Peer-Instruction: An interactive learning strategy to promote students' conceptual reasoning

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Teaching

- Ph.D. Program, began 2010
- 20 Ph.D. research scholars
- Faculty members
  - Core
  - Associated (from IITB Depts – EE, CSE, ChE, HSS, IDC …)
  - Visiting (from India and abroad)
- PhD Students
  - Coursework
  - Research projects
  - Outreach activities

Ph.D. theses – IIT Bombay ET

Learning pan-domain cognitive skills

- Framework for scaffolding programming to Hindi-medium learners
- Development and assessment of engineering design competencies
- Computer-based training for improvement of spatial skills
- Development the scientific ability of modeling using learning objects
- Development of students' problem posing skills

Teacher use of ET

- Teacher integration of technology in classroom
- Framework for customized visualization selection and integration

Effective design of educational technology

- Interactive Visualizations in engineering education
- Development of guidelines to design and evaluate Virtual Labs
- Collaborative approach for programming using Spoken Tutorials

Automated content generation & assessment

- Automated generation and evaluation of assessment instrument
- Automation in constructing customized textbooks from lecture transcripts

Outreach

- T10KT workshop (Feb. 2013):
  Research Methods in Educational Technology
  - 4000 engineering college instructors participated
  - 50 participants mentored to conduct action research
  - 12 participants presented paper in T4E 2013 conference

- 20+ Workshops on:
  - Integrating educational technology in engg. education
  - Effective teaching-learning strategies for engg. education

- Materials uploaded under Creative Commons at
  - http://www.et.iitb.ac.in/resources
  - http://www.it.iitb.ac.in/nmeict/eVideos/RMET_Teachers/content/content.html

What is active learning?

Approach to teaching and learning whose goal is to engage students with the content via specific activities that get <u>students</u> to talk, write, reflect and express their thinking.

- There are several instructional strategies that can come under active learning.
- Many informal strategies may have the same goal, but to be termed as active learning, they need to meet the following requirements.

<u>Requirements of active learning strategies:</u>

- 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.

D. E. Meltzer and R. K. Thornton. "Resource letter ALIP–1: active-learning instruction in physics." *Am.J.Phys* 80.6 (2012): 478-96

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?

