Teaching Philosophy

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My primary goal is always for my students to be scientists, rather simply learning about science. To that end, and with the understanding about the crucial nature of active learning over passive lecture, my first choice when students encounter new concepts is for them to be hands-on, modeling the natural world through experiment. Even with gravitation or other topics ill-suited to classroom experimentation, there are times when exploration through simulation can make this approach feasible. A small amount of focused direct instruction is helpful at times, as well, particularly in communicating accepted notation, terms, or conventions, and is effective *after* students have developed mental models of the concepts, but simply lack common terms for them or are missing small details.

When applying known concepts, in place of written practice (though group problem-solving on whiteboards is a staple of my courses) I often use lab practica, where their predictions' accuracy is determined by their success, rather than by my or a book's authority. This reinforces that what we are doing is modeling the real world. To further cultivate that understanding and to sharpen their eyes for physics in the world around them, I will also use videos or images as prompts, without specifying questions for them to answer; finding situations in which concepts apply is at least as difficult as applying them, and students need regular practice to develop those skills and to encourage their creativity as scientists. It is vital to build student comfort with concepts, but also with the idea that they will not necessarily know the answer before an experiment starts, what to do next, or even what the most interesting question is at the moment. Their willingness to jump into the experiment, confident that they can figure things out after missteps, is the single most important thing that they learn from me.

In my courses, new physical models generally arise when we “break” previous ones. Early on, students build a constant-velocity particle model, which was violated by a particular moment in the video analysis of a ping pong ball rolling into and bouncing off of a wall; seeing that the previous model was not an adequate description, the need for a new model (constant-acceleration particle model) was created. Similarly, collisions between air track gliders necessitated development of what they would learn to call momentum. *All* previous knowledge in my courses is always “in play,” because it is in the connections between concepts that students build the most robust and transferable understanding.

The group work inherent in the large amount of lab work/discussion that occurs in the course (approximately 50% of instruction time, with another 35% of group problem solving) allows groups to move at different rates. In each investigation or problem set, there will be a variety of tasks to accomplish, and the last few will be more challenging or in-depth. Faster groups will be able to tackle these, such as the challenge to use their springs to determine the masses of the carts, while groups that need more time can be afforded that. Each group does not necessarily need to complete all of the tasks; rather, there is an "end point" for each activity that I have in mind as sufficient, while always giving opportunity to do more, either in class or outside of class.

The biggest supporting factor for students in my courses, however, is the standards-based grading (SBG) system. Throughout the term, students may, having done work to correct mistakes and to practice further, request individual reassessments on any topics that they have had trouble with. These will be new questions testing the same principles. The ability to control their learning and the incentive to improve their understanding that they get by having this opportunity afforded to them means that many of the traditionally lower-achieving students in my classes end the year with much higher understanding than they did before implementation of SBG. Students having trouble the first time through a topic know that there is still an immediate and tangible reason to keep working on it, building a stronger base for later topics in the process. This also helps my higher-achieving students by explicitly disincentivizing cramming – any subsequent lower scores on a learning objective would replace the earlier higher score, discrediting that dubious strategy. As a whole, SBG has allowed me to greatly increase the average level of understanding of my students, prioritized learning over speed, and allowed me to only evaluate students on their understanding, teaching students the value of engaging with their mistakes and creating a non-adversarial relationship between us, focused only on learning and improvement.

In addition to in-class assessments, students have the opportunity to continue to practice and improve and to demonstrate that improvement on individual reassessments, which means that, in reality, every assessment that a student takes is a formative assessment; the culture built is to use feedback received to improve understanding, whether a task is a "formal assessment" or not.

The ongoing information on student learning that I receive through these – especially through monitoring their discussions – helps guide me to choose their next activity. The set of practica and other problems is never the same from year to year. The frequent use of these group-based activities gives me the data that I need to respond to the needs of my current set of students.

In addition to written assessment questions involving calculations, I routinely ask students to make qualitative predictions, rendering their explanations in text or diagrams. The conceptual foundation that is so important must be specifically assessed, as it cannot be taken for granted to be present beneath a correct number at the end of a numerical problem. The Force Concept Inventory (FCI) results showing a minimal conceptual gain in traditional courses illustrate that conceptual understanding and problem solving are not the same thing. Additionally, I like to have at least one problem per assessment involving students taking information from a video, photo, audio clip, or lab apparatus. These miniature lab practical questions help to assess student ability to frame questions, find information, and make physical connections between observations and analysis.

The process of defining questions and making assumptions is practiced often by my students when they solve "goal-less problems," where a situation is outlined, but no particular question is given. This is a group-based version of a small independent project, lasting only half an hour or so. The culmination of a term's (or year's) work can be an open-ended project – a student application of the physics that they have learned to a situation that they need to find, define, analyze, and communicate. The charge of finding applications of physics in the world around them really tests conceptual understanding, problem framing, the identification of appropriate assumptions and approximations, and the analysis of complicating factors. Building a musical instrument (at the end of the regular physics course), designing an independent friction lab (regular and honors courses, first term), and a totally self-directed project (honors course, end of year; AP, each term) are some of these experiences.

While our school does not give state or national standardized assessments, I have data for two widely-normed external indicators of learning. The Force Concept Inventory is a conceptual diagnostic test which addresses fundamental concepts in motion and force analysis which underpin the understanding of mechanics. The large published data set includes high schools, colleges, and universities; conceptual gain on this is a central goal in much of the physics education research literature.

Research indicates that pretest scores average about 26% and that posttest scores in traditional courses (avg.: 42%) do not change based on the experience or subjective quality of the instructor. 42% falls well below the “Newtonian threshold” of a posttest score of 60% (taken to show that a student has shifted mindset from Aristotelian to Newtonian). That is, very few students actually change their understanding of physics after taking a traditional physics course, even if those students can solve complex problems. Similar pretest scores exist for students in modeling classrooms, with posttest averages of 52% and 69% for “novice” and “expert” modeling instructors, respectively. My students’ pretest average (six years of data) is 27%, with a posttest average of 69%. The scores for my students on the AP Physics C: Mechanics exam during the years that I have taught it exceed the national average (4.4 vs. 3.5) by a wide margin.

Student success, however, is measured by more than scores and conceptual gains. Seeing students pursue engineering, physics, or related fields, or reporting high confidence when they take college physics is tremendously satisfying, but especially validating is hearing the experiences of students who took only an introductory physics course from me (mainly focusing on mechanics). I have had many talk to me a few years later about how both of their college intro physics courses were easier for them because of the techniques that they learned – because they learned better how to learn, how to think, and how to navigate new material and contexts. Not everyone becomes a scientist, of course, but if students can take with them increased abilities to construct and apply understanding, a curious and engaged attitude, and an appreciation for the process of science, they will only benefit in their chosen fields.