# Peer-Instruction: An interactive learning strategy

## How to promote student conceptual reasoning in your course

### Sahana Murthy

IDP in Educational Technology
Indian Institute of Technology Bombay

February 27, 2014

# *From Tomorrow's Professor, Feb 25 2014*

*Sometimes at the end of a workshop, a participant asks: "If I want to try just one thing you told us about, what should it be?"*

*My answer is always **active learning**.*

*[...] that means engaging students in course-related activities in class other than watching and listening to the instructor. They may be asked to answer a question, begin a problem solution or derivation or figure out the next step, explain a concept, interpret an observation, brainstorm a list, predict the outcome of an experiment, or any of a hundred other things.*

*Stanford Center for Teaching and Learning*

# A quick word on nomenclature

Active learning

Interactive learning

Interactive engagement


Different names used by different communities but all are learner-centric strategies

# Requirements of active learning strategies

- Instructor creates carefully designed activities that require students to talk, write, reflect and express their thinking.

- Students go beyond listening, copying of notes, execution of prescribed procedures.

- Explicitly <u>based on theories</u> of learning.

- <u>Evaluated repeatedly</u> through empirical research.

Note:

Many informal strategies may have the goal of engaging students, but to be termed as active learning, they need to meet the above requirements.

Meltzer, David E., and Ronald K. Thornton. "Resource letter ALIP–1: active-learning instruction in physics." *American journal of physics* 80.6 (2012): 478-496.

# But my lectures are plenty interactive!

- I often pause to ask students if they understood the material

- Students can even interrupt with doubts

- I never hesitate to answer their questions
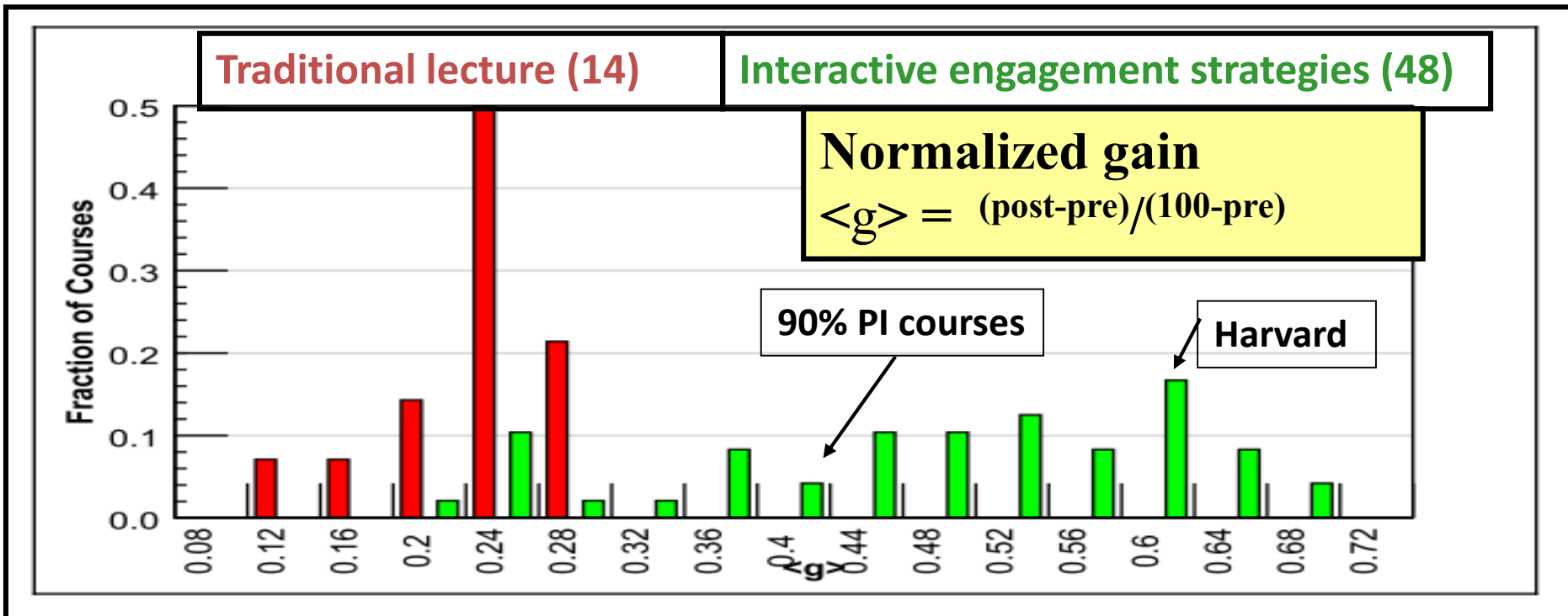
- I show them demos and videos

….

*Aren't these enough?*

# Lecture quality does not seem to matter

| EXPERIMENT Two videos of same instructor | Group 1- 'Fluent' video speaks fluently, no notes, upright, maintains eye-contact | Group 2 – 'Disfluent video speaks haltingly, often sees notes, slouches, poor body language |
|---|---|---|
| MEASURE-MENT | student performance by post-test on topic | |
| | | |
| RESULTS | Perceived learning greater than actual learning | Perceived equal to actual learning |
| | Same actual learning for both groups | |

*If it is not quality of lectures, what does lead to better learning?*

S. K. Carpenter et al. "Appearances can be deceiving: instructor fluency increases perceptions of learning without increasing actual learning". *Psychonomic bulletin & review*,*20*(6), 1350-1356, 2013.

