FOCUS: EDUCATION — CAREER ADVICE

The Bench vs. The Blackboard: Learning to Teach During Graduate School

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Many science, technology, engineering, and mathematics (STEM†) graduate students travel through the academic career pipeline without ever learning how to teach effectively, an oversight that negatively affects the quality of undergraduate science education and cheats trainees of valuable professional development. This article argues that all STEM graduate students and postdoctoral fellows should undergo training in teaching to strengthen their resumes, polish their oral presentation skills, and improve STEM teaching at the undergraduate level. Though this may seem like a large undertaking, the author outlines a three-step process that allows busy scientists to fit pedagogical training into their research schedules in order to make a significant investment both in their academic career and in the continuing improvement of science education.

Imagine you are a new professor of biology at a large research university addressing a lecture hall of introductory biology students on the first day of class. You have arrived at this lectern after a marathon of education: four years of college, from which you graduated with top marks; six years of graduate school, during which you published several papers in prestigious journals; and four years of a competitive yet successful postdoctoral fellowship. Thanks to your extensive scientific training, you are an expert in your field who is adept in hypothesis generation and experimental design. In short, you are an excellent young scientist. However, as you begin your very first lecture, facing an auditorium of eager undergraduates, you realize that you are unqualified to teach a science course.

This not so far-fetched scenario raises two questions. First, how could someone who has completed more than a decade of

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†Abbreviations: STEM, science, technology, engineering, and mathematics; GTC, Graduate Teaching Center at Yale; CRLT, Center for Research on Learning and Teaching at University of Michigan; TA, teaching assistant.

Keywords: science education, job training
advanced education in order to become a college professor be unprepared to teach? The likely answer is that very little of that decade was spent thinking about the classroom or lecture hall. Many scientists believe teaching of any kind to be a “zero-sum” activity that detracts from the cutting-edge research that provides them with grants and recognition [1]. Subsequently, the graduate students and postdoctoral fellows who work in the labs of these scientists absorb such views [2] and choose to focus solely on research in the pursuit of an academic career that nonetheless includes teaching responsibilities. These attitudes result in the paradox described in the first paragraph: excellent professors who are not excellent teachers.

The second question is: Why should the professor described in the first paragraph need to be formally trained as a teacher? After all, he or she is familiar with the material to be taught and has been successful in the research world, which requires proficient oral and written communication skills. One might assume that such a person would deliver an adequate lecture to a group of students. However, those who have received undergraduate degrees in the sciences know that this is not always the case. A current science, technology, engineering, and mathematics (STEM) graduate student recalled a famous professor at a large research university who “was entirely unable to explain a complicated concept to an audience of college students because he couldn’t acknowledge that we weren’t also career scientists.” Another student, who studied at a prestigious college, noted that her undergraduate organic chemistry courses were uninspiring as they were “completely geared toward memorization” rather than understanding. Though anecdotal, these examples are supported by educational studies, discussed in detail later, that identified pedagogical shortcomings in college level science courses. Simply put, an expertise in research does not always translate to an expertise in teaching.

The reality is that many students go through the academic career pipeline without ever learning how to teach effectively, resulting in inconsistent qualities of STEM education at the undergraduate level. To foster better science education and improve their own presentation abilities, all current graduate students or postdoctoral fellows who have their eye on an academic job should receive training and experience in teaching, which should ideally include the opportunity to develop and evaluate their own teaching style. While this may seem like a large undertaking, this article explains how teacher development can be incorporated into a busy research schedule.

THE GRADUATE SCHOOL PARADOX

STEM PhD programs at American graduate schools specialize in producing research scientists who can think critically, work independently, and solve problems creatively. Although this is an attractive skill set for many professions, the acknowledged purpose of many STEM graduate programs is to prepare students for jobs in academic research — a career goal for the majority of STEM graduate students and postdoctoral fellows [3]. An academic job consists of writing research grants, running an independent laboratory, and publishing papers in scientific journals. Because most universities also require that research professors teach one or more undergraduate course per year, academic jobs almost always include teaching responsibilities.

That graduate students are both trained for and pushed toward academic jobs while remaining unprepared for a key aspect of these jobs results in “the graduate school paradox.” STEM programs themselves usually do not offer formal or informal training in teaching, and any requirements for teaching often are viewed as a chore rather than a learning opportunity. A current STEM postdoctoral fellow recalls that his graduate advisor once sympathetically referred to his teaching assistant position as an “annoyance,” failing to understand how much he enjoyed and valued teaching. But while degree programs may not offer teacher preparation, many universities boast excellent teaching centers that provide offerings such as semi-
ners on course design and classroom observation services. Unfortunately, many STEM students do not take full advantage of the services provided, citing time constraints due to lab work or perceiving teaching to be more important for humanities graduate students. Overall, the STEM graduate experience is one that rightly emphasizes research while wrongly neglecting teaching.

