The Effect of Animation on Students' Responses to Conceptual Questions

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Computer animations were added to the FCI using the Animator Physlet®, a scriptable Java Applet designed for physics education. It was found that animation can alter a student's response to these types of questions, and that it can either increase or decrease the likelihood of a correct response.

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With rapid developments in technology, and increasing access to computers, assessment is no longer limited to pencil and paper questions. In traditional assessment, motion must be described or represented by a static diagram. Students' understanding of physics concepts can now easily be probed with computer animations that allow motion to be viewed dynamically. But when and how should these questions be used? Most research in the area of animation has focused on the effect of animation on students' reading comprehension and in "learning-by-doing" interactive activities. There is little previous research on the effect of animation on students' performance on problem solving activities or conceptual reasoning questions[1]. In an effort to address this lack of information, we have been investigating how animation influences the way students answer conceptual questions about forces such as those found on the Force Concept Inventory (FCI)[2].

We have added animations to all of the FCI questions[3] using Animator, one applet in a suite of educational physics Java applets called Physlets developed by Wolfgang Christian at Davidson College[4]. Because the question author can use JavaScript to create objects and define their equations of motion, this applet allows for the animation of many situations found in typical physics questions. Students can control the animation using VCR-like control buttons and can collect data by clicking on objects or by simply viewing position and time data if they are displayed. Figures 1 and 2 show examples of animated questions. Once written, these questions and animations are easily delivered to students via the World Wide Web.

We gave the animated version of each question to a group of students and the traditional version to either a control group of students or the same group of students. In all, we collected data from over 600 students at three state universities, one small liberal arts college, and one high school. From this data we have been able to answer several questions regarding the use of animations for assessment.

Does seeing an animation, instead of a static picture or description of motion, affect students' responses to a conceptual question?

Yes. Approximately 130 students answered each animated question from the second version of the FCI. They were compared to a control group of about 260 students from the same population who answered each question in its traditional form.[5] This particular group of students took the FCI v.2 as a pre-test. Of the 30 questions, 10 showed significant differences[6] between the two groups when the distribution of responses (correct and incorrect) was compared. For example, the students in both groups were equally as likely to answer question #2 correctly. But the animation did have the effect of shifting students from one wrong answer (D) to another wrong answer (B). Similar results were found in a pilot study in which parts of the first version of the FCI, and a portion of the FMCE[7], were animated and given as a post-test.

These results indicate that when students see an animation (instead of a description of motion or a diagram) it can change the way they respond to a question. As important and interesting as that fact may be, it is important to note the animation did not always have an effect. In fact, for the majority of the FCI questions there was no difference in student answers when the animation was added to the problem. This result is important because there has been a tendency to apply new technologies broadly as if technology could solve every problem.

Although technology can be helpful in certain situations, it is sometimes just a more complex, time-consuming, and expensive alternative to traditional methods. We have found no evidence to support the use of computer animations for all assessment. Our work indicates that animation only has an effect for particular kinds of questions. As computer access has become more and more common in classroom, the need for research to understand when and how this resource can best be used increases.

Does animation increase the probability that students will give the correct response to a conceptual question?

Sometimes. Ten of the questions from the FCI v.2 showed significant differences when all possible responses (including incorrect responses) were considered. Seven questions (see figure 3) showed a significant difference when only the fraction of correct responses was compared between the animation group and the traditional group. Of these questions four (#3,#7,#14,#26) came out in favor of the animation group. For the rest, (#1, #19, #20) the traditional group performed better. (See table I)

These results indicate that the effect of an animation on students' ability to answer a conceptual question correctly depends on the particular question being asked. Although animation can alter a student's response, it is not clear whether this is a positive or negative result. There are several possibilities.

In order to answer a traditional question involving motion, the student must interpret a description of motion or diagram. An animated question eliminates this step because the motion can be viewed directly. Animated questions may help students to answer correctly because misunderstandings of the diagram or description are eliminated.

Alternately, the animation may be written in such a way that the student is confused or mislead. Or, it may distract the students in a way that causes them to answer incorrectly even though they have a correct understanding. Just as a traditional question could be poorly worded, animated questions could be poorly scripted.

