Tricks of the Trade: Navigating teaching opportunities in the research-based engineering PhD

Ana Cristina Estrada, University of Virginia

Ana Estrada is a PhD Candidate in Biomedical Engineering at the University of Virginia. She earned her undergraduate degree in Bioengineering from Rice University in 2013. She currently works on computational modeling of post-myocardial infarction cardiac growth under the mentorship of Dr. Jeff Holmes.

Dr. Lindsey Taylor Brinton, The Ohio State University

Lindsey Brinton is a Postdoctoral Researcher at The Ohio State University in the laboratory of Dr. John Byrd. She earned her PhD in Biomedical Engineering at the University of Virginia in 2016. Her dissertation research under the mentorship of Dr. Kimberly Kelly focused on the development of liposomes targeted to the stromal compartment of pancreatic adenocarcinoma. She has taught Nanomedicine and been a teaching assistant for Calculus I and Physiology II.

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Abstract

Engineering graduate students will ultimately face the decision of whether to stay in academia, work in industry, or pursue a different career path. Of those that elect to remain in academia, most will face balancing substantial research, teaching and service requirements. Yet, a graduate education typically focuses predominately on preparing students to lead research projects, without an emphasis on development of pedagogical skills. Especially in engineering fields, graduate students may not automatically be required to teach, receive pedagogical instruction, or engage in other career development aspects beyond research. The exact reason for this is unclear but may be linked to underestimating the positive impact of teaching by graduate students. Yet, there appear to be concrete benefits for both the graduate students and the students taught by them. In fact, many graduate students are interested in teaching and would like to better prepare for that aspect of their future career. Although perhaps not obvious, there are many opportunities to gain teaching experience throughout graduate school. In this *Tricks of the Trade* paper, we will discuss our journey preparing for the teaching side of a faculty position. We will, in particular, discuss the role of professor preparatory programs, graduate teaching assistantship, co-instruction, participation in education research and education-based conferences, as well as in-lab mentorship on the development of graduate students as educators.

Introduction

Getting a doctoral degree in engineering requires gaining a depth of knowledge about a specific topic and a breadth of knowledge about related topics and techniques. The ultimate focus is on the research completed and the candidate's ability to conduct research. Perhaps this is, in part, because the positive impact of graduate teaching is underestimated. It may seem plausible that graduate students already have a large enough workload and need to focus solely on their dissertation research without additional compromises. Another concern may be that experienced faculty members would be better able to teach undergraduates. However, a recent study reveals that undergraduates are twice as likely to choose to major in a subject when taught by a graduate student compared to students taught by faculty and that "graduate students who teach more frequently are more likely to graduate in a timely manner and more likely to subsequently be employed by a college or university in their early careers [1]." Thus it appears there is benefit for both teacher and those taught when graduate students take on teaching roles. Yet, for most disciplines within engineering, the doctoral student will complete a certain amount of coursework, pass qualifying exams, and most importantly, make a meaningful contribution via research and showcase that contribution by publications and a dissertation. He or she will have minimal or no teaching requirements.

By the end of the tedious process, students have a Ph.D. in hand and a capacity to solve engineering problems, especially ones related to their expertise. Universities such as Purdue have recognized that there is a difference in preparation for students that pursue post-master's degree training depending on their end-career goal. In explanation of the necessity of a separate professional doctorate, they state:

> "But first, What [sic] is a professional doctorate and how is it different tha[n] the other doctorates (PhDs) typically offered by research and doctoral intensive flagship universities? Simply put, professional doctorates focus on in-depth, cutting edge

> technologies, innovation skills and the leadership and effective organization of teams and corporate unites. Such programs seek to prepare advanced level practitioners for business and industry rather than basic researchers for the academy [2]."