This oversight contributes to the substandard STEM education at the undergraduate level described earlier. In their seminal study on the attrition of STEM college students, Seymour and Hewitt noted that approximately half of the hundreds of students they surveyed had switched out of their STEM programs by their senior year of college and that many of these “switchers” cited shoddy teaching as a major factor in their switch [4], findings that were replicated in several other studies [5,6,7]. Although some have argued that mediocre undergraduate education is a form of “benign neglect” that allows strong students to enter the academic pipeline while filtering out weaker candidates [1], it succeeds only in discouraging and excluding under-prepared yet talented students. Furthermore, poor undergraduate science education may alienate those who will go on to become policy makers and voters. For example, people who have fond memories of their required science courses and have a proficient understanding of research are more likely to support increases in scientific funding. Therefore, improved science teaching would likely benefit the research community as well as the community at large.

It also should be stated here that there is an additional “graduate school paradox.” As mentioned, graduate programs strive to produce scientists who will go on to seek academic jobs, a goal shared by the majority of graduate students and postdoctoral fellows. However, recent reports have identified a growing crisis in the PhD system precipitated by an increase in academic job candidates but no equivalent increase in academic jobs [8,9]. Graduate schools are preparing students for jobs that are simply more and more difficult to obtain, a growing problem that may require a complete overhaul of the current academic pipeline [10]. To land an academic job, current graduate students and postdoctoral fellows must not only have more publications than ever before but must also highlight attributes that will make them stand out to hiring committees. Training in science education may increase the competitiveness of a job candidate. Although most current STEM faculty admit that they would favor a candidate with only a strong research background over one with only strong teaching skills [1], a strong publication record married to a demonstrated interest in science education could suggest to hiring committees that an applicant has even more to offer a university than his or her excellent research skills. Learning to teach can therefore benefit one’s resume as much as it can benefit the scientific community.

HOW TO LEARN TO TEACH (WITHOUT NEGLECTING THE BENCH)

The first sections of this article have argued that learning to teach as a STEM graduate student can provide benefits for science education, the scientific community, and the job search. However, like any worthwhile pursuit, teacher preparation takes time, and most graduate students are saddled with lengthy and complicated experiments, lab meetings and department seminars, stacks of research literature to read, and family and social obligations, not to mention eating and sleeping. Graduate students are busy people. Is it possible to fit in an additional responsibility without sacrificing the primary undertaking of research? Can graduate students focus on teaching while avoiding the zero-sum effect [1] described by current scientists?

The remainder of the article outlines a three-step process by which graduate students can develop their teaching abilities on their own terms and by their own timetable. The first step is to work on improving oral presentation skills, which can be achieved parallel with research responsibilities by evaluating lab meetings and seminars and reflecting on one’s own presentations. If this step alone is completed, it will contribute
greatly to future teaching endeavors and directly benefit a research career, which relies on excellent presentation ability. Furthermore, since this step can be completed within the laboratory and conference room, it need not conflict with research. The second step is to seek out formal training through on-campus teaching centers or Internet resources, which represent more of a time commitment but can still be scheduled into most research work days. The final step is to practice teaching in university or K-12 classrooms in order to evaluate and experiment with various teaching techniques. Using these steps as a guide, graduate students or postdoctoral fellows can make an investment in their careers by developing an effective and unique teaching style.

**Step 1: Development of effective oral presentation**

Shouldn’t PhD candidates at prestigious universities already know how to give confident and effective talks? After all, a significant part of graduate education is presenting data at informal lab meetings as well as department- or college-wide seminars. However, many graduate students never seek out formal instruction on presentation and subsequently do not learn how to introduce and summarize key points, use repetition, and structure their talks in order to effectively communicate to their audience. Furthermore, many students do not receive adequate feedback and may not recognize a problem, resulting in the confused and substandard talks often delivered by senior graduate students, postdoctoral fellows, or even tenured professors. Development of effective oral presentation skills, therefore, is beneficial both for teaching ability as well as one’s research career. Scientists who can effectively and elegantly communicate their data gain more esteem from peers (or hiring committees) and spark increased interest in their work as audiences can fully understand and appreciate what they are presenting.

