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TEACHING EXPERIENCE

Education is not the filling of a pail, but the lighting of a fire.
–William Butler Yeats

As a teacher, one of my main goals is to help my students develop personal methods for learning effectively. The most important value I convey to my students is the need to participate actively in their education and take responsibility for understanding what they are learning. This goes hand in hand with helping my students foster a motivation for taking such ownership. This isn't always the easiest route, but I love to teach. I have, therefore, found a way to teach in some formal capacity consistently since my sophomore year of college. For me, teaching is a way to share and transmit my enthusiasm for physics, and more generally, my enthusiasm for learning. I strive for the moment when a student understands a concept with which he or she has been struggling.

I have learned techniques and skills for helping my students take personal ownership of material from my classroom teaching experience in *Genetics* (advanced undergraduate class at Brown), in *Reality Physics* (distribution requirement for non-majors at Harvard), and in *Principles of Electricity and Magnetism I* (advanced undergraduate class at the University of Colorado). I have also improved my teaching through tutoring and research mentoring, volunteer teaching children, specific trainings aimed at teaching development, and research and training on best practices is education. I have had great success with implementing these techniques for taking personal ownership, including use of conceptual questions, use of questions that have personal relevance, peer instruction and small group work in lectures, and use of discussion-based or small-group-work based sections. I also enjoy continuing to develop my repertoire of techniques with each new teaching challenge I undertake.

Classroom teaching

I began my classroom teaching in the course *Genetics* while I was a junior at Brown. One technique that I admire from that course was the assignment of a popular science book about cancer genetics and the stages of cancer. This book was a good way to tie the technical details of the class to real-life problems students might encounter and encourage students to think about the material they learned long after the course was finished. If I were to design this class, I would further encourage discussion on subjective questions requiring knowledge of the course material that are also relevant to ethics and current events. For instance, "What are the pros and cons of genetically modified crops? Should they be encouraged or discouraged?" To fully participate in this discussion, the students would need to understand how the crops are modified as well as how the modified genetic material can be exchanged between organisms. Though it is easier in the field of biology to relate the material to ethical and personal matters, I have been able to take this technique learned in biology classes and transfer it to physics classes.

I was able to apply the lessons I learned from teaching *Genetics* to teaching for *Reality Physics*. I believe the material for this course – which covered several topics of immediate interest in daily life including electricity, lasers, nuclear power, radiation, and medical imaging – is ideal for introducing students to science in way to encourage personal ownership of the material and of learning. However, despite the course's great potential, this class encouraged a plug-and-chug type mentality. As a Teaching Fellow, I was constrained in the changes I could make to the course, but I discovered I could still employ techniques to encourage personal ownership during my section. I started every week with a short discussion of a conceptual question (e.g. "Would you rather live close to radioactive material with a short or long half life? What kind of half-life would you choose for a chemotherapy drug?"). I also tried to ask questions without a clear factual answer (e.g., "What are some solutions for disposing of nuclear waste? Which solution do you prefer?"). I also fostered discussion as much as possible during the material review portion of my sections: I asked other students to answer their peers' questions, and had the class guide me through solutions while I followed their directions on the board. At the end of each section, I related the material to daily life with funny anecdotes or stories. For instance, after a section about radiation, I showed a slide of the x-ray machines that were once used to fit shoes in shoe stores and mentioned how detrimental this was to the stores' employees. While I greatly enjoyed teaching my section, I believe students take more ownership of the material if sections are entirely discussion-based with some small-group problem solving.

At the University of Colorado (CU) I was able to apply my idea for a discussion-based, small-group problem solving recitation sections in the junior-level physics-major electricity and magnetism (E&M) class. Instead of traditional recitation sections, I ran a weekly tutorial in which groups of 3-5 students work together on a whiteboard to solve a series of related problems. These problems are often conceptual in nature, and require extensive discussion amongst the group members. The problems also generally involve making predictions and have sense-making components ("What does your answer imply physically? Does it make sense? Does it match your initial predictions?"). As an instructor I try to intervene in groups as little as possible as long as students are having a productive discussion, and when I do interrupt it may be to check that they have thought about a particular question, to make sure all group member have a chance to speak, or to guide them out of a wrong turn through Socratic questioning. From these small-group activities, students learn to communicate their scientific reasoning, and also the value of thinking both mathematically and conceptually and connecting the two. This sort of section creates an atmosphere of ownership in which students are focused on learning and understanding rather than getting to an answer. Students often stay long past the official end of the tutorial section to discuss lingering questions, frequently trying to relate the recent activity to practical real-life applications or to recent physics research. Students also enjoy these small-group centered tutorials, often listing them as their favorite part of the course.

