“Should we as scientists approach teaching with the same rigour and appreciation for evidence that we exercise in our research experiments in the laboratory ?”

Conceptual understanding [1]

- All teachers aspire at their students gaining a good conceptual understanding.
- How is good conceptual understanding best achieved collectively for a class?

  By active learning.
- This can be measured using concept inventory tests.
- The method is more important than the teacher !
- It so happens, as one intuitively can guess, that this ALSO improves success rates at final exams.

[1] : Carl Wieman (Nobel Prize Winner 2001, Bose-Einstein condensates) ,
Large-scale comparison of science teaching methods sends clear message, www.pnas.org/cgi/doi/10.1073/pnas.1407304111
Improved Learning in a Large-Enrollment Physics Class , www.sciencemag.org/cgi/content/full/332/6031/862/DC1

pnas.org/content/111/23/8410

RESEARCH ARTICLE

Check for updates

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

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

This article has a Letter. Please see:

Relationship between Research Article and Letter - July 14, 2014

Article | Figures & SI | Info & Metrics | PDF

Significance

The President's Council of Advisors on Science and Technology has called for a 33% increase in the number of science, technology, engineering, and mathematics (STEM) bachelor's degrees completed per year and recommended adoption of empirically validated teaching practices as critical to achieving that goal. The studies analyzed here document that active learning leads to increases in examination performance that would raise average grades by a half a letter, and that failure rates under traditional lecturing increase by 55% over the rates observed under active learning. The analysis supports theory claiming that calls to increase the number of students receiving STEM degrees could be answered, at least in part, by abandoning traditional lecturing in favor of active learning.

