Common Trends in Force Concept Inventory (FCI) Results

Marion Birch & Niels Walet,
University of Manchester
David Sands, University of Hull
Simon Bates & Robyn Donnelly,
University of Edinburgh

Background

- Manchester, Hull, Edinburgh been using the FCI* for 3 years or more
- Results pre- and post- instruction for 1st year courses in Newtonian Mechanics (after 5 weeks – Manchester)
- No significant differences between the cohorts from year to year – able to combine data

Percentage Correct Answers vs Question Number
(Manchester - 630 students, Hull - 142 students)

Blue: Manchester (post=mid)
Red: University of Minnesota – 10yrs of data (1997-2007) 5600 1st year science & engineering students
Newton’s Third Law

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

15. While the car, still pushing the truck, is speeding up to get up to cruising speed,
(A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
(B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
(C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
(D) the car’s engine is running so the car pushes against the truck, but the truck’s engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
(E) neither the car nor the truck exerts any force on the other. The truck is pushed forward simply because it is in the way of the car.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed $v_0$.
The constant horizontal force applied by the woman
(A) has the same magnitude as the weight of the box.
(B) is greater than the weight of the box.
(C) has the same magnitude as the total force that resists the motion of the box.
(D) is greater than the total force that resists the motion of the box.
(E) is greater than either the weight of the box or the total force that resists its motion.

26. 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 the 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.
Gender Gap - Manchester Data

Freshers' Week FCI Results

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean FCI Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>2012</td>
<td></td>
</tr>
</tbody>
</table>

Error Bars: +/- 1 SE

Gender Gap - Edinburgh Data

FCI Pre-test Scores as a Function of Time

<table>
<thead>
<tr>
<th>Year</th>
<th>Mean FCI Pre-test Score Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>15.3</td>
</tr>
<tr>
<td>2007</td>
<td>16.4</td>
</tr>
<tr>
<td>2008</td>
<td>16.2</td>
</tr>
<tr>
<td>2009</td>
<td>15.9</td>
</tr>
<tr>
<td>2010</td>
<td>19.8</td>
</tr>
</tbody>
</table>

Error Bars: +/- 1 SE
Gender Gap - Common trend

- Harvard, Colorado FMCE (Force Motion Concept Evaluation), Minnesota
- Harvard & Edinburgh – eliminated gender gap
- Colorado & Minnesota – barely changed.
- All used interactive teaching techniques – peer instruction, tutorials, co-operative problem solving activities

Percentage Correct Answers vs Question Number

Largest gender gap: Q23 & Q14

Blue: Male
Pink: Female
A spaceship drifts sideways in outer space from point P to point Q as shown below. The spaceship is subject to no outside forces. Starting at position Q, the spaceship’s engine is turned on and produces a constant thrust (force on the spaceship) at right angles to the line PQ. The constant thrust is maintained until the spaceship reaches a point R in space.

21. Which of the paths A-E below best represents the path of the spaceship between points Q and R?

23. At point R, the spaceship’s engine is turned off and the thrust immediately drops to zero. Which of the paths A-E will the spaceship follow beyond point R?
Hestenes suggests misconception 'A' might be due to the perceptual experience of dropping an object out of the window of a moving car.

Hestenes’ Taxonomy of Misconceptions
(modeling.asu.edu/R&E/FCI-RevisedTable-II_2007.doc)

1. **Kinematics (K)** – velocity & acceleration undiscriminated
2. **Impetus (I)** - intrinsic force that keeps things moving
3. **Active forces (AF)** – motion implies active force
4. **Action & reaction pairs (AR)** – greater mass implies greater force
5. **Concatenation of influences (CI)** – last force to act determines motion
6. **Other influences on motion**
   – resistance(R) & gravity(G) – heavier objects fall faster
Hestenes’ Taxonomy of Misconceptions
Sub-categories for Impetus

I1. Impetus supplied by ‘hit’ - For an object to move it must be supplied with impetus
5C,D,E; 11B,C; 27D; 30B,D,E

I2. Loss/recovery of original impetus - Impetus can be gained or lost in some way
7D; 8C,E; 21A; 23A,D

I3. Impetus dissipation - An object is like a container and can store impetus
12C,D; 13A,B,C; 14E; 23D; 24C,E; 27B

I4. Gradual/delayed impetus build-up
8D; 10B,D; 21D; 23E; 26C; 27E

I5 Circular impetus - Intrinsic force which tend to make objects move in circles – objects do what they have been ‘trained to do’
5C,D,E; 6A; 7A,D; 18C,D

Misconceptions - Manchester Data

Sub-categories of Misconceptions

- Light Grey – Males Pre-test
- Dark Grey – Males Post-test
- Light Red – Females Pre-test
- Dark Red – Females Post-test
Gender differences: K1, I5, R1, G7
R2 – males have more misconceptions than females

Conclusions

- Some interesting common trends across different institutions
- Significant gender differences in conceptual understanding – not always eliminated by instruction
- Further investigation needed of misconceptions
- Introduce remedial action