Robert Craig Group

Experience in Teaching and Outreach

I enjoy teaching. In fact, the challenges and joys involved in efficiently exposing students to powerful knowledge are exactly what brought me here to the University of Virginia.

My father was an English professor at a small college campus in South Carolina. As a result, I have always valued teaching as one of the most noble professions. Through my teaching responsibilities over the last 20 years at four different college campuses I have had the chance to lecture on multiple topics of physics. In addition, as a student I developed my teaching skills through many years of private tutoring. More recently, several focused teaching workshop have allowed me to continue to evolve my teaching techniques towards pedagogy proven effective by recent data-based studies.

The importance of excellence in teaching is overlooked far too often. I have made significant contributions to my research field over the course of my career; however, I hope that these will pale in comparison to the accomplishments of the students that I influence and the people I introduce to our field through outreach efforts. As a researcher, I know that my direct contributions are limited by my lifespan, but if I can pass along my interest in the topic, and my will to help a student discover the excitement of science, then I know my contributions to physics and to society will be far greater.

I am an experimental particle physicist. The goal of this field is to provide a complete description of how the universe was created and the how the fundamental laws that govern its evolution behave. In order to study these elementary particles and forces, my colleagues and I use particle accelerators to collide particles in a controlled environment and study the results of the collisions. Due to the prohibitive cost of these large machines this research can only be carried out at a few locations in the world. In the US, Fermilab, located 50 miles west of Chicago, is the major facility. Prior to coming to UVA I was a post-doctoral researcher at Fermilab. My work there was successful and I was presented with several choices for tenure-track employment including the Wilson Fellowship at Fermilab. The Wilson Fellowship would have paid more, been located at the premier US facility, and kept me with no teaching requirements – a dream position for a scientist. I chose UVA primarily because my dream had always been to be a professor, not just a scientist. So, the opportunity to teach and to work with students is truly one of the primary factors that brought me here to UVA.

I strive to be an excellent teacher, not a professor focused solely on research. During my first semester here I taught PHYS 2020, an introductory class of 200 pre-medical students. I survived that first semester, but it was challenging in ways that I didn't expect. That summer I attended the New Physics and Astronomy Faculty Teaching Workshop which is held annually by the American Association of Physics Teachers. The workshop is an intense three-day introduction to pedagogy that has been proven to be effective in teaching physics. The experience opened my eyes to new techniques and to a large body of research supporting the value of incorporating strategies that deviate from the classical lecture. When I taught PHYS 2020 again the next year I improved the class by incorporating several techniques

that I learned from the workshop. For example, I made the in-class response system a larger component of the lecture. When it was clear from the response system that a concept was not understood by the class, I encouraged discussion and allowed a few minutes for students to "convince their neighbor" before polling the class again. The response system combined with the follow-up peer instruction seemed to improve the effectiveness of our lecture time. Another related technique was to include a pre-class quiz before every lecture to encourage students to read the text. I promised them that I would not cover everything in the book, that as college students reading was their responsibility, and that I would use the extra class time for more interactive purposes. I assured them that these techniques were proven to improve their learning. I think that overall the class accepted this strategy, read more in advance of class, and learned more during our lecture periods.

I use many physics demonstrations in class. While teaching PHYS 2020 I realized that I was truly enjoying the process of setting up and learning how to use each of the demonstrations and presenting them to the class. I thought students might enjoy this too, so I presented it as a "Dream Idea" to the Mead Endowment at UVA. With the award, I hosted a series of meetings with Physics majors in which we investigated demonstrations that were available, and even purchased some new ones for the Physics Department. Two undergraduate students presented some of our demos at the annual "Physics Day" event in front of about 200 middle school students. I'm happy to say, it has has turned into a tradition to involve undergraduate students from SPS in the Physics Day presentation each year.

I enjoyed teaching the large general physics class for pre-med students, but I had the opportunity to transition to PHYS 1610. PHYS 1610 is the first-semester introductory physics class for students who might want to major in physics. There are about 50 first-year students in the class but only about half of them will actually go on to a degree in physics. A major challenge in this course is to present it in such a way that challenges even the brightest physics majors while making it a fair introductory test for the students who realize early in the semester that majoring in Physics might not be for them. Surprisingly, I find that helping students figure out that Physics might not be their best option is a very rewarding part of teaching the course. College is short; it is best to start pointing in the right direction as soon as possible.

