Active learning strategies for improving student learning and engagement

Sahana Murthy

IDP in Educational Technology
Indian Institute of Technology Bombay

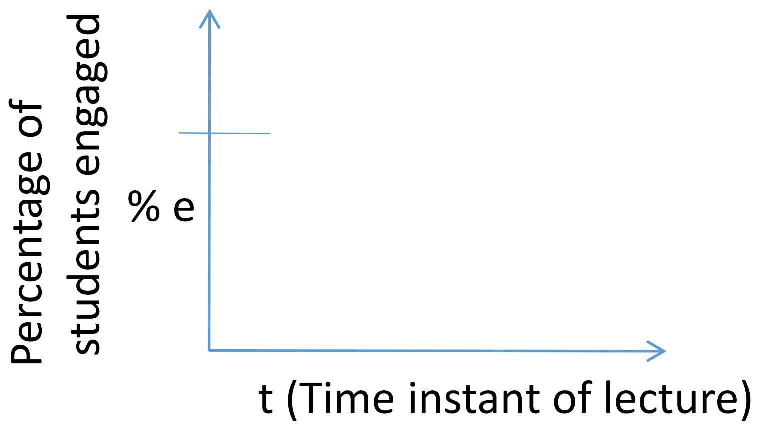
Colloquium at Dept of Electrical Engineering, IIT Bombay
November 4, 2015

How engaged are your students?

- Consider a large class. Example: EE 111/ 112 (N ~ 150?), CS 101 (N~250 per section)
- Imagine a 90-minute class in a large auditorium with fixed seats.

Think (Individually):

- Predict the percentage of students who may be showing "engaged" behaviour (with the content of the lecture), at various instants of time.
- Draw a graph of engagement versus time. [~1 min]



How engaged are your students?

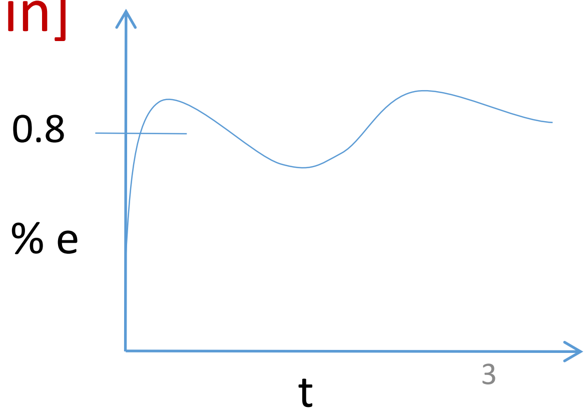
- Consider a large class. Example: EE 111/ 112 (N ~ 150?), CS 101 (N~250 per section)
- Imagine a 90-minute class in a large auditorium with fixed seats.

Think (Individually):

- Predict the percentage of students who may be showing "engaged" behaviour (with the content of the lecture), at various instants of time.
- Draw a graph of engagement versus time. [~1 min]

Pair (with your neighbour):

- Examine each other's graphs. [~1 min]
- Together, come up with two techniques that could be used to convert your graph into something that looks like the figure shown. [~3 min]



How engaged are your students?

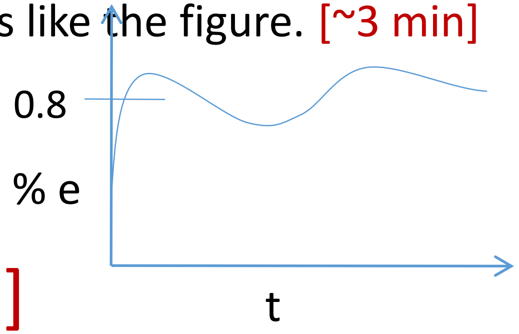
- Consider a large class. Example: EE 111/ 112 (N ~ 150?), CS 101 (N~250 per section)
- Imagine a 90-minute class in a large auditorium with fixed seats.

Think (Individually):

- Predict the percentage of students who may be showing “engaged” behaviour (with the content of the lecture), at various instants of time.
- Draw a graph of engagement versus time. [~1 min]

Pair (with your neighbour):

- Examine each other’s graphs. [~1 min]
- Together, come up with two techniques to convert your graph into something that looks like the figure. [~3 min]



Share (entire audience):

- Discuss pros and cons of some techniques. [~2 min each]
- Identify top three techniques that are likely to “succeed”. [~3 min]

How to maintain students’ engagement?

Active learning.

My lectures are plenty interactive!

- *I often pause to ask students if they understood the material*
- *I allow students to interrupt whenever they have doubts*
- *I never hesitate to answer their questions*
- *I show them demos and videos*

….

Isn’t this active learning?

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 based on theories of learning.
- Evaluated repeatedly 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): 478-496

Why bother with (strict defn of) active learning?