# Comparing good lectures with interactive engagement strategies



**Traditional lecture (14)**  **Interactive engagement strategies (48)**

**Normalized gain**

$$\langle g \rangle = \frac{(\text{post-pre})}{(100-\text{pre})}$$

**90% PI courses**  **Harvard**

- 6542 students
- 62 courses – Physics (many instructors with high evals)
- Variety of institutions: high school, college, university
- Standardized test used – Force Concept Inventory

R. Hake, "Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses" Amer. Jour. Phy., **66** (1998)

*Desirable to incorporate interactive engagement strategies*

# How can we achieve active learning?

- Think-Pair-Share [Frank Lyman, University of Maryland, early 1980s]

  (IDP-ET mini-workshop Dec 2013, Sridhar Iyer)

- Peer-Instruction [Eric Mazur, Harvard University, early 1990s]

- Team-Pair-Solo [Spencer Kagan, University of California, early 2000s]

- Many others:
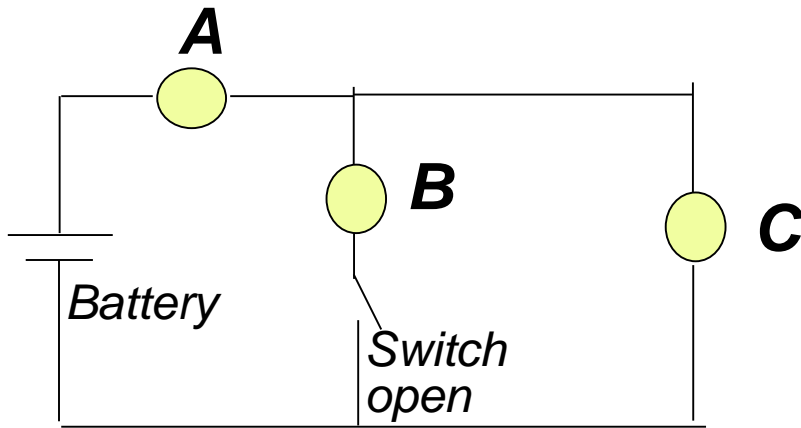  - Problem-based learning, Productive failure, Role-play, Jigsaw,

What exactly is Peer-Instruction?
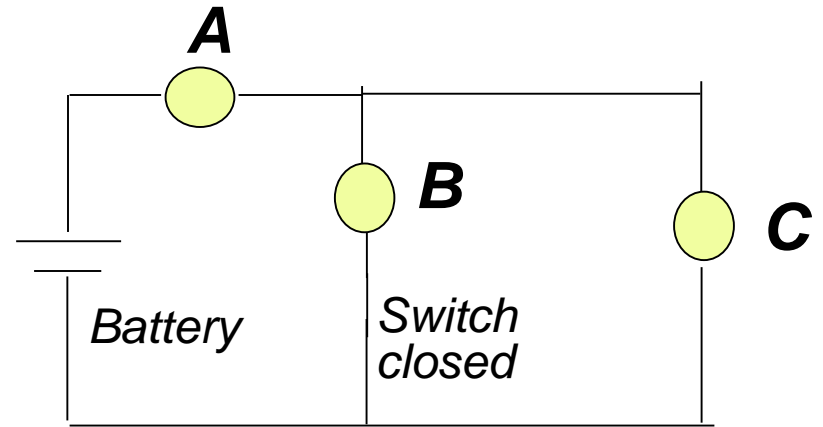
How is it different from other types of questioning?


How is Peer-Instruction related to clickers?

