natural sciences and science education

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Redesigning instruction to promote inquiry, interactive and collaborative learning in physics for large class settings

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teacher education ▪ research ▪ outreach

Background

- Pre-service primary science teachers
- Mostly non-(physical)science majors
- AS modules (content) + CS modules (methods)
- ASK401 Further Topics for Primary Science Teaching
  - 2 AU course (2h X 12 weeks)
  - 6 weeks – physical science topics (magnetism, electric circuits and density)
  - Typical lecture setting of about 150-200 STs
  - Assessment: end-of-course MCQs
- Constraints of course structure, logistics and time

Motivation & Objectives

- Research-validated active learning methods (Meltzer & Thornton, 2012).
  - e.g. Peer Instruction, Interactive Lecture Demonstrations, Tutorials in Introductory Physics, PbI, PhET, EJSs, etc
- Questions
  - How to restructure a traditional lecture course to promote better learning?
  - How effective is the redesigned instruction in promoting learning?
  - What are the features of the redesigned instruction that are particularly effective in promoting learning?

Method

- Participants
  - Pre-service BA(Ed)/BSc(Ed) primary school STs (2 cohorts)
  - Mostly non-(physical)science majors
- Instrument
  - DIRECT pretest and posttest (Engelhardt & Beichner, 2004)
  - Reflections and end-of-course survey
- Redesigned instruction
  - 3 weeks (2h/week) on Electric Circuits
  - Tutorials in Introductory Physics (McDermott & Shaffer, 2002)
  - Tools: lab kits, clickers, computer simulations, pre-recorded videos of lab experiments, demonstrations and online discussion forums

DIRECT (Adapted) – used 20/29 items

Concepts	Learning Objectives	Question
C1. Cct Diagrams	Interpret pictures-diagrams of simple circuits.	1,7,14
C2. Current	Understand and apply conservation of current for a variety of circuits.	5,11
C3. Resistance	Apply the concept of resistance for series and parallel circuits	2,8,15,17
C4. Short-Circuit	Identify a short circuit and differentiate it from a closed circuit.	6,12,13,18
C5. P.D.(1 battery)	Apply concept of p.d. to simple circuits.	3,9,16,19
C6. P.D.(multiple batteries)	Apply the knowledge that the amount of current is influenced by the p.d. of the batteries and resistance in the circuit.	4,10

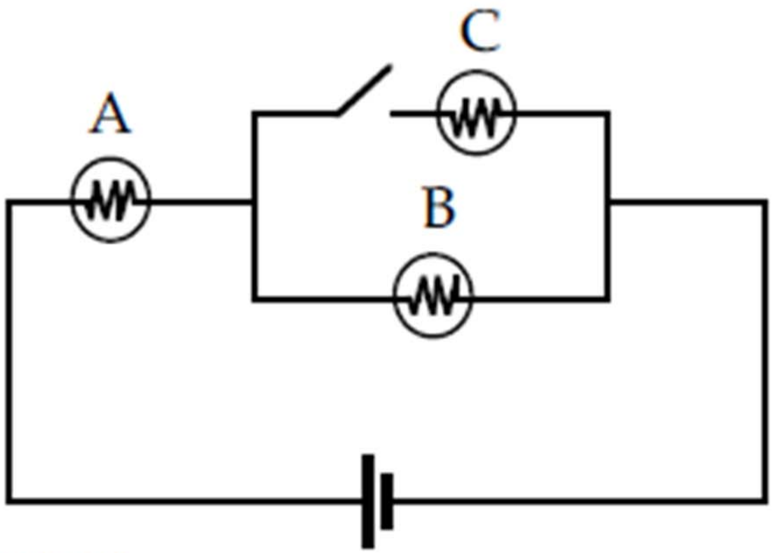
DIRECT (Adapted)

- Sample question (Q20)

What happens to the brightness of bulbs A and B when the switch is closed?