- *I often pause to ask students if they understood the material*
- *I allow students to interrupt whenever they have doubts*
- *I never hesitate to answer their questions*
- *I show them demos and videos*
- *I spend a lot of time preparing lectures.*
- *I deliver my lectures smoothly*

Aren't these enough?

Necessary but not sufficient.

Why not?

Why ‘interactive lectures’ may not be enough

- Students don’t pay utmost attention throughout the lecture.
- Students *think* that they understand because they can follow the lecture.
  - They are not confronted with their misconceptions immediately.
- Difficult to ensure that all students in the class participate actively.
  - Students with high motivation / achievement levels drive the pace
  - Students with low achievement levels get left behind.
- Students have a barrier to responding directly to the instructor.
  - Shy students don’t ask questions, or give answer, even if they have one.
  - Forcing all students to respond tends to be counter-productive.

Why ‘interactive lectures’ may not be enough

- Students don’t pay utmost attention throughout the lecture.
- Students *think* that they understand because they can follow the lecture.
  - They are not confronted with their misconceptions immediately.
- Difficult to ensure that all students in the class participate actively.
  - Students with high motivation / achievement levels drive the pace
  - Students with low achievement levels get left behind.
- Students have a barrier to responding directly to the instructor.
  - Shy students don’t ask questions, or give answer, even if they have one.
  - Forcing all students to respond tends to be counter-productive.

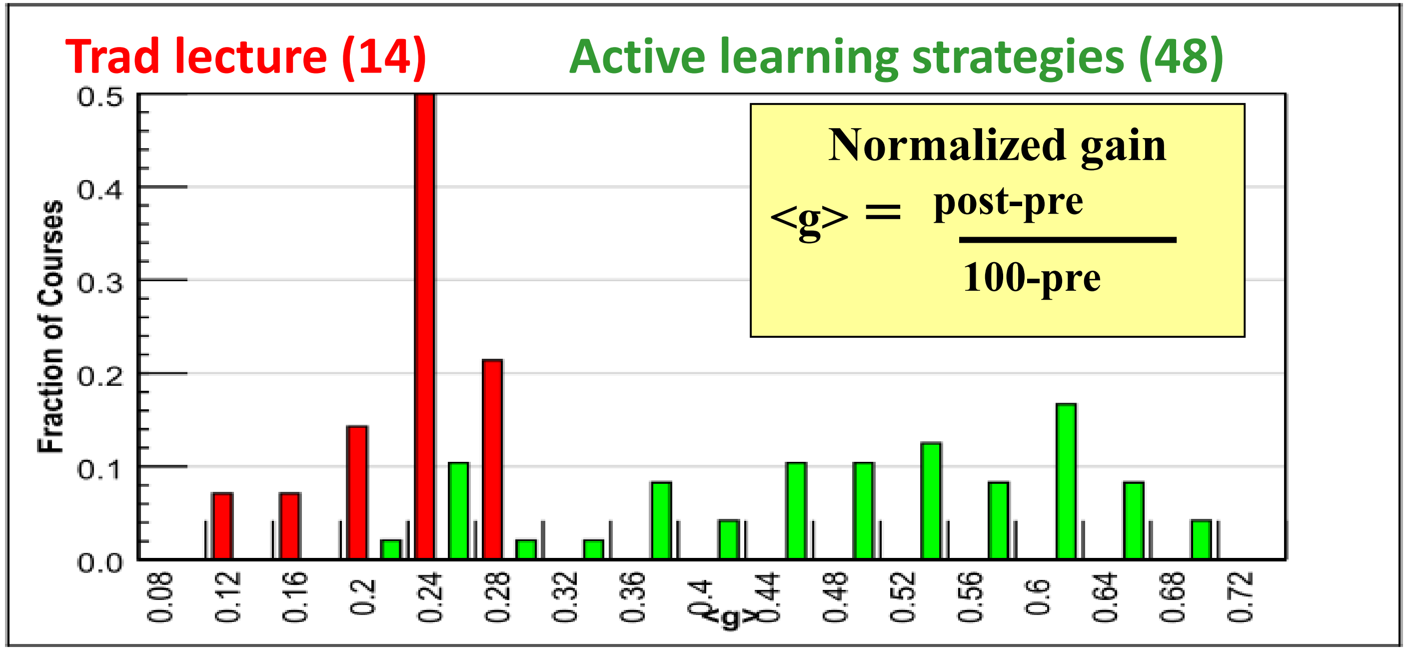
But … is there data? Evidence?

Let’s examine some empirical results.

Evidence for active learning – 1

Comparative study of 62 Physics courses (1998)

- 6542 students
- Variety of institutions: high school, college, university
- Test of conceptual reasoning – Force Concept Inventory
- Pre-post, semester long



IMPLICATION

Desirable to explicitly incorporate active learning strategies in our teaching-learning.