We struggle with similar problems

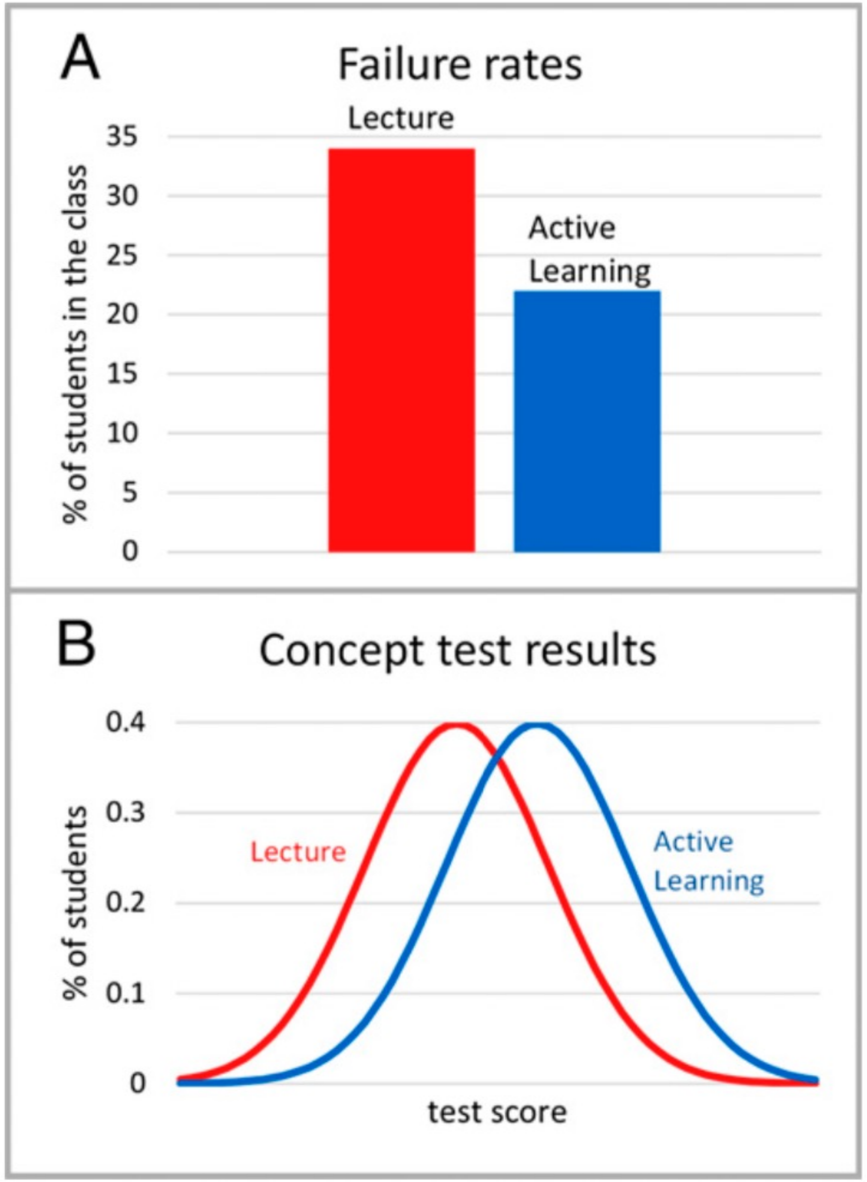


Fig. 1. Comparisons of average results for studies reported in ref. 3. (*A*) Failure rates for the active learning courses and the lecture courses. (*B*) Shift in distribution of student scores on concept inventory tests.

[1]

Wieman's conversion began in the late 1980s, when he noticed something about the graduate students coming into his atomic-physics lab — then at the University of Colorado Boulder. "They had done really well as undergraduates, but couldn't do research," he says. Over the years, they learned how to be good scientists, "but that had little to do with how well they had done in their courses".

In trying to figure out why, Wieman came across the already huge body of empirical research on learning — most of it totally unknown to science departments. Among the most striking findings, he says, was one[3] that explained his own observation. It showed that in the traditional way of teaching, students could pass the test, but did not get a basic conceptual model of the subject, he says.

By introducing active learning we also make better researchers ! It's a win for our research too

Active learning

The active learning methods are designed to

have the student working on tasks that simulate an aspect of expert reasoning and/or problem-solving

while

receiving timely and specific feedback from fellow students and the instructor that guides them on how to improve.

Examples of active learning tasks : answering questions using electronic clickers ; completing worksheet exercises ; discussing and solving problems with fellow students ; …

students who actively engage with course material will end up retaining it for much longer than they would have otherwise, and they will be better able to apply their knowledge broadly.

Active learning is not easy to implement [2]

- Make questions the students cannot answer simply by reading the course material — although they are expected to have done that before attending class. Instead, they have to apply what they have learned, which they do by clustering around tables in small teams and arguing over the options.
- requires substantially more preparation than do standard lectures — but benefits justify the time that the approach takes away from research.
- an active-learning class is more like improvisational acting, he says. “You have to go with the flow”, responding to questions and situations as they arise. Not easy.
- Active learning done badly is worse than a good lecture. Claim of using at least some active-learning methods is not enough, **teachers should develop their lesson plans in the same way as they design experiments.**

[2] M. Mitchell Walldrop, The science of teaching science, NATURE | VOL 523 | 16 JULY 2015

Active learning is not easy to implement [3]

VII. IMPORTANCE OF CAREFULLY DESIGNED EXPERIENCES

Carl Wieman has stated that "teachers spend enormously more time worrying about their lectures than they do about their homework assignments, which I think is a mistake. … To ensure that the necessary extended effort is made, and that it is productive, requires carefully designed homework assignments, grading policies, and feedback."[16] This statement applies to the use of class time as well. Teachers spend much more time worrying about what they are going to tell students than thinking about what experiences they are going to provide for students. To ensure that students learn in class requires carefully designed experiences that keep them engaged and make them think.