# Sample question – vote individually



BEFORE
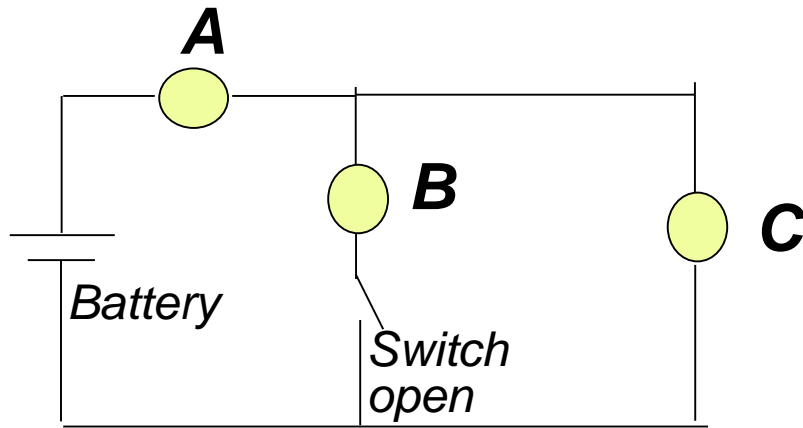
AFTER

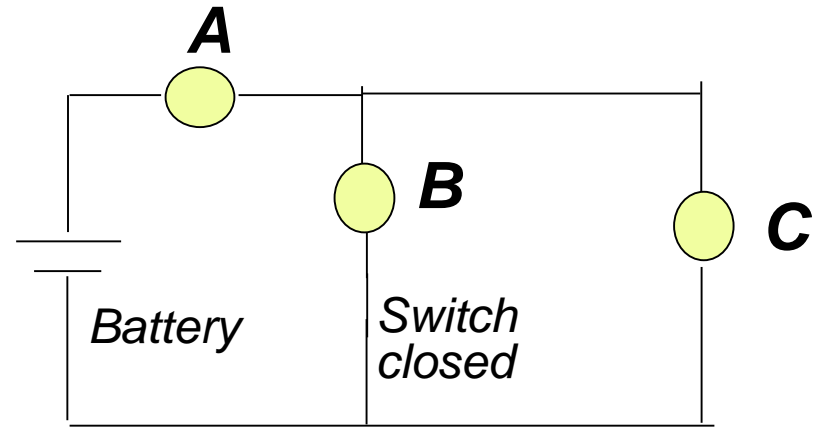What happens to brightness of bulb A *after* the switch S is closed?

1) Brightness of A decreases

2) Brightness of A increases

3) Brightness of A stays the same

4) I am not sure how to answer this
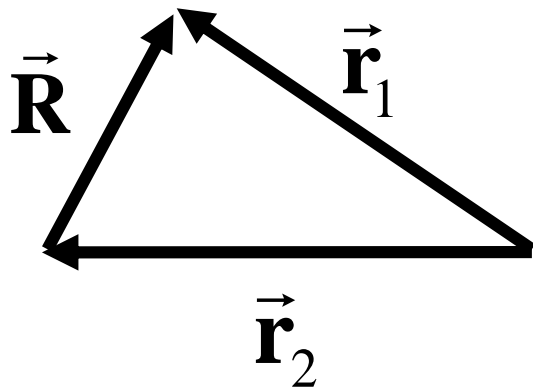
# Discuss with your neighbour, vote again



**BEFORE**

**AFTER**

What happens to brightness of bulb A *after* the switch is closed?

1) Brightness of A decreases

2) Brightness of A increases

3) Brightness of A stays the same

4) I am not sure how to answer this

# Another sample Peer-Instruction Question

What is the relationship between the vectors $\vec{r}_1, \vec{r}_2$ and $\vec{R}$ in the figure?



1) $\vec{R} = \vec{r}_1 + \vec{r}_2$

2) $\vec{R} = \vec{r}_1 - \vec{r}_2$

3) $\vec{R} = \vec{r}_2 - \vec{r}_1$

# When did I ask this question?

The first class after mid-sem (Electricity & Magnetism course) before I gave back student answers.

# Mid-sem question, result and action

QUESTION: Use Biot-Savart law to calculate the magnetic field due to a long wire carrying current $I$, as a function of distance from the wire.

RESULT: Students did not do well on the question. (Answer should be a formula with distance from wire as a parameter).

ACTION:
1) Identified main places where students went wrong:

      Setting up of integral → Vectors (r minus r-prime)
      Problem in vector addition of infinitesimal magnetic fields
      Many had nonsensical final answers – needed limiting case checks

2) Created a series of conceptual multiple-choice questions <u>aimed to elicit above common difficulties</u>. The questions required verbal and diagrammatical reasoning.

3) Did Peer-Instruction with these questions while discussing midsem. Discussion phase in PI helped students resolve these difficulties.
(see the PI Qs used, on next 3 slides)

# Peer-Instruction Q1

In the figure, with "dl" shown, which pink vector best represents $\vec{\mathfrak{R}}$ used in Biot Savart's law?
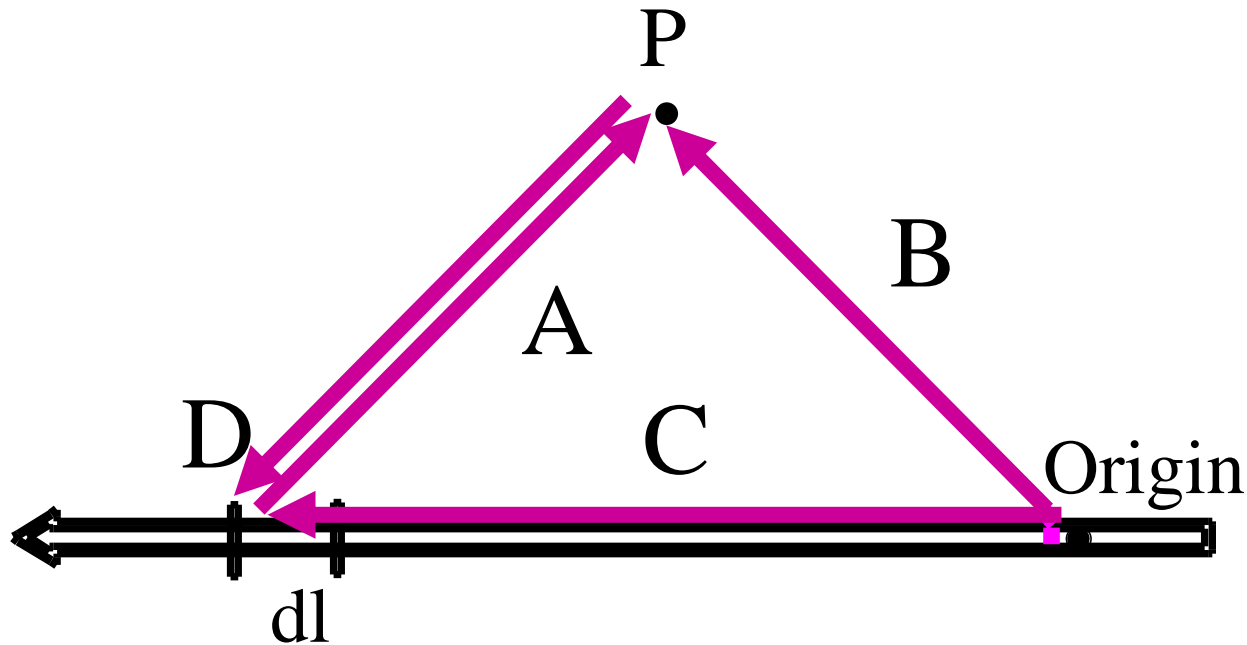