It is also possible that students may answer an animated question differently than its traditional counterpart because their views are not deeply rooted and can be easily altered by subtle differences in the question asked. The authors of the FCI found that students' responses to early versions of the FCI were inconsistent across questions.[8] They describe students' ideas as "bundles of loosely related and sometimes inconsistent concepts". If a student has an unstable understanding, his or her response may be easily shifted in a rather chaotic way.

Another possibility is that the animation is better at bringing out students' misconceptions. With any assessment there is the possibility of a false positive. Sometimes, a student may answer correctly on the traditional paper version even though he or she may have an incorrect understanding. It is possible that animations are better at getting at what the students really believe since they are responding to what they see instead of what they read.

Since our results show that adding animation to a question can produce mixed results, caution is in order when using this type of question. Before animated questions can be used effectively for assessment, more understanding of why a particular question affects a students answer is needed. We are in the process of conducting more research to determine why the animation diverted students in some cases and why it assisted them in others.

For what types of questions is the animation most likely to have an effect?

Although animations were provided for all questions, viewing the animation was not necessary to correctly answer all questions. For example, the traditional version of question #13 gives a statement about a boy throwing a ball in the air and then asks about the forces on the ball. The animated question is the same except that it also provides students the opportunity to view a boy throwing a ball in the air. In this case there was no information given in the animation that was not also given in the problem statement. There were also three questions for which the animation did not need to be viewed but viewing of the first frame was required to correctly answer the question. For example, question #5 asks about a force from q to O. The first frame must be viewed to establish the location of these two points. However, playing of the animation was not required to give a correct response.

In contrast, there were 14 animated FCI questions for which viewing the animation was required to answer correctly. For example, question #19 (shown in figure one) could not be answered unless the animation was viewed. Students needed the animation to get information about the blocks' velocity to correctly answer the question.

All seven questions, from the FCI v.2, for which significant differences were found in the likelihood of a correct answer, came from the 14 animated questions for which viewing the animation was required. The animation was most likely to have an effect when it was an integral part of the question. Although this result may seem obvious in hindsight, it is not trivial. Multimedia is often used to add flashy graphics or computer animation even when the addition is not central to the message. Our results indicate that such an addition may be wasteful at best. Superficial additions and changes in the problem statement did not change our students' responses.

We also looked to see if the effect of adding animation to a question depended on whether or not the original question had a picture. There does not seem to be a strong relationship. Of the seven questions with a significant difference, four were from questions for which a picture was given in the traditional version and three were from questions for which no picture was given.

These results indicate that simply adding animation is less likely to affect students than adding an animation with which the students must interact. Animation should have a purpose to be a worthwhile addition to a problem statement. Previous research[9] has found that students may not even view a video clip if it is not necessary to answer the problem statement. In this earlier study, students were asked to view a video clip of a problem but were still given all required information from the traditional version of the problem. Students had to click on a button to activate the animation. Some students answered the question without ever activating the animation.

Does the effect of animation depend on the background of the student and/or the type of instruction they have received?

Maybe. Our current research design does not allow us to answer specific questions about how animation might affect a student with a particular background but we did see enough differences in the groups that participated to warrant further research into this area. As with many educational approaches, animation may help some students to translate their ideas into words; other students may be distracted by the animation.

Figure 4 shows the distribution of student answers for four groups of students representing a range of academic backgrounds, socioeconomic statuses, and instructional styles. The distribution shows how students answered question #19, when taken as a post-test, as part of a pilot study[10]. Two groups (College and University-1) were most likely to give the correct answer E when the students saw either the animated version of the question or the traditional question. The other two groups (High School and University-2) were more likely to give an incorrect answer when they saw the animation and a correct answer when they saw the traditional version. There were many differences between these groups. It is not clear which differences led to the varied results.

We are in the process of collecting data regarding academic background, gender, race, and course performance for each student who takes the animated FCI. This data should enable us to identify if particular groups are more likely to be affected negatively or positively by viewing an animation.