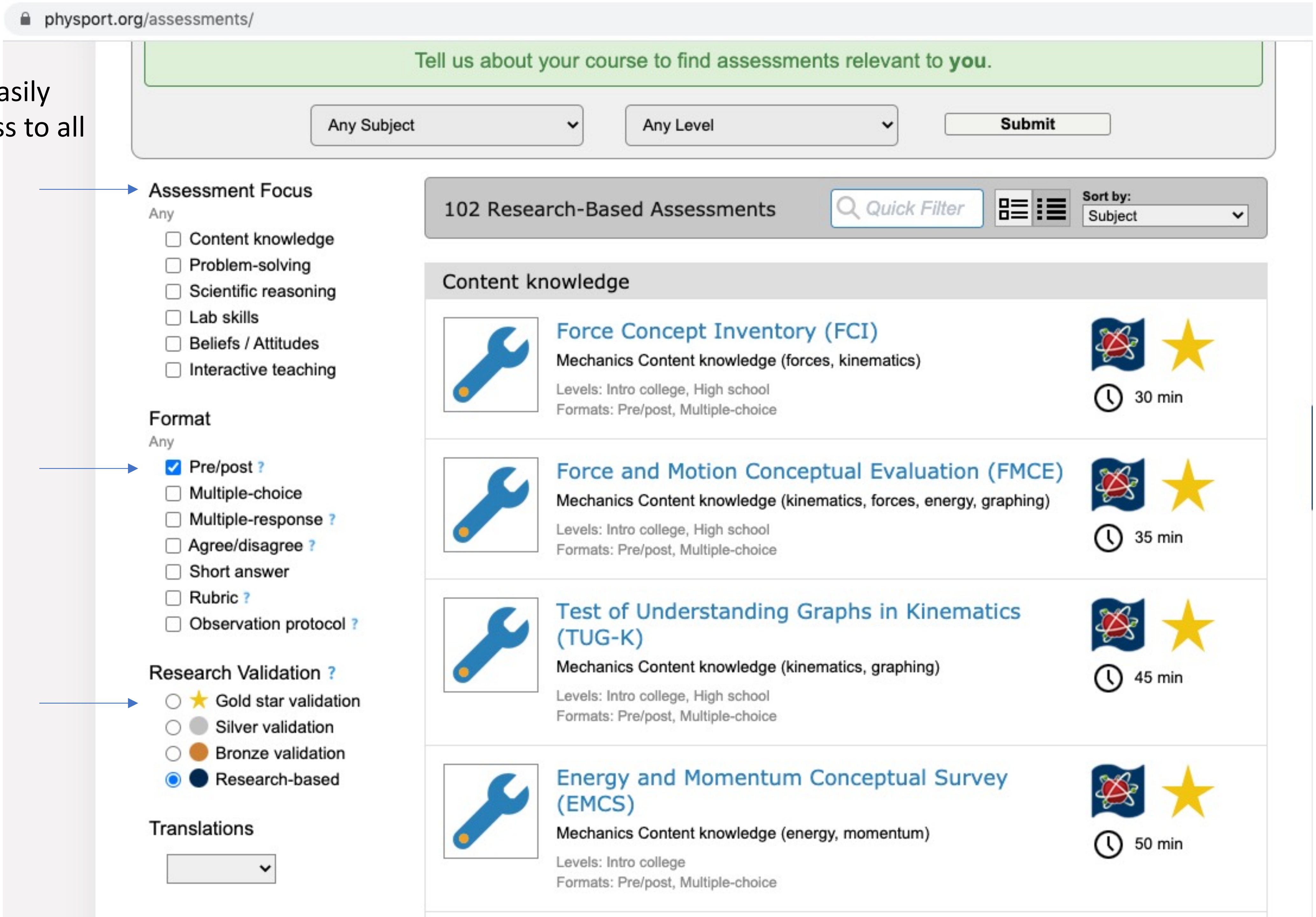
[3] : The implications of a robust curriculum in introductory mechanics , C.Hoellwarth , Am. J. Phys. 79 (5) May 2011

Concept inventory tests [4,5]

- CI tests help answering “I made a change to my teaching, did it work?” They have been rigorously designed and tested, so you know that (on average) your students’ scores reflect their understanding of physics and not a misinterpretation of the wording of the questions.
- Teachers use the *differences* in scores between pre- and post-test (e.g. raw gain, normalized gain or effect size), not the value of the scores themselves, to determine the effectiveness of their teaching. If scores were slightly inflated by guessing, looking at differences in scores cancels out this effect, and the comparisons remain valid.
- CI tests are not meant to replace other assessments such as exams, homework, clicker questions, discussions with students, etc. Conventional wisdom is that they should be used in concert with these other forms of assessment.
- CI questions can actually be much more difficult for students than typical end-of-chapter problems, or final exams, because they require **deep understanding.** There is evidence that focusing on the kind of basic conceptual understanding probed by concept inventories can lead to improvement on traditional problem-solving

