MANCHESTER 1824

The University of Manchester

Gender Difference in the Conceptual Understanding of Newtonian mechanics: a cross-institution comparison

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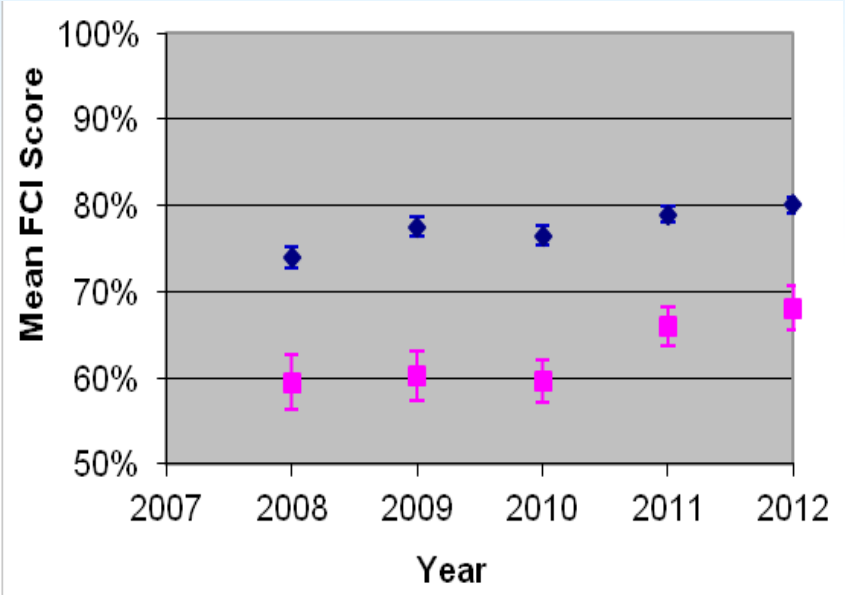
Introduction

- Traditional exams in Newtonian mechanics – memorising algorithms - plug-and-chug
- Conceptual understanding
- Force Concept Inventory (FCI) published in *The Physics Teacher* in 1992 by Hestenes, Wells, & Swackhamer
- Used extensively in US to evaluate effectiveness of instruction
- 30 multiple choice questions – purely conceptual

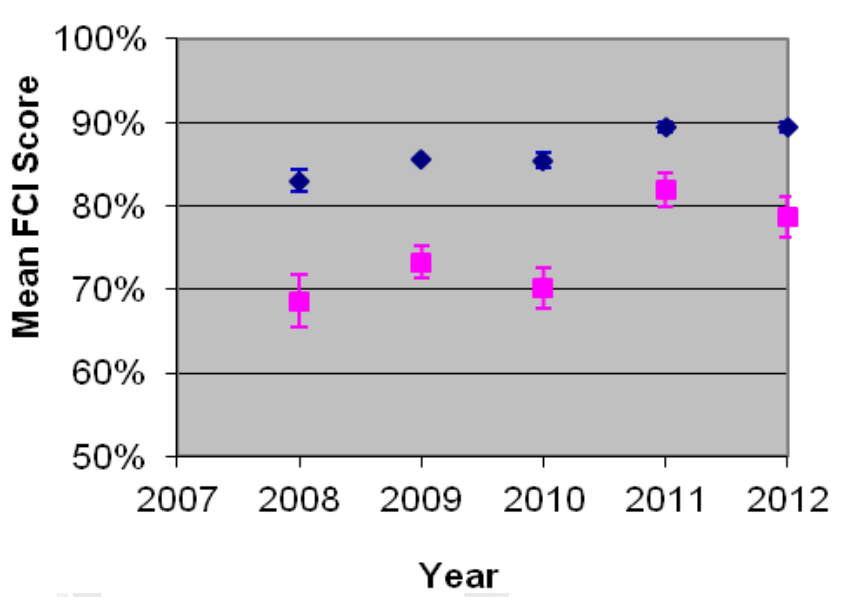
Background to Manchester Studies

- Using FCI at Manchester since 2008 – first year undergrad physics students
- 230-280 students/yr – approx 20% females
- Tested – Welcome Week & Mid-semester
- Results pre- and post- instruction