Inherent in their explanation is the fact that Ph.D.s typically offered by research-intensive universities are designed to prepare students for leading research within academia. And while many students will seek out industry or non-R1 employment after completion of their doctorates, this is the standard pipeline for students wishing to become a tenure-track R1 faculty member. For a student who follows the path to academia, there may be additional training as a postdoctoral researcher, where, once again, the focus will be largely on the research completed during training. The goal is usually for the student to gain a new set of skills and additional expertise to help him or her become successful at leading research as a principal investigator (PI). But when the student actually takes the job of PI, he or she will likely have considerable teaching and service requirements in addition to research. Given that research skills and expertise do not necessarily translate into effective teaching, it is necessary to also take measures to learn how to teach. Golde, *et al.* reports that half of graduate students surveyed say they lack experiences to prepare them for teaching and advising [3].

Other publications address teaching training during graduate school. [4] is tailored towards students who seek employment at a non-R1 institution and shares some valuable advice on teaching-oriented activities while focusing on the job search and application materials. [5] provides an elegant review of the Preparing Future Faculty (PFF) initiative and [6] applies Communities of Practice theory to PFF programs. Other literature describes formal training for engineering teaching assistants, such as the pros and cons [7], guidelines [8], and logistics [9]. In contrast, our *Tricks of the Trade* paper focuses on how graduate students can seek out and maximize training for teaching while fulfilling heavy research responsibilities. Our paper is centered on the question: How can doctoral students ensure that they will not only be ready for the research aspect of a future career as a PI, but also the teaching aspect? To answer this, we give detailed advice on how to seek out teaching-centric opportunities and advice on how to make the most of them. Topics include the role of professor preparatory programs, teaching assistantship, co-instruction, participation in education research and education-based conferences, as well as in-lab mentorship on the development of graduate students as educators.

Methods

The authors, Ph.D. candidate and postdoctoral researcher, team up to highlight key teaching experiences that have helped them prepare for becoming effective in the classroom. The authors share their personal experiences in narrative form, describing how they were able to maximize teaching instruction while obtaining a Ph.D. in Biomedical Engineering. They candidly share their lessons learned and offer "tricks of the trade" to other students interested in bolstering their teaching skills. Several faculty have also provided their insights, which is contained in "Professor Perspective" boxes. Advice for each section is summarized following each section.

Results and Discussion

Professor Preparatory Programs

The authors have both participated in Tomorrow's Professor Today (TPT) [10], a professor preparatory program at the University of Virginia (UVA) that provides useful resources and professional development opportunities for graduate students who seek to pursue an academic career. The program admits 25 graduate students from diverse disciplines every year and guides them through professional development opportunities to help them become well-rounded faculty in the future. The program has three main facets: (1) development of skills for the classroom, (2)

professional development more specific to each participant's discipline, and (3) more in-depth exposure to working life at a university. The program is thus set up to help students develop skills that will allow them to successfully fulfill the requirements of teaching, research, and service that will be expected of them in a faculty position. The teaching facet of the program is the most involved, as these are skills that can be more difficult to develop fully as part of a graduate program alone. The requirements involve a variety of tasks, including attending workshops specific to teaching skills, preparing course-related documents, and participating in a pedagogy seminar. The workshop requirements include a general teaching workshop for all graduate students who will work as GTAs, a workshop specifically about creating a reflective teaching statement, and additional workshops that may be more tailored to each participant's discipline.

Additionally, participation in a six-week-long pedagogy seminar is also required and provides a great opportunity for students to learn more about teaching methods across disciplines. The pedagogy seminar is designed so that students from diverse disciplines may learn about general teaching strategies and new strategies that are emerging, compare and contrast teaching strategies that are used in their own disciplines, as well as design a full syllabus for a class they would want to teach in the future. The seminar fosters open discussion about effective teaching, as well as engagement with the current literature on effective teaching and learning. The study and discussion of teaching methods and strategies to enhance learning serve as a starting point for interested students to pursue further involvement in the scholarship of teaching and learning (SoTL). The seminar is a very rewarding experience, as it provides a good foundation for syllabus and course design and builds a community of educators that can share teaching strategies with each other. The program is meant to foster collegiality amongst graduate students of different disciplines to help them develop as well-rounded academics. The program requirements include a series of classroom observations, where the participant must observe a faculty member teach, a peer teach, and be observed by a peer while teaching, then write reflective statements about each experience. Furthermore, the participant must teach at least a minimum number of hours of their own class, workshop, or discussion.