[4] : https://www.physport.org/recommendations/Entry.cfm?ID=119636
[5] : https://www.physport.org/assessments/

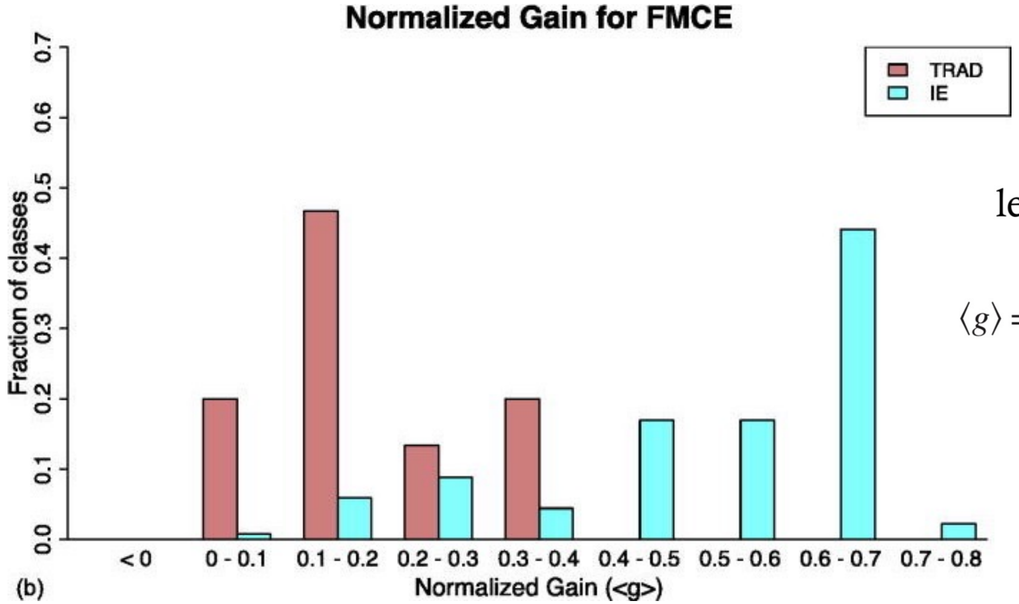
You can easily gain access to all tests



Example of one question

Force & motion

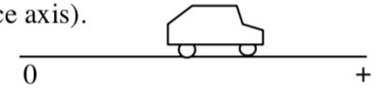
- https://www.physport.org/assessments/assessment.cfm?I=13&A=FMCE (you need a password)
- The average normalized gain is 0.52 for interactive engagement and 0.19 for traditional lecture.



learning gain

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

Questions 14-21 refer to a toy car which can move to the right or left along a horizontal line (the positive part of the distance axis).



Assume that friction is so small that it can be ignored.

A force is applied to the car. Choose the one force graph (**A** through **H**) for each statement below which could allow the described motion of the car to continue.

You may use a choice more than once or not at all. If you think that none is correct, answer choice **J**.