RESULTS:

- Maximum gain from lecture courses was 0.28
  - Many instructors had high scores on teaching evaluations
- Gain from active-learning courses had a wide range: 0.23-0.7
  - AL courses had gains 2-3 times greater than lectures

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

Evidence for active learning – 2

PNAS

Active learning increases student performance in science, engineering, and mathematics

Scott Freeman[a,1], Sarah L. Eddy[a], Miles McDonough[a], Michelle K. Smith[b], Nnadozie Okoroafor[a], Hannah Jordt[a], and Mary Pat Wenderoth[a]

[a]Department of Biology, University of Washington, Seattle, WA 98195; and [b]School of Biology and Ecology, University of Maine, Orono, ME 04469

Edited* by Bruce Alberts, University of California, San Francisco, CA, and approved April 15, 2014 (received for review October 8, 2013)

To test the hypothesis that lecturing maximizes learning and course performance, we metaanalyzed 225 studies that reported data on examination scores or failure rates when comparing student

225 studies in the published and unpublished literature. The active learning interventions varied widely in intensity and implementation, and included approaches as diverse as occasional group

Proc. Natl. Acad. Sc, 111(23), 2014

Meta-analysis of 225 studies (2014)

- Exam performance: higher by 0.47 standard deviations in active learning courses– ~ 1/2 letter grade average increase.
- Failure rates : 33.8% in traditional classes vs 21.8% in active learning courses
- Results hold across STEM disciplines, majors and non-majors, lower- and upper-division courses.
- Effect sizes greater for concept inventories than for instructor-written exams.

Features of active learning strategies

Students engage in problem-solving activities *during* lecture.

Students work collaboratively.

Students are asked to "figure things out for themselves."

Ensure (most) students participate

Students are asked to express their reasoning explicitly.

Qualitative reasoning, conceptual thinking are emphasized.

Target misconceptions

Specific student ideas are elicited and addressed.

Students receive rapid feedback on their work.

"… think they understand" ==> "… know whether or not understand"

How can an instructor do active learning?

Some strategies:

- Peer-Instruction (Eric Mazur, Harvard University, early 1990s)
- Think-Pair-Share (Frank Lyman, University of Maryland, early 1980s)
- Many others:
  - (lecture) Team-Pair-Solo, Problem-based learning, Just-in-Time-Teaching, Role-play, Jigsaw, Case-based learning, Peer-review, Productive failure …
  - (lab) Pair programming
  - (tutorial) TPS, TPS, PBL, Data-based problem solving
- Flipped classroom – with one of the above

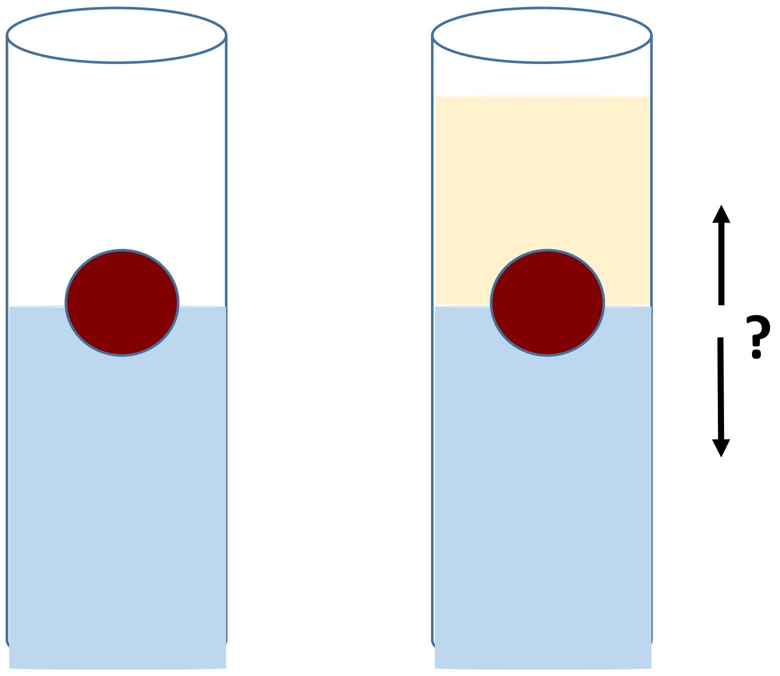
Peer Instruction

Vote individually

An object floats in water but sinks in oil. When it floats in water it is exactly halfway submerged.

