Teaching Conceptual Science with Technology

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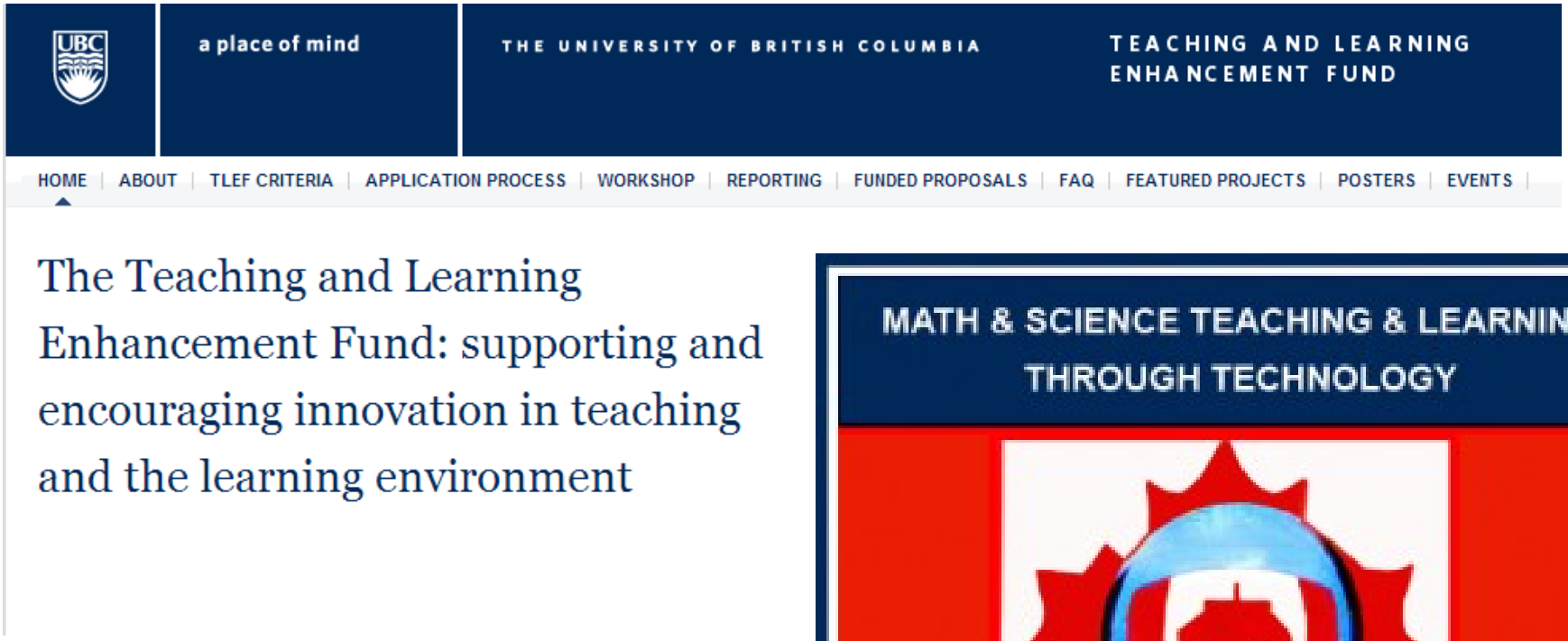
Surrey Science Teachers' Association Convention

Supported by UBC Teaching & Learning Enhancement Fund



Generously supported by UBC TLEF 2012-2015: $151, 000

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My Learning & Teaching Trajectory

- My mom is a math & physics teacher
- M.Sc. In physics, Ph.D. in Science Education
- Physics and math teacher since 1991 (gr. 3 – college) in Canada, US, Israel and Ukraine
- Used various technologies in STEM teaching
- Teaching awards: NSTA, AAPT, UBC, Ryerson, CAP
- Teacher educator since 1995
- Still learning and I want to learn with you today

Workshop Outline

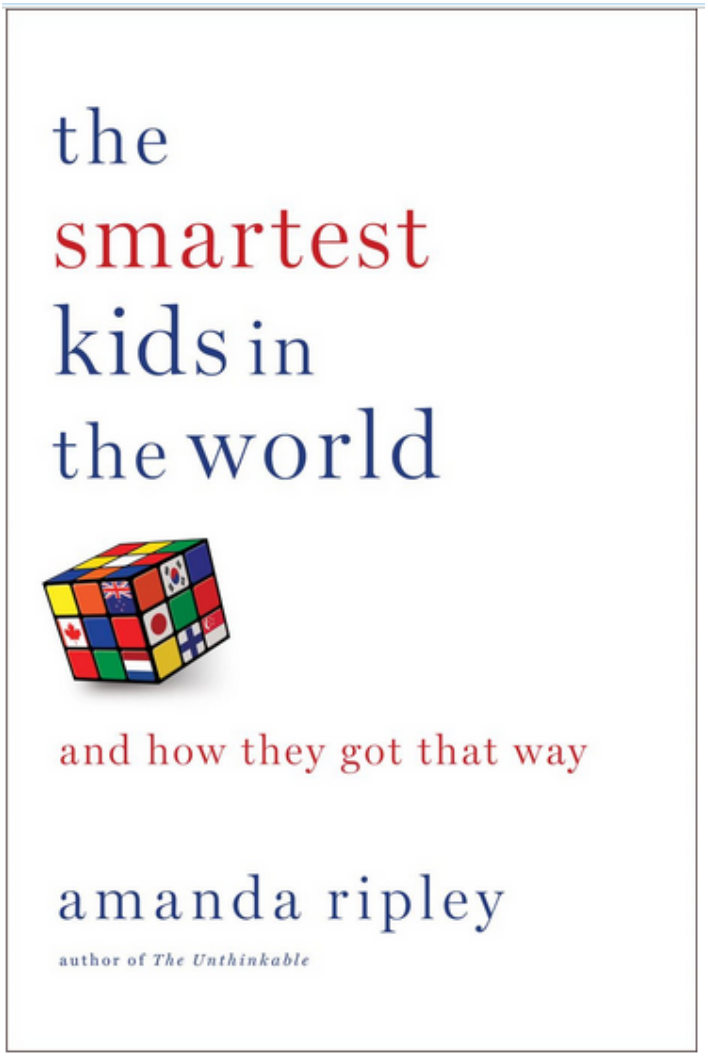
1. Introduction: why conceptual science and why technology
2. Experiencing Peer Instruction: Active engagement with clickers
3. Discussion: Using technology in Science and Meath teaching
4. Summary: What is next

