Clarifying the Force Concept Inventory via Think-Aloud Interviews

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Over the past two years we have conducted three iterations of think-aloud interviews with students as they grappled with questions on the Force Concept Inventory (FCI). Doing so has shown us that the difficulties they have with some questions have nothing to do with their understanding of physics. These difficulties involve diagrams, notations, and vocabulary that make perfect sense to physics teachers but can easily confuse beginning students. Informed by those think-aloud interviews, we have been modifying a subset of questions to improve clarity and then administered each version of the clarified FCI to students in two introductory physics courses. In addition, the latest version contained some new questions also motivated by student input. Here we discuss the specific construction of these questions and how students responded to them on our latest version of the clarified FCI administered prior to instruction.

Our First New FCI Question

New Question 4
4. A book is resting on your desk. Consider the following forces:
1. A downward force due to gravity
2. An upward force exerted by the surface
Which of the above forces are acting on the book?
(A) 1 only
(B) 2 only
(C) Both 1 and 2
(D) Neither

We now compare the results of Question 4 with those of Question 11. Question 11 has been modified by emphasizing the word “after.”

Use the statement and figure below to answer the next four questions (8 through 11).

1. Acceleration is the change in velocity of an object over a specific period of time. A tennis ball after it has left contact with the racquet and before it Gladstone the ground.
2. An upward force exerted by the surface
3. A downward force of gravity, and a force in the direction of motion.
4. A downward force of gravity and an upward force exerted by the surface.

A physicists uses similar reasoning to answer both questions 30 and 31. Because of this we looked at students who correctly answered question 31 to see if they are more successful on question 30.

Another New FCI Question to Consider

New Question 31
31. A soccer player kicks a ball on a calm day.

At which of the points shown is the ball moving the fastest?

This question was inspired by a conversation with a person during a soccer game. After a player in the game was kicked in the face with a soccer ball, the person said, “Good thing he wasn’t standing further back or he would have been hurt.” Further conversation found that this person felt that the ball needed more distance to “get up to speed.”

During class, a video was shown to students depicting a similar situation and students were asked where they would stand if they were to be kicked in the face by the ball. Students responded with a variety of answers, similar to the FCI response profile. There were similar arguments for the ball getting up to speed. Also, there was a strong argument against standing further away because “gravity would cause the ball to accelerate.”

In an interview with a student, they were able to correctly identify the best place to stand; but, could not identify where the ball was traveling the fastest. This was because the student was using the conservation of energy along with thinking about the x- and y-components separately, but forgot about gravitational potential energy.

Although 48% of the student population answered this question correctly, the other 52% surprised us by picking the other distractors. In particular, 20% gave response B which fits with the getting up to speed reasoning.

Comparison of Response Profiles for the Unmodified Questions

We previously reported at AAPT 2013 the comparison between our first revised FCI V. 1 to answer the question, “Are the percentages of correct responses statistically different between the historical and new data set?”. We compared correct responses on unmodified questions both by individual question and as a whole. A few additional questions have been modified and now we have 9 questions to compare.

Per question: Standard error was determined for individual questions assuming a binomial distribution: sistorical = 1.9%, sne = 3.2%.

Difference in % correct ranges from: 0.04% to 7.5% which is within the 95% expected distribution range.

Total score: An average score on the FCI for the 9 unmodified questions was compared between the historical data and the new data.

Historical: 32.49 +/- 1.00%
New: 32.48 +/- 1.72%

Chi-squared: We used Chi-squared to compare the pre-test responses of the recent historical responses. The percentage of each of the unmodified questions. A p-value greater than 0.10 indicates differences in the profiles are likely due to chance. The profiles for question 2, which is now question 1, show significant variations. However, the other questions have response patterns that are statistically similar with p-values ranging from 0.10 to 0.77.