Computer Simulation vs. Demonstration in the Introductory Physics Lecture

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Abstract

In view of the student population today spending a large amount of time in front of a computer, we investigate if learning can be enhanced by replacing traditional lecture demonstrations with computer simulations. We replaced four demonstrations with simulations in an introductory physics course and compared the learning outcomes with a pre and post-test.

Keywords: Introductory physics, computer simulations, lecture demonstrations, teaching methods.

1. Introduction

Demonstrations have always being used by physics instructors to motivate and explain concepts. We bring equipments into the classroom, like carts, balls, tracks, to mention only a few, to reproduce nature's events, raise questions and curiosity. Ultimately we aim into teaching concepts and correcting misconceptions. Research shows that from the student's perspective it is a helpful learning tool (Stefano, 1996). In the last decade, we have seen an increasing number of physics computer simulations. The experiment is performed on a computer screen. Despite the fact of not being hands-on, they have some advantages over traditional demos, as for instance, allowing quantitative analysis. Variables can be changed and the consequences observed with the click of a mouse. It has being shown that students exposed to simulations outperformed the ones exposed to real experiment in the lab environment (Finkelstein, Adams, Keller, Kohl, Perkins, Podolefsky, Reid, & LeMaster, 2005). Students today belong to a computer generation. They grew up playing video games and using computer for all their learning and entertainment needs. In some cases, more time is spent with technology than playing with `real toys'. In view of this new student profile, it is worth asking the question if learning can be enhanced by replacing traditional demos with simulations in the lecture setting. The intent of this study is to compare the learning outcomes when traditional demonstrations are replaced by simulations.

2. Procedure

This study was performed on two sections of the first semester of an introductory physics course. The student population (N = 40) consisted of science and math majors. The course is algebra-based and about 25% of the students did not have a formal high-school physics course. We replaced four lecture demonstrations with computer simulations. This section will be referred as section sim throughout the paper. We kept the demonstrations for the other section (section demo). The replacements were limited by the availability of simulations that fulfilled the content to be covered.

Simulations were obtained from a variety of online sources. The links for all sims were placed on a folder on an account on ComPADRE website ("Compadre.org"). Therefore it was easily accessible and well organized.

At the first day of classes, a pre-test was given to all students. There was no grade associated with it. There were 8 questions selected from the Force Concept Inventory (FCI) (Hestenes, Wells, & Swackhamer, 1992) and Force and Motion Concept Evaluation (FMCE) (Thornton, & Sokoloff, 1998). The choice of questions was based on the physics concept being introduced by the simulation and/or demonstration.

The post-test was spread throughout the course. Usually within a week or two after the simulation or demonstration was performed the question from the pre-test related to the concept was repeated on an exam. At this time, if the answer was correct, the students would receive a bonus grade.

The first replaced demo was free fall, a coin tossed in the air. The demonstration consisted of throwing an object up and catching it later on. The kinematics of the motion was discussed while the experiment was performed several times.

The simulation (Titus) had, in addition to the experiment, graphs of position, velocity and acceleration. Questions 1-3 (FCME questions 27-29) refer to the direction and magnitude of the acceleration as the coin goes up and down.

The second demo was a cart on an incline. We brought into the classroom a cart and a track attached to a rod to provide different inclinations. As the cart was going up and down, we discussed kinematics and dynamics concepts. The simulation (Esquembre, 2010) allowed the incline angle to be changed while showing the force vectors. Questions 4-6 (FCME questions 8-10) refer to the net force acting on the cart as it goes up and down.

The third demo was for circular motion explanation. It consisted of a ball attached to a string. The simulation ("Uniform circular motion") showed the velocity vector and acceleration of the ball throughout the motion. Question 4 (FCI question 4) asks about the path of the ball in the event the string breaks.

The last demo was on collisions. We used two carts on a track. The simulation ("Collision lab") showed velocity and momentum vectors and allowed the adjustment of several variables. Question 5 (FCI question 2) asked about the force exerted between a large truck and a small car during a head-on collision.

An attempt was made to maintain the same overall conceptual explanation regardless of using demo or sim.

3. Analysis

As can be seen in Figure 1, the sim group showed a greater overall gain in all questions except questions relating to demo/sim 2. The free fall concept refers to demo/sim 1. The sim group had an overall better result than the demo. For question one, 33.3% (sim) scored correct on the post-test while only 15.8% on the demo group. The data also shows a greater improvement for the sim group in comparison to the pre-test in all three questions.

Demo/sim 2 refers to the cart on an incline. Although both groups performed poorly, the demo showed a better gain on question 3. But there were no correct answers from both groups on post-test questions 1 and 2. Therefore the result is inconclusive.

The circular motion and collision concepts represented respectively by demo/sim 3 and demo/sim 4 again showed greater overall gain by the sim group if we compare pre and post-test results. Although 73.7% of the demo group scored the correct response for demo 3, still the gain was greater by the sim group changing from 16.7% correct responses on the pre-test to 56.3% in the post-test. Interestingly, the demo group showed no change in the collision concept. In fact, the same students with one exception, scored correctly on the pre and post-tests.

4. Discussion

We replaced four traditional demonstrations with computer simulations in an introductory physics course. If we compare the pre and post- test results, the sim group showed a greater overall gain than the demo group in three out of four replacements. Although the demo group performed better on one of the concepts, this result was not in agreement in all three questions related to the concept.

Even though the results here point out to an overall better learning outcome from the sim participants, we cannot generalize. We believe real demonstrations are an essential part of a physics course and as such should continue being used. In fact, some demonstrations were still performed during the lectures as they seem more appropriate. The computer simulations have a clear advantage in showing a quantitative analysis. The real time vectors and graphs are great teaching tools. Possibly students nowadays relate more to simulations due to their use of computer and video games. Although, I know from student course evaluations that they also appreciate in class demonstrations.