If we slowly pour oil on top until the oil completely covers the object, does the object:

1) Move up
2) Stay in place
3) Move down

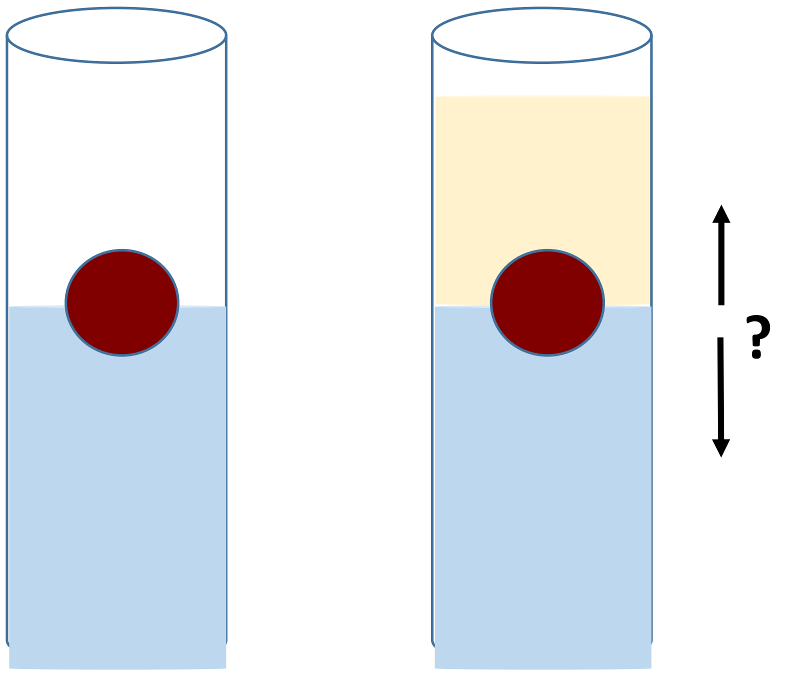


Convince your neighbor

An object floats in water but sinks in oil. When it floats in water it is exactly halfway submerged.

If we slowly pour oil on top until the oil completely covers the object, does the object:

1) Move up
2) Stay in place
3) Move down

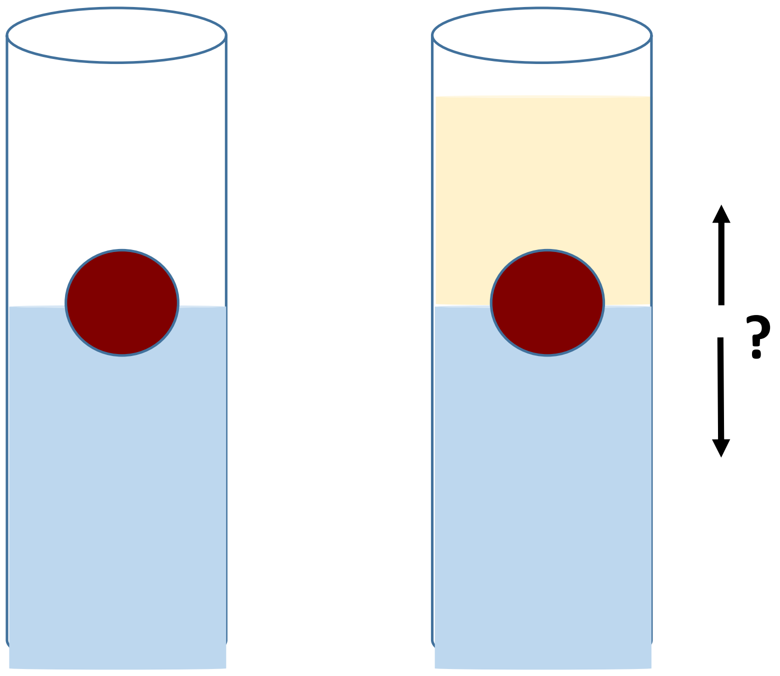


Converge … and vote again

An object floats in water but sinks in oil. When it floats in water it is exactly halfway submerged.

If we slowly pour oil on top until the oil completely covers the object, does the object:

1) Move up
2) Stay in place
3) Move down



Peer Instruction Anatomy

Ask Question

(May vote individually)

Peer Discussion

Vote

Debrief / Class Discussion

...Lecture...