1. Intro: Why Conceptual Science & Why Technology?

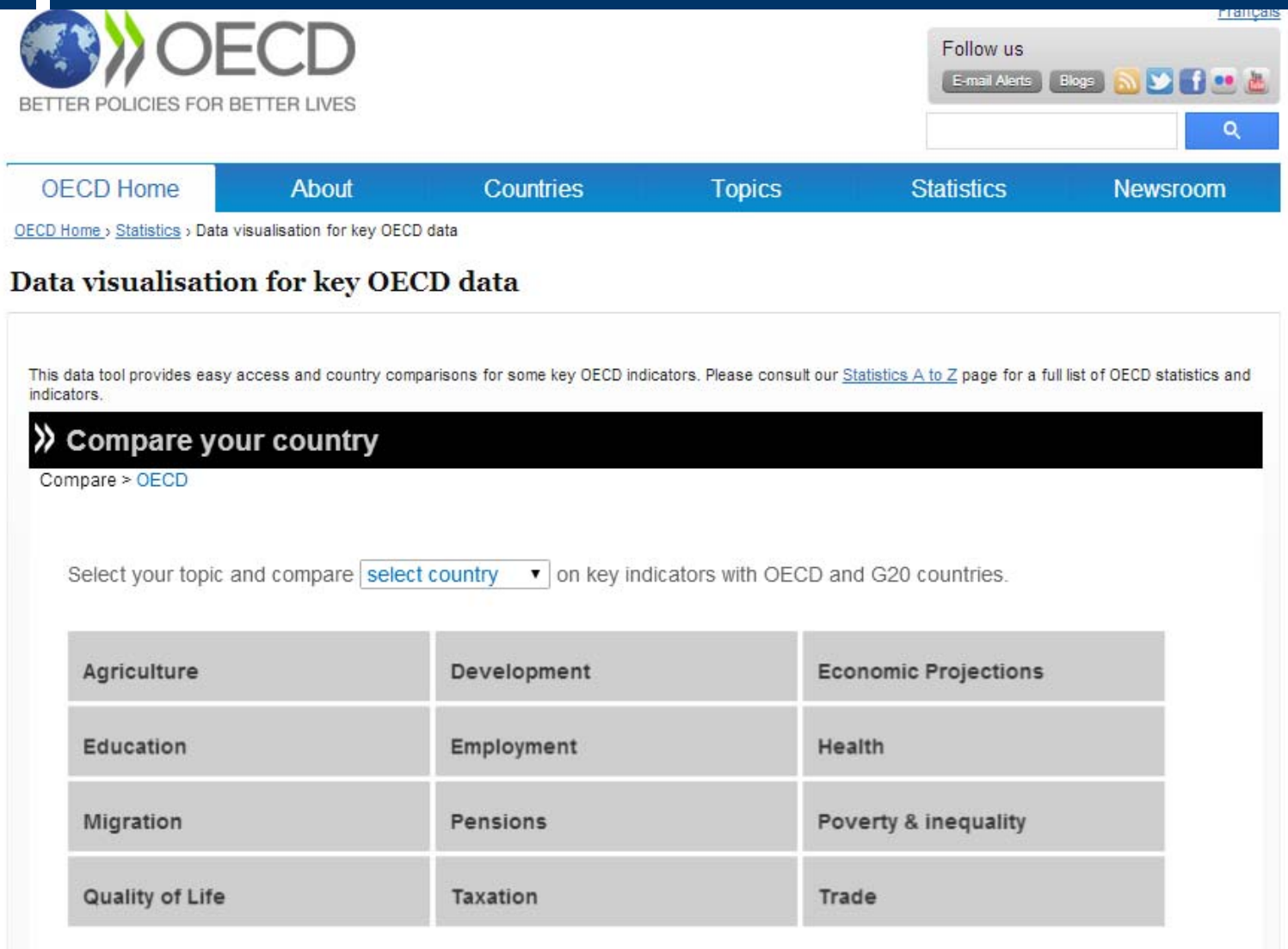
OECD

BETTER POLICIES FOR BETTER LIVES

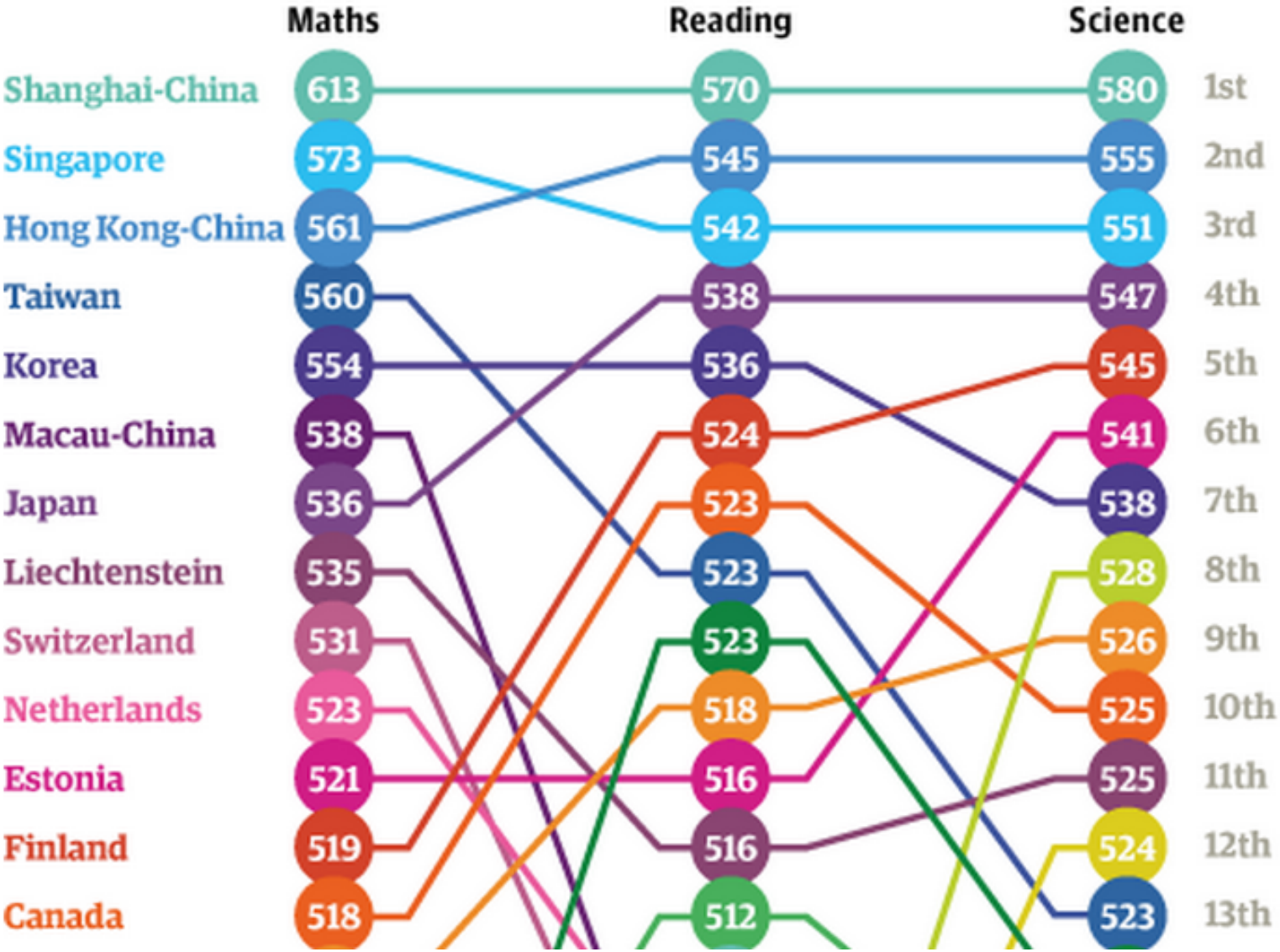
http://www.oecd.org/



The Value of Conceptual Science Learning



PISA 2012 Results



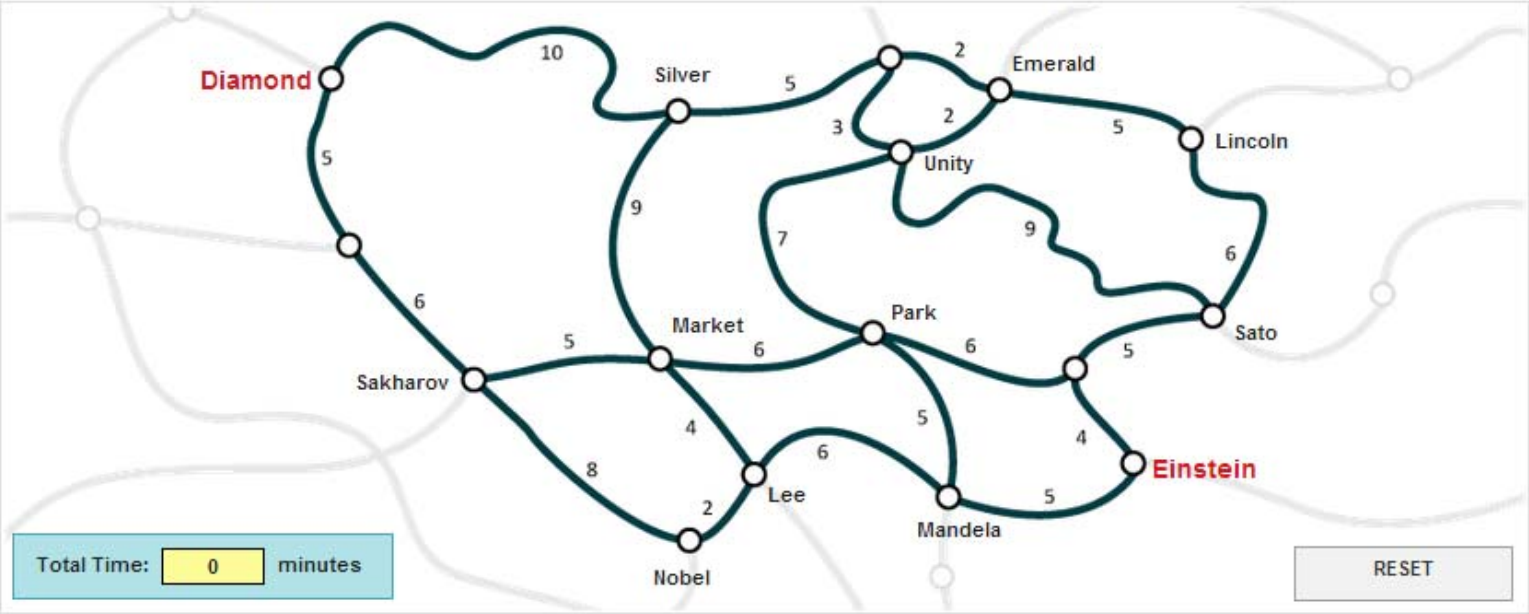
[OECD, PISA 2012 Results]

Example of a PISA Question

TRAFFIC

Here is a map of a system of roads that links the suburbs within a city. The map shows the travel time in minutes at 7:00 am on each section of road. You can add a road to your route by clicking on it. Clicking on a road highlights the road and adds the time to the **Total Time** box.