$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \int \frac{\vec{dl} \times \hat{\mathbf{R}}}{\mathbf{R}^2}$$

# Peer-Instruction Q2

To find the magnetic field B at P due to a current-carrying wire we use the Biot-Savart law,
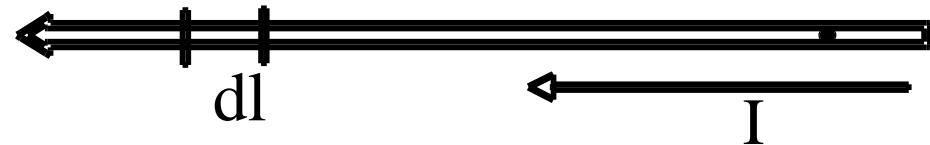
$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\vec{l} \times \hat{\mathbf{R}}}{\mathbf{R}^2}$$

What is the *direction* of the infinitesimal contribution $\overrightarrow{d\mathbf{B}}$ at point P created by current in $\overrightarrow{d\mathbf{l}}$?

A) Up the page

B) Directly away from d**l** to left (on the plane of the page)
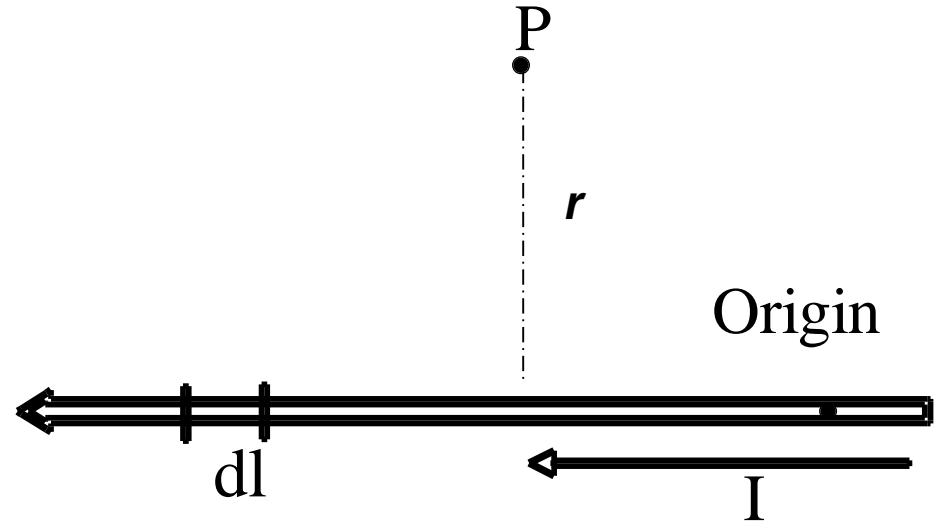
C) Into the page

D) Out of the page

P

Origin

dl

I

# Peer-Instruction Q3

Which of the following expressions makes sense for the magnetic field B at P due to a current-carrying wire?

P

$r$

Origin

dl

I

1) $\dfrac{\mu_0 I}{2\pi\, r}$

2) $\dfrac{\mu_0 I}{2\pi}$

3) $\dfrac{\mu_0 I}{2\pi}\, r$

# Dissecting Peer-Instruction method

**What did students (you in the previous slide) do?**

Talk, argue, listen (sometimes), reason, draw => Actively engaged

Learn from each other, teach each other (teach<=>learn)

Those who don't know willing to think, reason, answer

Those who do know also participate

Pre-existing thinking is elicited, confronted, resolved (*How many of you changed your answer?)*

