ramps. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| I wish there had also been a hands-on lab exercise to explore ramps. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Answer the following by selecting the best choice, a-d.  A 2 kg mass slides down a ramp with an angle of  = 30 degrees, and a coefficient of kinetic friction 0.25. How far down the ramp would it reach after 3 seconds?   1. The mass is not going to move. 2. Not enough information to tell. 3. It will slide with an acceleration that depends on the angle , the kinetic coefficient of friction and g. 4. It will move with constant velocity. | | | | | |
|  | | | | | |
| This semester I learned how to solve problems involving energy. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| A hands-on lab exercise to explore energy would have increased my understanding and problem solving ability. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| The PHET virtual lab about energy was helpful for my understanding of energy. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Answer the following by selecting the best choice, a-d.  A coin is dropped from a building, how would you describe its total energy at any time instant. What is conserved?   1. Potential energy. 2. Kinetic Energy. 3. Their sum. 4. Neither. | | | | | |
|  | | | | | |
| This semester I learned how to solve problems involving projectile motion. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| The PHET virtual lab about projectile motion was helpful for my understanding and problem solving ability. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Hands-on experiments with the ballistic pendulum was helpful for my understanding of projectile motion. | **1**  Disagree strongly | **2**  Mostly  disagree | **3**  Neither agree nor disagree | **4**  Mostly agree | **5**  Strongly agree |
| Answer the following by selecting the best choice, a-d.  A piece of wet clay with mass m1 and velocity v1 strikes another piece of clay at rest in space, and the two pieces stick together and move at a velocity v2. What is the total momentum before and after the collision? Is it conserved?   1. Before - m1v1, After - m1v1 + m2v2, Not conserved. 2. Before – 0, After – m2v2, Not conserved. 3. Before – m1v1, After – (m1+m2)v2, Conserved. 4. Before – m1v1 +m2v2, After – m2v2, Conserved. | | | | | |