Conclusion

It is often difficult to assess students' understanding because the results will inevitability depend on the way we ask the questions. As students' understanding is measured, error will be introduced into students' scores on whatever instrument is used. We believe that animations may provide a valuable way to assess students' understanding of forces in some cases. If a student is able to answer a question correctly when he or she views an animation but not when viewing a static diagram or description of motion, then suspicions arise that there is a problem with the way the question is being asked. Granted, we want students to be able to understand text and interpret a static diagram. But if the goal is to test their understanding of a concept, rather than their ability to interpret a picture or question statement, then some traditional questions may not be valid. Students' responses to animation-enhanced questions may give us a more accurate "picture" of what they believe because they are responding to what they see rather than how they interpret the question.

It is also important to understand when seeing an animation may distract students from the correct answer. It is possible that animation may sometimes confuse a student, in which case is should not be used. Or, the animation might bring out a misconception that is otherwise dormant. Of course, if the goal of the assessment is to probe student misconceptions then this type of animation would be helpful.

There are many tools available to the physics teacher today that make it easy to ask students to answer questions or solve problems about a dynamic situation they can view and manipulate. Although we found that the animation does not always affect students' ability to answer questions, it often does change their response when the animation is an integral part of the question. Sometimes the animation can increase the probability that students will answer correctly, and sometimes the animation will have the opposite effect. We are in the process of conducting further research to clarify when animation is useful at creating conceptual questions that more accurately measure a student's conceptual understanding.

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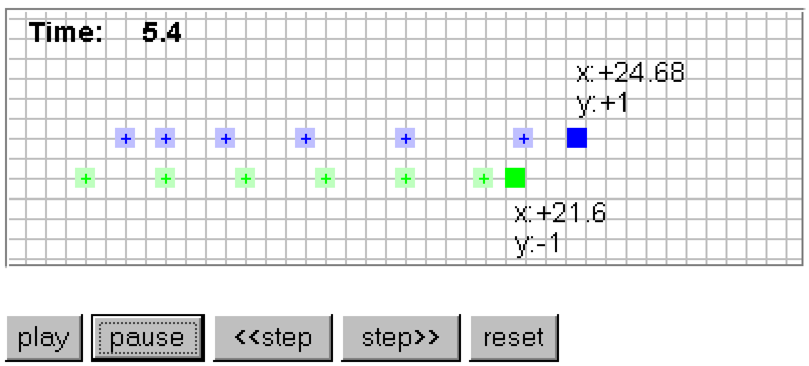
Table I
Significant results from FCI v.2, taken as a pre-test, when comparing responses given to animated and traditional versions of each question.

Question #	% Correct (N)		Z
	Animation	Traditional	
1	57% (135)	71% (265)	2.70**
3	67% (136)	56% (264)	2.03*
7	80% (134)	64% (262)	3.22**
14	76% (134)	51% (262)	4.86**
19	34% (131)	51% (256)	3.14**
20	24% (131)	47% (257)	4.40**
26	21% (126)	5% (251)	5.01**

*p<0.05 **p<0.01

Figure 1
Question #19 from FCI v.2 (corresponds to question #20 on FCI v.1). Shown in animated and traditional form.



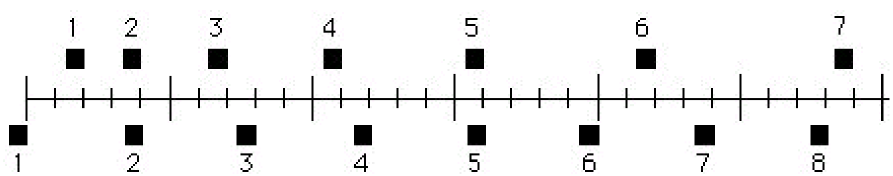
Two blocks are moving as shown in the animation. Do the blocks ever have the same speed?

Start Animation

- A) No
- B) Yes, at t=1s
- C) Yes, at t=4s
- D) Yes, at t=1s and t=4s
- E) Yes, at some time during interval 2s to 3s

Animated Version – Students must view the animation to determine positions of the blocks as time progresses.

The positions of two blocks at successive 0.20 second time intervals are represented by the numbered squares in the diagram below. The blocks are moving toward the right.

