Using Peer Instruction for Teaching ***Quantum Physics***

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- Werkcollege more efficient than *conventional* hoorcollege
- Peer Instruction is an answer and a bonus
- What is it, how and why does it work? (Quantum Physics)
- Demonstrate it on the way
- Hi-tech versus low-tech
- Student response, time investment

The paradox

Research shows

- Traditional hoorcollege is very inefficient

- Werkcollege is much more efficient than traditional hoorcollege

So, why not only use werkcollege?

Still, hoorcollege is most widely used (!?)

Still, I had the feeling hoorcollege is crucial for..........?

The answer: Peer Instruction

Eric Mazur (**& others**), Harvard University
Development 1991 - today
http://mazur-www.harvard.edu/education

Mazur's observations (teaching physics)

- Students can use complex mathematical tricks, but have insufficient insight to answer questions that seniors assess as much easier

- Students request more demonstrations of problem solving

- Students get frustrated about the study when it is only recipes, that are sometimes even not valid

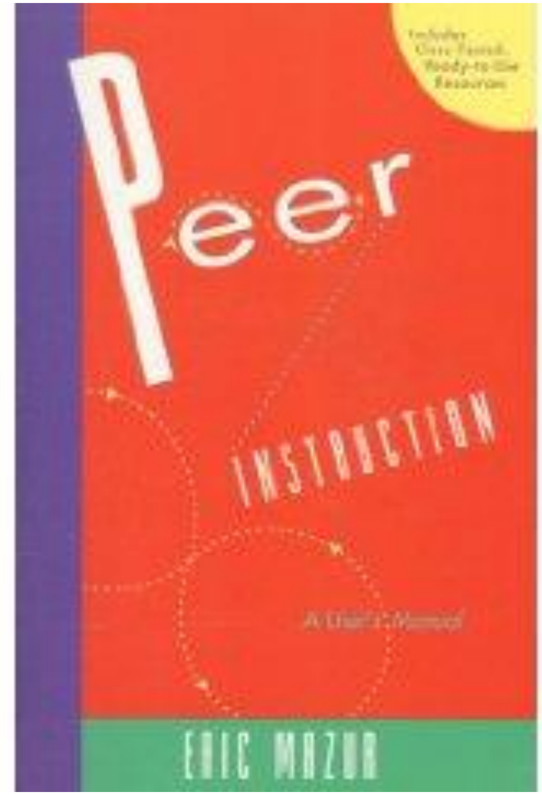
Why use it?

Just follow the scientific evidence.

Nothing is perfect:
Goal is to get the maximal educational effect for the 90% of the students between the best and the hopeless.

Good book

Peer Instruction: A User's Manual
Eric Mazur



Paperback: 253 pages
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http://mazur-www.harvard.edu/education

Peer Instruction: Ten years of experience and results

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(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 also discuss ways we have improved our implementation of PI since introducing it in 1991. Most notably, we have replaced in-class reading quizzes with pre-class written responses to the reading, introduced a research-based mechanics textbook for portions of the course, and incorporated cooperative learning into the discussion sections as well as the lectures. These improvements are intended to help students learn more from pre-class reading and to increase student engagement in the discussion sections, and are accompanied by further increases in student understanding.
[DOI: 10.1119/1.1374249]

What is the key problem with the conventional hoorcollege?

A The students are too passive.

B The teacher cannot explain it in the right way for everybody.

