Teaching Conceptual Science with Technology

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Friday, May 2, 2014
Surrey Science Teachers’ Association Convention
The Teaching and Learning Enhancement Fund: supporting and encouraging innovation in teaching and the learning environment

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
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
Intro: Why Conceptual Science & Why Technology?

http://www.oecd.org/
The Value of Conceptual Science Learning

Data visualisation for key OECD data

This data tool provides easy access and country comparisons for some key OECD indicators. Please consult our Statistics A to Z page for a full list of OECD statistics and indicators.

Compare your country

Select your topic and compare select country on key indicators with OECD and G20 countries.
PISA 2012 Results

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<th>Maths</th>
<th>Reading</th>
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[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.

![Traffic Map](image)

**Question:** TRAFFIC

Maria wants to travel from Diamond to Einstein. The quickest route takes 31 minutes. Highlight this route.
Example of a PISA Question

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.
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%  What % of what the students could have learned in our traditional lecture-based courses is actually learned?
B. 30%-44%  
C. 45%-59%  
D. 60%-74%  
E. 75%-90%

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

FCI Gain Data

Course gain: \[ <g> = \frac{\text{Post }\% - \text{Pre }\%}{100\% - \text{Pre }\%} \]

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?

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


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

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Teaching a large first-year physics course has always been a challenge for a young physicist. So I thought that a peer response system might help. I began using a peer response system in the fall of 2004. The system is based on the technique described in the fall 2004 issue of the Physics Teacher. Over the past three years I have modified the system based on experiences and feedback.

Clickers beyond the First Year Science Classroom

Marina Milner-Bolotin
Tetyana Antimiroya
Anna Petrov


Abstract:

This case study’s primary objective is to describe the implementation of the electronic response-system (clickers) in a small (N=25) secondary school. A detailed description of a student-generated peer instruction approach, commissioned by the school and the teacher, is also included.
Modeling Active Engagement Pedagogy through Classroom Response Systems in a Physics Teacher Education Course

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Abstract One of the most commonly explored technologies in Science, Technology, and Mathematics (STEM) education is Classroom Response Systems. These systems allow instructors to pose questions in class, and students can respond using handheld devices. One challenge of implementing Classroom Response Systems is motivating students to enter responses. In this study, instructors generate in-class discussion by soliciting students' responses.
Clickers or Flashcards?

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

Mission is to design, test, evaluate and disseminate exemplary, research-based technology-supported instructional materials for mathematics and science K-12 programs through creating a community of science and mathematics educators, researchers and students.
Blocks and a Pulley

\[ m_1 \quad m_2 \]
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?
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 \(m_1 g\). Therefore, applying Newton’s second law, one can see that the acceleration of the system must be less than \(g\):

\[
a = \frac{m_2 g}{(m_1 + m_2)} = \frac{m_2}{(m_1 + m_2)} g < g
\]

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 \(m_1 g\). Thus the system is NOT in a free fall. Compare this questions to the previous one to see the difference.
Navigating the Resource

FORCES

Blocks and a Pulley

Exploration of free body diagrams, two body acceleration, and Newton's law through the system of two blocks attached through a pulley and one of them resting on a table.

acceleration, forces, friction, Newton's laws, pulleys, string tension

rating ★★★★★ (No Ratings Yet)

Blocks on a Pyramid

Exploration of free body diagrams, two body acceleration, and newton's laws through the system of two blocks resting on a pyramid and attached by a pulley.

acceleration, forces, friction, gravitational acceleration, net force, normal force, weight

rating ★★★★★ (No Ratings Yet)
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!
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.
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
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)
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
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.
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