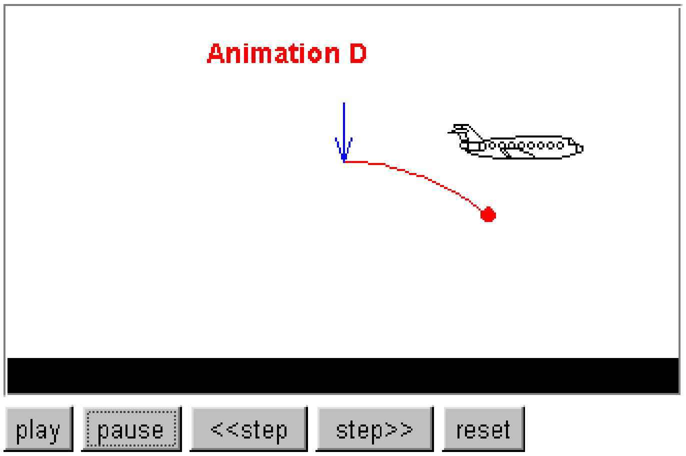


Do the blocks ever have the same speed?

- A) No
- B) Yes, at instant 2
- C) Yes, at instant 5
- D) Yes, at instant 2 and 5
- E) Yes, at some time during interval 3 to 4

Traditional Version

Figure 2
Question #14 from FCI v.2 (corresponds to question #23 from FCI v.1). Shown in animated and traditional form.



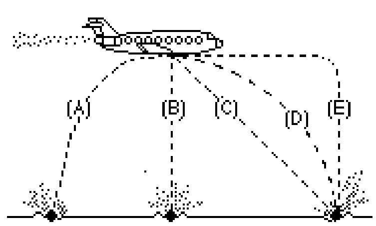
A bowling ball accidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As observed by a person standing on the ground and viewing the plane as shown in the animations, which animation shows the path the bowling ball would most closely follow after leaving the airplane? (note that the bowling ball falls out at the point indicated by the blue arrow)

- ○ Start Animation A
- ○ Start Animation B
- ○ Start Animation C
- ○ Start Animation D
- ○ Start Animation E

Animated Version – Students must view five animations to determine which most closely matches reality.

A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?

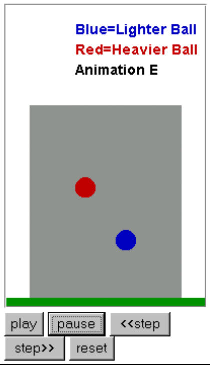
- ○ (A)
- ○ (B)
- ○ (C)
- ○ (D)
- ○ (E)



Traditional Version

Figure 3 (appears on next page)
Five of the seven questions for which significant differences were found in the proportion of students answering correctly on the animated and traditional version of the question. The animated version is shown on the left and the traditional version is on the right. The remaining two questions for which significance was found are displayed in figures one and two.

Question 1



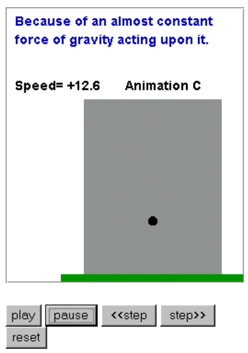
Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. Which animation best represents how the balls would fall to the ground below?

- Start Animation A
- Start Animation B
- Start Animation C
- Start Animation D
- Start Animation E

Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:

- (A) about half as long for the heavier ball as for the lighter one.
- (B) about half as long for the lighter ball as for the heavier one.
- (C) about the same for both balls.
- (D) considerably less for the heavier ball, but not necessarily half as long.
- (E) considerably less for the lighter ball, but not necessarily half as long.

Question 3



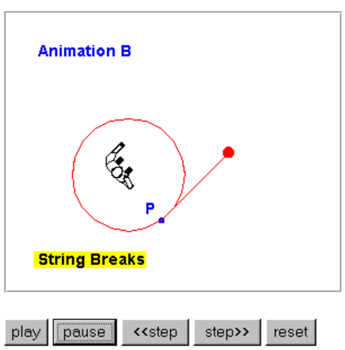
Which animation best represents the way a stone dropped from the roof of a single story building falls to the surface of the earth?

