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Statement on Teaching

My Philosophy

The job of a teacher is to promote and facilitate learning, and to promote learning a teacher first must make sure that their students believe they *can* learn. This is especially crucial to do when teaching physics because students often feel that their natural talent for physics, something fundamental and unchangeable about the way their brain works, is the only thing that determines if they will do well in the class. This "fixed mindset[1]" can limit a student's progress in learning and understanding physics because they won't see their own capacity to develop [1,2]; physics educators who approach teaching with this same mindset are less able to foster an inclusive classroom environment [3]. To maximize student learning, physics educators need to instead promote a "growth mindset," the mindset that a person's intelligence and capabilities are developed over time. Most importantly, having a growth mindset to me means believing that <u>anyone</u> can do physics.

To make my students believe this as well, the core tenet of my class is, as Einstein said, that "the whole of science is nothing more than a refinement of everyday thinking." By focusing on physics *thinking* – how to use, build upon, revise, and apply ideas about how the world works – rather than simply physics *correctness*, students learn how to chart their development in a series of small steps; instead of seeing success as whether they "get" physics or not, a seemingly insurmountable gap, students see gradual progress in the refinement of the physics thinking they are already capable of. Evaluating learning in this way is itself a skill, a skill which is as important for my students to develop as any physics I can teach them.

Students don't practice physics thinking by listening to me lecture [4], so in my classes I give the students the agency to develop ideas and make connections between them. I frequently use ConcepTest[2]-style questions with clicker systems to spark the students' thinking about physics concepts, challenge their thinking and preconceptions, and force them to refine their thinking through interrogation and collaboration. As an example, at the start of an introductory mechanics class I might ask a multiple-choice clicker question along these lines: if you want to open a door the most easily, how do you push on it? The students would choose their answers, and I'd ask for some students to explain their thinking to the class. This question is fairly basic, so maybe some students say "I just know from experience that you should push farther away from the hinge." That's great – leveraging everyday experience *is* physics thinking! The next step would be to apply that physics thinking in other situations: for example, how would you change the shape of a screwdriver to make it easier to turn? For these sorts of questions, where the students may have fewer or even conflicting experiences at their disposal, I have students give their initial answers, discuss their thinking with their neighbors, and then answer the question again to see how they've revised their thinking. Maybe the second time around a rough consensus decides here that a wider screwdriver is easier to turn because you can push on it farther away from the center, just like pushing on a door. At this point the students are developing a general structure of thinking which I can provide a name for: torque. The mathematical relationship to force and radial distance now validates and codifies the great physics thinking the students have done. The students can claim epistemological ownership of this concept since they were the ones to develop it – they now have proof that they can do physics.

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[1] The terms "fixed mindset" and "growth mindset" were developed and popularized by psychologist Carol Dweck, beginning with her 2006 book *Mindset: The New Psychology of Success.*

[2] ConcepTest questions are conceptual multiple-choice questions originally designed by Eric Mazur at Harvard University. Examples can be found on Carl Wieman's webpage: http://www.cwsei.ubc.ca/resources/clickers.htm

With the students leading the class, my job is to demonstrate and promote active listening and to guide their physics thinking. While the students are talking with each other, I walk around the room and ask them to explain their thinking to me as if I were another student. When I need to step in to clarify something, I first walk through how I gather useful information and apply the physics tools at the students' disposal, as if I were approaching the problem from their vantage point. After all, I am trying my best to teach them how to practice physics thinking, not just the answers to various problems; time in physics class should be spent on developing and applying concepts, not on memorizing facts. This is especially true when it comes to math in physics: the mathematical models we use in class give a concrete precision to the concepts students are discussing, which makes solving problems more efficient and patterns more easily identifiable. By focusing on concepts and not on memorizing formulas sheets, students can handle more complex math than they would otherwise.

For example, my absolute favorite topic to teach is LCR circuits. I first have students think in groups about how the charge in the circuit will flow based on what the individual circuit elements do. We come together as a class to discuss the various hypotheses (perhaps even making a clicker question to vote on the most popular ones) and I then demonstrate the circuit in action with a PhET[3] demo. The students often point out that the charge is *oscillating* – it moves in one direction, stores on the capacitor, and then discharges the other direction. This is my cue for the big reveal: we walk through the math describing the movement of charge in the circuit and see that it is identical to the math describing the movement of a damped harmonic oscillator, such as a pendulum with friction. From there we can make a table mapping the variables in one equation to those in the other and develop some physical intuition for hard-to-grasp concepts, e.g. that inductance in this circuit is analogous to the rotational inertia of a pendulum. The calculus involved is sometimes beyond what the students have encountered before, but that's not a problem: even a student who hasn't learned much calculus can follow the process (because, again, the math represents the physical sense the students have developed) and see the similarities between the two systems. Students with a wide variety of mathematics backgrounds have told me that the demo and physics thinking we do beforehand make the math make sense, which is why I always look forward to teaching this class.

While I am teaching, I am exuberant, cheerful, and at times boisterous as I respond, verbally and emotionally, to my students' thinking. Above all else, I want to convey to my students my passion for physics, my investment in their achievement, and my interest in their thoughts. Physics classes should change how students see the world around them but also how they see their own capacity for success.

