

Reforming Graduate Science Education: Start in the Classroom

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In his *New York Times* op-ed, Mark Taylor makes some radical suggestions for reforming graduate education. Taylor's suggestions include a restructuring of the graduate and undergraduate curricula to make it "cross-disciplinary and cross-cultural," "abolish[ing] permanent departments ... and creat[ing] problem-focused programs," "expand[ing] the range of professional options for graduate students," and imposing mandatory retirement and abolishing tenure in order to retain researchers and teachers who "continue to evolve and remain productive."

All of these reforms require one key element to make them work: high quality and creative teaching. Unfortunately, great teaching is not a top priority in many graduate science programs, where the emphasis is instead on top-notch research and the big grant funding that it brings in. Before dismantling departments and completely restructuring curricula, we need to make sure that we have great teachers and mentors who can engage, excite, and inspire students. So I present a different set of proposals from Taylor's.

Preparing Experts in Science Pedagogy

Inspired classroom instruction and diligent mentoring equip students with the skills to think critically and design creative solutions to problems. However, university teaching in the sciences is of variable quality. In a study of why undergraduate students switch out of science majors, 90% of students who switched cited poor teaching as a common concern (Seymour 1995, 200). This is not because of a lack of effort by researchers, but a lack of preparedness. Most faculty members learn to teach on the job. Teaching requirements for science graduate students are often minimal and do not afford a real opportunity to learn about pedagogy. Other critical skills for future faculty, like mentoring, are also learned on the job. Training our graduate students to be competent teachers, mentors, and managers will not only prepare future professors for these demands, but will also prepare graduate students for jobs outside of academia, as these are skills that improve performance in many different professional arenas.

Excellence in teaching and mentoring requires faculty members dedicated to science teaching—people who will put as much thought and effort into their classroom as their laboratory. Because so many of the current faculty were not trained for these skills and may not enjoy teaching, a solution is to create more positions for full-faculty scientist-teachers. Creating such positions would free researchers up to spend more time managing their labs and so would lead to more grant money. These teaching specialists could also team up with science research faculty to create innovative courses that emphasize both cutting-edge research and pedagogy. Grants are gradually becoming available for scholars of science education, so teaching faculty could be expected to bring in some of their own funding. These positions need to be developed, and there need to be postdoctoral fellowships where Ph.D. bench scientists can gain the necessary skills to fill them.

Hiring teaching faculty would also bring progress in the use of new pedagogy. We all know that computerized slide presentation programs, like Powerpoint, have become the standard format in the science lecture hall. Yet educational research shows that students learn best when engaged in active learning and that passive formats like a traditional slide lecture leave most students disengaged after only fifteen minutes (McKeachie and Svinicki, 2005). There are responsible ways of introducing new technology into the classroom, but this should always be done with an effort to assess the benefits to teaching and learning.

Creating courses available for distance learners is a necessity at the modern university, but designing effective curricula for courses where the students and professors are not even in the same classroom presents a whole new set of challenges. Taylor suggests that different universities collaborate to teach courses, allowing universities to eliminate staff in a subject area and rely on faculty members from another institution to teach those classes via the internet. However, effective instruction in these cyber-classrooms requires educational specialists who can teach faculty to optimize the use of these educational technologies so that they actually result in a well-educated student. This requires rigorous research into the use and content-specific applications of these technologies and their effects on the quality of teaching and the improvement of student understanding. Such rigorous research requires a path for Ph.D.s to become further trained as educators and education researchers.

Whereas Taylor suggests tying different universities together, it appears that science graduate students would benefit instead from training from other schools within the university. Joint degree programs in science and education

would create a training path for scientist educators. Such programs would not only prepare scholars for the demands of thoughtful and well-executed university teaching, but would also prepare Ph.D.s to go on to teaching at other levels. The variable quality of science education in K-12 schools has been a pressing issue garnering national attention (Committee on Prospering in the Global Economy, 2007). Although many science Ph.D.s might like to go on to K-12 teaching, the hurdle of pursuing another expensive degree is difficult to overcome. Business consulting is a popular career interest for new science Ph.D.s, not only because of the salaries, but because the path is obvious. Recruiters come to campus and make the opportunities known and clear. Becoming an educator in the sciences, especially in K-12, where science and math teachers are in such high need, is a much murkier career path.

Preparing Students for the Job Market

Taylor correctly claims that “most graduate students will never hold the kind of job for which they are being trained.” In the sciences, there are too many graduate students and too few academic positions. Taylor’s proposal is to help prepare students for work in fields other than higher education. This fix sounds sensible enough, but how do we train graduate students for these other kinds of jobs?

Opportunities for science Ph.D. candidates to seek another degree concurrently, such as an MBA or M.A. in public health, would help prepare graduate students for diverse careers. Many medical schools offer such joint degrees. These sorts of practical training opportunities should exist for science graduate students as well.