Professor Perspective

"TPT participants are unquestionably better prepared for teaching at the collegiate level than before they engage in the program. This doesn't seem surprising at first, but it isn't a foregone conclusion. After all, those who choose to participate in TPT are already thinking about education as a major component of their career. Many have already engaged in teaching assistantships, and have a firm handle on what they believe constitutes good and poor instruction. TPT imbues its participants with a much deeper understanding, and specific skills of durable value."

~Dr. Will Guilford, UVA associate professor and TPT mentor

Participants are expected to team up with the university's Center for Teaching Excellence (CTE) to solicit direct feedback to the participant on their teaching, either through direct observation or through review and consultation of course design materials. The CTE also helps review teaching documents, including the reflective teaching statement and course design materials. These documents can later be included as part of the participant's teaching portfolio, which is a component of job applications for faculty positions. The professional development facet of the program includes workshops for writing a CV or a Cover Letter and academic interviewing, attending discipline specific conferences, presenting research, and interviewing faculty members to learn more about their career trajectory. The academic life facet includes workshops on the tenure and promotion process and student advising, as well as service involvement in the university. Participants also complete a series of interviews of faculty, including administrators, to learn more about their careers. Overall, the program provides a large set of resources, support, and guidance through professional development for graduate students who seek to be well prepared as educators while also getting

ready for the research and service requirements of the academic life.

In addition to university professor preparatory programs, there are also short, intensive workshops offering exposure to faculty responsibilities and how to prepare for them. For example, at North Carolina State University, the NSF-sponsored Building Future Faculty (BFF) Program is a two-day workshop for doctoral students and post-doctoral students [11]. University of Michigan's NextProf is a two-day workshop to aid participants in exploring and preparing for faculty positions in engineering [12]. Unlike professor preparatory programs, which generally have requirements spanning a couple of years, such workshops could provide important insight with only a two-day time commitment.

How can I get the most out of a Professor Preparatory Program?

- Seek out additional teaching mentors who can share their expertise with you and potentially endorse your teaching abilities in the future
- Learn current pedagogy and develop your own teaching philosophy
- Gain realistic insight into the responsibilities of being a professor
- Begin creating a teaching portfolio, especially the teaching statement

Professor Perspective

"GTAs are part of the life blood of our undergraduate program. From a purely selfish standpoint, faculty at a research university rely on GTAs for instructional continuity amid our busy travel schedules – schedules that pay little or no heed to teaching obligations – that is in addition to the grading, office hours, and many other services they provide. Good GTAs make the class partly their own, and force us as faculty to question how *we* teach.

TPT participants and Teaching Fellows take the latter to a whole new level. They bring what they learn in TPT not only to the classroom itself, but also to meetings with the faculty. We're forced to confront our own ideas and predispositions in light of what is learned in TPT. Teaching Fellows truly take 50% ownership of the class to which they are assigned. That forces *them* to confront their own beliefs, and to grow to meet the needs of the real instructional world. It creates an opportunity for renewal of the course, to the benefit of instructors and students alike."

~Dr. Will Guilford, UVA associate professor and undergraduate program director

Graduate Teaching Assistantship (GTA)

The authors have been GTAs for four courses: Engineering Calculus I, BME Physiology I, BME Physiology II, and Biotransport. GTA positions have the potential to become great preparatory experiences, but are not always inherently so. To the extent possible, we recommend that students optimize their experience as GTAs by actively seeking to maximize their hands-on teaching experience and try to avoid being glorified graders. It is also extremely helpful to approach the program director and/or professor and request that students fill out an evaluation for the GTA independently from the evaluation they do of the lead Professor. The ratings that students give and, importantly, any specific comments that they make about the GTA's contribution to their learning provide feedback to improve and evidence of his or her teaching experience to use during their job search. We describe how we were able to get the most benefit from our GTA positions.