For these reasons, each and every graduate student, even those who plan to avoid teaching responsibilities in their career or enter a non-academic job pathway, should work to develop their oral presentation skills. Conveniently, this ability can be honed in the laboratory setting and contributes to, rather than detracts from, research responsibilities.

Begin by paying close attention during lab meetings and research talks. Which talks are the easiest to understand and the most engaging? Think about what the presenters did: how they structured the talk, set up new ideas or experiments for the audience, and summarized sets of data. Then, apply these ideas to your own talks. Conversely, take notice of poor presenters. What makes a presentation confusing or boring? Identify negative attributes such as weak organization or sparse explanation and take measures to avoid these. Even the simple acts of reflecting and evaluating can result in significant improvements in oral presentation.

Continue your development by seeking feedback. Start by analyzing the questions you are asked during and after a lab meeting or research talk. For example, are you asked to clarify experimental details that you had previously described? This may suggest that your explanation of experiments is vague or it is not clearly linked to resultant data, causing confusion in your audience. Direct feedback is also helpful. Discuss your presentations with colleagues and your advisor, focusing on clarity and organization. Often, more senior lab members and principal investigators are expert in delivering research talks and can provide advice from their own experiences. However, getting feedback from any audience member can be helpful since it allows you to perceive your presentation from the viewer’s perspective and make any necessary changes.

Planning the organization of a lecture, emphasizing key concepts and explaining them effectively, and speaking engagingly are important skills for scientists presenting their data and for teachers instructing a class. Because the built-in responsibilities of a graduate student (attending and presenting research seminars and lab meetings) offer multiple opportunities for improvement, all graduate students can work to improve their oral presentation skills in order to benefit their research and teaching.
Step 2: Formal training

There are concepts important to teaching that cannot be gained within the confines of a laboratory. Once a graduate student feels confident speaking to a class, he or she may also want to develop more classroom-specific skills, such as course design, exam writing, and grading. As mentioned, many universities, including the University of Michigan, University of Florida, Washington University in St. Louis, and Yale University, have dedicated teaching centers that offer workshops and seminars on teaching topics and provide services such as classroom observations. For example, the Graduate Teaching Center (GTC) at Yale conducts a series of seminars, each lasting an hour and a half, that cover topics such as generating course goals and writing syllabi, and the University of Michigan’s Center for Research on Learning and Teaching (CRLT) offers two-hour seminars on teaching strategies for the STEM disciplines. These courses offer the opportunity for significant development in teaching ability without a significant time commitment.

For even more personalized attention and in-depth training, teaching centers often provide services such as classroom observation, in which a trained member of the teaching center staff sits in on a teacher’s course and provides individualized feedback or offers teaching consultations to discuss teaching strategies and effectiveness. These unique opportunities provide much needed feedback and fresh ideas to help an academic hopeful continue to polish his or her teaching skills.

While not all universities have teaching centers, graduate students can seek out a multitude of Internet resources. For example, both the GTC at Yale and the University of Michigan CRLT offer teaching modules and resources through their websites [11,12], which can be accessed from anywhere, by anyone, and used to replace or supplement the courses that would be offered through a brick-and-mortar teaching center. Additionally, students who find it too difficult to schedule time for teaching seminars can use these resources during downtime in the laboratory. Overall, teaching centers provide excellent, easily accessible opportunities for teacher development to graduate students.

Step 3: Practice and experiment

The most effective way to improve and develop your teaching is to actually teach. Most STEM graduate students work as a teaching assistant (TA) for one or more courses. Although some TA positions may involve only grading or exam proctoring, most TA experiences involve holding discussion sections, which are meant to complement lecture sections by providing a review of key points and additional detail on specific concepts. This makes the discussion section a unique opportunity for a TA to practice lecturing using his or her well-developed oral presentation skills (Step 1). Seek out TA opportunities that include discussion section responsibilities and carefully plan your review lectures, applying strategies you have learned from delivering research talks and from attending teaching center seminars. By soliciting feedback from students (either through anonymous paper forms or online surveys), you can evaluate how effective your lecture style is and identify deficiencies in your teaching. TA opportunities are a great way to start teaching.

