

Physics education research and student development

Thirty years ago, while teaching a physics class, I noticed that most of the students answered certain test questions incorrectly—in exactly the same way—because of a common misconception. I went back to my lecture notes and beefed them up, but I got the same results from the next class. Finally, I said the magic words, “This will be on the test; be sure you understand it.” On my subsequent tests, students gave me the answer I wanted. But in the next semester, those same students had reverted to their original viewpoints. That behavior was pointed out in the Quick Study by Andrej Favia, Neil Comins, and David Batuski (PHYSICS TODAY, August 2016, page 74).

Suppose a problem involves a package being dropped from a moving aircraft, with the package being initially at rest relative to the plane. If the student draws a diagram with a straight down or triangular trajectory, the mathematics that follows is correct, but the answer is wrong. Knowing that the trajectory is parabolic is crucial to the correct solution.

Unknown to me, other faculty members in the US were noticing the same phenomenon and began making lists of misconceptions, which have been presented at meetings of the American Association of Physics Teachers and in online forums. Beginning in the 1990s, the Force Concept Inventory—a test of those misconceptions—was formed,¹ and more than 12 000 students were tested, both with and without reformed instruction—which involves active student engagement during lecture and laboratory in various tested forms.

The key to correcting common errors is eliciting the misconception in preliminary questioning, confronting it with contrary hard evidence, and then guiding students in the formation of a new understanding.

The method worked. Testing before and after its use revealed significant gains in busting misconceptions—reform teaching was *substantially* better.¹ The reform effort fostered the Physics Education Research (PER) Group at multiple physics departments in the US.

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Many converts came on board, but there were doubters. Academic freedom has allowed a mix of reform and nonreform classes to coexist in physics departments, and that coexistence has remained.

The optimal place to implement the new process is the laboratory. In traditional labs, students follow terse and often confusing cookbook instructions, have little understanding of what they are doing, and move one foot in front of the other. They then go home with reams of raw data in handwritten tables—to make graphs, draw conclusions, and answer final questions. Alone.

In the five venues where I have tried to reform the labs, only one department embraced the change. As I look back, the failure to adopt was related to the fact that faculty do not have academic freedom in laboratories; usually, the entire department uses the same materials. Diverse views about what are the crucial points cannot be accommodated easily. And so there develop factions, hard feelings, and sometimes sabotage of reform efforts.

To successfully implement laboratory reform, the entire department has to agree on several components:

- Eradicating misconceptions must be a major purpose of experiments. That includes guiding students to manipulate experiments and understand the

measurement process, learn by inquiry, replicate important equations, and apply the scientific method.

- Following one’s intuition about best teaching practices does not trump what extensive PER research has found to be most effective.
- Attending one conference does not make a faculty member a PER expert. Multiple techniques must be tested in the local academic culture.
- Sending students home with huge tables of data to be analyzed—the way I was taught—should be abandoned.

My preferred method for laboratory work is to quickly take all-encompassing data by computer acquisition, perform automatic graphing, and have a summative small-group-guided

interpretation period during the lab time. In my view, a student should meet 90% of the lab goals while still in the lab, not in take-home work.

Not attaining department agreement on the above items leads to failure. Few physics departments in the US have implemented laboratory reform and maintained it over several years. The University of Colorado, Washington University, and Dickinson College have continually provided leadership in developing techniques and resources for improving student outcomes.

Reference

1. R. Hake, *AAPT Announcer* 24(2), 55 (1994).

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Fracking and the future of fuels

The July 2016 issue of PHYSICS TODAY carries an article by Michael Marder, Tadeusz Patzek, and Scott Tinker entitled “Physics, fracking, fuel, and the future” (page 46). The article claims “to contend with the challenges of fueling modern society” and invites physicists to

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