(1) Engineering Calculus I is an introductory course that is taught to

undergraduate students from diverse engineering disciplines. The expectation of the lead Professors was that the GTA would run two homework help sessions each week and assist with the grading. This GTA position is an example of one that was less flexible. The professors were not open to having the GTA lecture in the class or to have a role in exam development. However, the homework sessions usually meant that the GTA was explaining the more difficult concepts to small groups of students. This type of training, while maybe not as obviously beneficial as the opportunity to jump in and teach a few lectures, allows for practice in taking complex material and finding a way to explain it that will reach struggling students. Additionally, while it is likely more ideal to participate in the generation of exam questions and projects, it is still worthwhile to begin taking note of the types of questions tested and how successful or not they are in testing students knowledge. Instead of just grading, take the time to dissect a question and determine whether this question is a simple check of memorized facts or if it is more probing for students to synthesize and apply material. Additionally, this is an opportunity to try to see patterns in students' answers. Is there a concept that trips up multiple students and how could that be addressed in a homework help session? Large introductory courses also take quite a bit of structure and organization to run smoothly because of the sheer number of students and the typically diverse backgrounds. It was helpful to note how the Professors handled these challenges and to think about what could be done differently.

(2) BME Physiology I is a required course for BME majors generally taken in the fall of their second year. The course is set up with two main portions, a classic lecture on fundamental concepts in physiology and separate scientific paper discussions, which are led by the GTA. While the main lecture is designed for a larger class, usually about 150 students, the paper discussions were held in separate 20-30 person sessions. The GTA was responsible for leading six discussion sections where they would guide the students through specific papers related to topics studied in the lecture portion of the class. The purpose of the discussion sections was to teach students to think critically about the literature, as well as to help them develop more effective methods of reading scientific papers. For assessment, the students were expected to write critiques of each of the papers in small groups. The responsibilities of the GTA included guiding them through the paper and teaching them effective and concise writing techniques for the critiques. The GTA graded all the critiques and developed the rubric, the specifics of which were discussed with the Professor. The small group discussions allowed for more direct interaction with each of the students and opportunities to develop skills in encouraging classroom participation from students. One of the key outcomes was helping the students develop confidence discussing both the positive and negative aspects of published papers. While the GTA was not involved in development of exam or homework questions, leading individual sections of students was a great opportunity to gain teaching experience.

(3) BME Physiology II is a required course for all BME majors, generally taken in the spring of their second year. The expectations of the GTA were to run office hours and assist in exam generation and grading. The Professor of this course was much more open to the GTA's request to take on some additional responsibility.

Professor Perspective

"I suppose giving a GTA freedom to design course activities gives him/her practice for later career steps with feedback from a faculty mentor. The feedback and debriefing step is important for learning how to design course activities. In terms of making the GTA better training than it otherwise would have been, my opinion is that participating in teaching should be a part of your professional training in grad school if you have an academic career in mind. The co-instruction model ups the ante a little bit by including you more in the course design instead of just in individual activities. The approach should be the same, though. Practice identifying learning goals and designing activities and assessments to achieve those goals."

~Dr. Brian Helmke, UVA associate professor

Office hours each week were begun lecture-style, re-teaching a few of the more difficult topics from class that week. Although each office hour session included only a portion of the students enrolled in the course, this still offered the opportunity to teach about 20 students and to try out some active learning techniques in a real setting. In addition to grading, the GTA submitted questions for the Professor to include on the exams, generated the rubric for grading the exams, and graded the exams. The GTA observed that many students were struggling to keep up with the material because a lot was covered in a short amount of time. This presented an opportunity to try to enhance the course and so the GTA began to (with the lead Professor's permission) post her class notes. Before posting them, she would try to pick out what she thought was causing students the most difficulty and provide a little more foundational information for those topics. The GTA also invited students to email topics to her so that she could provide notes and office hour lectures on them.