Mean FCI scores differentiated by gender



Pre-instruction

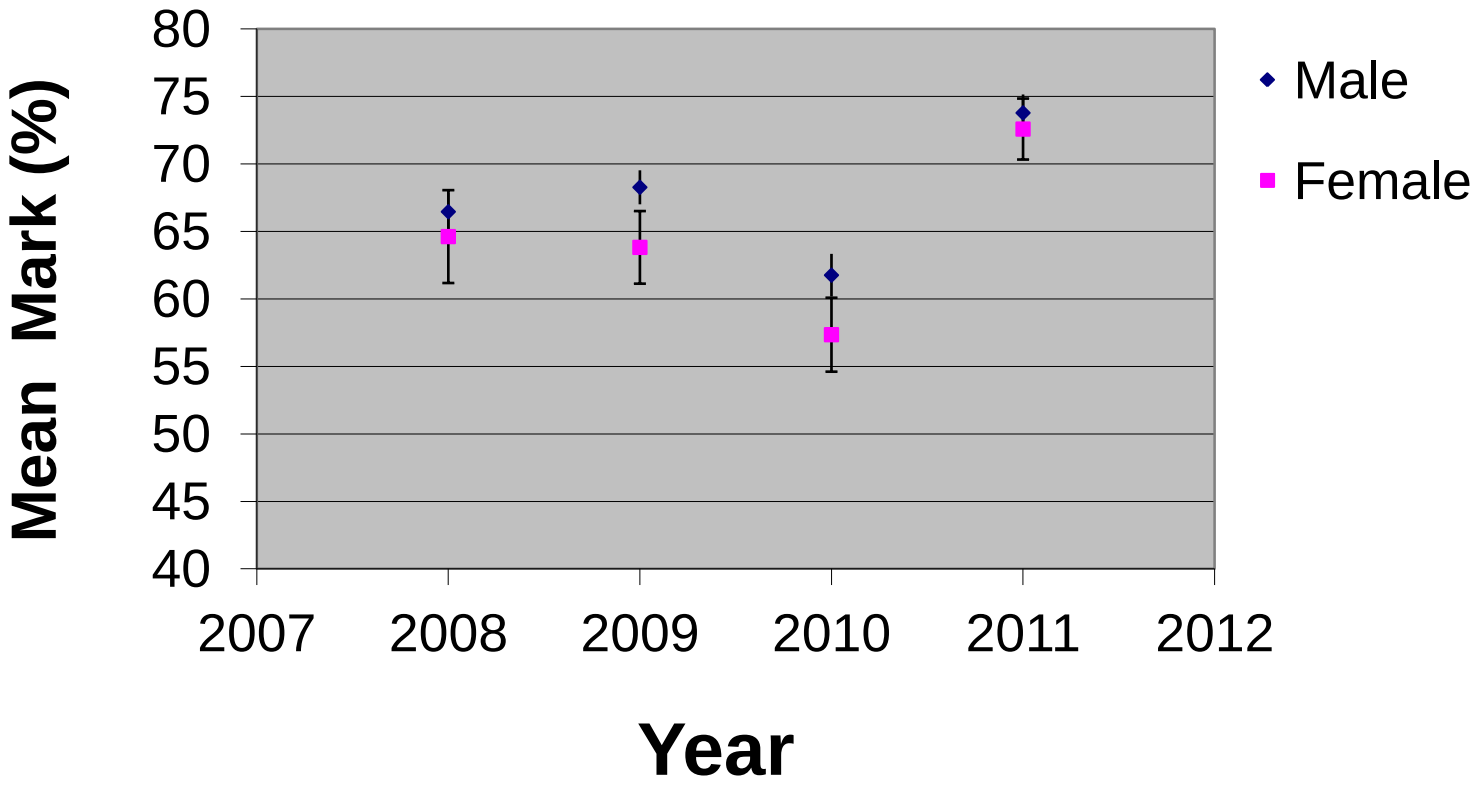


Post-instruction

Blue = males, pink = females,
Error bars represents 1 standard error

No statistically significant differences between the 2008, 2009, 2010 cohorts – able to combine data