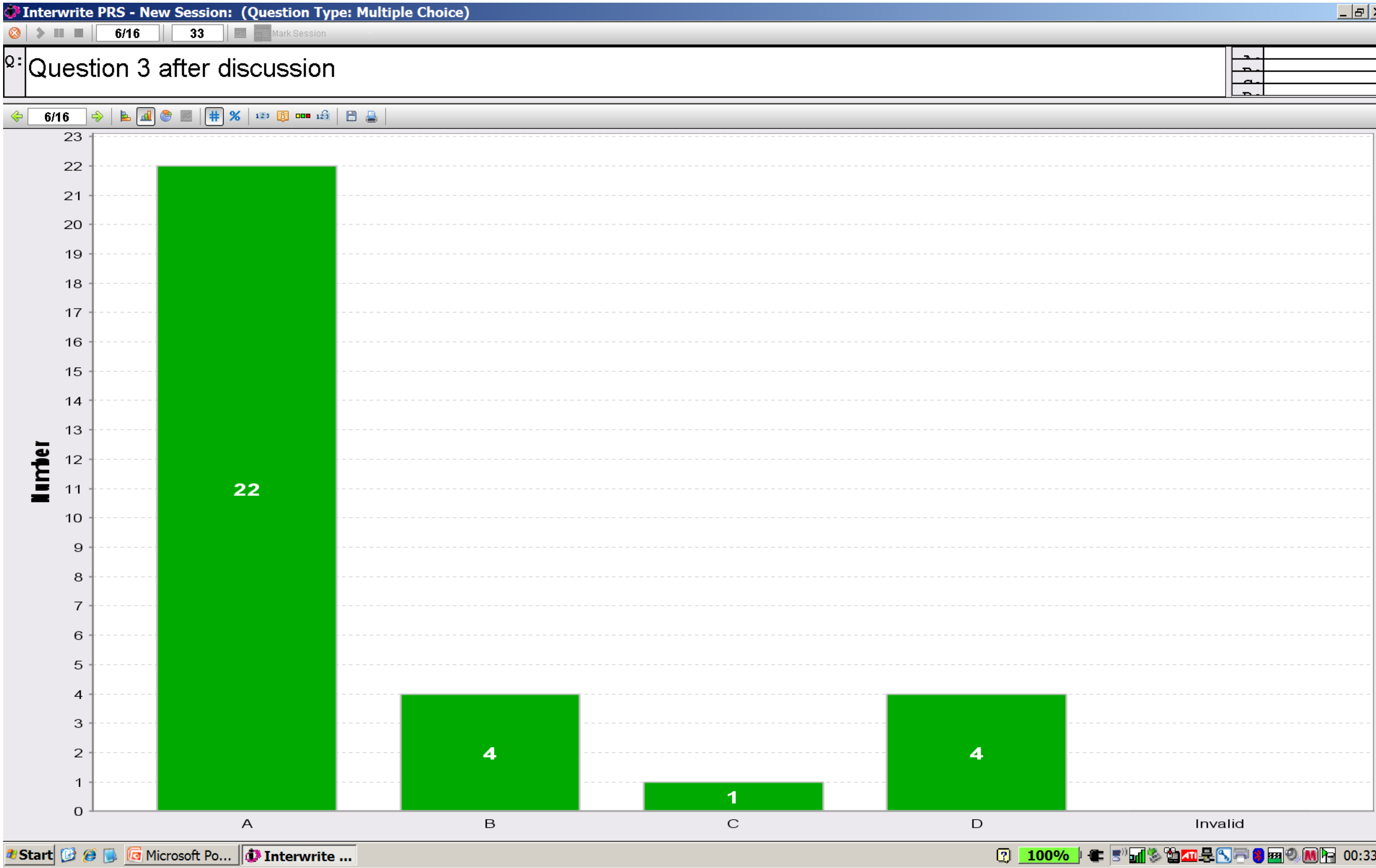
C Students learn by doing: hoorcolleges are indeed quite useless as compared to werkcolleges.

D The students are too much focussed on passing the exam.

(select what you consider to be the main reason)

Example of immediate feedback on a computer after voting with electronic answering system

(not related to question on previous slide)



The idea

Get the student brains more active during a lecture

Train in using *conceptual* reasoning

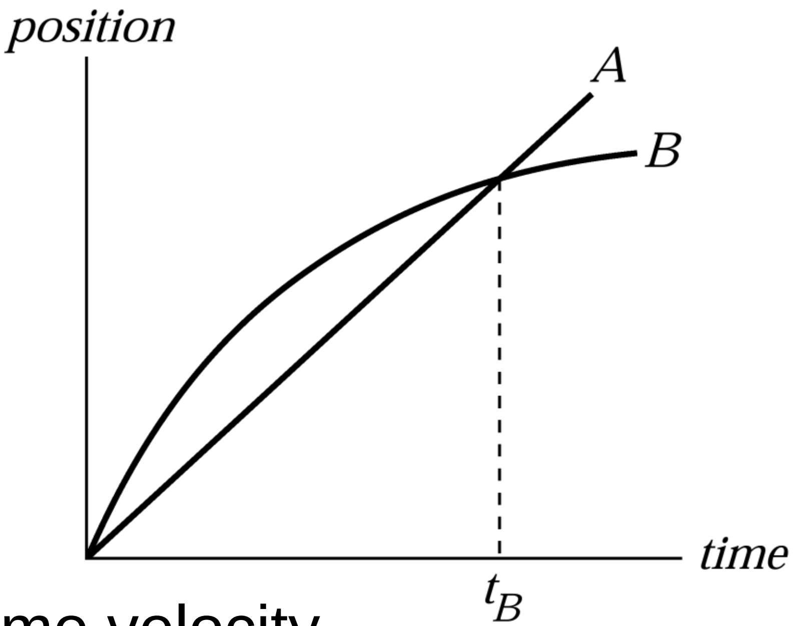
How?