You can remove a road from your route by clicking on it again. You can use the RESET button to remove all roads from your route.



Question : TRAFFIC

Maria wants to travel from Diamond to Einstein. The quickest route takes 31 minutes. Highlight this route.

SUBMIT

RESULTS

Example of a PISA Question

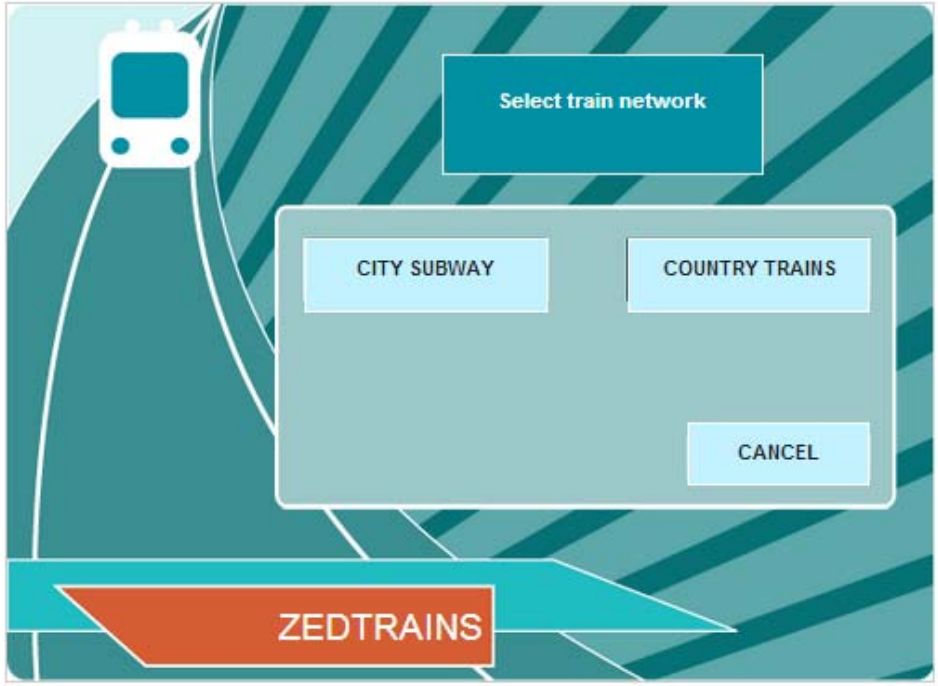
PISA › Try the test › Test questions › Question 4

TICKETS

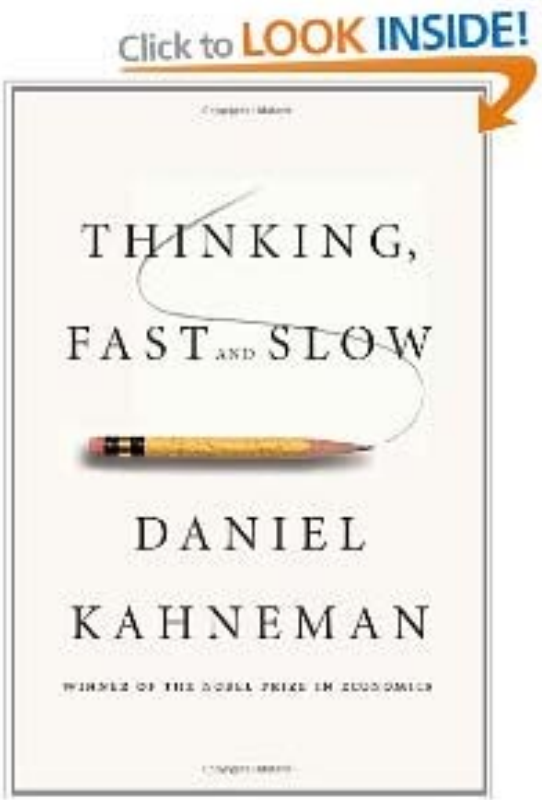
A train station has an automated ticketing machine. You use the touch screen on the right to buy a ticket. You must make three choices.

- Choose the train network you want (subway or country).
- Choose the type of fare (full or concession).
- Choose a daily ticket or a ticket for a specified number of trips. Daily tickets give you unlimited travel on the day of purchase. If you buy a ticket with a specified number of trips, you can use the trips on different days.

The BUY button appears when you have made these three choices. There is a CANCEL button that can be used at any time BEFORE you press the BUY button.



Thinking Fast and Slow by Daniel Kahneman, 2011



Central thesis: a dichotomy between two modes of thought:

"System 1" is fast, instinctive and emotional; "System 2" is slower, more deliberative, and more logical.

It delineates cognitive biases associated with each type of thinking by highlighting several decades of academic research to suggest that people place too much confidence in human judgment.

Do Students Learn to Use System 2 in our Science Courses?

A. 15% - 29%
B. 30%-44%
C. 45%-59%
D. 60%-74%
E. 75%-90%

What % of what the students could have learned in our traditional lecture-based courses is actually learned?

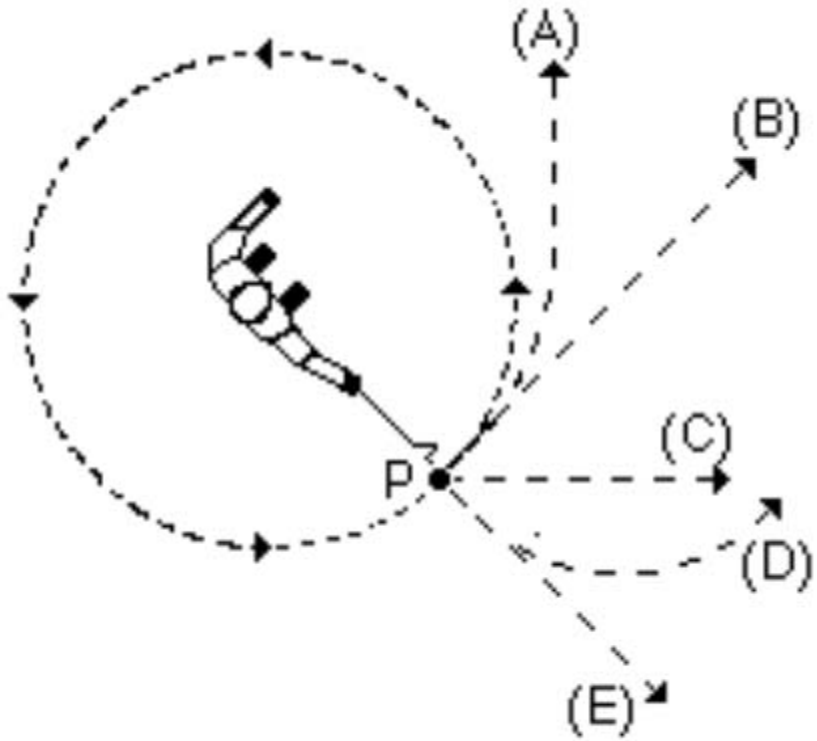
$$\text{Course gain:} < g > = \frac{\text{Post (\%)-Pre(\%)}}{100\% - \text{Pre(\%)}}$$

Force Concept Inventory Example

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.