Dynamics Exam Results



Error bars: 1 SE

UK Cross-institutional Analysis 2011-12

		Mean Pre-test Score %	Mean Post-test Score %		Difference between mean male and female scores, G %		∆ G %
					Pre-test	Post-test	
Edinburgh	Male	67.4 ± 1.9	86.0 ± 1.3				
	Female	56.8 ± 3.2	78.3 ± 2.7		10.6	7.7	-2.8
Hull	Male	61.5 ± 2.7	77.3 ± 2.6				
	Female	42.8 ± 6.1	67.2 ± 4.6		18.7	10.1	-8.6
Manchester	Male	79.4 ± 1.0	89.4 ± 0.7				
	Female	66.3 ± 2.4	81.9 ± 2.0		13.1	7.5	-5.6

Quartile Distribution (2011-12)

- Split each cohort on the basis of pre-instruction test performance into quartiles (of approx equal size) at each institution
- Further separated each quartile into male and female subgroups

Looked at relative proportions of males and females in each quartile

Fraction of males and females in each quartile group of pre-instruction FCI scores

Institution				Quartile 1 (highest)		Quartile 2		Quartile 3		Quartile 4 (lowest)	
	N_{tot}	N_M	N_F	f_M	f_F	f_M	f_F	f_M	f_F	f_M	f_F
Edinburgh	161	116	45	0.30	0.13	0.24	0.20	0.22	0.22	0.23	0.44
Hull	46	40	6	0.20	0.00	0.33	0.00	0.25	0.50	0.23	0.50
Manchester	258	198	60	0.21	0.03	0.30	0.20	0.29	0.27	0.21	0.50

N_{tot} = total no. of students
N_M = no. of males
N_F = no. of females

f_M = fraction of total no. of males in each quartile group
f_M = fraction of total no. females in each quartile group

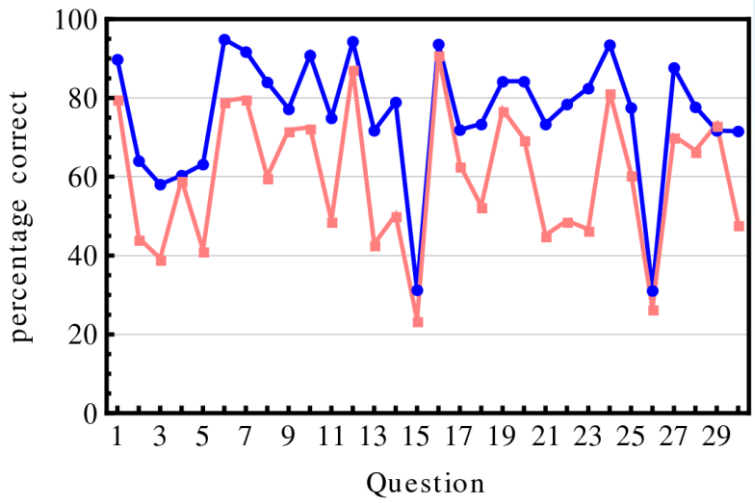
Gender Gap

- Harvard, Colorado, Minnesota*
- Harvard – decreased gender gap
- Colorado & Minnesota – barely changed
- All used interactive teaching techniques – peer instruction, tutorials, co-operative problem solving activities