N = 329

PRE	POST	
44%	27%	(A) A stays the same, B dims
26%	**53%**	(B) A brighter, B dims
5%	12%	(C) A and B increase
12%	1%	(D) A and B decrease
12%	6%	(E) A and B remain the same

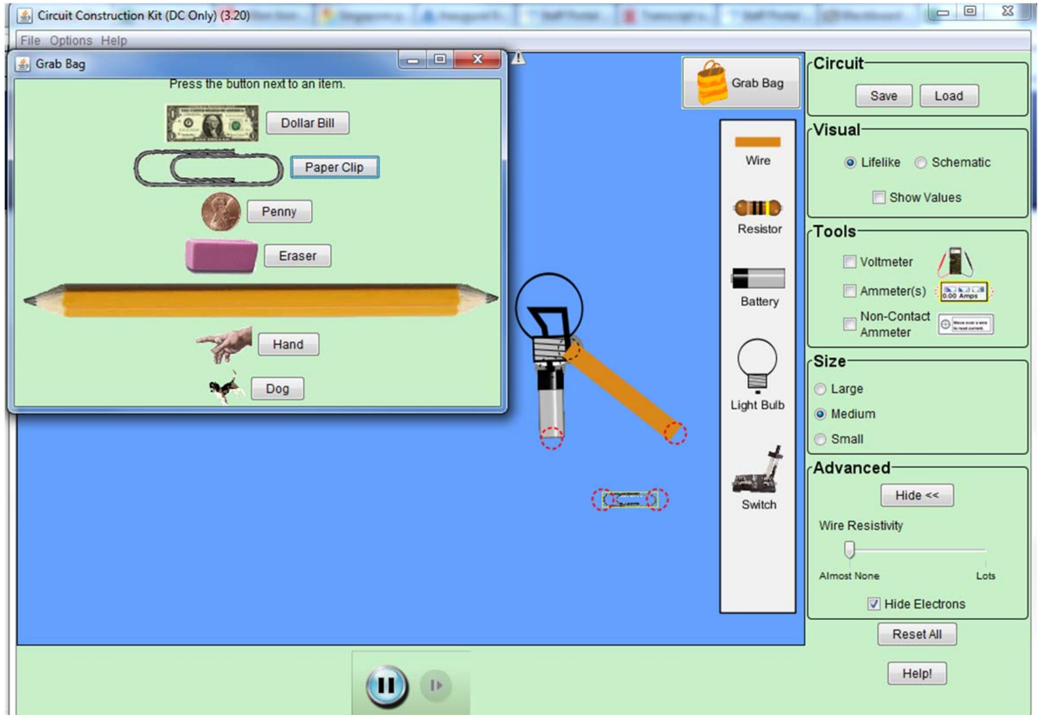


Features of Redesigned Instruction

- 2011 (Lab setting) versus 2012 (Lecture setting)

S/N	Features of the Redesigned Instruction	2011	2012
F1.	Working through inquiry worksheets with peers.	✓	✓
F2.	Hands-on experience with materials in class.	✓	-
F3.	Hands-on use of computer simulations in class.	-	✓
F4.	Use of clickers to promote discussion.	✓	✓
F5.	Small group checkouts to monitor learning.	✓	✓
F6.	Use of demonstrations to reinforce concepts.	✓	✓
F7.	Whole-class checkouts to consolidate learning.	✓	✓
F8.	Whole-class checkouts using pre-recorded videos.	-	✓
F9.	Use of computer simulations outside of class.	✓	✓
F10.	Reflecting on learning using online discussion forum.	✓	✓