**What are other benefits? To instructor? To class atmosphere**

Immediate feedback to instructor

Students realize that even others are struggling

Builds a friendly, yet scientific atmosphere

Improve communication

# Anatomy of Peer-Instruction method
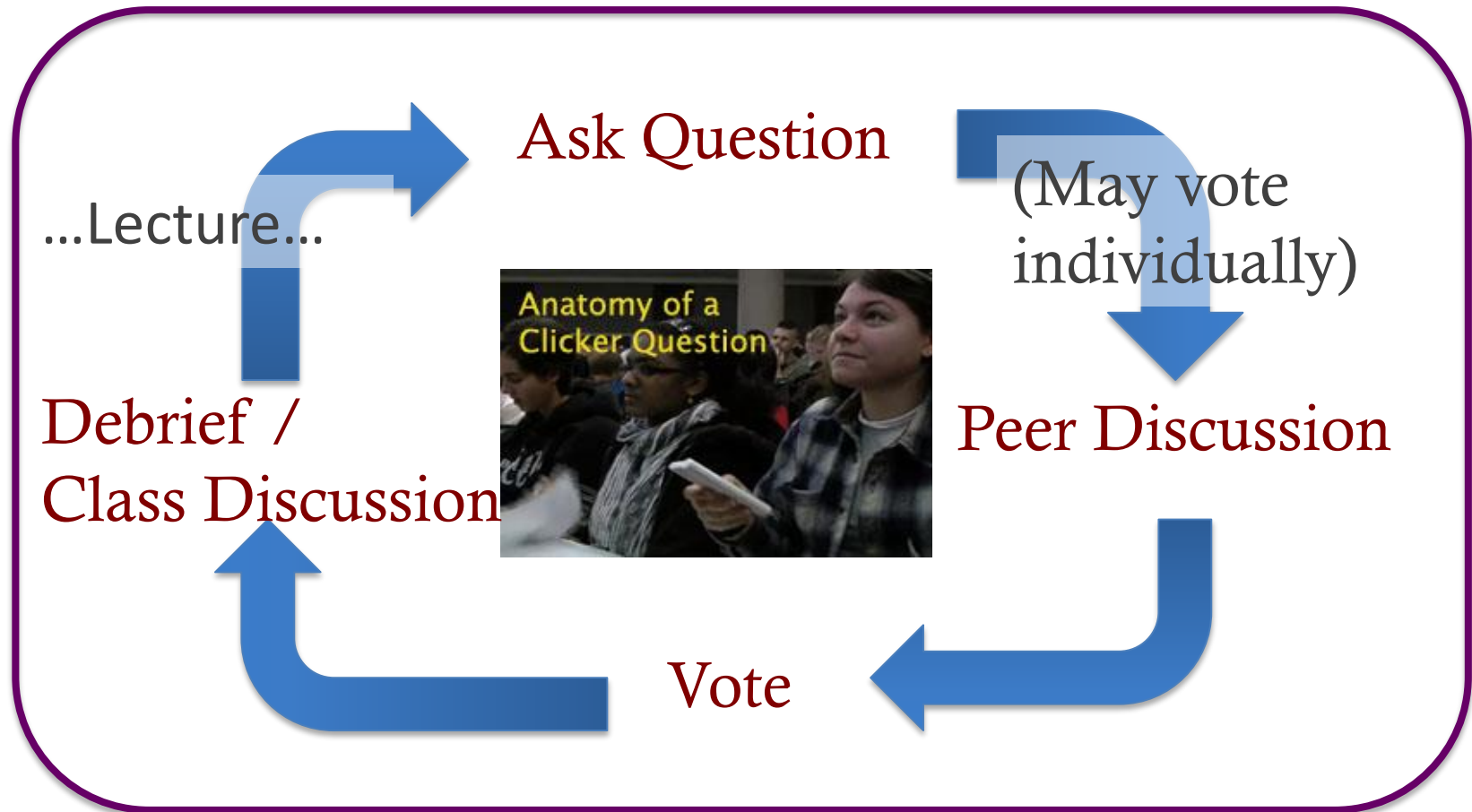


...Lecture...

Ask Question

(May vote individually)

Debrief / Class Discussion

Peer Discussion

Vote

# Peer-Instruction with clickers

# But clickers are not Peer-Instruction



MIT TEAL classroom



From blog.peerinstruction.net

# Peer-Instruction without clickers – 1

A

B

C

D

OR:

A4 sheet of paper

Fold it in four

Marker – A, B, C, D

# Peer-Instruction without clickers - 2

# Research on Peer-Instruction

# PI one of the most widely researched* strategies

*(\* This is good because …)*

- Extent of research
  - 300+ research articles
  - Physics, biology, chemistry maths, CS, engineering, psychology, medicine & nursing …
  - Many controlled studies using standardized tests

- Courses using peer instruction outperform traditional lecture courses on a common test

- Students can better answer a question on their own, after peer instruction discussion, (especially difficult questions) –  study with 16 pairs of isomorphic  questions *Smith et al, Science 2009*

- Research on student perception says: clickers help students show up for class, feel part of class community, make their voice heard, hold them accountable …

From 'iClickerJan292014' ppt, Stephanie Chasteen / Science Education Initiative/ CU-Boulder .

# Activity: Write your own Peer-Instruction question, based on a mid-sem question

- Consider a mid-sem question in your course.

- Identify what points the students might find difficult in answering it (if you have already graded this, you know exactly what)

- Choose one such difficulty / error.