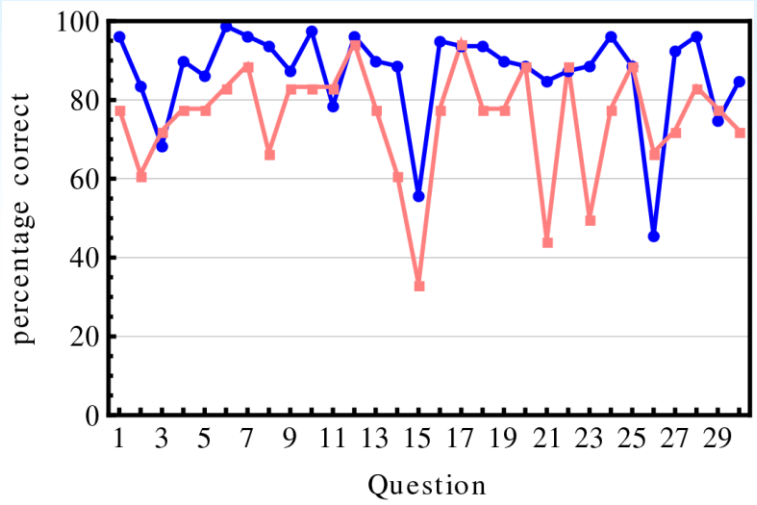
Docktor & Heller, American Institute of Physics Conference Proceedings Vol:1064(1): 15-18, 2008