References:

[1] "*Exploring mindset's applicability to students' experiences with challenge in transformed college physics courses," Little et al.,* https://journals.aps.org/prper/pdf/10.1103/PhysRevPhysEducRes.15.010127

[2] "*How Can We Instill Productive Mindsets at Scale? A Review of the Evidence and an Initial R&D Agenda," Yeager et al.,* https://labs.la.utexas.edu/adrg/files/2013/12/Yeager-et-al-RD-agenda-6-10-131.pdf;

[3] *"Expectations of brilliance underlie gender distributions across academic disciplines," Leslie et al.,* https://science.sciencemag.org/content/347/6219/262

[4] "*Active learning increases student performance in science, engineering, and mathematics," Freeman et al.,* https://www.pnas.org/content/111/23/8410

[3] PhET simulations are interactive computer applications in which topics in physics, biology, and other subjects can be explored and demonstrated. The physics simulations available can be found here: https://phet.colorado.edu/en/simulations/category/physics. I find the circuit simulations extremely helpful.

Teaching Interests

The part of being a physics instructor that I find the most inspiring is the chance to change a student's mindset towards physics and towards learning. Given this, I look forward to teaching any of the core undergraduate courses in physics, including Mechanics, Electromagnetism and Electrodynamics, and Quantum Physics, where I can help new physicists develop their thinking. If you had asked me several years ago which of these courses in particular I would be most excited to teach, I would have without hesitation answered Mechanics because the material is arguably the easiest to connect to students' everyday experiences; because of this, I thought it would be the most fertile ground for developing physics thinking. As I've gained more teaching experience, however, I've realized that it's often more powerful for students to uncover these connections where they least expect to because they gain an even stronger sense of how physics can help them understand the world around them. This means I am even more excited to teach Electromagnetism and other courses where these connections aren't as readily apparent; I find the challenge of finding and presenting these connections to students highly rewarding. There is a substantial "wow" factor in understanding, for instance, how a bizarre phenomenon such as magnetic induction is responsible for speakers being able to produce sound.

My background as a high-energy physicist also has me interested in developing undergraduate courses on topics not often taught at this level: Particle Physics and the Standard Model, and Physics through Symmetry. Both courses focus on topics which are more often left for the graduate level even though they address fundamental structures of the universe – the building blocks of matter and forces, and the symmetries underlying them. I also find that many students are extremely interested in these topics when they are brought up tangentially in intro courses. I will wholeheartedly admit that a more personal reason behind creating these classes is my own desire to understand the topics better – after all, we often learn even more from teaching than we do from being students. I find that teaching a subject is incredibly effective at filling in my own gaps in understanding, which is a big reason why I find teaching so personally rewarding.

Statement on Diversity

My approach to supporting students of diverse backgrounds is closely tied to my teaching philosophy: I believe in developing students' physics thinking from the foundations of their everyday reasoning, and I also believe in making physics relevant to their interests and experiences. This places inherent value on each student's background, perspective, and the ideas which they bring to class. As a result, I believe that my most important job as an educator is to create a classroom environment which celebrates the thinking and contributions of every single student. I have refined my approach to creating an equitable classroom environment through numerous professional development opportunities, including my current membership in the American Physical Society's Inclusion, Diversity, and Equity Alliance (APS-IDEA), my past leadership on the Tufts Physics and Astronomy Department's Diversity, Equity, and Inclusion committee, and a course on anti-racist STEM pedagogy, and I have tested and evaluated my approach in small, liberal arts classrooms and large university lectures. My current approach centers on active listening, referring to my students as creators and scientists, and consistent displays of empathy.

A central component of my courses is consistent active listening. When students are working together in groups, I walk around the classroom to ask them what they are thinking and what they have figured out. During the first few classes, students expect me to be evaluating their progress; they are unsure of their own reasoning and are often eager to ask me if they have done things correctly. As the semester progresses, however, students begin to understand that I truly am curious about how they are working through problems, and they get more comfortable and confident justifying their work to me. This growing comfort also extends to their conversations with their classmates, to which I pay particularly close attention: because I emphasize that science is built on discourse and collaboration, it is a fundamental requirement of my classes that students give each other's ideas equal merit and respect. "Diversity" also includes diversity of opinion and physics background.

Helping each student develop a sense of physics identity goes a long way toward convincing them that they can do physics. One simple approach I take is to use a diverse roster of names, including the names of current and past students, in my example problems, homework assignments, and exams. I portray my students as curious observers, engineers designing the solution to the problem, or people engaging in everyday activities. I make a point of selecting names, including preferred pronouns, of students from different ethnicities, nationalities, and genders. I do this primarily because physics textbooks tend to use student names which are traditionally white or Caucasian in a disproportionate majority of their problems. In my classes, I am careful not to make the same mistake.

I genuinely care about my students' perspectives and well-being, and I respect them as people, not just as students. I ask my students about their lives, their passions, and their days, and I talk about my own. I do my best to use correct pronouns, memorize my students' names, and practice their pronunciation. My course guidelines are strict but flexible: homework assignments are not accepted more than two days late, but if a student asks for an extension, and has a good reason for doing so, I am likely to grant it; I repeatedly tell my students their health is most important and to not rush back from illness; I always drop the lowest homework score because we all have weeks where it feels like everything is too much to manage. I regularly solicit students' feedback, both anonymously and through one-on-one check-ins, to set a standard of open communication. This extends beyond the classroom: I listen to students who are struggling with non-academic challenges, ranging from family illnesses to general burnout, and I respond to their feelings with empathy, kindness, and, when appropriate, tips and external resources. By respecting my students as human beings with lives outside of my classroom, they are happier, healthier, and get more out of the course.

These steps I take are not supplemental to the way I teach, but fundamental; it is not going the extra mile for my students, but rather supporting my students' success to the best of my ability.