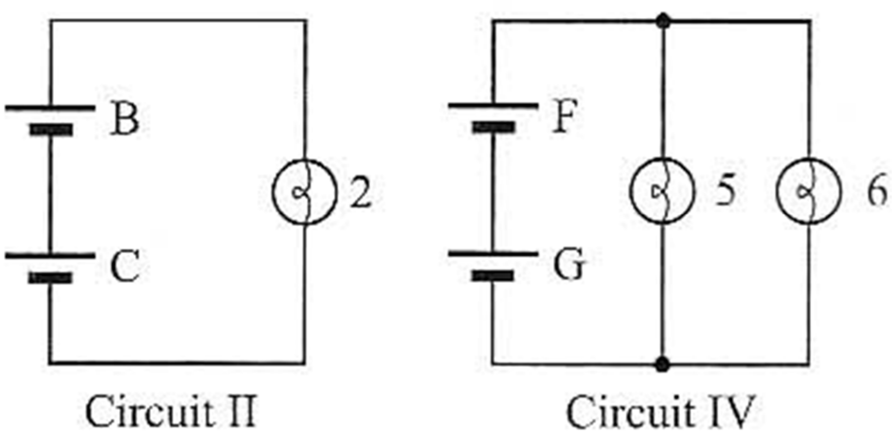
Task: Using the PhET simulation, observe and record the bulb brightness when various materials are inserted into the circuit.



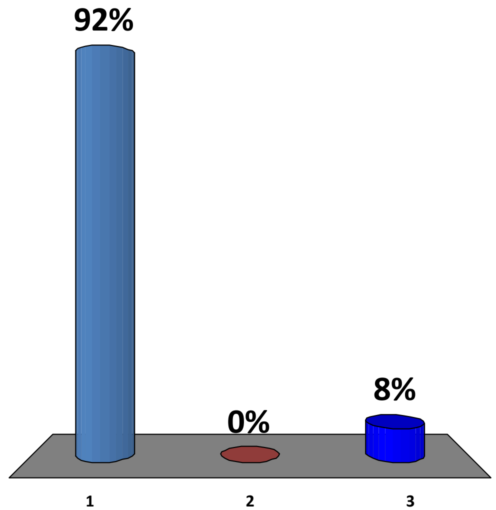
Materials	Brightness
Paper clip	
Dollar bill	
Penny	
Eraser	
Pencil lead	
Hand	
Dog	

What is similar about most objects that let the bulb light? TodaysMeet

Q: Based on the observation of relative brightness of the bulbs, the *current through battery*



1. F > B
2. F < B
3. F = B



Method

- Reflection Questions (Discussion Forum)
  - State one conceptual difficulty or misconception you faced for this topic prior to the lesson.
  - Describe how your thinking about this concept changed after attending the lesson and what was it that was effective in helping you to overcome your specific learning difficulty or to enhance your understanding of the topic.
  - State one thing in the lesson that you still have doubts or questions about.
- End-of-course Survey
  - Describe specifically the ways (e.g. science content, process of science, inquiry-based learning pedagogy, active learning strategies, etc) you have benefited from this course.

Sample Survey Response (2011)

Issues & Challenges

- It did push us to think harder and try to prove our stance. However, often, we were on the verge of giving up because of the complicated questions that keep hindering our progress. I would think that not all pupils can strive with inquiry tutorials, especially when we leave room with much uncertainties.
- It is great that we get to conduct hands-on experiment to discover or prove some concepts of magnetism and electricity. However, there is a chance that our experiment or result is wrong and we did not realise the mistake. This would affect our understanding and thus, affect our test or exams. This is because the answers were not gone through in class and we would only ask if we have any question. The problem here is that we might not have questions to ask, but we might have developed a misconception in our answers unknowingly.

Sample Survey Response (2011)

Issues & Challenges

- It would be better if more helpers are allocated to each tutorial group. Sometimes, we can't really clarify our doubts due to the lack of manpower and wrong concepts were learnt from the activities. Having a wrap-up of the tutorial will be ideal to reinforce learning.
- Conducting inquiry lessons are useful in real knowledge acquisition when we learn through understanding and not memorising but they are not designed to be achieved within a short period of time (i.e. 2 hours tutorial with too many experiments to complete coupled with active discussions).