Percentage Correct Answers vs Question Number

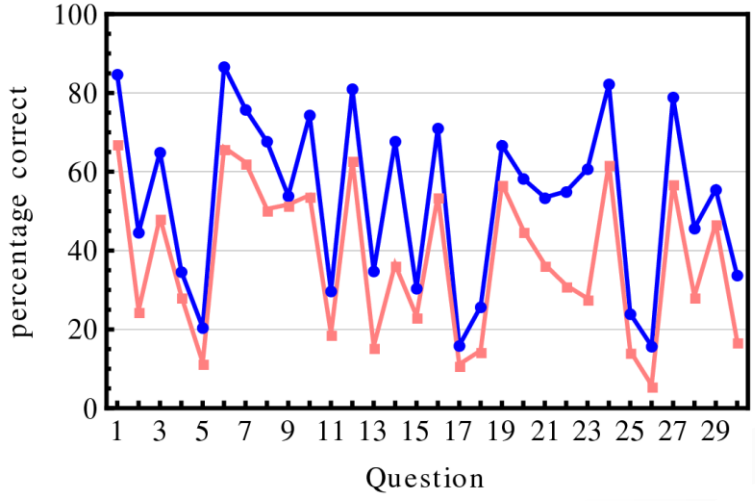
Manchester Pre-instruction



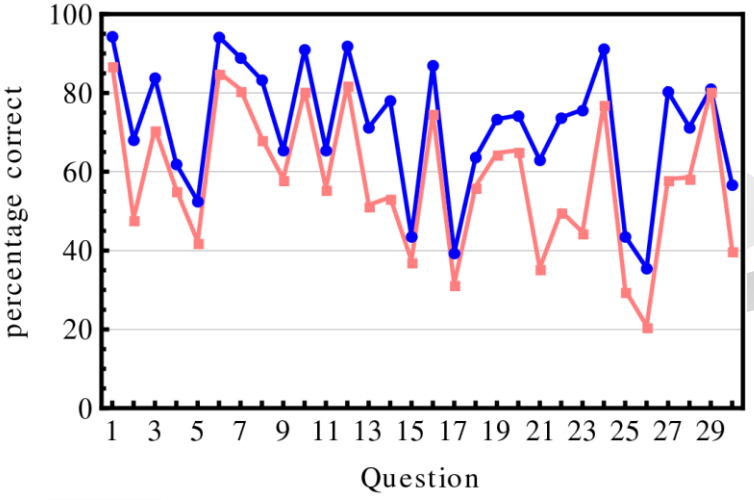
Manchester Post-instruction



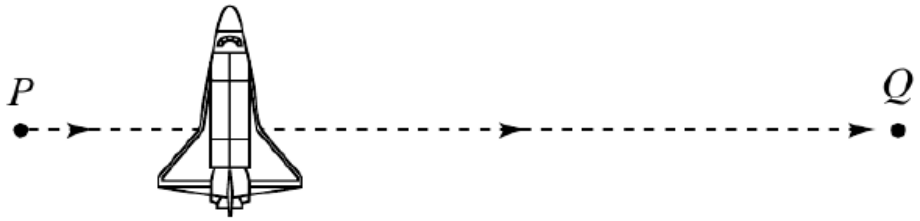
Minnesota Pre-instruction



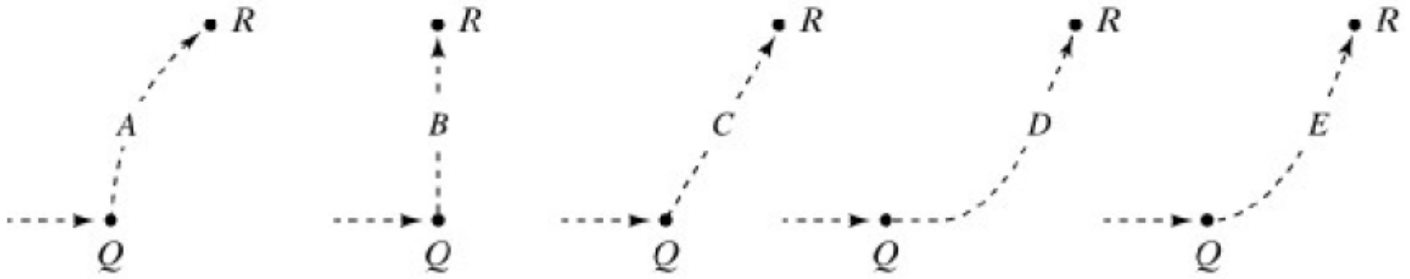
Minnesota Post-instruction



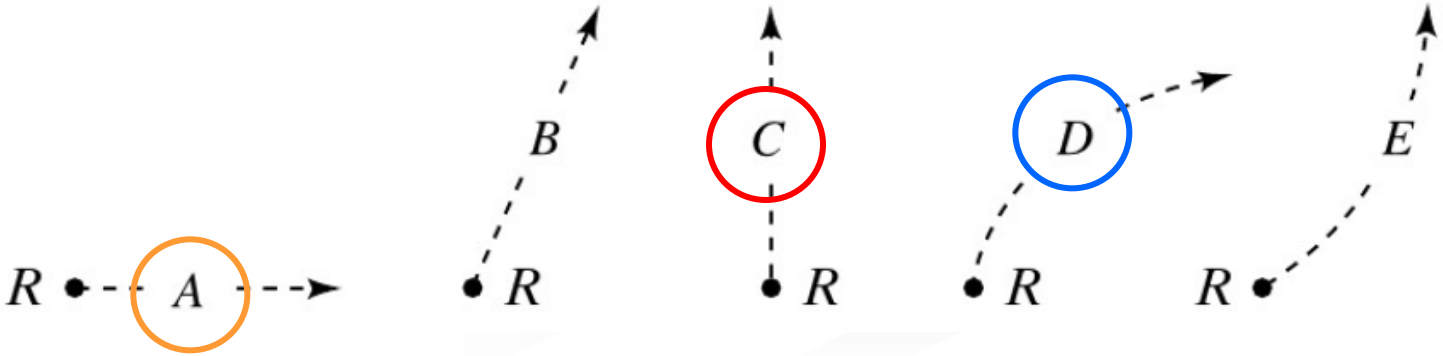
A spaceship drifts sideways in outer space from point P to point Q as shown below. The spaceship is subject to no outside forces. Starting at position Q, the spaceship's engine is turned on and produces a constant thrust (force on the spaceship) at right angles to the line PQ. The constant thrust is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