Many science Ph.D.s are going on to diverse jobs, such as industry, biotechnology, engineering, patent law, business consulting, and teaching. These are not alternative careers; by numbers, the academic job is the alternative career. However, often it is a struggle for students to identify non-academic opportunities and figure out how to transition into them. In part, this is because many faculty members of graduate programs still regard careers outside of academic research as second best, the jobs for graduates who can’t hack the academic route of bench science research. It is therefore no wonder that many students feel reluctant to discuss these other options with their advisors. The culture of graduate departments in the sciences needs to change to reflect the reality of the job market. Advisors need to be dynamic mentors and recognize their students’ particular strengths that will serve them in any future career.

Strengthening Interdisciplinary Science Education

Preparing scientists for the future also requires training flexible interdisciplinary scientists who will be able to respond not only to the changing marketplace, but to the changing world and the host of known and unknown problems that scientists will encounter in the future. Anticipating Taylor's example of a Program in Water which would bring together scholars from diverse disciplines, graduate programs in the sciences are reforming to be more interdisciplinary. This is necessary because, as modern scientific knowledge is so broad, no one person can be an expert in all of it. Programs in the mind and brain bring together neuroscientists, psychologists, computer programmers, and philosophers. Programs in cancer biology bring together molecular biologists, virologists, structural biologists, cell biologists, and biophysicists. Programs in synthetic biology bring together microbiologists, botanists, molecular biologists, engineers, and physicists. These types of consortia are those likeliest to come up with the solutions to the most pressing problems that we encounter today, and to those problems of the future that we can't even imagine.

What is typically missing from these interdisciplinary science programs, however, is a link to the humanities. With rare exception, these programs do not enlist faculty from political science, religion, or the languages. Unfortunately, the sciences are often geographically displaced from the humanities on the university campus. The challenges of the future, like water shortages, climate change, pandemic illnesses, and mass extinctions, will require creative scholars to devise solutions. Scientific knowledge alone won't be enough to deal with the range of ethical, political, and economic issues, and it will take the synergy of people with diverse expertise to create novel solutions. The typical university-sponsored colloquia on these interdisciplinary problems encourage faculty from various departments to come together, yet often for just a day, after which any momentum is lost. Yet dismantling traditional departments, as Taylor suggests, seems like too radical a solution. Instead, universities should first make a genuine effort to develop interdisciplinary courses that bring together faculty from diverse departments to teach approaches to modern problems. Such courses would foster longer-term collaborations between faculty with far-ranging specialties and encourage students to broaden their thinking to fields outside of their own. Yet effective instruction in these types of cross-disciplinary courses requires dedicated and creative teachers willing to put in the time and energy to learn new material, coordinate with faculty outside of their discipline, and create effective new curricula.

Unlike in the European schools that many modern American universities were modeled after, our students are not tracked for science before university. Moreover, most undergraduate science majors in the U.S. take a smattering of science classes in biology, chemistry, and physics, in addition to classes in their specific major. The upshot is that incoming science graduate students have diverse backgrounds with very varied knowledge of the basic sciences, and often their prior success in the lab is more important in the admission decision than their undergraduate coursework. Nonetheless, the quality and amount of preliminary course work that is required of incoming graduate students in the sciences vary wildly among programs. The nature of the problems that new scientists will face means, however, that they need some fluency in diverse scientific disciplines. Therefore, programs should offer core coursework to make sure that all graduate students have some graduate-level interdisciplinary science education before specializing in their small subfield. Offering such courses would require bringing together experts in various fields who may not be well versed in pedagogy. It makes sense to think, then, that faculty specializing in the art and research of teaching and learning should be called upon to help facilitate the development of these courses.

Retaining Excellent Teachers and Mentors

Taylor suggests abolishing tenure to encourage researchers and teachers to continue to “evolve and remain productive.” Whether tenure is retained or replaced by multi-year contracts, retention decisions should seriously take into account the teaching and mentoring contributions of teaching and research faculty members. It is a myth that a course can be perfected and then presented each year without modifications. Content and students change, and the instruction and curriculum must adapt with them; this is especially true in the sciences. For faculty members to be consistently excellent teachers requires constant work and attention. Although teaching is often critical for tenure decisions at smaller colleges, many big universities do not really consider teaching in science faculty tenure decisions. Teaching excellence might be one category in the tenure decisions, but most tenure committee members will readily admit that profitable research trumps bad teaching any day. Having faculty lines for scientist-teachers would allow for retention decisions to be made on excellence in teaching or research.

Universities are centers for the creation of new knowledge, and much of their support comes from grants; therefore the emphasis on high-quality fundable research makes sense. However, universities are not just research

institutes; they are educational institutions. They have a duty to prepare their students with the intellectual and practical skills that will lead to success in research and in their careers. Employment in the present and future job market requires more specialized training, and thus the university is not at risk of losing its consumers. For universities to remain competitive requires that they educate well-prepared graduates. This means that exceptional teaching and mentoring need to be as much a priority as high quality research.

In sum, Taylor suggests that universities restructure by eliminating departments in favor of interdisciplinary programs, increasing collaboration between universities in order to teach more classes with less staff, increasing professional development programming for graduate students to better prepare them for the job market, and eliminating tenure in favor of multi-year contracts to retain productive teachers and researchers. These are undoubtedly a bold collection of structural reforms. Yet in graduate science education, it is just as bold to focus on reforming the basics: outstanding teaching and mentoring.

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