(4) Biotransport is a required course for BME majors in their third year. While the course covers very technical material, it is taught with an emphasis on active learning rather than a traditional lecture course. The expectation for the GTA was to provide problem solving help during class as well as during weekly office hours. This course generally has an enrollment of about 90 students, which can be challenging in terms of implementing active learning strategies. The sessions were usually broken down into a shorter lecture summarizing the required reading for the day, followed by time for the students to work on practice or graded problems. The Professor would lead the short lectures, with a handful of opportunities for the GTA to lecture. During the latter portion of the class, both the Professor and the GTA would help students one-on-one or in small groups. In addition to teaching material specific to transport phenomena, one of the main purposes of the class and its structure was to teach students rigorous problem solving skills, such as more systematic ways of breaking down complex engineering problems and the types of assumptions that are reasonable. The class was graded based on homework problems, in-class problems, and a set of group open-ended challenge problems. The homework and in-class problems were developed by the professor, and the GTA was involved in the design of the challenge problems, fully writing some of them and developing detailed rubrics for each problem. The Professor saw the GTA more as part of the teaching team, so they would meet after every class to discuss what went well and what could be changed. The class was a great hands-on experience in designing open-ended problems and providing one-on-one help with complex problems. It was a good opportunity to learn how to help students who think through problems differently. However, providing one-on-one help to 90 students is challenging, as some students are more active in asking for help than others.

Generally, we have seen that the professors are open to the additional help and input, so they welcome involvement from a proactive GTA. This is especially true when the suggestions given by the GTA enhance the feedback and grading aspects of the course but do not involve shifting the course structure in significant ways. In courses where the GTA plays a more independent role by holding outside office hours or discussion sections, the professors tend to be more willing to hand over control to the GTA. However, in courses where the GTA plays a more direct role in the regular lecture portion, be it in an active learning setting or a traditional lecture, the professors may be more hesitant to incorporating suggestions from the GTA, not out of distrust but out of concern for maintaining the structure of the class. Overall, though, we have seen that professors respond well to GTAs wanting to be more involved in the class and are open to serving as additional mentors to help the GTAs prepare for the teaching aspect of their careers.

How can I get the most out of a GTA?

- Ask to take on additional responsibility such as course design and lecturing
- Try to get student feedback on your performance as a GTA independent from the instructor(s) for future job applications
- Pay attention to how courses are structured, material is presented, and students are assessed in order to assess pros and cons of different strategies

Co-instruction

An initiative of one of the Deans of Engineering at our university was to create a teaching fellowship funded by the Engineering School. The development of this internship was inspired by the Woodruff School Doctoral Teaching Intern Program in place at the Georgia Institute of Technology (for a detailed review of this program, please see [13]). Students could identify an instructor willing to co-teach a course with them and apply to win the fellowship. The fellowship paid the students' stipends for the semester that they taught. There were also meetings that included past and present fellows and the instructors co-teaching with them. These meetings acted as a forum for discussing what was and was not working and often pedagogical tools as well. The fellow was expected to teach at least half of the classes and to be instrumental in designing the course. In our opinion, this was the "gold standard" because it was practical experience for every part designing and executing a course while still providing the safety net of having an experienced professor as a guide. There were so many little tasks that had to come together to make the course successful and it would be very difficult to gain that type of experience in any way other than doing it. Because the fellows each had a seasoned professor working alongside them, they were not left to struggle but could rely on their mentor to help navigate new territory. There is also an enormous amount of design and organization required for a course to run smoothly that would be difficult to appreciate in any other way. Finally, the chance to teach whole class periods is incredibly valuable since that is exactly what one would have to do as a professor. If such a fellowship is not available, it may still be possible to get the chance to teach by approaching professors, expressing interest in teaching, and asking them for the chance to participate in their class. For example, one professor let one of the authors teach his course while he was out of town. Because engineering doctoral programs are so research-centric, it is often necessary to actively seek out chances to teach. In our experience, professors were willing to help us find ways to get hands-on experience in the classroom.

Professor Perspective

"I implemented the teaching internship program at UVA because in my own experience, my participation in a similar program at Georgia Tech was my single most valuable experience preparing for a successful career as a faculty member. I began my academic career teaching the course I already had experience co-teaching, thus significantly decreasing the time commitment required to demonstrate my teaching abilities while simultaneously establishing my research program. This enabled me to get a good head start on both my teaching and research agendas."