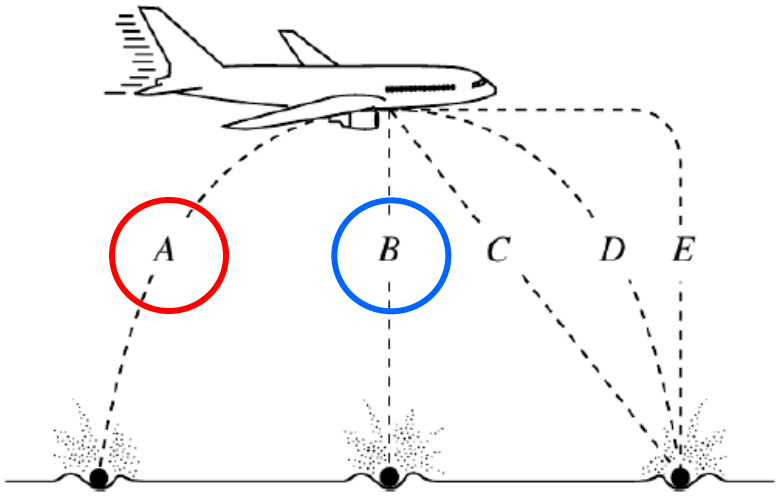
21. Which of the paths A-E below best represents the path of the spaceship between points Q and R?



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?



14. 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 below, which of the paths A-E would the bowling ball most closely follow after leaving the airplane?



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

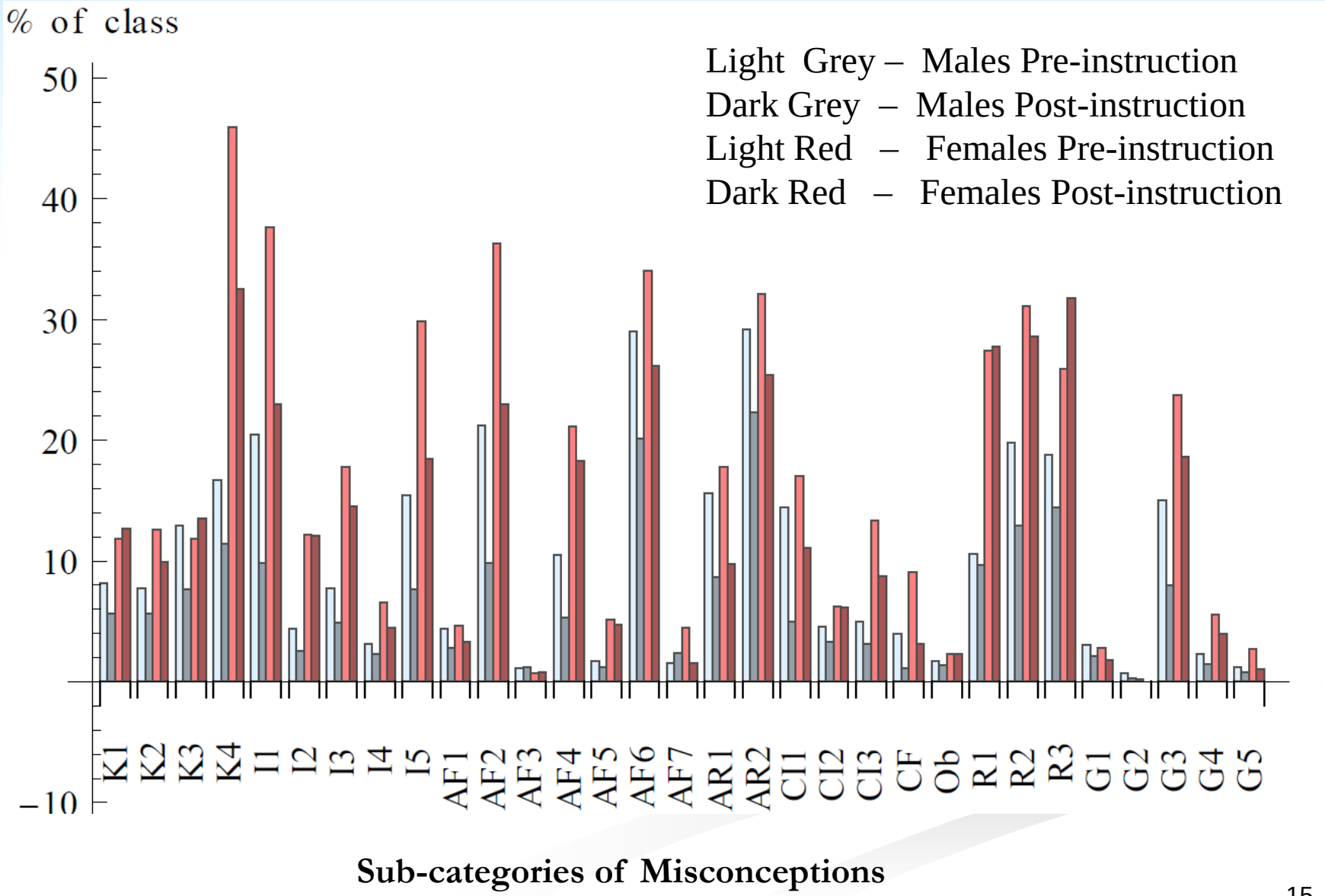
I2. Loss/recovery of original impetus **-** Impetus can be gained or lost in some way
7D; 8C,E; 21A; 23A,D