- Start Animation A
- Start Animation B
- Start Animation C
- Start Animation D
- Start Animation E

A stone dropped from the roof of a single story building to the surface of the earth:

- (A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
- (B) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
- (C) speeds up because of an almost constant force of gravity acting upon it.
- (D) falls because of the natural tendency of all objects to rest on the surface of the earth.
- (E) falls because of combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

Question 7

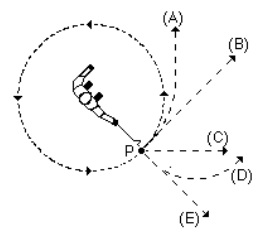


A heavy ball is attached to a string and swung in a circular path in a horizontal plane as shown in the animation. At the point P indicated in the animation, the string suddenly breaks near the ball. If these events are observed from directly above, which animation shows the path the ball would most closely follow after the string breaks?

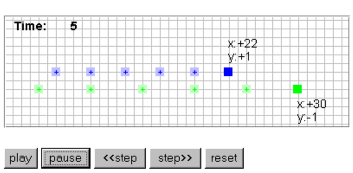
- Start Animation A
- Start Animation B
- Start Animation C
- Start Animation D
- Start Animation E

A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure. At the point P indicated in the figure, the string suddenly breaks near the ball. If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

- (A)
- (B)
- (C)
- (D)
- (E)



Question 20

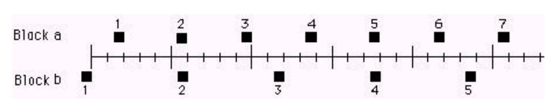


Start Animation

Two blocks are moving as shown in the animation. The acceleration of the blocks are related as follows:

- (A) The acceleration of "blue" is greater than the acceleration of "green".
- (B) The acceleration of "blue" equals the acceleration "green". Both accelerations are greater than zero.
- (C) The acceleration of "green" is greater than the acceleration of "blue".
- (D) The acceleration of "blue" equals the acceleration of "green". Both accelerations are zero.
- (E) Not enough information is given to answer the question.

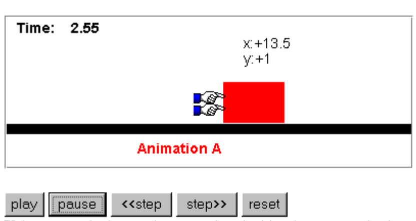
The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



The accelerations of the blocks are related as follows:

- (A) The acceleration of "a" is greater than the acceleration of "b".
- (B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.
- (C) The acceleration of "b" is greater than the acceleration of "a".
- (D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.
- (E) Not enough information is given to answer the question.

Question 26



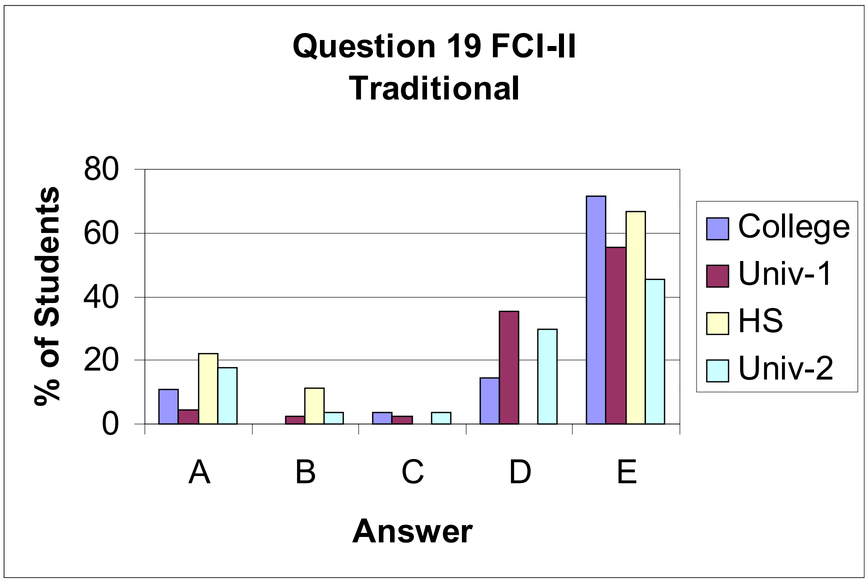
If the woman in the previous question doubles the constant horizontal force that she exerts on the box at t=2 seconds, which animation shows the correct way that the box then moves?