At CU I also had the chance to help students take ownership of their learning during lecture as a guest lecturer for several different courses in the physics department ranging from a 40 person junior-level E&M course for majors to a 200 person distribution requirement for non-majors. In all of these courses I was able to practice and improve my use of peer-instruction ("clicker questions") and observe how these types of questions (if done well) allow students to grapple with concepts during lecture time, and practice their scientific reasoning and communication skills by discussing their thinking with their peers. I have developed expertise at facilitating these types of discussions in lecture both in the lectures I have given and in the many I have observed, where I have been able to facilitate many discussions of clicker questions every week over the course of the semester.

I received both the Harold T. White prize for Excellence in Teaching of Physics from the Department of Physics and a Certificate of Distinction in Teaching awarded by the Harvard Faculty of Arts and Sciences for my teaching in *Reality Physics*, as well as a 4.7/5.0 rating in official evaluations from my students. While running the tutorial at the University of Colorado I received 5.6/6.0 on my student evaluations and a positive response to my facilitation of small-group work such as the comment from one student that I was "very helpful in leading us to answers instead of telling us."

Outside of the classroom

I have worked on and off as a tutor in physics and math classes since early in my college career. During this time, I have tutored all sorts of students in a variety of situations, ranging from volunteer tutoring of 6^{th} grade students with learning disabilities in basic math, to tutoring Brown University undergraduates in major-track physics classes. In general, during tutoring sessions, I try to write as little as possible, guiding students through the solution by asking questions: What is the information that we know? What bits are we missing? What is physically going on? Letting the student solve the problem as independently as possible helps him or her use problem sets to develop ownership of the material.

Another method I practice while tutoring is to create problems that relate to the interests of the student. For instance, a student of mine who planned to study physical therapy became very excited about a rotation problem that involved the arm and its muscles, and her interest and motivation remained heightened throughout the entire rotation problem set. Working one-on-one with students, I have been able to identify some problem-solving steps that are difficult for beginning students. For instance, one student had difficulty identifying the essential elements of information to extract from a physics question. Was it important that the sliding mass was a book? Or did she only need to know its weight?

I believe that encouraging students to take personal ownership doesn't stop with classroom material. I recently supervised a master's student visiting my research group and developed techniques for encouraging her to take personal ownership of our research work. I found that, in an experimental setting, my student took ownership of the material by facing challenges and working through them. We would discuss these challenges, but instead of giving her one "correct" answer, we would brainstorm ideas she could try. I plan to employ this technique in the future while supervising undergraduate research and senior thesis.

Teaching children

Because I enjoy teaching, I regularly volunteer to teach children. In 2004 I spent two weeks teaching conversational English to impoverished children in rural Thailand. In this setting, the biggest challenge was motivating my students to learn without speaking their language; I discovered games were the best solution. I have since come to recognize that games are an effective motivator for learners of all ages. In addition, from 2004-2008 I volunteered for Science Club for Girls, an after-school program in local elementary and middle schools whose goal is to improve girls' knowledge of and confidence with science. In this context I have honed by ability to provide simple explanations for abstract scientific concepts (i.e. friction and energy) and my skills for leading discussion by asking questions, both of which I find also extrapolate to teaching older learners.

Training

In addition to hands-on teaching experience, I have taken advantage of Harvard's Derek Bok Center for Teaching and Learning: I have attended two teaching conferences put on by the center, discussed student feedback with their advisors, and had my section videotaped and analyzed by one of their trained staff. I have also taken a graduate school course, *Scientists Teaching Science*. In this course we were taught "the secrets of lecturing well, leading discussions, connecting to real-world applications, and creating tests in any scientific discipline." In this course I read extensively on relevant education research and learned how to use the innovations of education researchers such as concept tests, discussion-based sections, and in-class polling. I learned and practiced relevant techniques including student interviewing, concept-mapping, and test question analysis and evaluation.

In my recent position as a Science Teaching Fellow at the University of Colorado, I attend weekly participatory workshops focused on the foundations of education research. For these workshops I learned (through workshop activities and relevant literature study) such topics as improving student motivation, fostering deliberate practice and effortful study, designing and using "clicker questions," implication of how students learn for lecture and other class activities, techniques for classroom observation and student interviews, and how to design and use learning goals. I have also read deeply and am familiar with the literature in physics education, and have attended several conferences focused on physics education. Many of the new pedagogical techniques I have learned have been shown to reduce learning gaps between students from a minority backgrounds and those from majority groups.