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

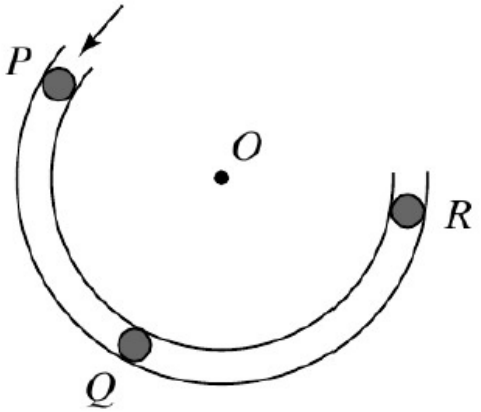
Misconceptions - Manchester Data



I5 - Circular Impetus – dominant incorrect answers

Use the statement and figure below to answer the next two questions (5 and 6).

The accompanying figure shows a frictionless channel in the shape of a segment of a circle with its centre at O. The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at P and exits at R.



5. Consider the following distinct forces:

A. a downward force of gravity.
B. a force exerted by the channel pointing from Q to O.
C. a force in the direction of motion.
D. a force pointing from O to Q.

Which of the above forces is (are) acting on the ball when it is within the friction- less channel at position Q?

(A) A only.
(B) A and B.
(C) A and C.
(D) A, B, and C.
(E) A, C, and D.

Answers C, D, & E all include a force in the direction of motion

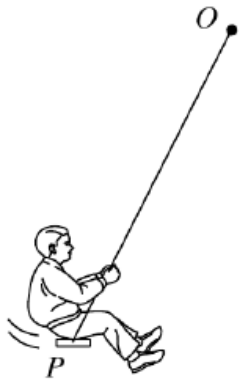
I5 - Circular Impetus – dominant incorrect answers

18. The following figure shows a boy swinging, starting at a point higher than P. Consider the following distinct forces:

A. a downward force of gravity.
B. a force exerted by the rope pointing from P to O.
C. a force in the direction of the boy's motion.
D. a force pointing from O to P.

Which of the above forces is (are) acting on the boy when he is at position P?

(A) A only
(B) A and B
(C) A and C
(D) A, B, and C
(E) A, C, and D.



Answers C, D & E include a force in the direction of motion

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.

27. If the woman in question 25 suddenly stops applying a horizontal force to the block, then the block
(A) immediately comes to a stop.
(B) continues moving at a constant speed for a while and then slows to a stop.
(C) immediately starts slowing to a stop.
(D) continues at a constant speed.
(E) increases its speed for a while and then starts slowing to a stop.

Conclusions

- Significant gender differences in conceptual understanding – not always eliminated by instruction
- Surprising similarities with US data
- Further investigation needed of gender difference
- Implications for the way Newtonian mechanics is taught