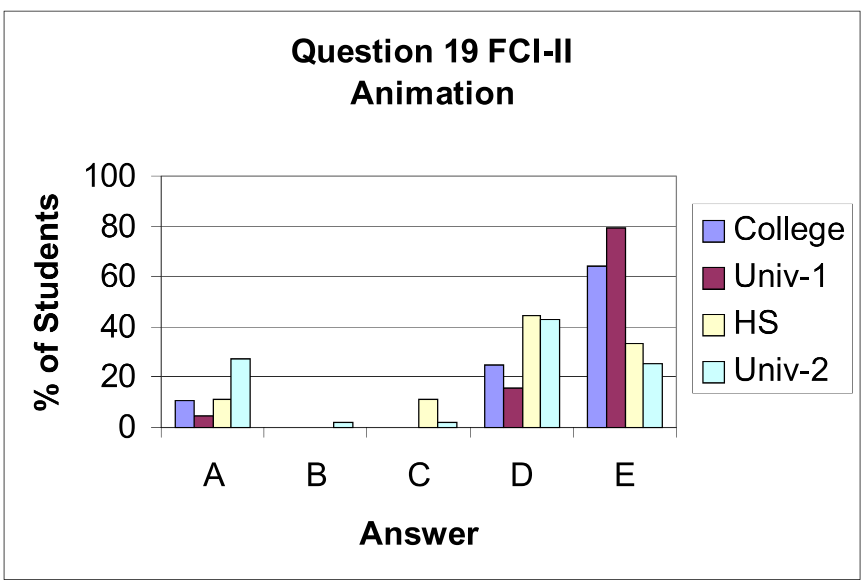
- Start Animation A
- Start Animation B
- Start Animation C
- Start Animation D
- Start Animation E

If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

- (A) with a constant speed that is double the speed "v_0" in the previous question.
- (B) with a constant speed that is greater than the speed "v_0" in the previous question, but not necessarily twice as great.
- (C) for a while with a speed that is constant and greater than speed "v_0" in the previous question, then with a speed that increases thereafter.
- (D) for a while with an increasing speed, then with a constant speed thereafter.
- (E) with a continuously increasing speed.

Figure 4
Graphs of student responses to question 19 from FCI v.2 (corresponds to question 20 from FCI v.1) The correct answer is E. While the Univ-1 students performed significantly better on the animated version, the other groups performed better on the traditional version (only Univ-2 was significant).





[1] Aaron Titus, *Integrating video and animation with physics problem solving exercises on the world wide web*. (Doctoral dissertation, North Carolina State University, 1998).

[2] The majority of our data came from the second version of the FCI which is published in Eric Mazur's *Peer Instruction*, (Prentice Hall, NJ, 1997). It can also be downloaded at http://modeling.la.asu.edu/modeling/R&E/Research.html once a password is obtained from the authors. Our pilot data came from the original version of the FCI published in The Physics Teacher. D. Hestenes, M. Wells, and G. Swackhamer, *Phys. Teach*. **30**, 141-151 (1992).

[3] The animated version of the FCI can be obtained by contacting the authors. It is also included with the book *Physlets* by W. Christian and M. Belloni (Prentice Hall, NJ, 2000).

[4] More information is available at http://webphysics.davidson.edu/Applets/Applets.html This site also contains numerous examples of physlet problems spanning the concepts of introductory physics.

[5] Except for question 10, for which only 26 students answered the animated version and 27 answered the traditional version.

[6] We performed a large number of statistical tests (five per question) which increases the number of expected false positives. Therefore, we are only reporting on those differences that were found at the $p \leq 0.01$ level on a two-tailed z–test for a proportion.

[7] R. K. Thornton, and D. R. Sokoloff, "Assessing student learning of Newton's laws: The Force and Motion Conceptual Evaluation and the evaluation of active learning laboratory and lecture curricula," *Am. J. Phys*. **66**, 338 (1998).

[8] I. A. Halloun and D. Hestenes, "Common sense concepts about motion," *Am. J. Phys*. **53**, 1056 (1985).

[9] See Ref. 1

[10] These groups answered the question in an early form when the animation showed the blocks moving across the screen without leaving the footprints shown in figure 1.