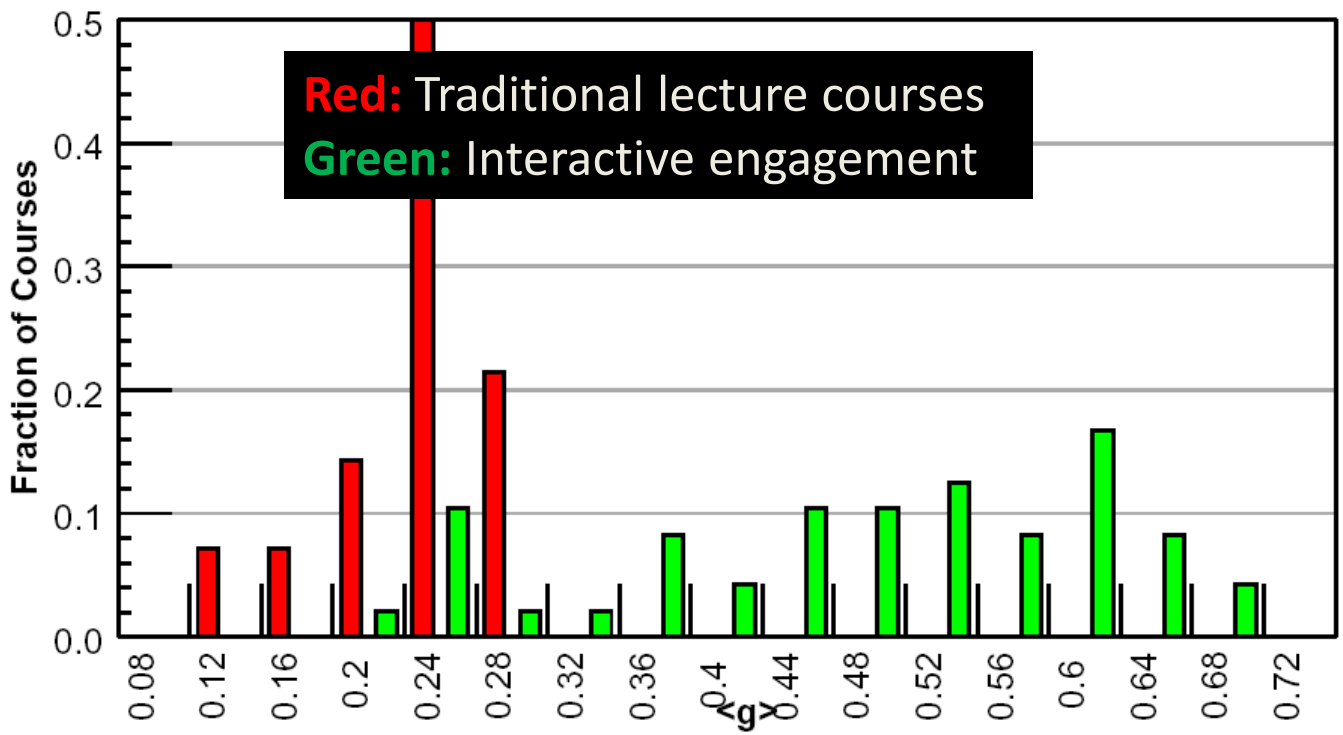
If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?



[Hestenes, D., Wells, M., & Swackhamer, G. (1992). Force Concept Inventory. *The Physics Teacher, 30*(3), 141-157.]

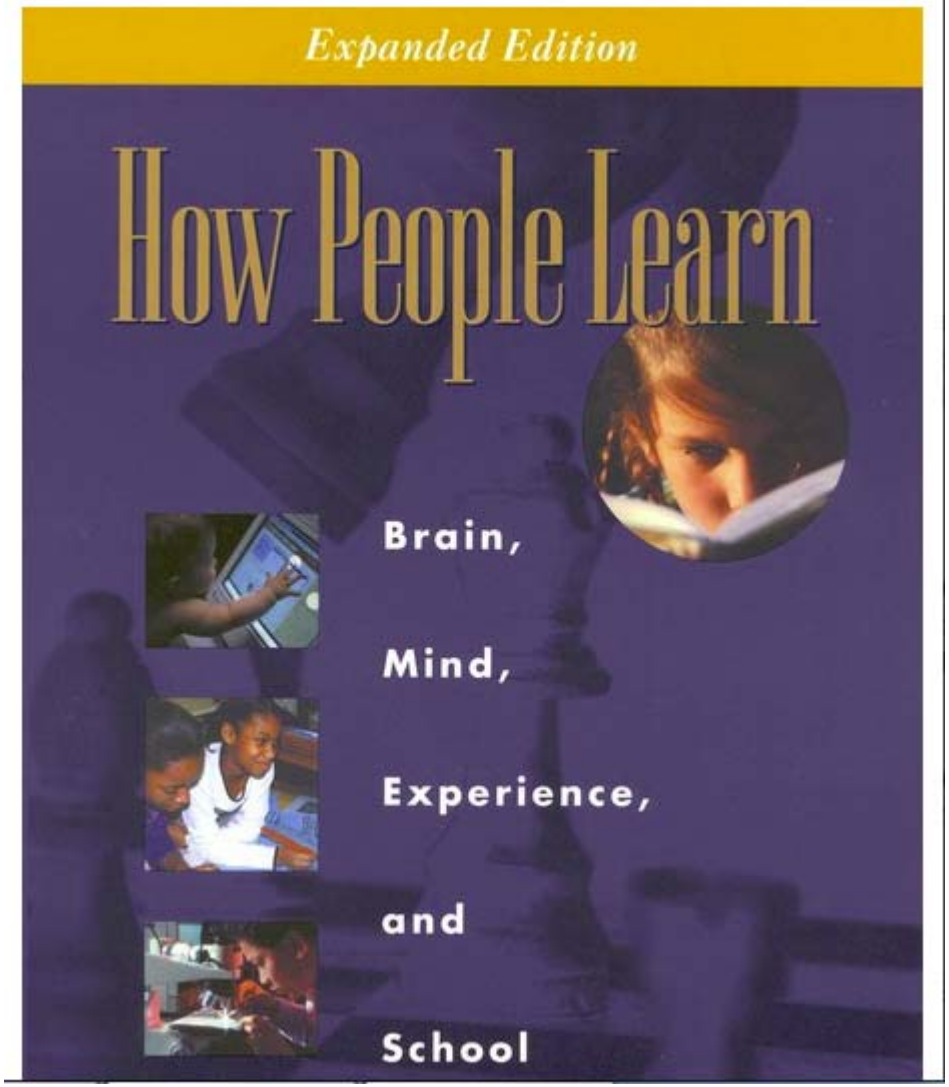
FCI Gain Data

$$\text{Course gain:} < g > = \frac{\text{Post (\%)-Pre(\%)}}{100\% - \text{Pre(\%)}}$$



R. Hake, "…A six-thousand-student survey…" AJP **66**, 64-74 ('98).

Are these Results Surprising?



FREE from the National Academies Press:

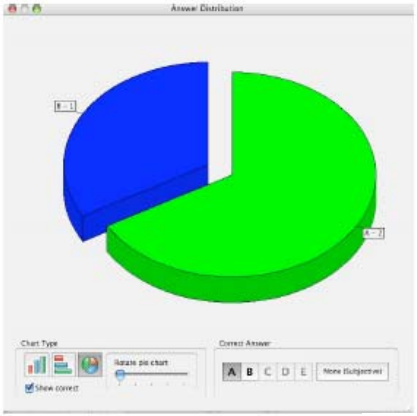
http://www.nap.edu/catalog.php?record_id=9853

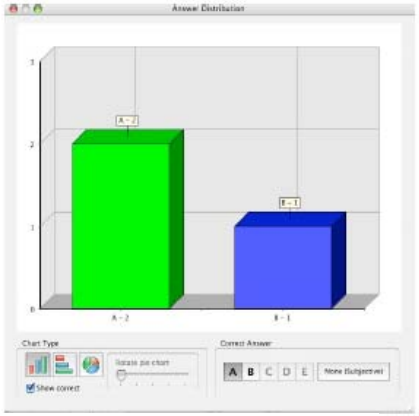
Why Should We Care?

