The special joy of teaching first year physics

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Citation: American Journal of Physics **75**, 581 (2007); doi: 10.1119/1.2716017
View online: https://doi.org/10.1119/1.2716017
View Table of Contents: https://aapt.scitation.org/toc/ajp/75/7
Published by the American Association of Physics Teachers

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During the forty years in which I have been privileged to teach at the University of British Columbia, I have found that physics at all levels is an excellent vehicle for nurturing the inquiring mind. However, in first year physics, almost everything comes together in a very special way for achieving the goals of teaching.

The general goals of any undergraduate physics course are to impart knowledge of the physics content; to enhance the students' sense of wonder, which is such an important human attribute, especially for the pursuit of science; to develop the students' analytical skills, which are essential not only for understanding physics but for almost any other field of human inquiry; to describe how science works and how effective mathematics is for this purpose; to contribute to life-changing experiences, which should be part of a university education; and to make the course a challenge to the intellect and an enjoyable learning experience.

A number of circumstances make the first year so special for attaining these goals. The students enter the university with great expectations, they are not jaded and their sense of wonder is largely intact, they respond to good teaching, and their learning ability appears to be at a maximum. The usual first year fare—which includes the edifices of Newtonian mechanics and electromagnetism along with the accompanying calculus—allows them to quickly reach great heights in science. All physics departments should capitalize on these first year circumstances.

The achievement of these general goals is much easier if the teacher establishes a rapport with the class, a rapport that I like to call "resonance." All teachers must learn for themselves how they can use their personality, their gestures, and their voice to achieve resonance. (Most physics teachers, unlike actors, never learn how to fill a room with the sound of their voice—even in very large halls I have never used a microphone.) The teacher must possess an innate fondness for students and be able to convey the excitement of the subject to the class. In a class with diverse student backgrounds and abilities the "resonance" must be tuned to the center of the class, and it needs to extend as far as possible to the extremes. Learning in the course is driven by the dynamics of the lectures, even though most of the learning is accomplished outside of the lecture hall, in tutorials, weekly assignments, laboratories, meetings between the teacher and individual students, and in the guided study of a good textbook by the students.[1]

Because the interaction between the students and the teacher is so important, there are as many different valid routes to good teaching as there are different individual personalities among teachers. I have always been skeptical of general methods, tools, and jargon emerging from the inexact science, research into teaching, even though it has produced some interesting results. I have never felt the need of special instruments to perceive when a sudden wall of incomprehension confronts the class, and the students need to be directly engaged in order to achieve clarity and understanding of difficult concepts. Easy direct engagement is one of the byproducts of "resonance."

To facilitate the resonant interaction with the students and to enliven the discussions in the lectures, I learn the names of many of the students at the start of the course, even in a large class, and use their names at every opportunity. Memorizing student names is time consuming, but the rewards of good teaching are commensurate with the time invested.

In first year physics there are endless opportunities to excite wonder and to make the students' eyes light up. One example that illustrates what works for me is Olber's Paradox, *Why is the night sky not infinitely bright?*, for which the proper formulation of the question leads to an analogy with the logic of Gauss' theorem in electromagnetism and the shell theorem for gravity inside the Earth. Beyond its helpfulness as an analogy, the paradox remains deeply embedded in the students' minds because it teaches them how astonishingly simple observations can raise profound questions. Another example is the extension of wave velocity in a string to the high wave velocity of tsunami waves. (The velocity of ocean waves is proportional to the square root of the height of the column of water displaced, which contrasts tsunami waves to shallow, and therefore low-speed, wind-driven ocean waves.) This application immediately relates to the familiar and compelling pictures of tsunami waves traversing the Indian Ocean and piling up on its shores. A general catalyst for wonder in the lectures is the relation of the core material being taught to ideas at the frontiers of physics. Because of my personal research interests, I find examples in cosmology and particle physics especially effective for me. The students like to be embedded in a living science.

The greatest high for my students comes from understanding the coherence of a physics edifice, such as Newtonian mechanics. How the combination of $F=ma$ and Newton's inverse square law of gravity, together with calculus, yields not only all of the conservation laws, but also leads immediately to all of the results of the "Clockwork Universe" such as the Kepler orbits and the Rutherford scattering law.[2] This cohesive edifice also serves to give the students an appreciation of how science was created by Newton and his immediate antecedents. To attain this appreciation and the intellectual high involved is an appropriate challenge, both for the teacher and the students.

The assessment of how well the goals are met is important, but is not straightforward. Systematic student appraisals of the course and the teacher are valuable, but high ratings should never be achieved, as often happens, by easy examinations or otherwise reducing the challenge. I learn much from students about how the course works for them when I meet them individually in tutorials or in my office. Even more is learned from encounters with students in later years after mature reflection about their learning experience. Over four decades, I have taught more than five thousand first-year students. I constantly meet former students in many professions who took my course many years ago. It is a special joy to hear what impact my physics course has made in their lives.

[1] I find that Robert Resnick, David Halliday, and Kenneth S. Krane, *Physics* (Wiley, New York, 2001), extended 5th ed., works best for me because its essential derivations are complete, and it rarely insults the reader with impressionistic approaches.

[2] My approach to these results for my first year lectures is given in Erich Vogt, "Elementary derivation of Kepler's laws," Am. J. Phys. **64**, 392–396 (1996).

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