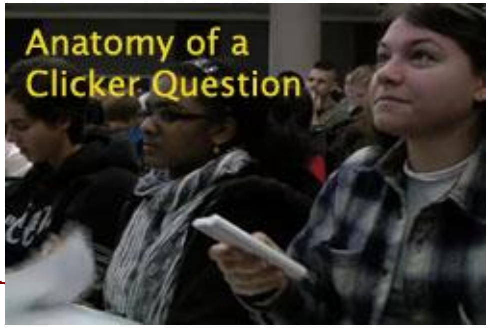
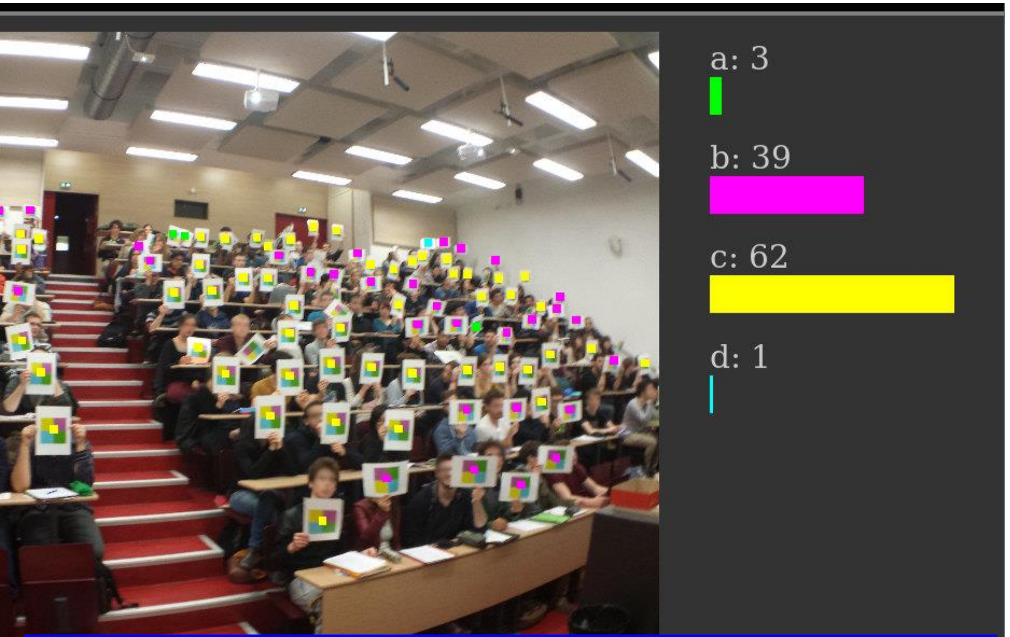
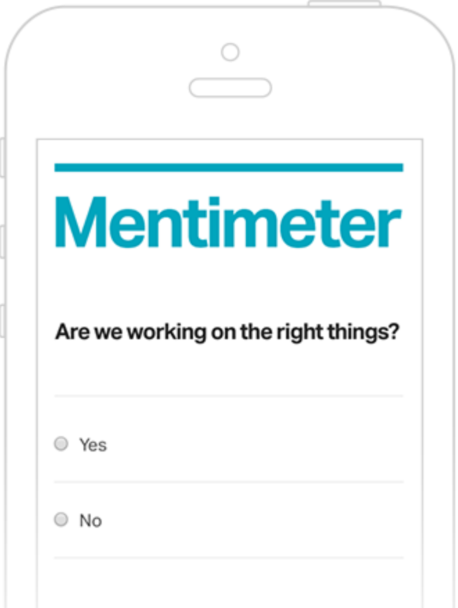


Figure attributed to: Stephanie Chasteen and the Science Education Initiative at the University of Colorado

Implementation of Peer-Instruction

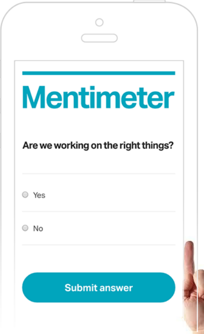


www.votar.libre-innovation.org



www.mentimeter.com

Implementation of Peer-Instruction



Example – Conceptual reasoning

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

What happens to the energy stored in the capacitor?

1. Increases
2. Decreases
3. Stays the same
4. I need more info to answer

Example - Predict the outcome (of an expt, video)

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

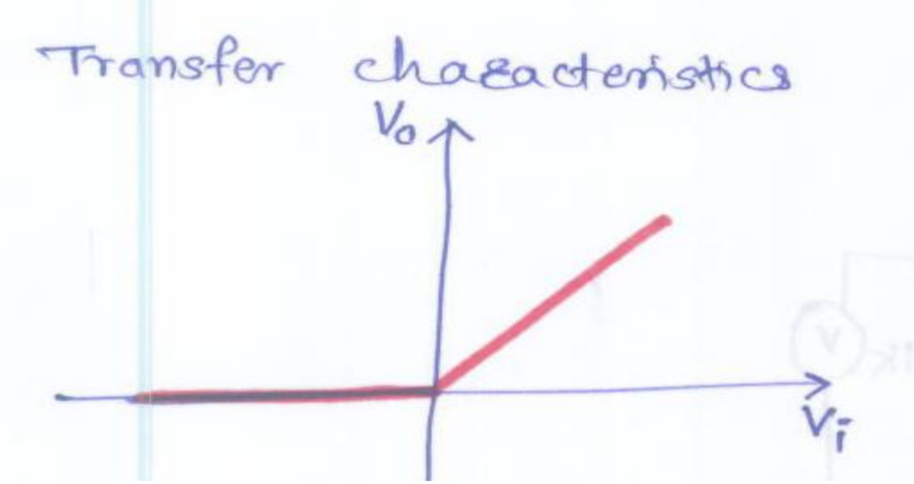
C) No

Let students vote, only then show movie for what happens.