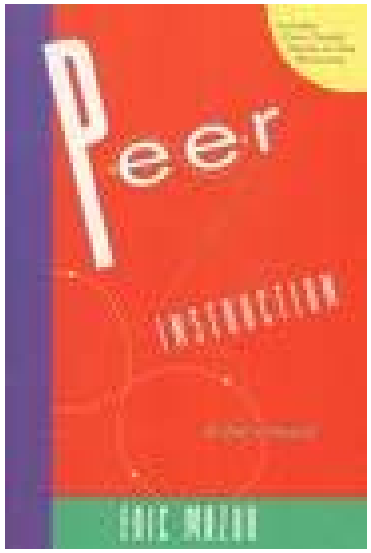
Let's Talk Science. (2013). Spotlight on science learning: The high cost of dropping science and math.

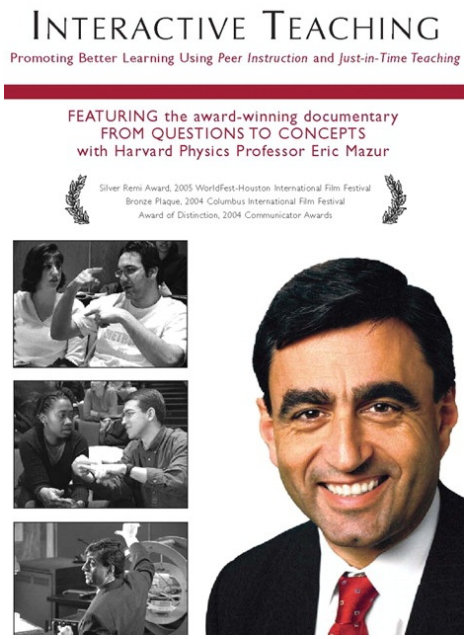
Increasing Student Engagement: Peer Instruction

A. Not familiar
B. Somewhat familiar
C. Watched it in action
D. Use it in my own classes









Peer Instruction & Active Learning

2004, The Physics Teacher, 42(8), 47-48.

Tips for Using a Peer Response System in a Large Introductory Physics Class

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Teaching a large
physics course
lenge for a young ph

Clickers beyond the First Year Science Classroom

Marina Milner-Bolotin

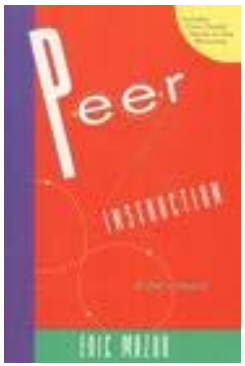
Tetyana Antimirova

Anna Petrov

2010, Journal of College Science Teaching, 40(2), 18-22.

Abstract:

This case study's primary objective is to describe the implementation of the electronic-response-system (clickers) in a small (N=25) second



Peer Instruction Pedagogy

LUMAT 1(5), 2013 [LUMAT: Research and Practice in Math, Science & Technology Education, 2013. **1**(5): p. 525-544.]

Modeling Active Engagement Pedagogy through Classroom Response Systems in a Physics Teacher Education Course

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Heather Fisher
Department of Curriculum and Pedagogy, Faculty of Education, The University of British Columbia

Alexandra MacDonald
Department of Curriculum and Pedagogy, Faculty of Education, The University of British Columbia

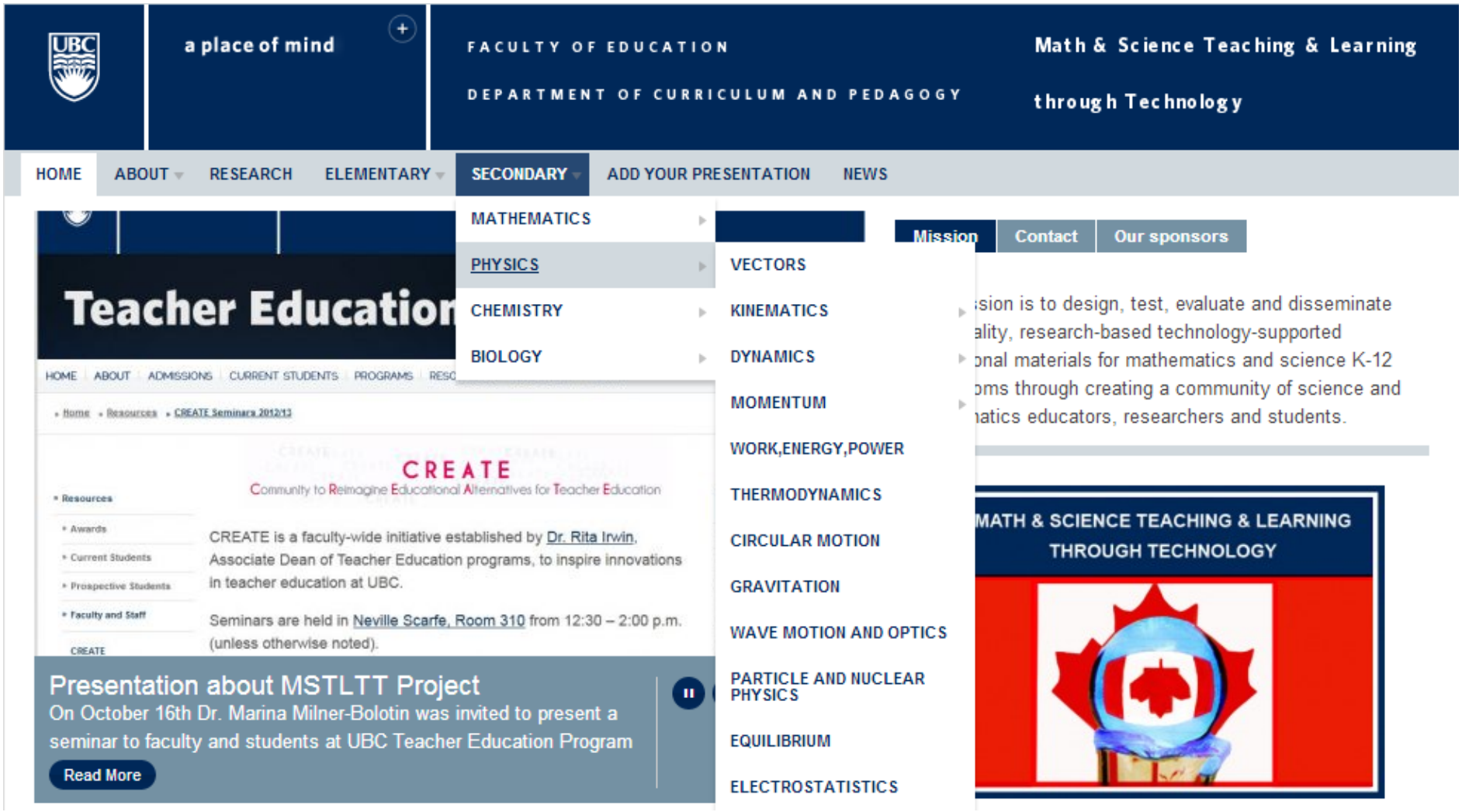
Abstract One of the most commonly explored technologies in Science, Tech
and Mathematics (STEM) education is Classroom Respo
instructors generate in-class discussion by solici

Clickers or Flashcards?

