Notes on teaching physics to biologists

Congratulations to Dawn Meredith and Joe Redish for tackling a long-overdue overhaul of physics for biologists ("Reinventing physics for life-sciences majors," PHYSICS TODAY, July 2013, page 38). I remember the frustration of teaching the course and feeling that the students had not gotten much out of it. For example, I explained what significant figures were, and the students continued to record as many figures as their calculators could generate.

However, the approach outlined in the article seems too abstract. I would base the topics on what a biologist or medical student would do in the laboratory. For example, how does a microscope work? That lesson involves the nature of light and how a lens works. What is the difference between weight and mass, as in space travel? Or between force and pressure, as with blood pressure? What is the difference between electrical current and voltage? A medical doctor once asked me what the difference is between volts and amps.

Physics professors have to constantly remind themselves that mathematics is a foreign language to most biology students. They are language oriented and can learn the names of countless chemicals and medicines that most physicists would not even attempt to master.

I think reinventing the course will be a long, hard task, but given its vital importance to society, it has to be done.

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■ **The article by** Dawn Meredith and Joe Redish must come as a wake-up call to all those who have been teaching the algebra-based general physics taken mostly by biology and pre-med majors. I have been teaching calculus-based physics and algebra-based physics on and off for more than 30 years. No two groups of students learning the same concepts and approximately the same techniques could be more different.

In algebra-based physics, I started out teaching a watered-down version of the calculus-based physics and slowly graduated to include more of what the authors call "superficial" examples from biology and medicine. Including those examples produced no discernible response from the students.

Meredith and Redish call for a complete revision of the content to focus on the concerns and interests of biologists. They even want to eliminate a number of topics and concepts that are vital to physics at any level.

Two problems are endemic to physics intended for biology majors. The first is the method of learning. The biology majors I have taught are comfortable with memorizing and reproducing. They have never been trained to solve problems. They have a fantastic memory power, and there is no way to make use of it in a physics course. The second problem is an aggressive and obsessive quest for an A. I think the pathological anxiety about grades stands in the way of learning a difficult subject like physics.

Although pre-med students perceive that anything less than a 4.0 grade point average spells doom, mediocre students with a less-than-average GPA routinely get into medical schools.

The two problems cannot be magically eliminated by sacrificing what are considered to be difficult and "irrelevant" topics. Meredith and Redish's example (box 4 in their article) of using scaling to determine how earthworms grow is interesting, and I will definitely use it in the future. However, it suggests a trend of replacing the existing physics for life-sciences majors with quantitative methods in biology.

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■ **The topics of physics** teaching and learning should be of the utmost practical importance to the physics community. However, the article by Dawn Meredith and Joe Redish leaves me bemused.

The authors go through some philosophical and anecdotal discussion of how physics might be adapted for biologists; they make no attempt to provide a serious inquiry into the literature of physics education or to develop their own systematic, quantitative studies as to what methods could achieve what results for different categories of students. No data are presented. Although the lack of data is pretty disconcerting on its own, there is much more.

In order to take seriously the authors' premise that typical physics instruction material has been poorly adapted for specialists of other professions, and particularly for biologists, one must assume some philosophy for what physics and biology are, what they mean, and how they should be learned and taught. The authors' philosophical assertion, as in their section entitled "The two cultures," is that physicists and nonphysicists are fundamentally different in their approach.

The authors' goal of attempting to recast physics for nonphysicists seems to me to be pretty much nonsensical—or at least hopeless—to begin with. Meredith and Redish assert that "physicists stress reasoning from a few fundamental principles . . . , view the world quantitatively and pay much attention to constraints," whereas biologists "focus on real examples and emphasize structure–function relationships . . . with many interacting parts that lead to emergent phenomena." Those unsystematic accounts reflect a psychometric compulsion for knowing a right answer, all too common in the sciences. It is puzzling how science educators strain to codify their subjects when their research is a matter of fundamentally open questions.

The authors also assume that traditional physics education poses an already admirable model, which only needs to be tweaked and redressed for their "overly simplistic assumptions" as they pertain to biology. Their assumption of the role-model nature of physics education for physicists is to me, as a longtime student, offensive.

What they might consider is that physicists and biologists have to think differently because the tools and methods of their research are highly distinct. Whereas physicists have traditionally been able to rely on analytic theory for many problems, biologists have generally faced an absence of tractable analytic theories even for relatively simple biological problems. That, I think, is at the heart of Meredith and Redish's complaints about biologists learning about masses on springs or about cylinders rolling down planes.

Biologists rightly have worked in a much more qualitative context than physicists. But with the advent of modern simulation, the intractability of analytic understanding is becoming less of a problem, and biology might be expected to become much more akin to computational physics. Therefore, we might think of educating biologists more in computational than analytic physics.

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