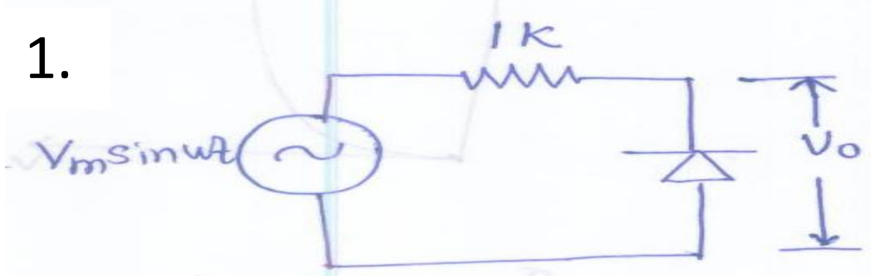
http://paer.rutgers.edu/pt3/experiment.php?topicid=13&exptid=121

Example – Reasoning with representations

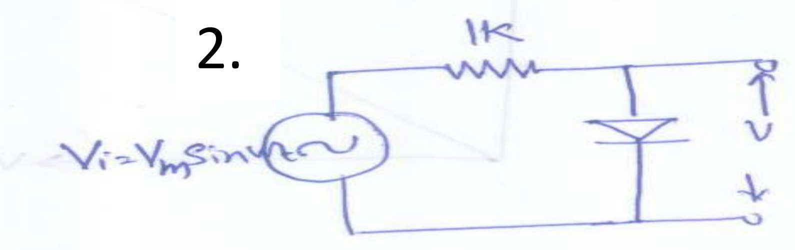
Which circuit will satisfy the given input-output relationship?



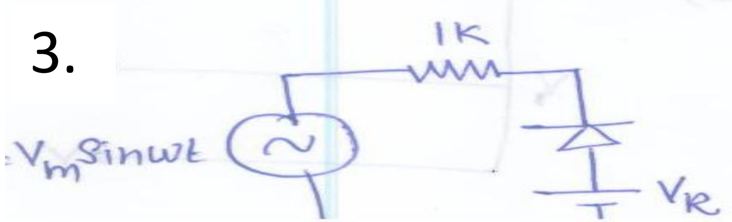
1.



2.



3.



4.

Example - survey

I think the toughest thing about using peer instruction in my class will be:

1. Writing good questions
2. Getting students to answer seriously
3. Getting students to share their reasoning with the whole class
4. It takes too long / I have a lot of content to cover

Research on Peer Instruction

- 300+ studies in various domains
- Meta-analyses
- Several measures:
  - conceptual understanding, problem solving, attendance, motivation, learning from peers, student perceptions of

Peer Instruction: Ten years of experience and results

Catherine H. Crouch and Eric Mazur[a)]
Department of Physics, Harvard University, Cambridge, Massachusetts 02138

(Received 21 April 2000; accepted 15 March 2001)

We report data from ten years of teaching with Peer Instruction (PI) in the calculus- and algebra-based introductory physics courses for nonmajors; our results indicate increased student mastery of both conceptual reasoning and quantitative problem solving upon implementing PI. We

Peer-instruction – some guidelines

WRITING. A ‘good’ PI question is:

- Is usually conceptual
  - Avoid long analytic computation
  - Avoid number crunching
- Elicits pre-existing thinking, conceptions
- Asks students to predict results / output
- Relates different representations
- Has believable distractors
- Is not ambiguous, leading or ‘trivial’

CONDUCTING PI in class:

- Do not skip the <u>peer</u> discussion part
- Focus on reasoning not only on right answer.
  - Avoid giving ‘rapid rewards’ (nodding)
  - Ask multiple students to give answers.
  - Discuss reasons for *right* & *wrong* answer
- Time - 2-5 min per question.
- Frequency - a “few” per class, 2-4.
- Credit - Do not assign heavy credit for right / wrong answers (“whiff” of credit for participation ok)

Think-Pair-Share

(recall first activity – predict engagement)

Think-Pair-Share – what & how

Students work on a series of questions posed by instructor

- Think: Teacher asks a specific question about the topic. Students "think" about what they know or have learned, and write their own individual answer to the question. [Takes 1-3 Minutes].
- Pair: Teacher asks another question, related to the previous one, that is suitable to deepen the students' understanding of the topic. Each student pairs with another. They discuss their "think" answers and reasoning with each other and proceed with the task. [Takes 5-10 Minutes].
- Share: Students share their solutions and reasoning with the entire class. Teacher moderates the discussion and highlights important points. [Takes 10-20 minutes].

Think-Pair-Share – Example – Conceptual reasoning

A student was sampling a sinusoid with frequency fm=10kHz with a sampling frequency fs=30kHz. Later she added one more sinusoid of frequency fm=20kHz to the original.

Think: Will she be able to analyze the signal properly? Why / why not?

Pair: Together with your neighbor: i) Do you agree with neighbor's answer? ii) Come up with possible rectifications the above student could make.