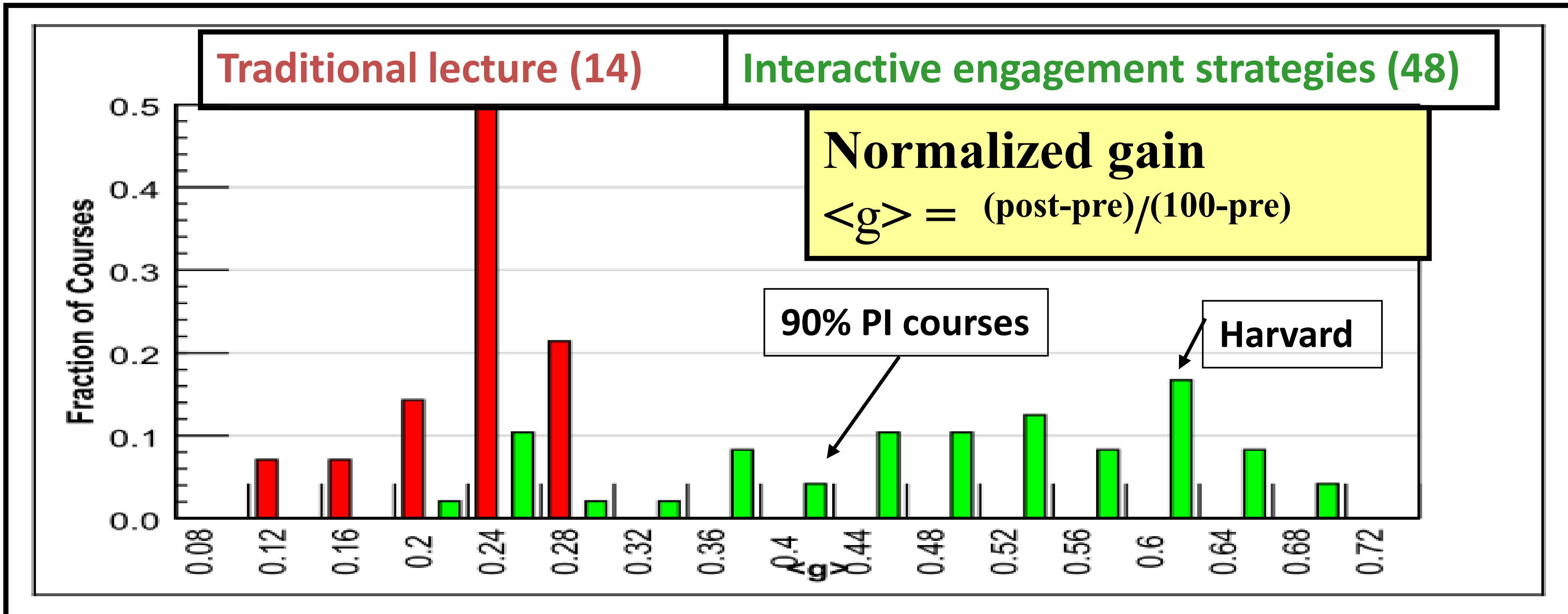
Lecture quality does not seem to matter

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



- 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?

- Peer-Instruction
- Think-Pair-Share

  This is the talk right after lunch – Prof Sridhar Iyer, IIT Bombay

- Team-Pair-Solo
- 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?

Student

Question - Vote individually

You toss an old 1-rupee coin and a new 1-rupee coin. Which is the most likely outcome:

1) Two heads
2) Two tails
3) One head and one tail
4) Each of 1, 2, 3 above is equally likely

Student

Discuss with your neighbour and vote again

You toss an old 1-rupee coin and a new 1-rupee coin. Which is most likely:

1) Two heads
2) Two tails
3) One head and one tail
4) Each of 1, 2, 3 above is equally likely

How many of you changed your answer?

