What Should We Expect Students to Learn?

A rejoinder to Sobel’s comment on “Are most people too dumb for physics?”

We read Michael Sobel’s response with much interest and appreciate his enthusiasm and commitment to physics education. Yet, we continue to find that our goals and methods differ markedly. Foremost, because we do not agree that physics is a “different category” of hard which is accessible to a select few (i.e., “a certain sort of very bright student”), we cannot agree that ordinary, nonscience students must be taught a different kind of physics. We object to the idea of two “types” of physics—one for the layperson and one for the specialist. Physics must have relevance for everyone.

About reaching the majority of students with authentic forms of inquiry into the discipline, Sobel writes, “That’s just not the real world.” In fact the inquiry-based and student-centered methods that we employ are designed with the real world in mind and do not require heroic efforts to be effectively implemented. What they do require is a change in one’s conception of instruction. Our goal is to reach a majority of students and provide opportunities that are demonstrated to be expansive and productive for the students and for society. Fortunately, in very diverse environments, we and the broader physics education community, especially those in physics education research, have repeatedly demonstrated that we can educate the vast majority of students in such a manner.

Our last point of contention is in methodology—not just in the classroom—but in our approach to thinking about physics education. Sobel claims that there is no consensus on the role and importance of problem solving. Problem solving and questioning indeed have, for a long time, been heralded as a standard goal of all education. Science technology engineering and math (STEM) education specifically, and physics education in particular. Furthermore, there is significant evidence on how we might go about teaching problem solving (and questioning) in our physics courses (two review articles are good places to start, along with summaries of the field and PER-Central).

As we engage in these explorations of what and how to teach, it is critical that we build on what is known in physics education and apply the same rigor, theory, methods, experiment, and public critique of our educational practices that we do in the more traditional pursuits of physics.

We would like to end by echoing Michael Sobel’s acknowledgement of Karl Mamola, whose editorial vision has enabled our community to initiate a dialogue on what students should learn.

References
4. J. Dewey, Experience and Education (Kappa Delta Pi, Indianapolis, IN, 1938 and 1998).
11. Physics Education Research Central, particularly Reviews in Physics Education Research; http://www.compadre.org/per/per_reviews/.

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Teaching Special Relativity

I was not one of those many AAPT members to whom Lawrence Ruby refers, that in 2007 received Elisha Huggins’ booklet containing the first chapter of a physics textbook espousing the new educational philosophy of teaching special relativity first in elementary physics.

Ruby’s recent paper proffers computations demonstrating that “all of the principal results of special relativity theory can be obtained by simple algebra.” He develops them in three sections titled: The Relativistic Doppler Effect, \( f = f_0 (1 – v/c)^{1/2}/(1 + v/c)^{1/2} \); The Variable-Mass Formula, \( m = m_0 (1 – v^2/c^2)^{1/2} \); and The Mass-Energy Equivalence Equation, \( E = mc^2 \).

However, therein lie two long-standing topics of debate in the physics literature. For example, in Paul Tipler’s 1976 publication of Physics, he states, “[T]he use of relativistic mass often leads to mistakes .... The experimental evidence often cited as verification of the assumption that the force equals the time rate of change of relativistic momentum.” And 10 years before, in the first edition of Taylor and Wheeler’s Spacetime Physics, they aver, “[T]he quantity \( m \) is the mass as mass is understood in Newtonian physics. Thus \( m \) is a constant, the same at all speeds, all places, and all times.” Ruby obtained “a relativistic mass” because he used the classical (Newtonian) momentum \( mv \) in his momentum conservation equation (his Eq. [6]).

The second topic of debate surrounds the most famous equation in the world, \( E = mc^2 \), with which Ruby’s paper concludes (his Eq. [14]). He writes that it is “the energy equivalent of mass in the rest system.” Actually, it is the rest energy equivalent of mass in any reference system. The Russian theoretician Lev Okun has championed a campaign these past 20 years for writing \( E_0 = mc^2 \), where \( E \) is the total energy of a free body, and \( E_0 \) its rest energy. In a 1989 Physics Today article, Okun explains, “[I]t is evident that ... \( E_0 = mc^2 \) and \( E = mc^2 \), are absolutely different. According to \( [E_0 = mc^2] \), mass is constant and the photon is massless. According to \( [E = mc^2] \) \( m \) depends on energy (on velocity) and the photon has mass \( m = E/c^2 \).” (See Ruby’s Eq. [11].)

It appears eminently prudent and worthwhile for Dr. Ruby (and Dr. Huggins), and perhaps the AAPT, to review the variable-mass and mass-energy equivalence expressions for use in future introductory physics textbooks of the 21st century.

References
6. Lawrence Ruby, “a relativistic mass” because he used the classical (Newtonian) momentum \( mv \) in his momentum conservation equation (his Eq. [6]).

The incorrect photo was in fact Antonia Maury, who received the Annie Jump Cannon Award in Astronomy in 1943. Her bio appears below:

Antonia Maury (1866-1952)
Birthplace: Cold Spring, New York, USA

The niece of Henry Draper was instrumental in classifying the stellar spectra as part of the Henry Draper Catalogue, which was first published in 1897. However, Antonia Maury did not want to limit herself to simply sorting the spectra in the same old way. Her refinement of classifying spectral lines by width and intensity was later recognized by Ejnar Hertzsprung as a distinction between dwarf and giant stars. Maury was the co-discoverer of the first two spectroscopic binaries, Mizar (in Ursa Major) and Beta Aurigae, and was the first to calculate their orbits.

Editor’s Note: Correction to the International Year of Astronomy trading cards (series 1) included with the September issue.

The photo that appears on Annie Jump Cannon’s card is incorrect. A photo of Cannon appears below:

Credit: Harvard College Observatory, courtesy AIP Emilio Segre Visual Archives