Originally published by The New York Times Company

A Conversation With Eric Mazur, physics professor at Harvard

Using the 'Beauties of Physics' to Conquer Science Illiteracy

By CLAUDIA DREIFUS

CAMBRIDGE, Mass. — In the halls of academia, it is the rare senior professor who volunteers to teach basic science courses to undergraduates.

But Eric Mazur, the Gordon McKay Professor of Applied Physics at Harvard, is driven by a passion. He wants to end science illiteracy among the nation's college students; specifically, he strives to open them to the "great beauties of physics."

Mazur's own Harvard course, Physics 1b, is the kind of science class that even a literature student might love — playful, engaging, something like a trip to a science museum. Indeed, Dr. Mazur, 52, is as experimental in his classroom as he is in his research laboratory.

"It's important to mentally engage students in what you're teaching," he explains. "We're way too focused on facts and rote memorization and not on learning the process of doing science."

Q. Why do you willingly teach an introductory physics course?

A. First, it's part of my job description. Professors are supposed to teach. The problem is how we teach, particularly how we teach science to undergraduates.

From what I've seen, students in science classrooms throughout the country depend on the rote memorization of facts. I want to change this. The students who score high do so because they've learned how to regurgitate information on tests. On the whole, they haven't understood the basic concepts behind the facts, which means they can't apply them in the laboratory. Or in life.

On a physics exam, the student will see a diagram and they'll classify it. Then, it's simply a matter of putting the right numbers in the right slots and, sort of, turning a crank. But this is algebra. It is not physics. When you test the students later on the concept, they can't explain what they've just done.

This saddens me. In my laboratory, we've made some important discoveries. Several were accidental — serendipitous. If we'd only functioned on the standard knowledge, we wouldn't have recognized what was before us.

Q. What were these findings?

A. Here's the biggest one: Just for the fun of it, we once put a silicon wafer into some gas we had lying around the lab. We then irradiated it with ultra-short laser pulses. What came out was a wafer as black as the blackest velvet. Until that moment, the conventional wisdom was that silicon was never black. So it certainly was possible to think of this thing as a mistake and to have tossed it away. Instead, we put it under an electron microscope where we saw that we had found a new material: 98 percent silicon, 2 percent embedded gas.
And today, we have a patent for this black silicon, which has important applications in communications and sensor technology.

Q. Where were you educated?

A. In Holland. At the University of Leiden. In my first year, we started out as 72 physics majors. By the second year, we were winnowed down to 11. Only those who could maintain themselves in rote memorization were able to continue.

I was one. But throughout my college years, I often thought of quitting, becoming an artist or a photographer instead. The lectures were deadening, frustrating. Only later, in graduate school, when I got into a laboratory did I see the creative part of science. It's beautiful to design an experiment.

Q. Do you think you're better than the instructors you experienced as a student?

A. When I first started teaching here in the 1980s, I didn't ask myself such questions. I did what everyone else did: lectures. And the feedback was positive. The students did well on what I considered difficult exams.

Around 1990, I learned of the work of David Hestenes, an Arizona State physicist studying how abysmally students in his region did in science. He'd given hundreds of undergraduates a test in concept comprehension before and after they'd taken their physics classes. The tests showed that even with a term of instruction, their understanding hadn't improved very much.

I felt challenged by this. I then tested my own Harvard students similarly. We had discussed Newtonian mechanics earlier in the semester, and the students had already solved some difficult problems. Yet, when I gave them a new "concept-based" exam, about half had no clue as to what Newtonian mechanics were about.

Q. Perhaps this concept-based test was flawed?

A. No. But it was different. It measured their knowledge of physics forces in daily life. If they'd really understood Newtonian mechanics, they would have aced it. One student asked me: "How should I answer these questions? According to what you taught me? Or according to the way I usually think about these things?"

That was the moment I fell out of my ivory tower. It was then that I began to consider new ways of teaching.

Q. Doesn't good pedagogy have a performance element to it?

A. It does, though that doesn't necessarily translate into better learning. I used to get in front of my students and do all the science for them. I should have been showing them how to do it themselves. If they were studying the piano, I wouldn't have gone, "sit down, I'll play the piano for you."

Q. How do you teach undergraduate physics today?

A. I have the students read the text before the lecture. This is standard practice in the humanities, but a heresy in science. I don't know why. I think perhaps science professors like to "present" material.

In my class, we talk about the applications of physics in everyday life. The lectures are broken up with these "concept tests," where the students move into groups to work on a physics problem together. They talk, argue — they teach each other. After some discussion, they enter their answers into a computer that tabulates their collective response. From that, I can see if they've understood the topic before we move on.

We don't grade on a curve. Modern science is a cooperative endeavor.

Q. You permit students to take their textbooks into the final exam. Why?

A. Life, you know, is an open book. They can bring any book they want to class. My objective is to see if they can solve a problem.

Q. When a task force on teaching at Harvard gave its report this past January, its chairwoman, Theda Skocpol, cited you as one of Harvard's most innovative teachers. Have many of your colleagues since asked to observe your classes?

A. A few. At Harvard, teaching is left to the individual professor. There isn't a lot of cross-pollination. The upside is that this "every tub on its own bottom" credo has made it possible to experiment with my own classes and not get much interference.

Now, I've walked into science classrooms here to see what the others do. Some of it makes me burn. You know, these great, fantastic performances by energetic professors where attendance is miserable and half the students seem asleep. Toward the front of the room, you see a handful of kids furiously taking notes, while others fiddle with their laptops. "Any questions?" the professor asks. There are none.

Q. When you teach Physics 1b, do you give "fantastic performances?"

A. You know, I've come to think of professorial charisma as dangerous. I used to get fantastic evaluations because of charisma, not understanding. I'd have students give me high marks, but then say, "physics sucks." Today, by having the students work out the physics problems with each other, the learning gets done. I've moved from being "the sage on the stage" to "the guide on the side."