- Write a PI question to help address the above difficulty / error. Some possible questions:

  - Ask students to reason conceptually (increase / decrease, greater / less, left / right, what would happen if … )

  - If different representations are part of the problem, create a question based on the representation (translate words to diagram, equation to graph … )

  - Give a few possible choices and ask students to argue plausibility of answers using dimensional analysis, limiting cases

# Writing effective Peer-Instruction questions

# Group Brainstorm: What are features of a "good" multiple-choice question?

- DISCUSS

- DISCUSS

# What makes a good peer-instruction question?

An effective peer-instruction question:

- Is usually conceptual (avoid long analytic computation)
- Elicits pre-existing thinking, students' alternate conceptions
- Has believable distractors
- Asks students to predict results of experiment, or algorithm
- Makes students apply ideas in new context
- Relates different representations

- is not ambiguous
- is not leading
- is not 'trivial'

Adapted from Clicker Resource Guide, Science Education Initiative/ CU-Boulder .

29

# Types of Peer-Instruction questions

# Different questions for different goals, pedagogical strategies

1. Conceptual reasoning "one right answer" questions
2. Discussion "no one right answer" questions
3. Predict an outcome (e.g., of experiment, program)
4. Embed reasoning in answers (give choice and its reason)
5. Reason using representations
6. As a stepping stone to problem-solving
7. Recall point from previous lecture
8. Survey questions / personal opinion

# Facts and Concepts - reason towards the "one right answer"

A small acorn over time can grow into a huge oak tree. The tree can weigh many tons. Where does most of the mass come from as the tree grows?

A) Minerals in the soil

B) Organic matter in the soil

C) Gases in the air

D) Sunlight

A Private Universe; Annenberg Media

*This is an important fact / concept. Can use this question to start discussion on plant growth, photosynthesis etc. Can repeat the question after instruction.*

# Facts and Concepts - reason towards the "one right answer"

A parallel plate capacitor is charged to a total charge Q and the battery removed. A dielectric slab is inserted between the plates.

What happens to the energy stored in the capacitor?

A) Increases
B) Decreases
C) Stays the same

*Typical conceptual reasoning question.*

# Discussion - "no single right answer"

A block m sits on a rough inclined surface, attached with a spring (extended) to a fixed point at the other end. As the block moves up the incline a small distance, how many forces are exerted on the block?

- One force

- Two forces

- Three forces

- Four forces

- Five forces

- More than five forces

- Impossible to determine

- None of the above

*Good question to get students to model a physical system*

# Activity – write your own question

Choose one of the two goals:

1. Conceptual reasoning "one right answer" questions

2. Discussion "no one right answer" questions

Write a peer-instruction question for your course.

(Make sure you include the choices too ~ 3 to 5)

# Predict the outcome
# (of an experiment, video, program)

A helium balloon is attached to a string tied to the bottom of a cart on wheels. The sides of the cart are encased in clear plastic. A person will abruptly push the cart to the left. Will the balloon move?

A) Yes, to the left

B) Yes, to the right

C) No

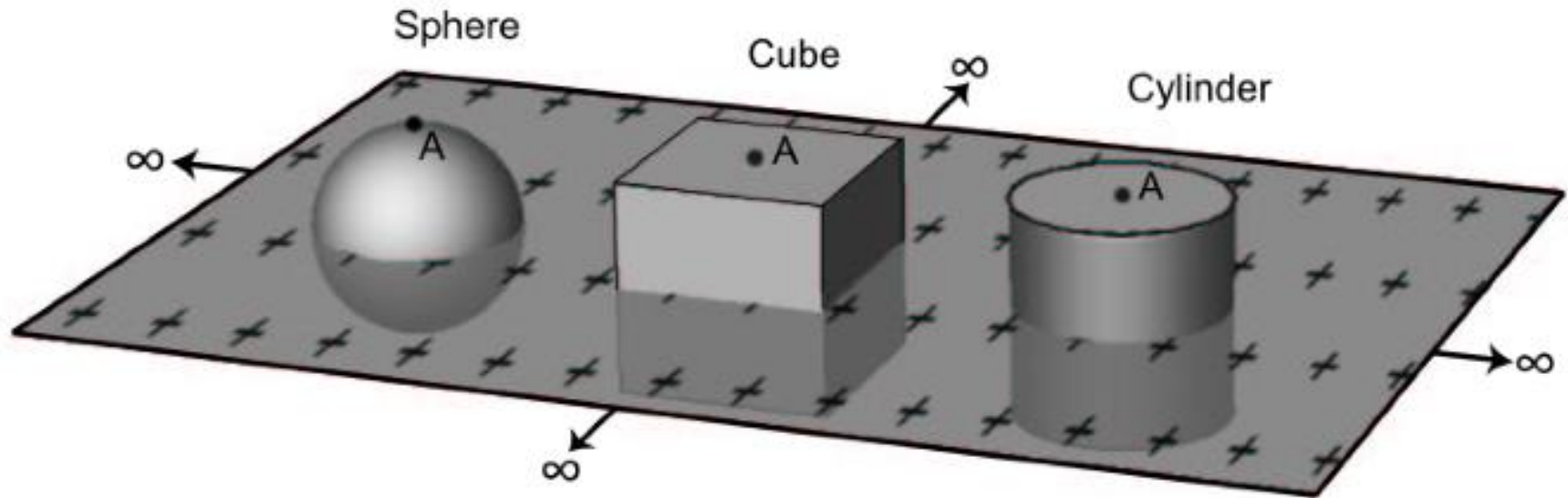Let students vote, then show movie for what happens.

http://paer.rutgers.edu/pt3/experiment.php?topicid=13&exptid=121

*Get students to predict, show video URL, discuss reasoning in wrap-up*

# Beyond Yes / No: Embed reasoning in answers

For which of these Gaussian surfaces will Gauss' law help us to calculate E at point A (top center) due to the infinite sheet of charge?