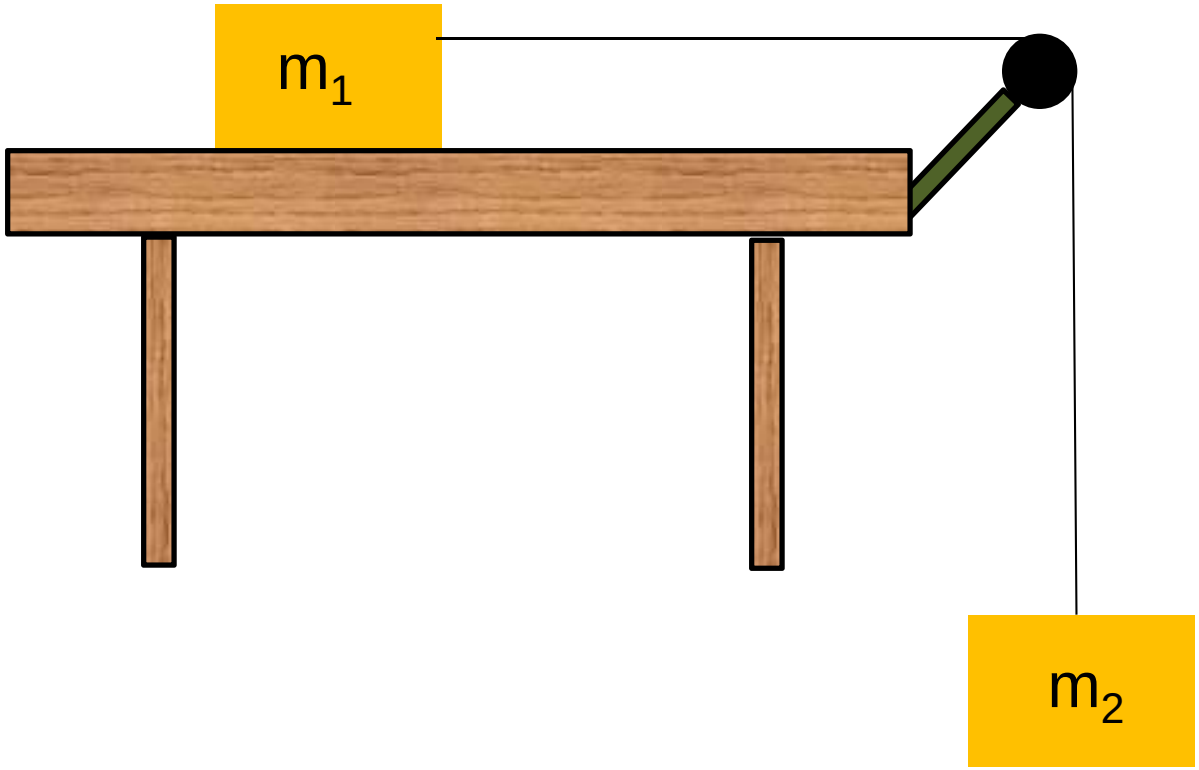
Electronic response systems (clickers) in K-12 classrooms…

[Lasry, N. (2008). Clickers or flashcards: Is there really a difference? *The Physics Teacher, 46*(5), 242-244.]

Math & Science Teaching & Learning through Technology

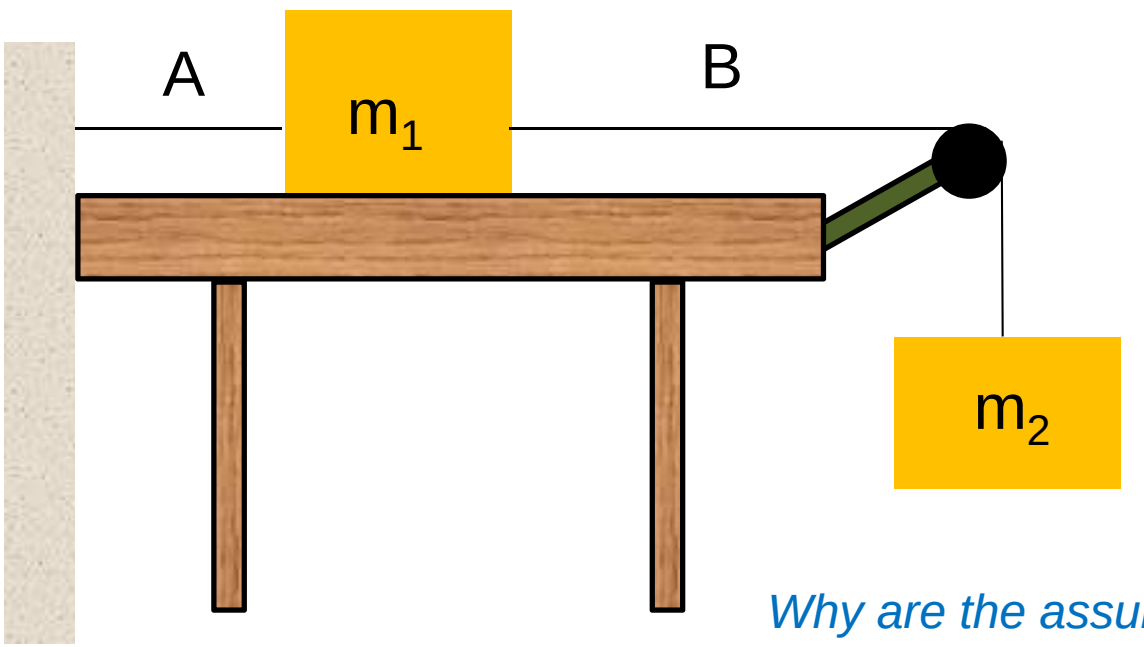


Blocks and a Pulley



Blocks and a Pulley II

Two blocks are connected via a pulley. The blocks are initially at rest as block m_1 is attached to a wall. If string A breaks, what will the accelerations of the blocks be? (**Assume** friction is very small and strings don't stretch)



A. $a_1 = 0;\ a_2 = 0$

B. $a_1 = g;\ a_2 = g$

C. $a_1 = 0;\ a_2 = g$

D. $a_1 = g;\ a_2 = 0$

E. None of the above

Why are the assumptions above important?

Solution

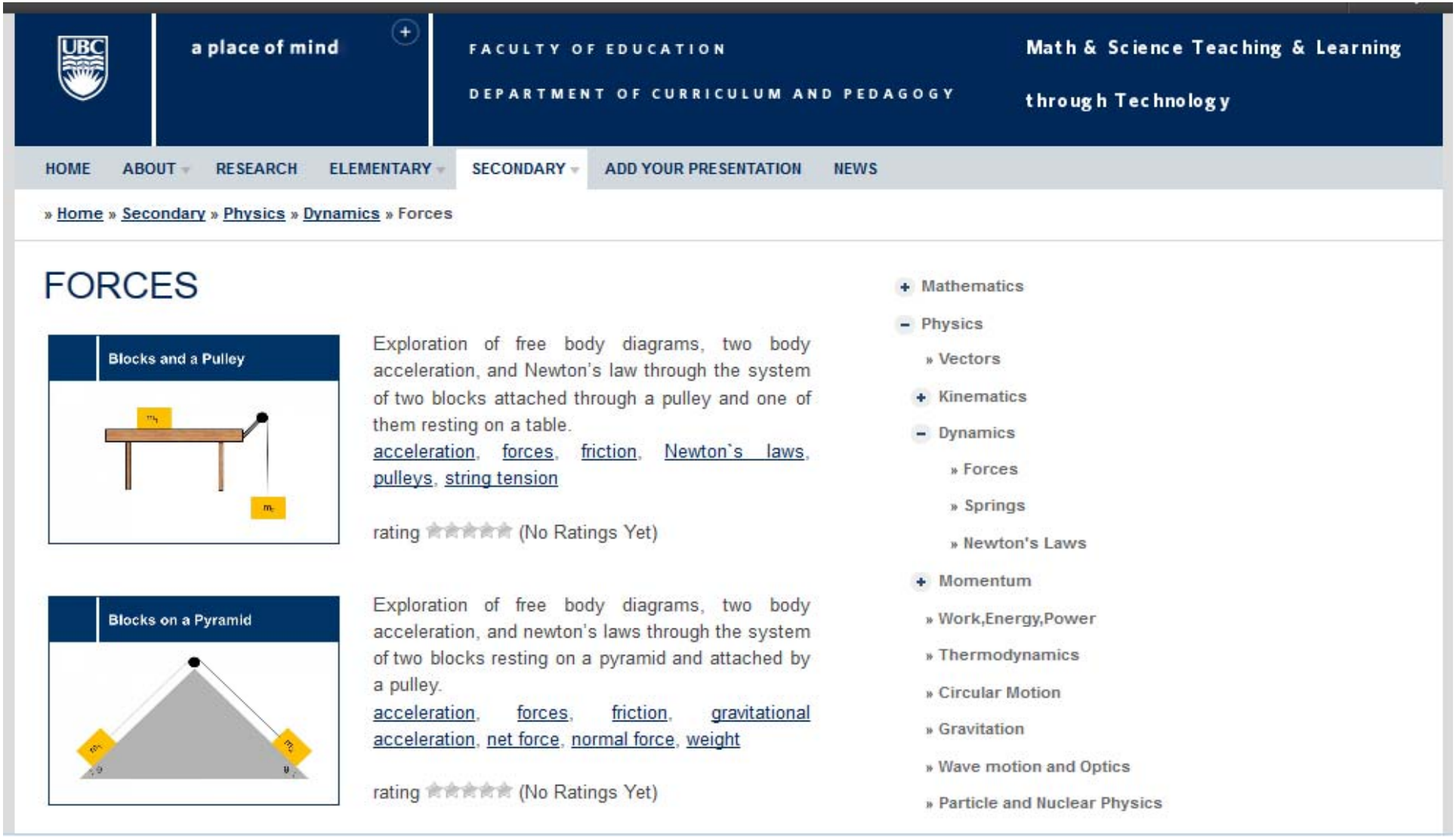
Answer: E

Justification: None of the above answers is correct. Consider two blocks as one system: one can see that the system has a mass of (m_1+m_2), while the net force pulling the system down is m_1g. Therefore, applying Newton's second law, one can see that the acceleration of the system must be less than g:

$$a = \frac{m_2 g}{\left(m_1 + m_2\right)} = \frac{m_2}{\left(m_1 + m_2\right)} g < g$$

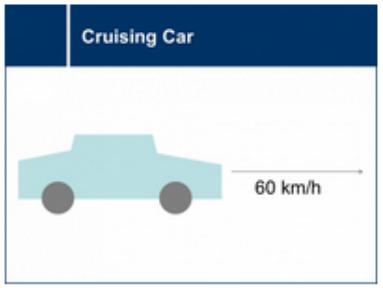
Some people think that the acceleration will be g. They forget that the system consists of two blocks (not just m_1) and the only pulling force is m_1g. Thus the system is NOT in a free fall. Compare this questions to the previous one to see the difference.

