New ways of investigating the canonical ball toss problem

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What we learn from students depends on how we ask them

Different questions will elicit different ideas.

It's not just when we ask them, it's also how.

Asking a single class many different kinds of questions at once lets us learn about the student understanding in the space between total understanding and being totally incorrect

Research Study: Split a class into three groups

Each group gets a different form of the question (see below).
Administered as an online survey at end of first week of classes.
All students got MC version of #1.

Purpose: Does asking question #2 differently affect what we learn about student understanding.

Design: investigate what a *class* knows, not what as student knows.
Data from Q1 suggest student populations are similar.

Canonical version of #2: Multiple Choice
Choose from answers A–G. N =58

Modified #2: Consider Only One Option
"Is the acceleration zero at the top?" N=62

Modified #2: Given incorrect answer
a≠0 at the top. Explain. N=62

Consider the most common incorrect response to the well-studied coin or ball toss problem:

Questions 1–3 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (A through G) to indicate the acceleration of the coin during each of the stages of the coin's motion described below. Take **up** to be the **positive** direction. Answer choice J if you think that none is correct.

A. The acceleration is in the negative direction and constant (CORRECT)
B. The acceleration is in the negative direction and increasing
C. The acceleration is in the negative direction and decreasing
D. The acceleration is zero.
E. The acceleration is in the positive direction and constant.
F. The acceleration is in the positive direction and increasing.
G. The acceleration is in the positive direction and decreasing.

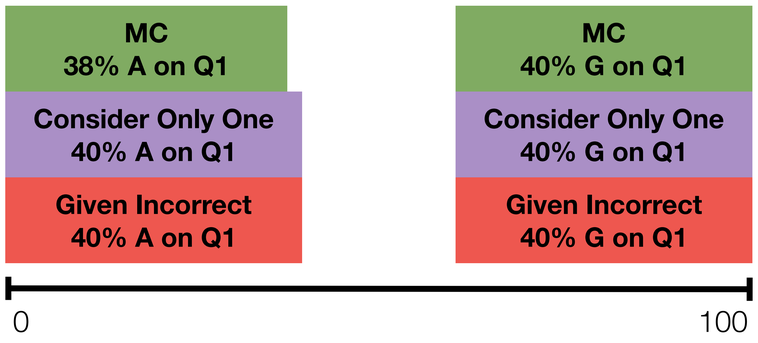
G 1. The coin is moving upward after it is released.
D 2. The coin is at its highest point.
B 3. The coin is moving downward.

How common is the D response to #2?

On a survey asked of 165 students before all instruction:

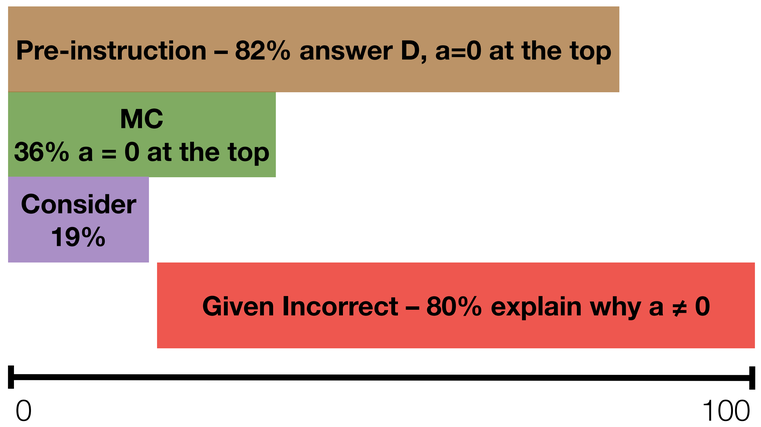
82% of students answer D, a=0 when coin is at its highest point
96% who give G for #1 (58% of students) answer D for #2

Performance on Q1, sorted by Q2 format



Within the context of the question, these populations answer in similar proportion both on the correct answer (A) and the most common incorrect answer (G)

Many students give an answer that they could also explain is incorrect



Some subset of students are inclined to say **a=0** at the top, AND can explain why **a≠0** at the top.