In 2015, I participated in the Course Design Institute at the University of Virginia. The goal was to redesign 1610 into a new 5-hour course (1710) that would help us combine our 3-semester introductory sequence into a 2-semester sequence. While designing the course, I realized that one of the things I wanted to accomplish in the course was to teach students what it takes to be a successful college student, a successful physics major, and to wellcome them to our department. I now do several activities to insure that the students reflect on their learning. For example, I introduce them to SPS early with the hopes that they will find community in our department.

More recently, I had the opportunity to teach Modern Physics. This was a joy, and there was no need to redesign the course, as I inherited a great course from the previous instructor.

Most recently, I have focused my efforts on computational physics and data science. I taught our "Introduction to Scientific Computing" class for 3 years. It was based on C,

and focused on solving some simple physics problems computationally. I recently started a new course in the physics department called "Introduction to Python for Scientists and Engineers". Along with an introduction to the PYTHON programming language, the course introduced three core skills: analyzing data, simulating data, and visualizing data. In the last two weeks of the course we discussed machine learning and even introduced Scikit-learn and trained and evaluated a neural network. The course assumes no prior programming experience or knowledge about the inner workings of computers. It concentrates on applications to common problems in science and engineering and with an emphasis on general data science tools.

In addition to my teaching, I have undertaken several efforts to mentor students and enhance the undergraduate atmosphere in the Physics department. The Mead program above is one example. In my second year here I used a grant from the Jefferson Trust to start an undergraduate research program called the Particle Physics Research Adventure in which UVA physics majors compete to spend a summer at Fermilab. This was a year-long program in which students applied to the program in the winter, began their work in the spring, spent the summer at Fermilab working full time on their projects, and then gave a talk at a regional conference in the fall semester. Typically, two students were selected each year. The program was highly competitive, and the students successfully contributed to experiments at Fermilab. I'm proud of this program, and it was been a joy to mentor these students and witness their first research experiences.

Another example where I have worked to enhance the atmosphere in the Physics department is through serving for 8 years as the faculty advisor the the Society of Physics Students and the physics honor society, Sigma Pi Sigma. Since I taught the first-semester introductory course for physics majors I already know most of the SPS members before they joined a meeting. I think this made them feel more comfortable in the group as junior students. My philosophy with SPS is to let the students lead their group. However, I encourage their activity and negotiate with the department for resources to support SPS efforts. I hold meetings at the beginning of each semester with officers and take past and newly-elected officers to lunch each year after the election to ensure a smooth transition. During my time as advisor, SPS has been quite successful and we were recognised by the national SPS organization as an "Outstanding" or "Distinguished" each year. I understand that less than 10 percent of chapters receive this distinction. I was also honored to be nominated by the students twice for the SPS advisor of the year award.

In addition to yearly inductions, our ΣΠΣ honor society two major events each year. I started a luncheon, which we hold each year shortly after the inductions. This is a chance for ΣΠΣ students and ΣΠΣ faculty members to get to know one another in an informal setting. Each year, ΣΠΣ hosts an undergraduate research symposium. This is a chance for our students doing research to present their work in a friendly environment. I did not found the symposium, grew significantly over my time as faculty advisor.

In my opinion, the most important thing that scientists can do as a role model is to donate some of their time to another interested mind. Often, this effort results in a greater understanding for both parties! In my short career, I have taken advantage of many opportunities to stimulate interest in physics research in the classroom and through outreach

activities. For Introductory physics courses, I always take the last lecture to show them how the physics they learned in class could help them understand my research. I also invited them to the Hoxton public lecture that is held every spring stating that "this was the closest they would probably ever be to being a physicist, so they should attend and maybe even enjoy the lecture". I always invite the potential Physics majors in PHYS 1610 to the meetings of the Society of Physics Students and encourage them to "Think like a scientist!". For the last few years I've instigated the policy of taking three or four top performers to lunch at the Garden Room after every exam. My classes have been rather large, and this gives me a chance to get to know some of the top students in the class in addition to the ones that are struggling and that I meet through repeated visits at my office hours. In office hours or outside of class I'm always thrilled when a student asks about my research.

In summary, I'm here at UVA because I want to teach and mentor students and I have put every effort that I can afford into doing it well. I work hard to have a positive impact in the classroom and to serve as a mentor to students both in and outside of class. I rank my success as a mentor and a teacher among my highest accomplishments and I look forward to the opportunity to teach students of physics at every level and to improve my technique for years to come.

For completeness, I include a list of my past teaching and outreach experience in my CV.