Results

	Cohort (N)	Mean	SD	SE	<Gain>	<g>
Pre	2011	8.5	2.5	1.9	3.6 ±	**0.30 ±**
Post	(N = 188)	12.1	3.0	1.8	0.2	**0.02**
Pre	2012	9.3	2.9	1.9	3.3 ±	**0.30 ±**
Post	(N = 141)	12.6	3.7	1.8	0.3	**0.03**

Hake factor, <g> = (post% – pre%) / (100 – pre%). (Hake, 1998)

- Traditional courses: <g> = 0.23 ± 0.04 (SD)
- IE courses: <g> = 0.48 ± 0.14 (SD)

Results

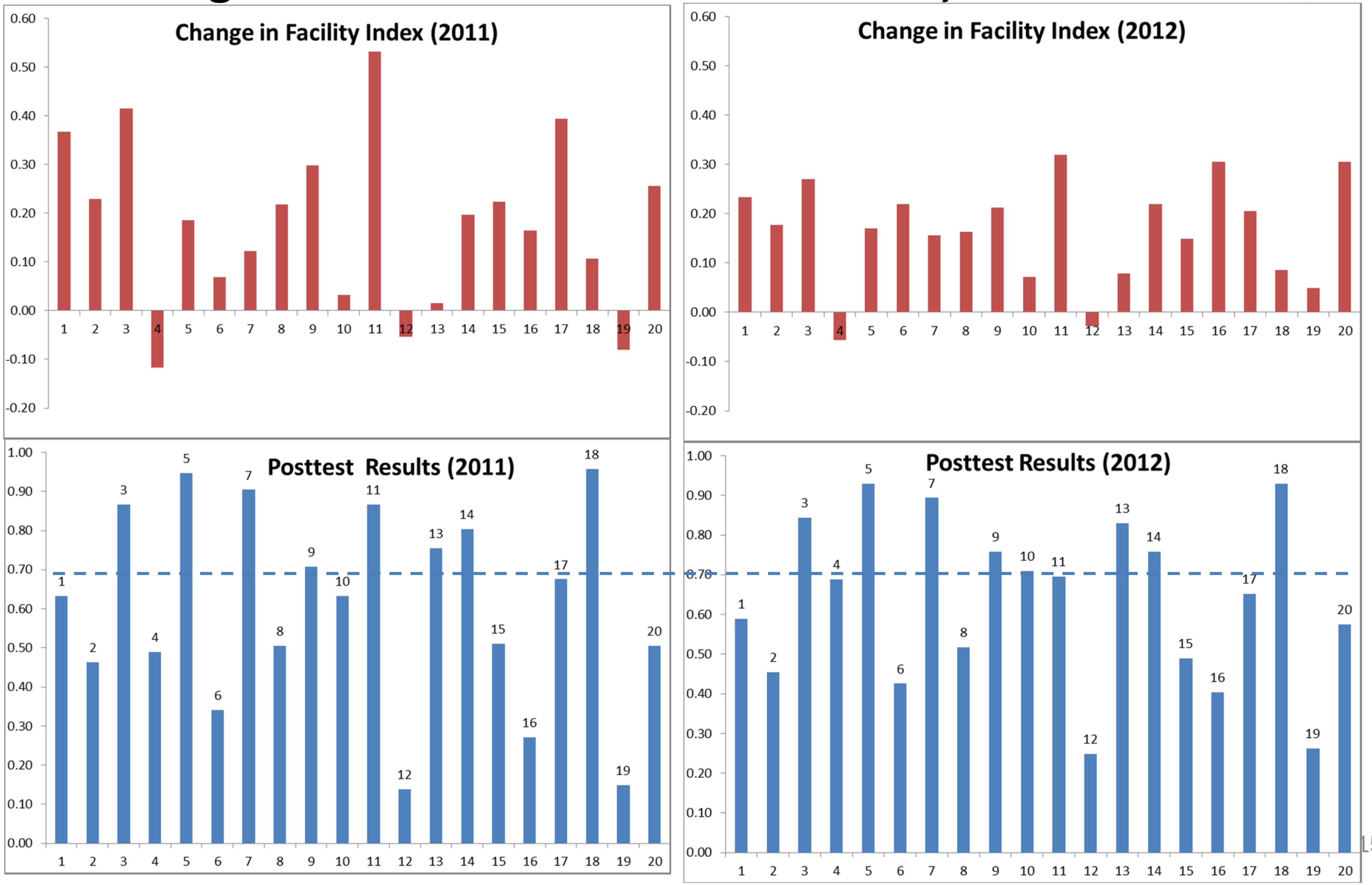
- Change in FI by Concepts