In addition, discussion sections are perfect laboratories to experiment with different teaching styles or strategies. For example, active learning, in which students are expected to participate in planned class activities, rather than passively absorb lectures, has been lauded as a teaching method that improves student understanding and retention [13]. Design an active classroom activity focused on a key concept and try it out on your discussion section, then assess the students’ understanding and solicit feedback about whether they found this activity helpful. By reading education research journals such as CBE Life Sciences Education or the Journal of Engineering Education, you can discover various teaching methods that have been scientifically tested for efficacy and subsequently implement them in your own classes; the informal atmosphere of discussion sections makes them ideal for this sort of experimentation.
Overall, working as a TA during graduate school is an excellent start to a successful academic career, as it allows for teaching practice and experimentation. However, working as a TA can be extremely time-intensive, requiring attendance at lectures and discussion sections, hours of class preparation, grading, and office hours with students. Although graduate students simply cannot spare the time to teach more than one or two semester-long courses during their graduate careers, less demanding teaching experiences may be found through volunteering. For example, due to partnerships between universities and local schools, graduate students and postdoctoral fellows are often invited to assist groups of middle or high school students with their science fair projects. Participation in these programs usually takes up less time than working as a TA while still providing a meaningful teaching opportunity and a noteworthy community service. Similarly, graduate students should try to avoid TA assignments that require grading or exam proctoring only, as these experiences tend to sap time away from lab without providing opportunities for teacher development — a true zero-sum activity.

Although Step 3 is the most challenging and time-consuming segment of the proposed process, gaining hands-on experience in teaching is the best way to test and evaluate one’s abilities and to refine one’s teaching style.

CONCLUSIONS

Because of its considerable benefits for both future teachers and future students, teacher preparation should be more of a priority for STEM graduate programs. It helps scientists improve or refine their presentation skills and ensures that future generations of STEM students will be well taught and inspired by the sciences. However, the reality is that STEM graduate programs and research mentors often de-emphasize teaching, a complicated problem that may not be overcome in the near future. Therefore, the most effective way to improve STEM undergraduate education is for current graduate students to become excellent teachers on their own initiative by following one or more of the steps proposed in this article.

Imagine again that you are a new professor of biology at a large research university, addressing a lecture hall of introductory biology students on the first day of class. You are a talented researcher, due to your years of scientific training, but you are also a skilled and thoughtful teacher, thanks to the commitment that you made to teacher preparation as a graduate student. Your carefully developed teaching style benefits your students, who enjoy your course so much that they are inspired to pursue STEM careers or become scientifically literate citizens, and it also benefits your research, as you can deliver an engaging and clear scientific talk to your peers thanks to your well-honed oral presentation skills. Due to the well-considered investments in teaching that you made during your graduate studies, you are qualified to be an excellent science educator.

REFERENCES

1. Savkar V, Lokere J. Time to Decide: The Ambivalence of the World of Science Toward Education. Nature Education [Internet]. 2010 Apr Available from http://i.zdnet.com/blogs/time-to-decide-nature-education-report-1.pdf.
2. Kelman HC. Interests, relationship, identities: Three central issues for individuals and groups in negotiating their social environment. Annu Rev Psychol. 2006;57;1-26.
3. Roach M, Sauermann H. A taste for science? Ph.D. scientists academic orientation and self-selection into research careers in industry. Research Policy. 2010;39(3):422-34.
4. Seymour E, Hewitt N. Talking About Leaving: Why Undergraduates Leave the Sciences. Boulder, CO: Westview Press; 1997.
5. Rayman P, Brett B. Women Science Majors: What Makes a Difference in Persistence after Graduation? The Journal of Higher Education. 1995;66(4);388-414.
6. Seymour E. The loss of women from science, mathematics, and engineering undergraduate majors: An explanatory account. Science Education. 1995;79(4);437-73.
7. Kardash CAM, Wallace ML. The Perceptions of Science Classes Survey: What undergraduate science reform efforts really need to address. Journal of Educational Psychology. 2001;93(1);199-210.
8. Cyranoski D, Gilbert N, Ledford H. Education: The Ph.D. Factory. Nature. 2011;472:276-9.
9. Taylor M. Reform the Ph.D. system or close it down. Nature. 2011;472:261.
10. Fix the Ph.D. Nature. 2011;472:259-60.
11. Yale Graduate Teaching Center [Internet]. c2011. Available from: http://www.yale.edu/graduateschool/teaching/modules.html
12. University of Michigan Center for Research on Teaching and Learning and Teaching [Internet]. c2010. Available from: http://www.crlt.umich.edu/tstrategies/teachings.php
13. Handelsman J, Ebert-May D, Beichner R, Bruns P, Chang A, DeHaan R, et al. Scientific Teaching. Science. 2004;304(5670):521-2.