Teacher

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

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

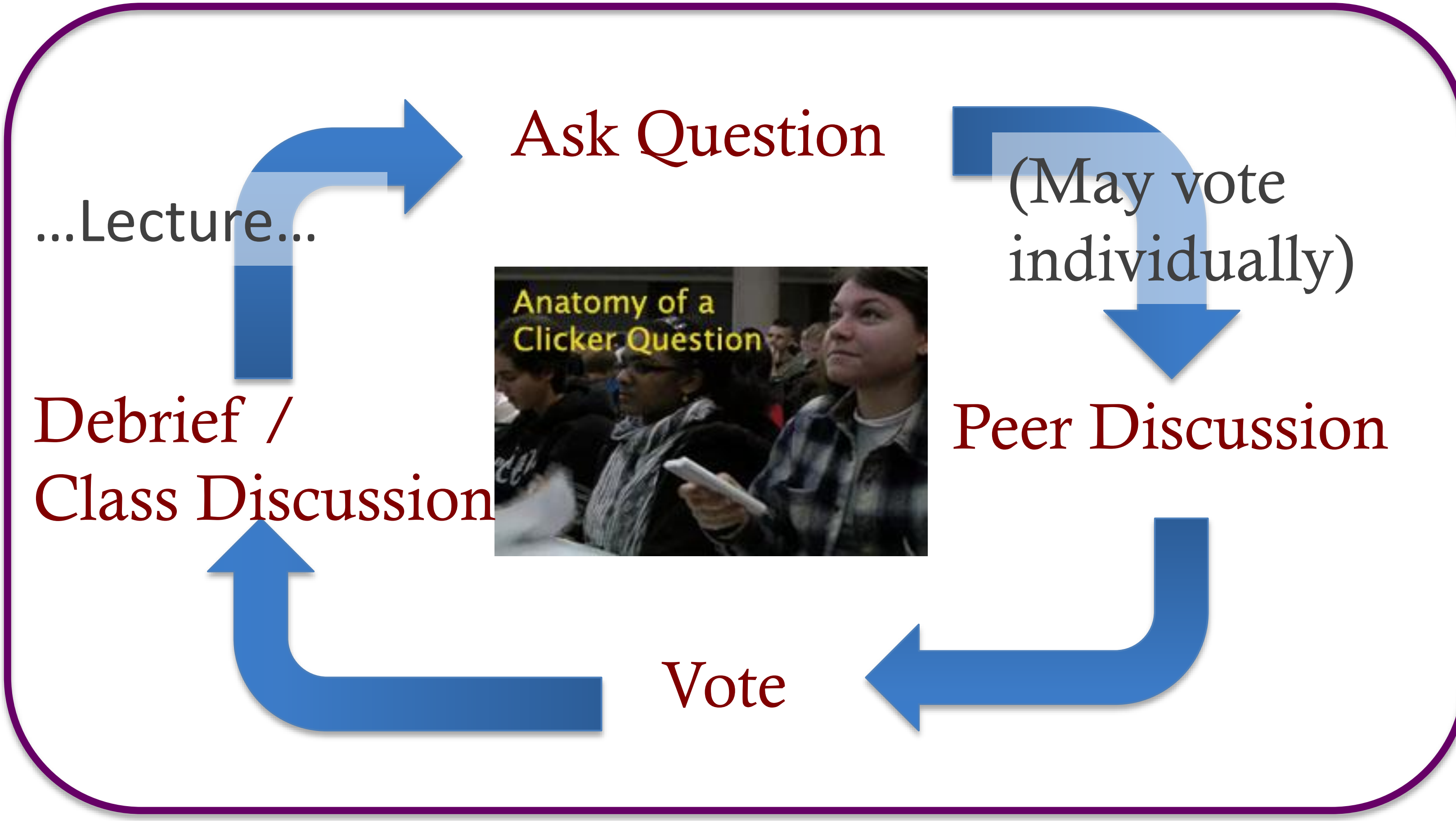


Figure attributed to: Stephanie Chasteen and the Science Education Initiative at the University of Colorado

See also: Peer Instruction, A User's Manual. Eric Mazur.

Peer-Instruction with clickers

But clickers are not Peer-Instruction

MIT TEAL classroom

From blog.peerinstruction.net

Peer-Instruction without clickers – 1

Image from Monash University Peer Instruction in the Humanities Project
http://tinyurl.com/kh7uo2o

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 .

Writing effective Peer-Instruction questions

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
- Asks students to predict results of experiment, or algorithm
- Makes students apply ideas in new context
- Relates different representations
- Has believable distractors

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

Types of Peer-Instruction questions

Survey questions

I would like to know a little about your background. Which domain do you identify with the most?

1. Physics
2. Chemistry
3. Computer Science
4. Electrical Engg
5. Mechanical Engg
6. Other engg domain
7. None of the above

Survey questions

Since this is the first class of PH103 – Electricity & Magnetism, I would like to know your background. Are you familiar with vector calculus?

1. I only know basic differentiation and integration
2. I have heard the terms gradient, divergence, curl, but I do not know how to calculate them
3. I can calculate gradient, divergence, curl of functions but I do not know how to draw the functions
4. I can calculate vector derivatives as well as comfortably draw the functions

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

Different questions for different goals, pedagogical strategies

1. Survey questions
2. Conceptual reasoning
3. Predict an outcome (e.g., of experiment, program)
4. Reason using representations
5. As a stepping stone to problem-solving
6. Recall point from previous lecture
7. Personal opinion

Conceptual reasoning

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.

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

Predict results of experiment

A light bulb lights up when it's connected to a power source through a weak acid.

What will happen if we use a 100% acid solution?