Concepts	Question No.	ΔFI(Ave) 2011	ΔFI(Ave) 2012
LO1 - Circuit Diagrams	Q1, Q7, Q14	0.23	0.20
LO2 - Current	Q5, Q11	0.36	0.24
LO3 - Resistance	Q2, Q8, Q15, Q17	0.27	0.17
LO4 - Short Circuit (R = 0)	Q6, Q12, Q13, Q18	0.03	0.09
LO5 - P.D. (1 battery)	Q3, Q9, Q16, Q19	0.20	0.21
LO6 - P.D. (multiple batts.)	Q4, Q10	-0.04	0.01
LO7 - Synoptic question	Q20	0.26	0.30

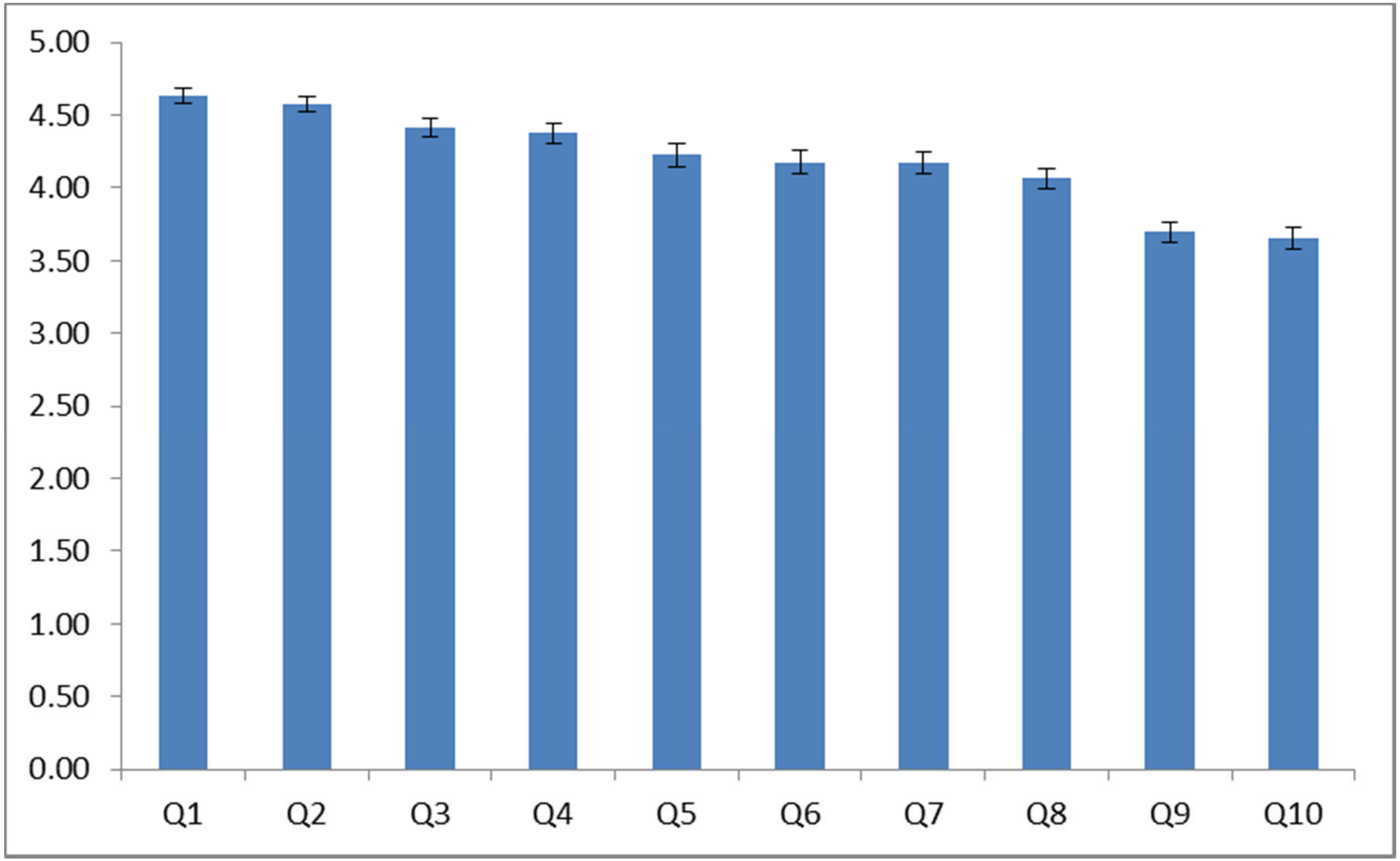
- Blue – more than 70% correct for posttest; Red – negative ΔFI