Per lecture several loops of

1. Mini-lecture, single concept **5 min**
2. Multiple choice, ***CONCEPTUAL*** question **1 min**
   (insight, no calculation)
3. ***Peer-to-peer discussion (2-3 students)*** **2 min**
4. 2nd answering round on same question **1 min**
   (and show feedback = histogram of chosen answers)
5. Discuss (when useful) **2 min**

…. Say we just finished a lecture about position, velocity and acceleration

The graph shows position as a function of time for two trains running on parallel tracks. Which is true:



A At time t_B ,both trains have the same velocity.

B Both trains speed up all the time.

C Both trains have the same velocity at some time before t_B .

D Somewhere on the graph, both trains have the same acceleration.

Applied to quantum physcis

There is a difference with Pre-Med classical mechanics....

Students have little initial knowledge and intuition
about *quantum trucks* and *quantum light cars.*

First quantum course:

Many many new concepts

Lots of new formalism

But I want them to get intuition, feel for quantum physics.
What do the formulas mean?

How to assist them to learn it easy, remember it long?

Angular momentum

Let's look in the book by Griffiths…..

Typically, the potential is a function only of the distance from the origin. In that case it is natural to adopt **spherical coordinates**, (r, θ, ϕ) (see Figure 4.1). In spherical coordinates the Laplacian takes the form[2]

$$\nabla^2 = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial}{\partial r}\right) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\left(\frac{\partial^2}{\partial\phi^2}\right). \qquad [4.13]$$

In spherical coordinates, then, the time-independent Schrödinger equation reads

$$-\frac{\hbar^2}{2m}\left[\frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial\psi}{\partial r}\right) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial\psi}{\partial\theta}\right) + \frac{1}{r^2\sin^2\theta}\left(\frac{\partial^2\psi}{\partial\phi^2}\right)\right] + V\psi = E\psi. \qquad [4.14]$$

We begin by looking for solutions that are separable into products:

$$\psi(r, \theta, \phi) = R(r)Y(\theta, \phi). \qquad [4.15]$$

…etc

Angular momentum

(I do this normally on the blackboard)

The the solution appears in a very simple form, governed by a few discrete numbers.
Why could you have expected this?

A	If you measure a state, you get a discrete answer.

B	One should expect a role for quantum interference, since rotations return back on their original state.

C	You always get this type of solution in quantum physics, since it is always about quanta.

D	Calculating the eigenstates and eigenvalues uses complex mathematics, where you always have functions in the form exp(i m φ) with a periodic phase.

High-tech versus low-tech

Hands or cards versus computer (feedback, memory)

Computer and traditional blackboard

Robust use of computer

E-clickers versus daily-life wireless (phones etc.)

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How, and how fast, would you teach in a one-on-one setting?

Conclusion, final remark

- If you believe in science, use it!

- You can start with 15 minutes in a set of 16 two-hour lectures.

THANKS

Some extra slides with other notes and remarks

Student response

- Very strong participaction.

- Mid range student come to class for it.

- Some top / serious students do not like it at first, or never.

Why does it work?

Students are ACTIVE, and build conceptual structures and insight in their brains while talking and thinking.

Student receive personal custom-made lecture, specific for their background and state of confusion.

Student builds more confidence:

- it is normal to struggle.
- when I simply start and try, I get to success.

Students develop the ability to actively use CONCEPTS, now in addition to getting trained to mathematically solve problems.

More fun = better student performance!

....but more advantages

Instant feedback to a student’s own performance.

Instant feedback to the teacher about progress of students.

Tool to study and improve the teaching for the next year.

Better learning: Conceptual insight and understanding, not only learning boring recipes.

....but also

It eats up time in your lecture.

Preparing good questions takes time.

How much time does it take preparing?

It takes me a bit more time.
(no extra time if I were an ideal teacher)

You can start with 15 minutes in a set of 16 two-hour lectures.

Hint: A = higher
B = the same
C = lower
D = cannot be determined