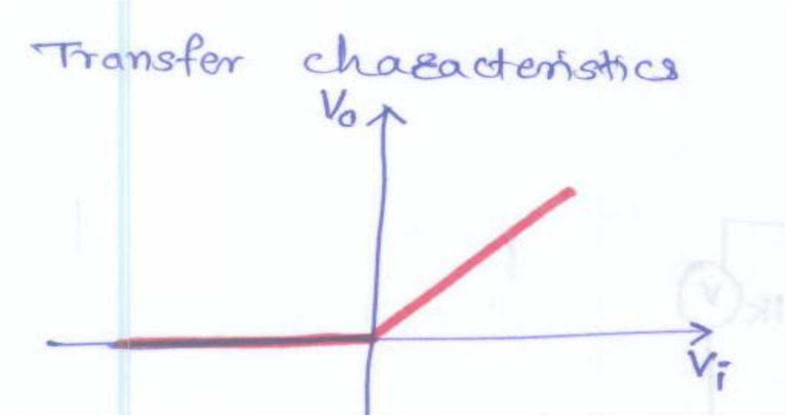
A) Brighter

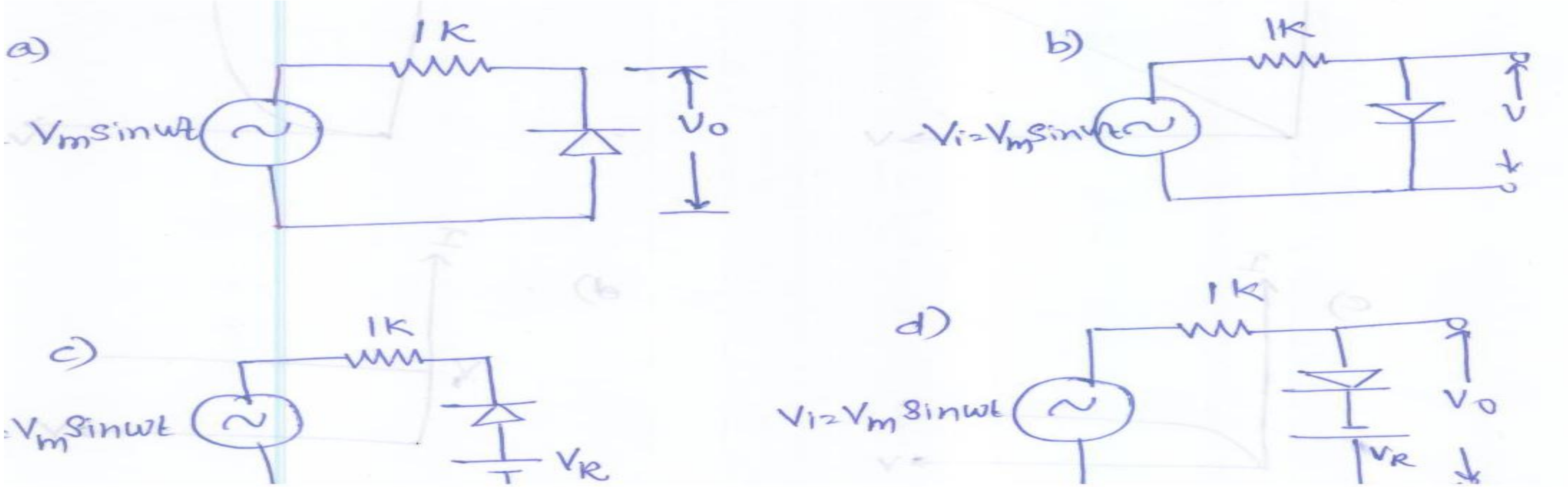
B) Dimmer

C) Same brightness

Reasoning with representations

Which circuit will satisfy given input output relationship?





Diagrammatic representations in question AND choices

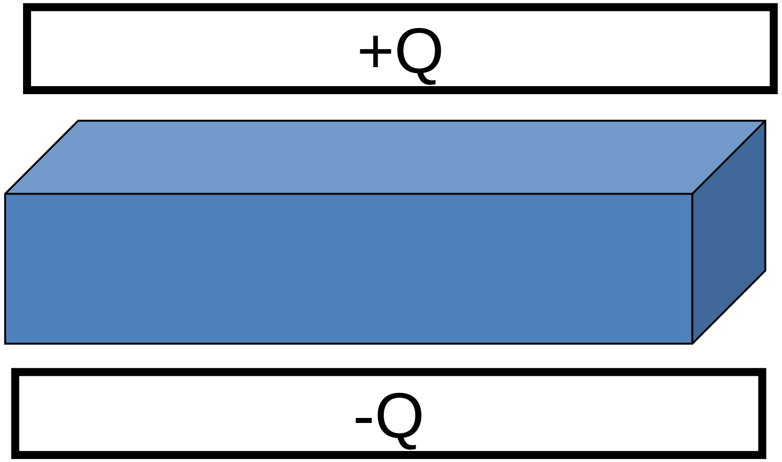
As a stepping stone to problem-solving

A very large capacitor has charge Q. A neutral dielectric is inserted into the gap . <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) $\oint \vec{D} \cdot d\vec{a} = Q_{free}$

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



Which equation would *you* use first?

A) The one with P
B) The one with Q_{free}
C) The one with Q/ε_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.

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

Question based on Concept Test from University of Colorado Upper Division Electrostatics course

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. Survey questions
2. Conceptual reasoning
3. Predict an outcome (e.g., of experiment, program)
4. Reason using representations
5. As a stepping stone to problem-solving
6. Recall point from previous lecture
7. Personal opinion

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

Peer Instruction Resources

Carl Wieman Science Education Initiative - Clicker Resources
http://www.cwsei.ubc.ca/resources/clickers.htm.

Used over 20 years in physics – several repositories, books
“Peer Instruction: A User’s Manual” by Eric Mazur

Becoming popular in intro CS courses
www.**peerinstruction**4cs.org

Lots on Google …

Challenges and Best Practices

Challenges you might face

REPORTED CHALLENGES	RECOMMENDED STRATEGIES
The class is too quiet.	Be patient – students' reluctance to discuss improves after 3-4 iterations 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 PEER 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!