Further investigation with different concepts would be needed for generalization. In addition, comparison with other institutions would help to generalize the preliminary results obtained here.

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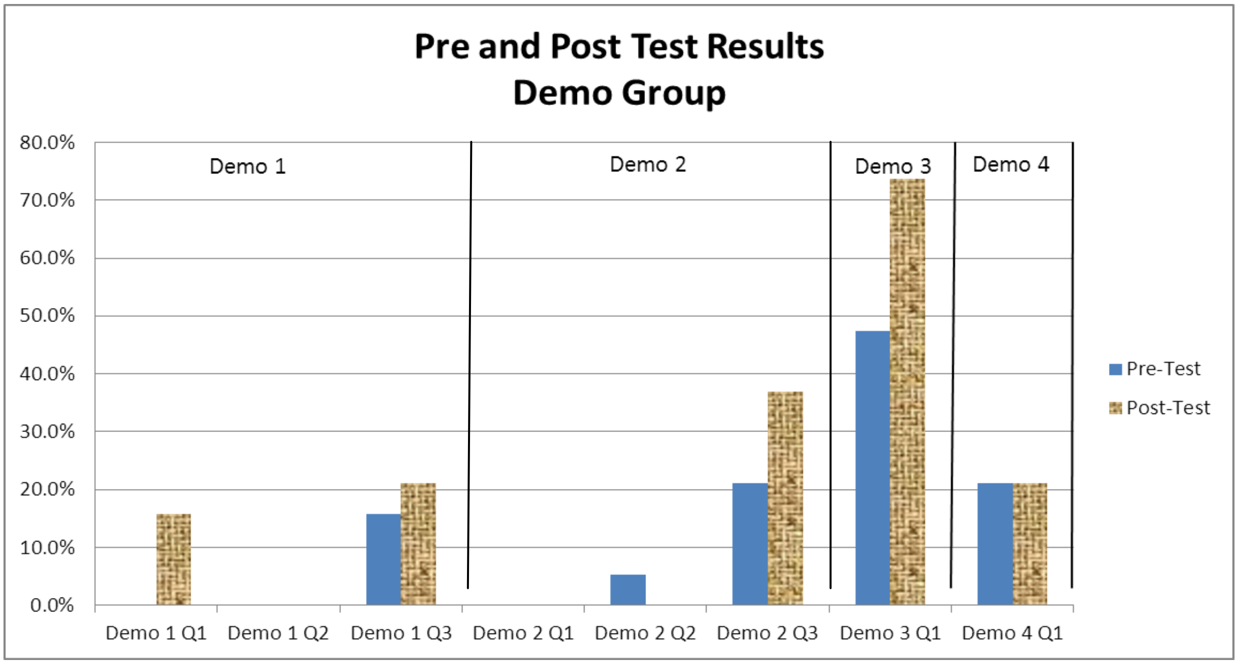

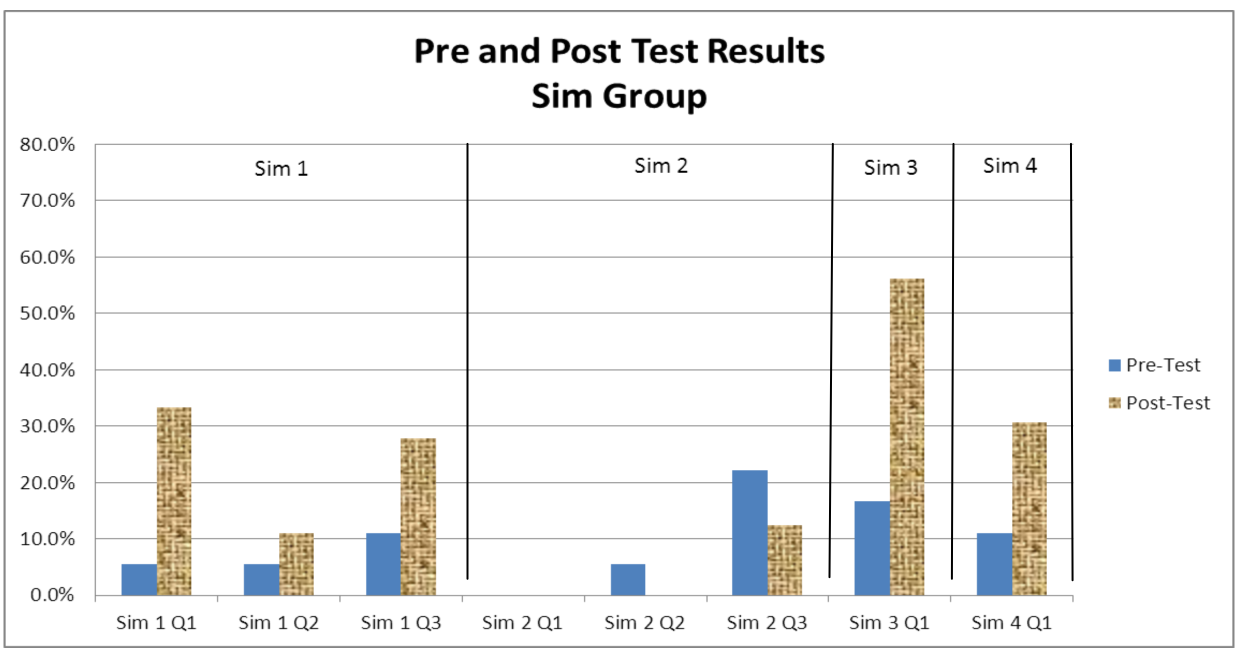

Fig 1: Pre and Post test graphs.