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Preparing students for the 21st century: Physics is the perfect playground

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One of the most influential experiences of my career happened early, when I was an undergraduate tutoring engineers and pre-medicine majors. These programs attract top talent, but some hardworking, intelligent, and capable students saw physics as an almost insurmountable barrier. Trying to find a systematic, research-based way to communicate this difficult material more effectively ultimately led me to pursue a doctorate in Physics Education Research (PER). Empowering students who had been close to quitting allowed me to support them in understanding concepts they thought they could never master. Ultimately, it helped them to acquire confidence and develop a mindset that applies beyond academics.

For me, teaching physics transcends physics concepts and laws. Physics is a vehicle to train students in thinking critically, solving complex problems, modelling real world situations, and communicating technical information. I believe that these goals are synergistic with developing a deep theoretical and applied understanding of the discipline.

Early in my career, I was lucky to spend time in places with a holistic approach to teaching physics. After my degree, I learned that approach is not widespread, and frustration with seemingly antiquated teaching philosophies, methodologies, and priorities caused me to take a break from academia. Before that break, when I advocated for developing transferable skills while teaching physics courses, I had a serious weakness: minimal tangible experience with the world outside universities. Now, as a supply chain consultant, I am even more convinced that educators need to consider real world trends and be strategic in preparing their students for success in a world in which knowledge is always changing. I have more authority in my background with which to push that argument.

I am circling back with that industry experience to you, the people in a position to make a change. As early career faculty, you have a wonderful opportunity to expose students to these skills within the context of your classes. The Joint Task Force on Undergraduate Physics Programs put together a thorough report on preparing physics students for 21st century careers. In this guest editorial, I describe the factors that influenced what I implemented in the classroom, factors that helped me pull that off as an early career academic. I also describe skills that I appreciate after the time spent in academia and industry. I hope this will provide ideas and motivation for those in early careers to mix things up in their classroom.

There are many ways to bring real world skills into tertiary physics courses. For brevity, I will limit my description to the SCALE-UP approach at North Carolina State University, which I experienced as a teaching assistant during graduate school. SCALE-UP, “Student Centered Active Learning Environment with Upside-down Pedagogies,” uses classroom and curriculum design to encourage active and collaborative learning in an integrated lab, “lecture,” and tutorial environment. Students solve ill-defined problems that required estimation, evaluation of information on the internet, making connections and collaborative teaching, both within groups and across groups.

After graduation, I proposed to bring SCALE-UP style teaching to the University of Auckland in New Zealand to reduce typical problems in their calculus-based physics courses, including poor performance in class, low information retention by the second year, and low attendance. In addition, I explicitly incorporated skill development in the stated learning goals of the two course series. I developed a first year lab sequence with simple equipment but open-ended experimental challenges, where students had to design a procedure within a team environment. Students summarized their approach and findings in a one-page, argument-based report. This idea, science as an argument, initiated profound conversations about how science happens, who funds science, and who does science. For many, this new format significantly deviated from structured high school labs and it took effort to produce a report that was not a regurgitation of the lab manual or textbook. Despite the challenge, many mentioned the laboratory exercises as one of the most impactful aspects of the course. In the second semester course, students used minimally working programs in Jupyter Notebooks to develop coding skills while visualizing abstract electromagnetic phenomena.

As an early career department member, my impact was enabled by a supportive department and a department head who was ready to embrace a more radical solution to current challenges. It helped that the department was large enough (approximately 40 faculty) to have resources but small enough to reach consensus in promoting consistency across courses. First year enrollments of about 300 students in introductory physics meant all first years went through the studio experience. Departmental leadership rotated instructors through teaching in this format, creating a critical mass of people familiar with more studio-centered pedagogy. The courses minimized unnecessary grading through online homework assignments, detailed rubrics, and peer review. But teaching assistants graded the argument-based lab reports and Jupyter notebooks. Finally, skills-based learning goals complemented the University’s efforts to roll-out an institutional graduate profile that promoted critical thinking, solution seeking, communication and engagement, independence and integrity, and social and environmental responsibilities, in addition to disciplinary knowledge.

I use my academically acquired skills on supply chain problems that can serve as inspiration to students; these are the kind of challenges for which you are preparing your
students. One example was a coefficient of friction problem in a plastic film manufacturing plant, where inconsistent slipperiness leads to scrap and downtime. I approached this with theoretical research, the development of hypotheses, and testing, skills more or less familiar in academic work. Unlike most academic problem solving, however, this challenge also involved a great deal of communication, management, and consideration of costs and time.

Real world skills have analogies in academia and by the nature of where you are today, you have mastered them to an extent that you can model them for your students, and hopefully incorporate them in a structured way. Academics write grant proposals, evaluate manuscripts with peer review, create compelling data visualizations, manage teams while running a lab, mentor students, and prioritize competing demands for time. Many of us never receive formal training, we just “figure it out” through emulating role models, practicing, failing, and doing it better next time. While faculty may feel uncomfortable teaching, and especially assessing “soft skills,” we cannot perpetuate this cycle by keeping the real world outside the classroom. Traditional tools may be insufficient for assessment but peer review, self-assessment, group work, and reflection tools can help. When students write about physics, apply ideas to ill-defined problems and work in teams, students develop a more nuanced, relevant, and deeper understanding of the content while becoming more adaptable and well-rounded as humans. When you provide students with opportunities to engage with physics in non-traditional ways, remind students what skills they are practicing and why. Then, they are more likely to have awareness of their strengths and capabilities and examples to vocalize in job interviews.

In closing, I would like to encourage those of you teaching students to think creatively about how you can integrate some of these skills into your classes, into your undergraduate research projects, and into your research labs. As an early career faculty member, you have more opportunities to design courses from scratch, and it is easier to incorporate these learning goals and activities from the beginning. Do not think about the “content” you will have to sacrifice. Think about how much you will have to gain when students join you as future collaborators or show up as your financial advisor, dentist, doctor, or peer reviewer.

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