Share: Participate in discussion of your solution and others.

Question adapted from Prof V M Gadre and Abhinav Anand

Think-Pair-Share – when

- Multiple valid approaches to solving a problem
- Pros-cons analysis
- Multi-step / multi-process problem solving
- Design a solution to a complex problem

Think-Pair-Share – Example – Design a solution

"Design a taxi scheduling service for an airport as follows:

(i) When a driver arrives, his ID is entered in an array

(ii) When a customer arrives the earliest waiting driver is assigned

Think: What structures and variables are required?

Pair: Come up with the pseudo-code for the functions that are required.

Share: : Follow instructor led discussion of your solutions and others.

Question from CS101, Spring 2014

Think-Pair-Share – some guidelines

Three points to keep in mind:

1. Ensure that there is a clear 'deliverable' for each phase. This drives the action in that phase.

2. Ensure that the phases are logically connected. They should use the output of one phase in next.

3. Ensure that there is sufficient time for each phase.

   Too little ==> Frustration; Too much ==>Boredom.

   Move on when 80% of the class has finished

Active learning in IITB courses – Research results

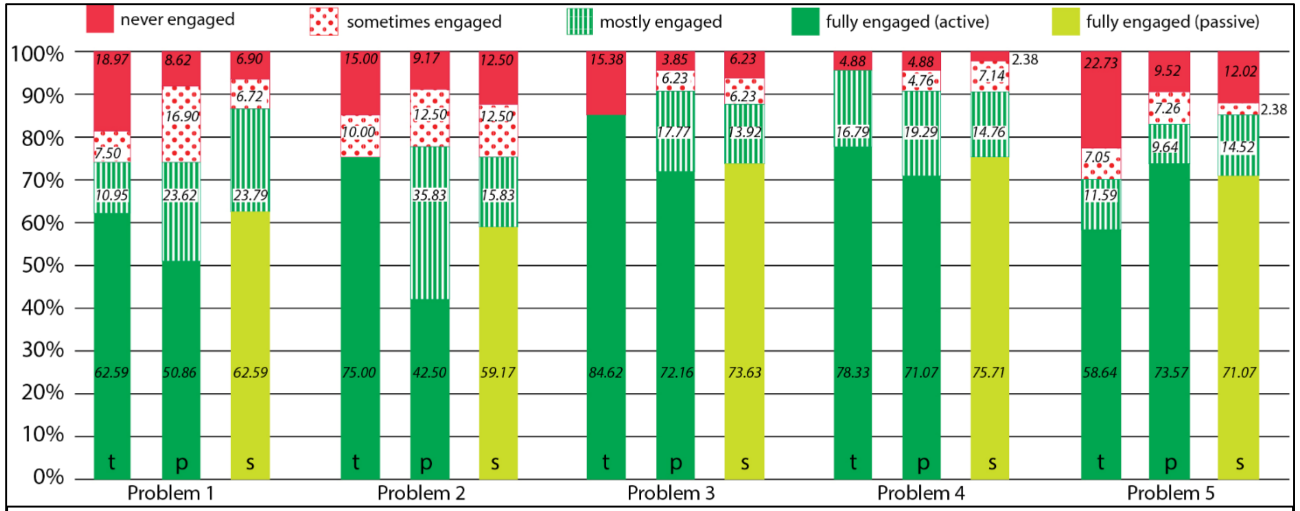
Research studies on active learning techniques

	COURSE	ACTIVE LEARNING STRATEGY	RESULT
CS101	Intro to computer prog. 2013 & -14 Prof Sridhar Iyer	Think-Pair-Share, Peer Instruction	83% students engaged (observation protocol) Higher learning than lecture (controlled expt) High student perception (survey, course eval)
EE 590	Foundations of projects 2014 Prof Bipin Rajendran	GPGP – Guided Problem-solving and Group Programming	Significant pre-post gain on problem-solving skills; High perception of learning
EE 746	Neuromorphic engg 2013 Prof Bipin Rajendran	Delayed Guidance – in-class ill-structured problem solving	Higher problem solving skills compared to traditional methods (controlled expt); Wider range of problem solving heuristics
CS 213	Data structures and algos. 2014 Prof Ganesh Ramakrishnan	Think-Pair-Share	Relative gain twice for TPS topic than traditionally taught topic Majority students wanted more TPS topics
CS 716	Intro to computer networks 2009, -10, -11, Prof Sridhar Iyer	Analogical problem solving, TPS, TPS	Students able to apply concepts from real life to solve networking problems in new unseen topic
CL 692	Digital control 2009, Prof Kannan Moudgalya	Flipped Classroom (before phrase became popular)	Students perceive VoD, Moodle useful for learning, Perceptions depend on student & instructor competency with ICT, notions of “learning”.