Navigating the Resource



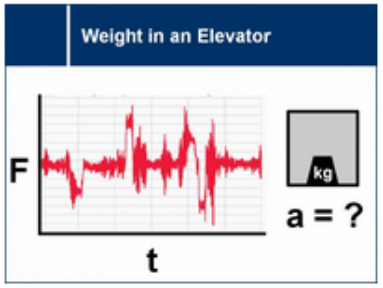
Navigating the Resource

rating (No Ratings Yet)



An introduction to acceleration and newton's laws using a demonstration of a commuting car.
acceleration, displacement, distance, forces, net force, velocity

rating (No Ratings Yet)



How does a reading on a scale change when on a moving elevator? Scenarios with an elevator moving at different velocities and acceleration will be considered. The concepts learned will then be used to analyze data from a real-life experiment.
acceleration, gravitational acceleration, mass, net force, normal force, real-life data, velocity, weight

rating (No Ratings Yet)

The following set of questions apply Newton's Second Law to scenarios with multiple blocks held together by the tension force from strings.

acceleration area centripetal force common ratio conservation of energy conservation of momentum Conversion Factors counting current displacement distance elastic collisions forces frames of reference free-body diagrams friction graphs gravitational acceleration gravitational potential energy inelastic collisions kinetic energy molar mass mole net force normal force numbers patterns percentages permutations power probability projectile motion ratios rectangles resistance sequences series tension triangles trigonometry unit circle vectors velocity voltage weight

http://scienceres-edcp-educ.sites.olt.ubc.ca/

2. Experiencing Peer Instruction

Now it is your turn to get engaged!

Algebra I

If m and p are positive integers and $(m + p) \times m$ is even, which of the following must be true?

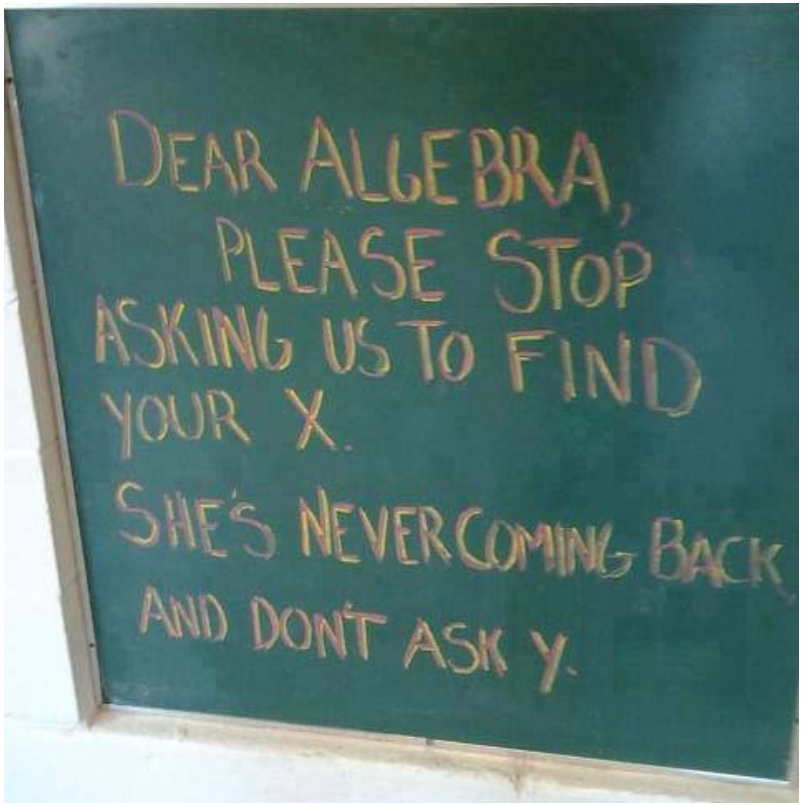
A. If m is odd, then p is odd.

B. If m is odd, then p is even.

C. If m is even, then p is even.

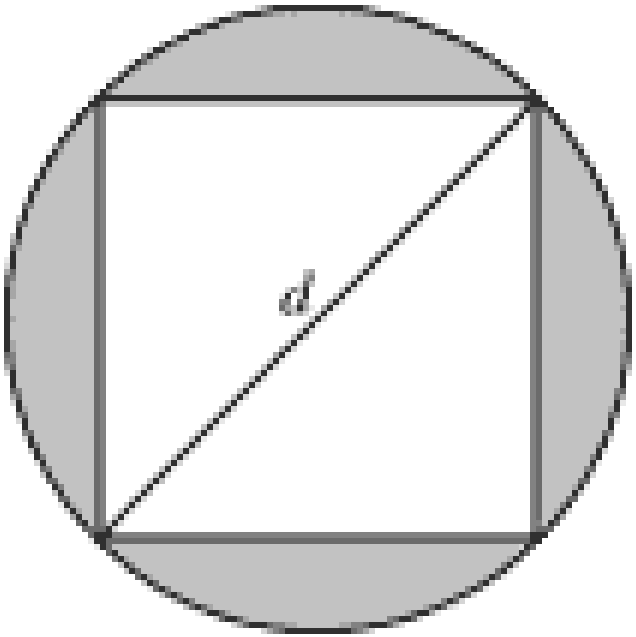
D. If m is even, then p is odd.

E. m must be even.



Algebra II

In the figure below, a square is inscribed in a circle with diameter *d*. What is the sum of the areas of the shaded regions, in terms of *d* ?