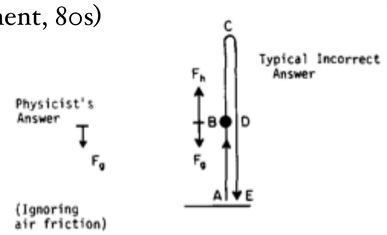
Twice as many say a=0 on the MC than when asked directly.

Possible Reasons for the G-D-B response

Failure to differentiate…
(McDermott, 80s & 90s)
Students fail to recognize the difference between a quantity and a change in that quantity (v and dv/dt)

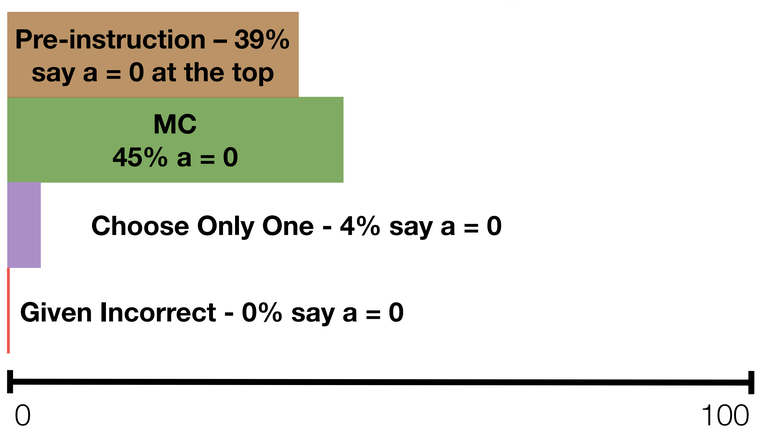
Novice image of motion
(Dykstra, 90s)
Students have not disambiguated "motion" into "velocity" and "acceleration"

"Motion Implies a Force" Preconception
(Clement, 80s)



Impetus Theory
(McCloskey, 80s)
The force of the throw stays in the hand and gets used up as the object travels to the top - then gravity takes over.

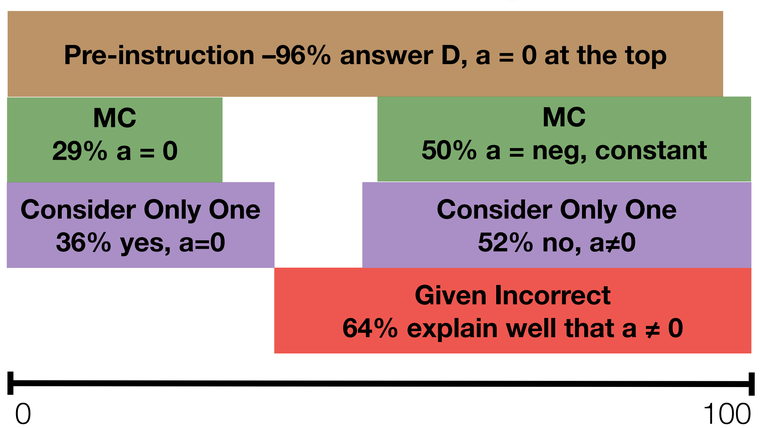
OF THOSE WHO ANSWERED A ON #1 how many say a=0 at the top, for #2?



On the Choose Only One and Given Incorrect questions, students on the "right track" with A on the way up stick with the right answer.

Nearly half the Multiple Choice students go from correct to incorrect at the turn-around point

OF THOSE WHO ANSWERED G ON #1 how many say a=0 at the top, for #2?



Pre-instruction data suggests answer G predicts answer D.

Great discrepancy between pre-instruction and survey requires an explanation.
It is likely due to instructor intervention.

Fewer Given Incorrect students explain a≠0 well.
Supports idea that a=0 at the top is a compelling answer.