Measuring student engagement and learning - CS101

Observation Protocol

observation protocol	codes	students	1			2			3			n		
		observations	1	2	3	1	2	3	1	2		1	2	3
	W	Writing in notebook.			x	x						x		
	RN	Reading own or neighbours notes.											x	
	RS	Reading the screen.	x						x					x
	T	Talking to peer on topic.		x						x	x			
	L	Listening to peer on topic												
	IQ	Ask question about the problem posed												
	IP	Group discussion, more than two people.												
	IR	Respond to teacher question.												
	LN	Looking at own or neighbours laptop.												
	OS	Out of seat.												
	MO	Playing with mobile, tablet, pen etc.												
	F	Fidgeting in seat.												
	LA	Looking around room.					x	x						
	SA	Staring away.												
	HD	Head down/ sleeping.												
	TF	Talking off topic with peers												
	LD	Looking down; doing other work.												



Overall engagement across T, P, S (N=228). Av. = 83%

Experimental group Mean (N-250)	Control group Mean (N=169)	p
1.91 (1.65)	0.88 (1.3)	0.001**

Learning – problem solving test, 2 groups

Scores of TPS group higher than control group

A. Kothiyal, R. Majumdar, S. Murthy and S. Iyer, "Effect of Think-Pair-Share in a large CS1 class: 83% sustained engagement" ACM International Computing Education Research (ICER), San Diego, 2013

Why do active learning techniques work?

What do students do?

Talk, argue, listen (sometimes), reason, draw, … ==> *engaged with content*

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

Those who don’t know are willing to think, reason, answer

Those who do know are willing to participate (teach? show-off?)

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

Improves communication

Flipped Classroom

Flipping the classroom - From

Information Transmission → In class

Assimilation → Outside class

Flipping the classroom - From

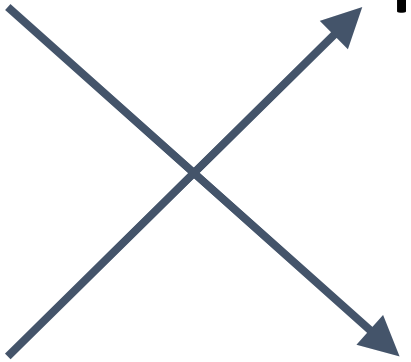
Information Transmission → In class (lecture)

Assimilation → Outside class (HW problems)

Flipping the classroom - To

Information Transmission

In class



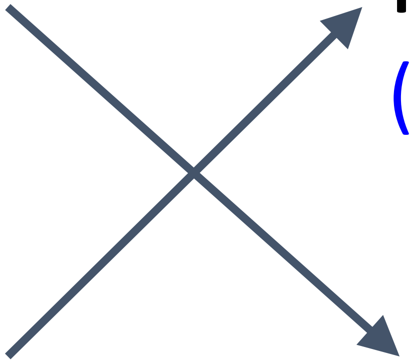
Assimilation

Outside class

Flipping the classroom - To

Information Transmission

Assimilation



In class
(active learning)

Outside class
(videos, reading)

Example – Flipped class

Course: Communication Networks; Topic: IP Addressing

Pre-class activity (home) – Watch a video that describes a basic mechanism for assigning IP addresses in a network.

In-class activities:

1. Peer Instruction questions on IP address classes.
2. Debate pros and cons of hierarchical addresses.
3. Think-Pair-Share to design solutions to reduce inefficient use of address space.

Flipped class - why

- Class time is spent in assimilation (difficult), rather than information transmission (easier)

- Class time is spent in higher cognitive levels (apply, analyze, create), rather than lower levels (recall, understand).

- Support of peers and instructor is available **while** working on higher cognitive levels.

Guidelines – out-of-class

1. You can flip only a part of your course (say 2 weeks).
2. Try to use existing resources – MOOC videos, NPTEL, Spoken-Tutorial, …
3. Keep videos short.
4. Good idea to have some short self-assessment Qs along with videos
5. Provide incentives for students to prepare for class.

Plenty of how-to's if you want to create your own technology

Guidelines – in-class

Not merely asking / getting clarifications

Not 'going over' information already present in video

Do structured active-learning strategies that require students to apply their learning (from out-of-class) and develop higher level thinking skills.

Good practices

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.

- Try to follow an active learning strategy as prescribed, first
  - Know the research, then tweak if you'd like

- Plenty of resources – use, and contribute ☺
  - www.et.iitb.ac.in --> Resources -->Teaching Strategies (PI, TPS activity constructors)
  - PI: CWSEI www.cwsei.ubc.ca/resources/clickers.htm , http://blog.peerinstruction.net/ (many how-tos)
  - Flipped Classroom: CfT Vanderbilt https://cft.vanderbilt.edu/guides-sub-pages/flipping-the-classroom/

Education research study in your class?

If interested please get in touch.

(but will require some time + effort commitment from your end)

IDP-ET PhD students trained in education research methods can participate.

Thank you.