$(a)\ d^2\left(\frac{\pi}{4}-\frac{1}{2}\right)$

$(b)\ d^2\left(\frac{\pi}{4}-\frac{1}{4}\right)$

$(c)\ d^2\left(\frac{\pi}{2}-\frac{1}{4}\right)$

$(d)\ d^2\left(\pi-2\right)$

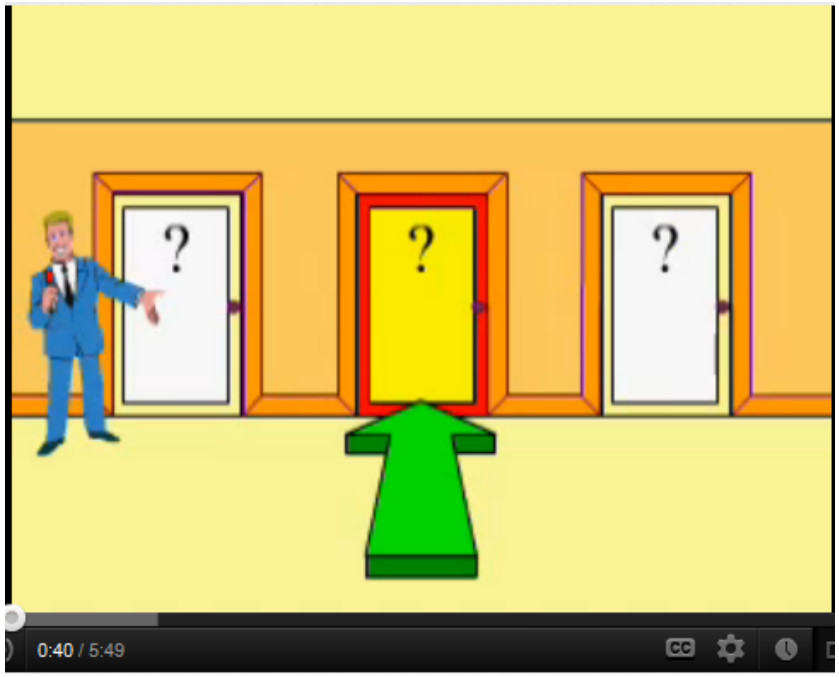
$(e)\ d^2\left(\pi-1\right)$

Let Us Make a Deal: Monty Hall Problem

A. Stick with the original choice

B. Swap doors

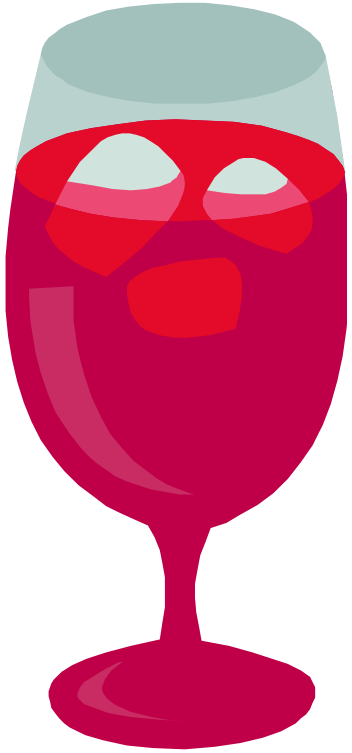
C. It doesn't matter



Science I: Playing with Buoyancy

A cup is filled to the brim with water and a floating ice.

When the ice melts, the water level:



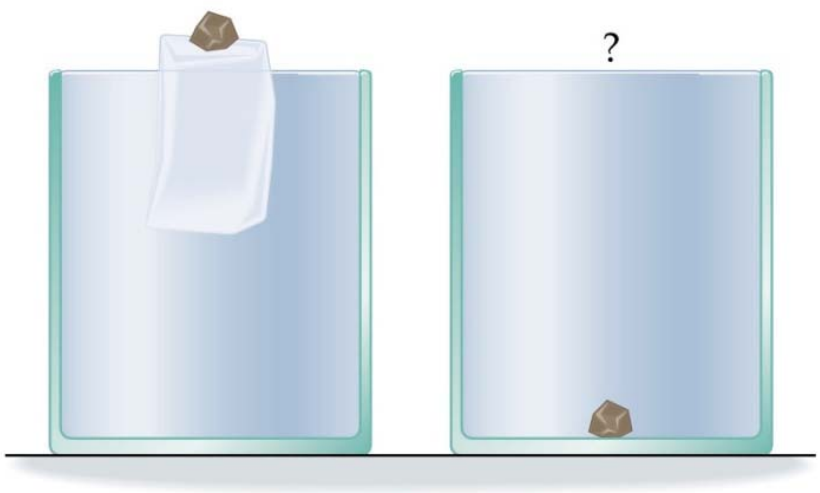
A. Decreases

B. Remains the same

C. Increases (the water spills over)

Science II: Playing with Buoyancy

A cup is filled to the brim with water and a floating ice. A small pebble is placed on the ice. When the ice melts, the water level:



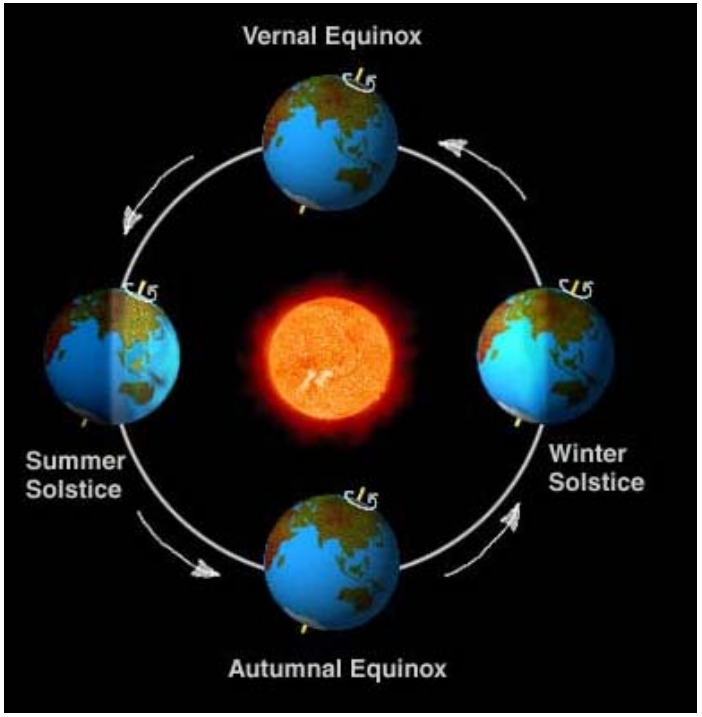
A. Decreases

B. Remains the same

C. Increases (the water spills over)

What Causes Seasons?

A. The tilt of the Earth
B. The Earth-Sun distance
C. The weather patterns
D. The position of Sun spots
E. All of the above



Why Does Tilt Cause Seasons?

A. Because one part of the Earth gets closer to the Sun
B. Because the tilt changes the amount of direct light
C. Because the tilt and the clouds produce cooler weather
D. Because the tilt makes another of the Earth to be farther away from the Sun
E. Because the tilt prevents the Earth from absorbing Sun's Energy

Discussion

1. Which questions generated the most productive discussion? Why?

2. How do you think clickers supported/hindered problem solving? How did clickers affect class dynamics?

3. Were there multiple ways to solve the problems? How were multiple interpretations dealt with?

4. What level of understanding did each question address? How did you engage with each type of question?

5. What did the teacher do to support the students during the activity? What could have been done differently? Was everybody supported?

4. What is Next?

If you would like to start using Peer Instruction with clickers or flashcards and to use the questions from our online resource and need help to get started, e-mail me: marina.milner-bolotin@ubc.ca

If you are interested in M.A., M.Ed. Or Ph.D. in Science Education at UBC, please let me know. I am looking for knowledgeable and motivated science teachers

Feedback from H.S.

- It was really interesting because we had very good discussions as a group. For the question with the cannon ball being fired in the direction of the target but the target was dropped at the same time as being fired, it was a very unexpected result. Afterwards, it made sense after further discussion.
- I liked these questions and would like to see more of these in class. Questions like these make you think and personally I can't understand physics without thinking about the principles I learn in class.
- The questions challenged me and really made me think, it was more than just plugging in numbers.
- The question with the free falling target was a very good question. It really got me thinking about it. It was confusing to begin with, but then when it was explained , it made more sense.
- As a teacher I think MSTLTT is a very valuable resource because the questions are engaging, address common misconceptions, they can generate great class discussions promoting critical thinking and they motivate students to carry out further practical work to confirm predictions.

Your Feedback

A. Excellent, very useful
B. Good, useful
C. Neutral, somewhat useful
D. Bad, not very useful
E. Horrible, I just wasted my time

If you would like to start using Peer Instruction or clickers and need help to get started, e-mail me: marina.milner-bolotin@ubc.ca

Additional Resources

1. Beatty, I., Gerace, W., Leonard, W., & Defresne, R. (2006). Designing Effective Questions for Classroom Response System Teaching. *American Journal of Physics*, *74*(1), 31–39.

2. CWSEI Clicker Resource Guide: An Instructors Guide to the Effective Use of Personal Response Systems (Clickers) in Teaching. (2009, June 1).

3. Lasry, Nathaniel. (2008). Clickers or Flashcards: Is There Really a Difference? *The Physics Teacher, 46*(May), 242-244.

4. Milner-Bolotin, Marina. (2004). Tips for Using a Peer Response System in the Large Introductory Physics Classroom. *The Physics Teacher, 42*(8), 47-48.

5. Mishra, P., & Koehler, M. J. (2007). Technological pedagogical content knowledge (TPCK): Confronting the wicked problems of teaching with technology. In *Society for Information Technology & Teacher Education International Conference* (Vol. 2007, pp. 2214–2226). Retrieved from http://www.editlib.org/p/24919/

6. Milner-Bolotin, Marina, Fisher, Heather, & MacDonald, Alexandra. (2013). Modeling active engagement pedagogy through classroom response systems in a physics teacher education course. *LUMAT: Research and Practice in Math, Science and Technology Education, 1*(5), 525-544