~Dean Pamela Norris who initiated the teaching internship program

How do I get the most out of co-instruction?
• Participate in the course design and implement new teaching strategies
• Document the real life experience for developing your teaching portfolio
• Begin learning to balance the multiple demands on time of faculty, including responding to students needs

Participation in Education Research and Education-based Conferences

Becoming a quality educator often necessitates some learning by trial and error. Through implementation of new and creative approaches to active learning, one is able to see what it successful and what is not. While there will probably always be a fair amount of failing involved in the process, it is extremely helpful to see where others have been successful. Education-based conferences, such as the American Society for Engineering Education (ASEE) annual conference, allow students to learn about the field of engineering education as a whole and see the results of other teachers' attempts to improve learning. It opened our eyes to many possibilities for teaching that we gladly brought back to our own classrooms. It was also a chance to be surrounded by teachers who are passionate about bringing the best educational experience to their students and to engage in meaningful conversations with them. After attending the ASEE annual conference, one of the authors was inspired to conduct her own education research, by designing a study that looked at the effectiveness of a new system of worksheet-based active learning [14]. Designing metrics from the outset that would test the value of these techniques provided for more objective conclusions and enhanced the author's reflection. Interestingly, one of the hardest parts of the process was finding a way to explain the purpose of the research to the students such that they did not feel like guinea pigs. Therefore, we learned that it is absolutely essential to be thoughtful when designing an education-based study that will involve students taking a course and to be intentional in one's explanation of the purpose and benefit. Overall, it was an exciting and rewarding experience to try out new techniques, assess their efficacy, and share that with a broad audience to hopefully contribute to the educational experience of students at other colleges and universities.

How can I make the most out of participation in education-based conferences or workshops?
• Gain an overall view of other teaching and pedagogy research
• Conduct your own education research
• Volunteer for a position or to be a reviewer

In-lab mentorship

Teaching experience can also be gained through one-on-one mentorship of undergraduate students or even new graduate students. While not as structured as classroom-based teaching, in-lab mentorship still provides a great platform for developing teaching skills, both in terms of guiding students through more deeply involved research topics and teaching them hands-on lab techniques. Often, undergraduate students have not had any research experience; however, those who choose to pursue research are interested in going deeper into the science, so they are very willing to accept

Professor Perspective

“I'm an Associate Professor in the Department of Engineering and Physics at Elizabethtown College, a small liberal-arts college in southeastern Pennsylvania. I obtained my Ph.D. from the University of Notre Dame, in South Bend, Indiana. Teaching in my department has been a very positive and interesting experience, in that it's relatively uncommon to find ABET-accredited engineering programs housed within small liberal arts colleges. As one might expect from such a setting, teaching is prioritized very highly in terms of expectations for faculty and in tenure and promotion decision. I believe my teaching experiences as a graduate student helped prepared me very well for my role as a faculty member.

“Like many institutions, Notre Dame offered opportunities for graduate students seeking to improve their teaching abilities or simply expand their teaching portfolio prior to seeking a full-time faculty position. My first experiences involved being a teaching assistant for an electronics laboratory course. I was in charge of grading lab reports and of assisting students while they did their experiments. While this may not be considered a particularly "glamorous" role, it prepared me for issuing feedback and help to students quickly, thinking on my feet, and not getting frazzled when many students needed my help at once. Later I had the opportunity to be a teaching assistant for an upper-level control systems course. I sat in on the theory portion of the class, ran the lab section, and provided tutorial and after-hours help for students needing assistance with homework or preparing for exams. I made the most of this opportunity by going above and beyond the usual expectations for graduate students, and, not only did I gain a lot of experience, but I was rewarded with the Graduate Instructor of the Year award for my work. Additionally, this experience made it clear to me that I would much prefer seeking full-time employment at an institution where my duties would focus on the teaching aspect: while working on my dissertation research was interesting, teaching gave me an unparalleled sense of fulfillment.

“Beyond these fairly traditional roles for graduate students, Notre Dame offered a number of workshops through their Kaneb Center for Teaching and Learning. Attending these workshops was not mandatory, but in my experience they were definitely helpful in providing a theoretical foundation for what I would carry out in practice. During my years as a graduate student, Notre Dame also pioneered the First Year Engineering Teaching Apprenticeship Program. Through this program, a select group of graduate students would be instructors for a Learning Center section of a first-year engineering course, collaboratively working with more experienced instructors in matters of pedagogy and instruction.