__14. The car moves toward the right (away from the origin) with a steady (constant) velocity.

__15. The car is at rest.

__16. The car moves toward the right and is speeding up at a steady rate (constant acceleration).

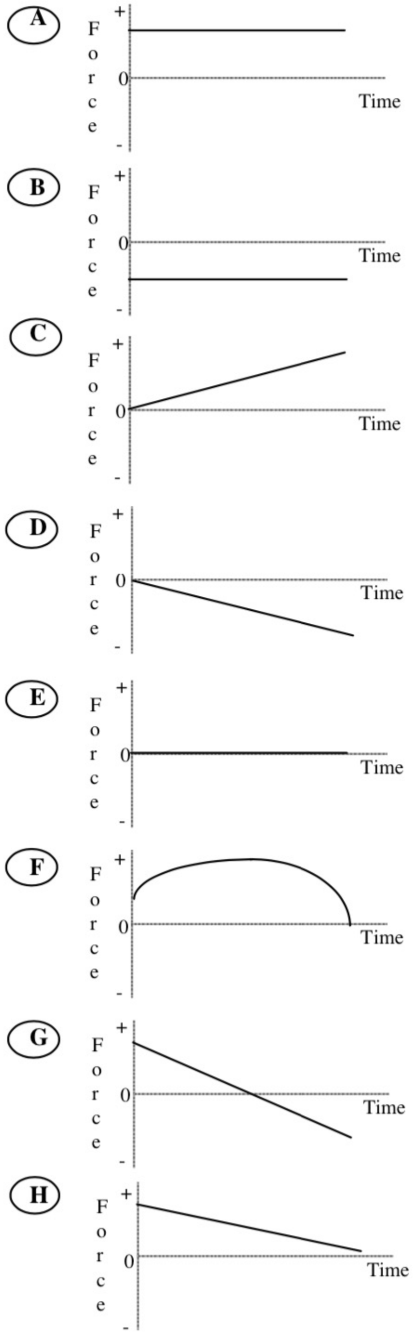
__17. The car moves toward the left (toward the origin) with a steady (constant) velocity.

__18. The car moves toward the right and is slowing down at a steady rate (constant acceleration).

__19. The car moves toward the left and is speeding up at a steady rate (constant acceleration).

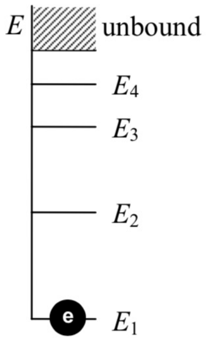
__20. The car moves toward the right, speeds up and then slows down.

__21. The car was pushed toward the right and then released. Which graph describes the force after the car is released.



J None of these graphs is correct.

3. An electron in an atom has the energy level diagram at right. The electron is in its lowest energy state, as shown in the diagram. What is the lowest energy photon that it can absorb?



A. It can absorb a photon of any arbitrarily small energy.
B. E_1
C. E_2
D. $E_2 - E_1$
E. $E_4 - E_3$

4. True or False: In the absence of external forces, electrons move along sinusoidal paths.

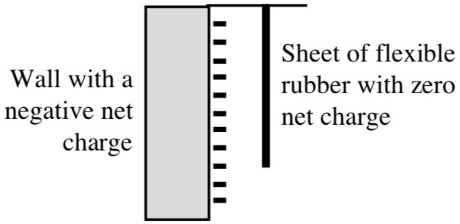
A. True
B. False

QM

Example of one question

EM

A non-conducting wall is given a negative net charge. Next, a sheet of very flexible rubber with zero net charge is suspended from the ceiling near the charged wall as shown below.



→ **Q7** The rubber sheet will:

(a) not be affected by the charges on the wall since rubber is an insulator.
(b) not be affected by the charged wall because the rubber sheet has zero net charge.
(c) bend away from the wall due to the electrical repulsion between the electrons in the rubber and the charges on the wall.
(d) bend away from the wall due to the polarization of the rubber molecules by the charged wall.
(e) bend toward the wall due to the polarization of the rubber molecules by the charged wall.
(f) none of the above.

What do we do about this, here at NBI?

- We will focus on active learning and Concept Inventory tests in the University Pedagogy course (practical part) for our Assist. Prof. from now on. Those of you who are or will become departmental supervisors can help with this.

What do we do about this, here at NBI?

- We have seen the evidence , from other physics institutes.
- Do we think this is what we should try more, all of us, in order to further improve the students performance, reduce the drop-out rate, decrease their delay, make them better at research or jobs afterwards?
- If yes, then ….

Questions we should ask

- Why do we keep lecturing?
- Which questions/activities engage students in productive thinking?
- How to give and receive feedback efficiently?
- How to diversify opportunities to a heterogenous audience?
- How to define and assess our learning goals?

- Can we help each other in this group? Share what works and what not?

Share, Discuss