A) Only the sphere <u>since</u> it is the only one with full symmetry
B) Only the cylinder <u>because</u> it has circular symmetry and side walls have zero flux
C) Only the cylinder and the cube <u>because</u> they have side walls perpendicular to the sheet and end caps parallel to the sheet
D) Only the sphere and cylinder <u>because</u> they have circular cross section
E) All surfaces will work <u>because</u> they are all symmetric

Question based on Concept Test from University of Colorado Upper Division Electrostatics course
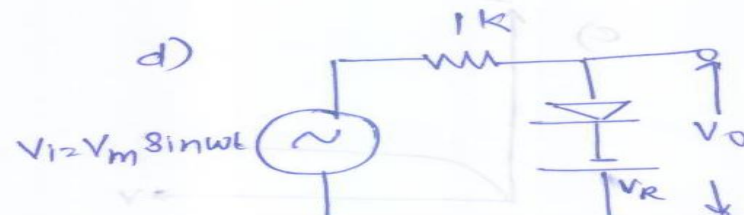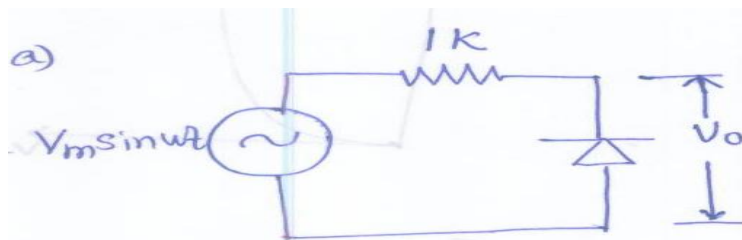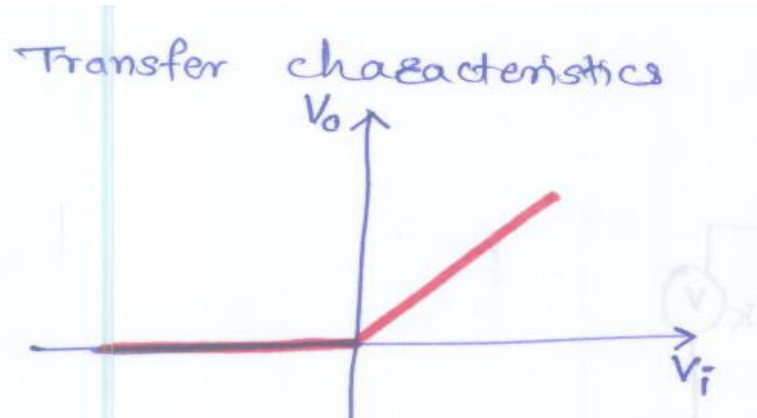
# Activity – write your own question

Choose one of the two goals:

3. Predict an outcome (e.g., of experiment, program)

4. Embed reasoning in answers (give choice and its reason)

Write a peer-instruction question for your course.

# Reasoning with representations

Which circuit will satisfy given input output relationship?



*Diagrammatic representations in question AND choices*

# As a stepping stone to problem-solving

A very large (effectively infinite) capacitor has charge Q. A neutral dielectric is inserted into the gap (and of course, it will polarize). <u>Your goal is to find **D** *everywhere.*</u> You can use the following relations:

i) $\vec{D} = \varepsilon_0 \vec{E} + \vec{P}$

ii) $\oint \vec{D} \cdot d\bar{a} = Q_{free}$

iii) $\oint \vec{E} \cdot d\bar{a} = Q / \varepsilon_0$



+Q

-Q
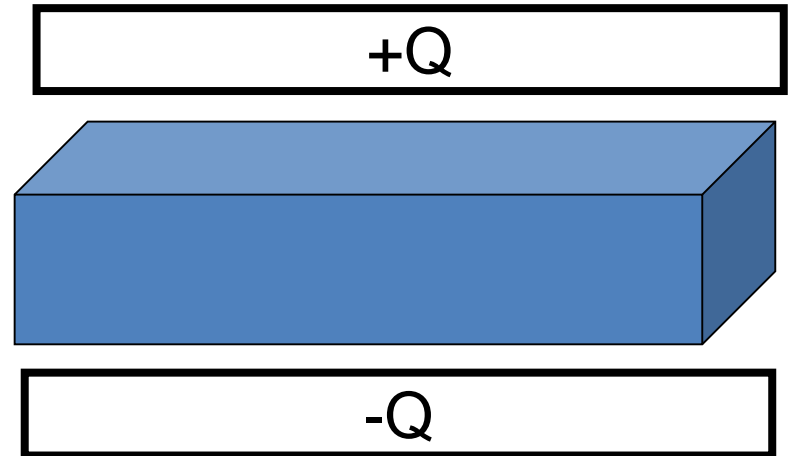
Which equation would *you* use first?
A) The one with P
B) The one with $Q_{free}$
C) The one with $Q/\varepsilon_0$
D) I can use any of them first

*Such questions are useful to start the problem solving process, before students begin to flex their mathematical muscles.*

# Activity – write your own question

Choose one of the two goals:

5. Reason using representations (for ex interpret graph) or translate between representations (for ex convert between graph / equation / words / diagram)


6. Conceptual question as a stepping stone to solve a problem


Write a peer-instruction question for your course.