“The greatest challenge I faced through this experience was the balance between teaching and research. I am fortunate to say that I have always been a "natural" at teaching, in that I feel very comfortable both presenting challenging material in front of a large group of students and mentoring students in small groups or one-on-one. However, because I was so passionate about improving my teaching, I would sometimes prioritize my teaching duties over research deadlines for my dissertation, which would then increase my stress level associated with that process. On the other hand, experiencing this tension or need for balance as a graduate student helped prepare me for my role as a professor, in that the need to manage one's time effectively (so as to meet or exceed expectations in teaching, research, and service) continues to be an integral part of the success of any faculty member.”

~Dr. Tomás Estrada, Elizabethtown College associate professor

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challenges. From the point of view of the graduate student, there are several potential responsibilities: teaching lab techniques and overseeing the undergraduate student, teaching the basic concepts behind most of the work in the lab, holding regular meetings to discuss the progress of the project, and often developing an appropriately complex project in the first place. This type of instruction can be especially challenging, because the student may not have taken enough courses to have a full foundation for the research project. Therefore, it is the graduate student mentor's responsibility to distill down the background in a way that will help the student develop the foundational knowledge at a pace that will be productive and not overwhelming. The mentor thus has to design smaller lessons to be taught throughout the duration of the project that will provide the student with enough information to understand the purpose of the work without detracting from the time spent developing the skills necessary to do the project.

Additionally, the mentor will need to demonstrate practical skills in a way that will make them straightforward to replicate and develop practice activities that accurately assess how well the student is learning the skills. The mentor should hold regular meetings with the student to check in on how the project progresses and to answer questions the student may have. These one-on-one meetings provide an opportunity to teach students about science communication, from the basic steps of how to explain the project in person and how to ask questions for efficiently troubleshooting problems, to writing about the science and creating presentations for larger audiences. Finally, the mentor often has the opportunity to practice project design skills when working with undergraduate students. Depending on the student's background when they begin the work, the complexity and specific goals of the project can be very different. The mentor, usually with the help of their PI, will have to design a project that has specific goals appropriate to the student's current level of knowledge but still provides a challenging research question that will help the student develop as a scientist. While inherently less structured than other styles of teaching, one-on-one mentoring in a lab can provide a great platform for graduate students to further develop their pedagogical skills.

How can I get the most out of being an in-lab mentor?
• Break down complicated scientific concepts to make them understandable to a student
• Figure out how to train newer scientists, which is also a responsibility of PIs
• Actively try to make connections between the in-lab mentorship and teaching skills

Conclusions

Engineering Ph.D. programs may be specifically designed with research rather than teaching in mind, but that does not preclude students from gaining meaningful teaching experience to prepare them for a career in academia. Professor preparatory programs are increasingly being offered at colleges and universities, which focus on rounding out the training of graduate students to include teaching and professional development. GTA positions come in many different forms, but each includes opportunity to grow as a teacher and this can often be enhanced by expressing an interest in teaching and asking for more responsibility from the lead professor. Co-instruction of courses gives hands-on experience to teaching and, importantly, course design while still under the guidance of an experienced professor. Education research and education-based conferences provide a critical forum for disseminating successful teaching strategies and gathering together educators passionate about enhancing student learning. In-lab mentorship is an often over-looked graduate student experience with many teaching opportunities that could easily translate to the classroom. The strategies

discussed in this paper can also be enhanced by seeking further engagement in educational communities and movements, such as SoTL. Also, in preparing for future faculty job applications, graduate students who seek to pursue a career in academia can begin to develop their teaching portfolio, including the details of their reflective teaching statement, using the skills and experiences gained from strategies discussed in this paper. Active participation in activities that further pedagogical training and reflection on how these experiences will influence their future teaching endeavors as faculty members can give graduate students the opportunity to better prepare for the faculty job search by beginning to build their applications early in their careers. Through the aforementioned ways and more, engineering graduate students can start preparing for the teaching aspect of a future career in academia.

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