Results

- Change in FI and % correct answers by Questions



Relative Effectiveness of the Features (2012)



Q1.Demonstrations; Q2.Hands-on experience; Q3.Pre-recorded videos. Q4.In-class use of simulations. *Q5.Out-of-class use of simulations; Q6.Group and class checkouts; Q7.Triggering prior knowledge using clickers; Q8.Discussing with peers answers to clicker questions; Q9.Checking internet/textbooks on my own; Q10.Discussion forum*

Sample Survey Response (2011)

- The inquiry based method of instruction that was used during the physics component was particularly memorable. The truth is that I remembered much of what I learned because I enjoyed it! I was actually (re) discovering science -principles and not simply reading notes or doing monotonous question after question.
- I will most certainly reuse this way of teaching science. I think students will, like me, enjoy learning science by discovering how concepts work rather than the old fashioned textbook and workbook routine.
- Inquiry also promotes in my opinion reflection of learning and creates long term motivation. The experience spills over outside of the classroom.

Sample Survey Response (2011)

- I have learned that the process of science is important in delivering content. This course requires me to participate in a lot of hands-on activities. From the hands-on activities, it actually built my knowledge of electricity better. Now, I feel that the process of carrying out science is very powerful in embedding knowledge.
- From this module, I realized that structuring questions correctly and prompting learners with open-ended questions were especially useful in generating their discussions. In addition, as the answers to the clicker questions were not given immediately and that we were able to discuss and carry out experiments to test our ideas and then repoll our answers which reflects our change in science ideas based on evidences from our experiments or peer discussions.

Sample Survey Response (2012)

- Instead of just memorising the facts which was given, there was more in depth understanding of why a particular thing will happen.. more in depth understanding.
- Inquiry based learning has helped me ask questions about scientific concepts that I have always assumed as naturally in that manner, which made me understand the concepts more.
- The inquiry based learning strategies, although mind boggling at times, allowed us to work through our misconceptions to derive at the right concept. It helps us understand what are the gaps in our learning are. It also shows us the kind of struggle our students will have in the process of understanding science. In science, it is not enough to know what the right answers are, but we also have to know why the answers are the way they are.

Concluding Remarks

- Large class lecture setting was shown to be as effective as large class lab setting when active learning instructional features were incorporated in the redesigned instruction
- Hands-on learning with real materials was ranked high by STs as an effective feature of the redesigned instruction
- Pre-recorded experiments which focuses on inferences derived from observations can help to consolidate learning of concepts
- The feature of having to ‘figure things out’ can both motivate some STs’ interest to learn yet cause other STs to feel that there is insufficient scaffolding, consolidation and feedback
- As instructors, we must constantly tune our instruction to find the ‘sweet spot’ and right balance of challenge and support to motivate and optimise student learning

Reference

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Thank you ☺