Philosophy of Teaching
A Path to Student Achievement: Overcoming Learning Struggles

By Jan Kmetko

How do we, the educators, know that our students learn well what we teach, especially when we teach an analytically demanding subject like physics? Even with today's intensive research in physics education, identifying effective pedagogy is difficult because we have not yet identified reliable indicators of quality teaching. If we were able to identify and quantify the desired outcome (a measure of student learning) in a scientific manner, we would simply maximize our efforts (a measure of our teaching) with respect to those outcomes. Instead, we often outline our approach to instruction through statements of personal beliefs and philosophies, treating teaching as an art. And perhaps rightly so – there may not exist a universal, right way of teaching because, for one, students take physics for many different reasons, and two, their learning needs are continually evolving with the current political, social, and economic conditions. In response, educators adjust their teaching strategies to suit the ever-changing educational needs. The pedagogy itself is evolving. Here, I shall outline what I think are the most common learning struggles of students in the context of undergraduate physics curriculum today, and how I help them overcome these struggles.

Students take physics for several reasons: they take introductory courses to fulfill a requirement (e.g. pre-meds); they learn physics as a prerequisite to understanding technical applications (e.g. engineers); and they take physics for the love of basic science (e.g. prep for grad school). Although students share similar learning struggles in each of these categories, I shall consider each category separately.

One of the problems in introductory courses is the large gap between what is presented and what students actually learn. Students often memorize the material and formulae, and mechanically apply the material to problem solving, without ever *learning* basic concepts. Researchers in physics education ascribe this problem mainly to the inability of educators to *interact* with students in the classroom; many professors simply disseminate information in chunks of one-hour monologues. Even professors who use a variety of didactic tools, e.g. videos, demonstrations, computer simulations, etc., are faced with students who, at the expense of learning, perceive lively lectures as passive entertainment. Astute educators agree that most students can only learn physics effectively by exerting immense mental efforts. This objective is primarily achieved by out-of-class assignments (e.g. homework, projects, labs, discussion sections, etc.), but there have recently been attempts at some universities to engage students *actively* in the classroom as well. The idea is quite straightforward (although an effective implementation can be a challenge, especially in large classes): the professor continually asks questions during the lecture, and allows students to respond, either by means of flash cards or other signaling devices. During my teaching assistantship at Northwestern University, I have always interacted with students, asking them questions, rephrasing problems, and checking whether the concepts have been understood. In the subsequent year, I have been assigned to help teaching physics in the Integrated Science Program, a highly selective curriculum of natural sciences and mathematics at Northwestern presented predominantly in small classes at an accelerated pace.

Students who take physics beyond introductory courses, but do not become majors, are engineers who need to learn physical theory behind applications in their fields. To engage these students, it is especially important to allow them to apply constructive models to predict and explain real-world phenomena and not just drill them in the mathematical machinery of physical concepts. As an example, consider a statement a professor once made. He said to his quantum mechanics class that it is not important to understand quantum mechanics – that nobody really understands quantum mechanics. He told them it is only important they should accept the postulates, learn the operator algebra, and do the problems. So the students went on finding quantum states of one-dimensional wells, calculating transmission resonances, and solving the harmonic oscillator, as they should, but they were doing it without any *understanding* of the concepts or the relevance of these exercises to the real world. Quantum mechanics, the most successful physical theory of all time, has been borne out of the need to explain physical observation and should not be reduced to a type of mathematical formalism. I have experienced and heard of many examples in almost all areas of physics where professors fail to encourage students to interpret physics formalism and apply it in the context of observation, applied physics, or chemistry. I always emphasize the physical concepts, say, by finding mathematically simplified versions of the problem so that the physical aspects (and possible applications) can shine through. To service the need of other science departments, it is also important to offer a variety of applied courses (or even workshops). I envision contributing in this area with courses in biological physics (applying principles of statistical mechanics, continuum mechanics, nonlinear and stochastic dynamics to biological problems) and x-ray physics (teaching fundamentals of various x-ray techniques, and methods of small and macromolecular structure determination).

In the final category, there are the students whom we convince to stick around and get a degree in physics. By convincing them, I do not mean 'talking' them into it; I mean *involving* them in our research – allowing them to be physicists along our sides, showing them it is worthwhile. I have had a chance to involve several undergraduate students in the research program at Cornell. New students who join research projects are still uncertain of the scientific method. So first, I help them make a distinction between merely collecting data and formulating a meaningful hypothesis. And second, I help them establish motivation: the ability to commit to a valued goal, the ability to sustain that commitment over time – even in the face of obstacles – and the ability to enjoy the effort of engagement. Evaluating their performance, I tend not to focus on the short-term outcomes that might make students look good, but on effort and strategies that lead to learning and long-term achievement. For me, the ultimate reward in teaching comes when students become proficient in critical thought – when they begin to question results from their research efforts without my guidance, when they begin to assess and scrutinize their measurements against the tests of the scientific method. And when that time comes, another scientist is born, and I am satisfied; I have done my teaching job and there is something I must have done well.