# Recall point from previous lecture

Positive ions flow right through a liquid, negative ions flow left. Is there a net current through the liquid? (Same density and speed of both ions)

A) Yes, to the right
B) Yes, to the left
C) No
D) Not enough information given

*I used this in the class after the definition of current was introduced*

# Survey questions

I would like to know a little about you. Choose the most appropriate response.

Are you familiar with vector calculus?

A) I only know basic differentiation and integration

B) I have heard the terms gradient, divergence, curl, but I do not know how to calculate them

C) I can calculate gradient, divergence, curl of functions but I do not know how to draw the functions

D) I can calculate vector derivatives as well as comfortably draw the functions

*I used this in the first class in PH103 E&M*

# Survey questions

Are you concerned about global climate change?
A)  Yes
B)  No
C)  I don't think the climate is changing
D)  I don't know if the climate is changing

*Use such questions to begin open discussions on topics where varied opinions exist*

# Personal opinion

The pace of this class is:

A) Too fast
B) Too slow
C) Just about right

*Useful as a mid-semester feedback every 4 weeks or so*

The quiz was:

A) Easy
B) Somewhat challenging, but I could do it
C) Too challenging

*Used right after Quiz 1*

# Summary: question types

1. Conceptual reasoning "one right answer" questions
2. Discussion "no one right answer" questions
3. Predict an outcome (e.g., of experiment, program)
4. Embed reasoning in answers (give choice and its reason)
5. Reason using representations
6. As a stepping stone to problem-solving
7. Recall point from previous lecture
8. Survey questions / personal opinion

# Activity – write your own question

Write a survey / personal opinion question as a peer-instruction question for your course.

# When to use Peer-instruction questions

# Questions within the learning cycle

| BEFORE | DURING | AFTER |
|---|---|---|
| Setting up instruction (beginning of module) | Developing knowledge (middle of module) | Assessing learning (end of module) |

*Questions to:*
Motivate
Discover
Provoke thinking
Assess prior knowledge

*Questions to:*
Check knowledge
Application
Analysis
Evaluation
Synthesis
Elicit misconception

*Questions to*
Relate to big picture
Demonstrate success
Review or recap
Exit poll

Adapted from From from "iClicker" by Stephanie Chasteen and the Science Education Initiative at the University of Colorado

# Challenges and Best Practices

# What are some challenges you might face

- Your concerns?

# Challenges you might face

| REPORTED CHALLENGES | RECOMMENDED STRATEGIES |
|---|---|
| The class is too quiet. | Be patient – students' reluctance to discuss improves after 3-4 iterations<br>Do solo vote, allow enough time |
| The class is too noisy. | That's ok, this is good noise. Most students are seen to be on task. |
| Some students just may not participate. | Explain why you are doing this, use challenging & interesting questions, … let them be |
| Students may not know how to reason. | This is not quite true provided questions are designed well |
| The class will get chaotic. How do I get students back? | Use a cue such as a bell |

# Best Practices

**On Writing Questions**

- Recommended – questions requiring conceptual reasoning (verbal, logical, diagrammatic)

- Avoid – questions involving number crunching (but can use PI to precede a numerical problem, for ex … )

- Recommend – Mix it up.
  - WHY: different pedagogical goals : bringing out a misconception, predicting an outcome, recall point from last class
  - WHAT: different types of questions: survey, representations, reasoning, Y/N
  - WHEN: at a variety of points during class (beginning / middle / end)

- Avoid - questions that can be answered by memorization (unless that's your goal, then use sparingly).

# Best Practices

**On Facilitating Peer-Instruction**

- DON'T SKIP ON <u>PEER </u>DISCUSSION (if single vote, only after group talk)

- FOCUS ON REASONING NOT ON RIGHT ANSWER.
    - Withhold judgment. Do not give 'rapid rewards' (nodding in assent)
    - Discuss reasons for *right* and *wrong* answers
    - Ask multiple students to give answers.

- TIME. Recommended 2-5 minutes per question.

- FREQUENCY. Recommended – a "few" per class, 2-4. (Some instructors for ex Eric Mazur entirely use PI, no lectures).

- CREDIT. **Do not** assign heavy credit for right / wrong answers. Some instructors (with clickers) assign a "whiff" of credit for participation.

- I like to circulate, listen to student reasoning, give individual attention

# Important good practice –
# Applicable for all active learning strategies

GET STUDENT BUY-IN.

  Create it by explaining why you are doing this.

  Better still demonstrate why you are doing this.

# Plenty of resources

- Peer-instruction How-tos, workshop slides, videos, research ... Carl Wieman Science Education Institute http://www.cwsei.ubc.ca/resources/clickers.htm and host of links from within

- Instructors in many disciplines have posted peer-instruction questions for their courses – physics, CS, Statistics – use Google (search with varied nomenclature – PI, clickers, PRS)

  BUT ...

- We need to create a library of questions for our courses, report experiences in our context. Please participate!