A Multi-Pronged Approach to Preparing Science Professionals for the Future

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Most university faculty members in the sciences and engineering disciplines believe that we prepare our students for employment in industry, not just for life in the 'ivory tower' world of academia. Traditionally, Ph.D.s in these fields are trained (and trained well) to function in a single-field environment: chemists trained to be chemists, engineers trained to be engineers, as if all students aspire to be faculty members. Traditional graduate research training in chemistry has largely been limited to the academic disciplinary context, with little exposure to how chemical research is conducted in industry. Chemical engineering students generally lack sufficient industrial experience to effectively use their research results in product development efforts.

The manager of business development for a chemical research firm told me recently that new Ph.D.s who enter his company are expected to work in teams, to manage projects (including Gantt charts, accounting, and budgeting), and to understand how all phases of a multidisciplinary project interact with each other. A vice president for technology at another major company has stated that in his experience it takes new hires (chemistry students as well as chemical engineering students) 2 -3 years before they are productive in the industrial R&D environment. Comments like these suggest that traditional graduate education does not always provide effective bridges from knowledge acquisition (classes) through research (learning methods and scientific inquiry) to practice in the real world. This problem results in part from a lack of awareness of the industrial environment on the part of faculty, as relatively few of us have worked in the chemical industry. The problem may be compounded by a lack of collaborative research projects that bridge the gap between academic labs and industrial labs. It appears that better-prepared chemists would be pseudo-chemical engineers, and better-prepared chemical engineers would be pseudo-chemists.

As part of Re-envisioning the Ph.D., a study by the University of Washington and funded by the Pew Charitable Trust, stakeholders in graduate education were asked for their concerns over the state of Ph.D. training in the U.S. Not surprisingly, business and industry leaders call for more 'context' within Ph.D. training. They decry the faculty's focus on "creating more of themselves" and on an unhealthy disconnection from the 'real world.' A representative comment from this study was:

"We would never make a plea for the fact that somehow the substance or specialty of a Ph.D. should be diminished. It is a call simply for some stimulus for students to contextualize their work, so that they are more adept at connecting it to the real world where they are obliged to operate in an environment other than the academy. There they can indulge this disconnectedness to their hearts' content. But there's no place else in the world that they can. So the rest of us are saying, 'Well, it's no help if you can't connect.'"

This issue of raising students who are deep in their field but disconnected from the world is not a trivial issue for the U.S. While new graduates take jobs in industry and national labs and develop into productive members of groups, the ramp-up time comes at a significant cost. There are obvious financial issues for the employer, but more important is the cost of lost imagination, creativity, and energy. The graduate and early career years are often the years when people are at their most creative and energetic, and we see that much of that time is lost to training new Ph.D.s to 'connect' to the real world. Graduate education in the U.S. is superb at training experts in academic disciplines, including chemistry and engineering. It is not clear that we do as good a job at training professional chemists or engineers.

Preparing Future Faculty (PFF) programs are well-established all over the country. There are few programs in Preparing Future Science and Engineering professionals. Typically, existing university programs for "Preparing Future Professionals" consist of resume preparation workshops and job searching skills. This focus is reasonable for a university-wide initiative, where the array of non-academic careers is so broad that a PFF-style program, one designed to serve all Ph.D. programs in a university. Such a program can't possibly address specifics for Ph.D. students in chemistry or chemical engineering as well as for students in non-technical fields such as English or history. As a result, there are few established programs that offer science graduate students the practical training that will help them be more than disciplinary experts upon graduation.

The UK Center for Applied Energy Research (CAER) creates an environment where students can perform research where they are not disconnected from the real world context. This enables them to:

- develop connections between academic-style research training and industrial research practice;
- participate in graduate education where Ph.D. students learn how potential commercial applica-

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tions can cue the pursuit of basic scientific questions, and how the answers to those questions are then put into practice;
- engage in graduate education in chemistry and chemical engineering that better prepares students with the skills needed to meet the expectations of chemical industry, through course work and research;
- take advantage of opportunities for active research in industry, defense, or national laboratory settings prior to transition to career positions; and
- use this integrated research environment to discover and to develop new materials and to facilitate the transfer of that technology and expertise to the national laboratories and to the chemical industry.

The Center for Applied Energy Research (CAER) is a unique resource at the University of Kentucky. CAER is an interdisciplinary research center with established expertise in clean fuels and chemical technology, bio-energy/biomass/renewable energy, environmental and coal technologies, and carbon materials. The research staff is led by Ph.D.s (mostly chemistry, chemical engineering, and mechanical engineering), and many have appointments on the UK graduate faculty and have adjunct professor appointments in academic departments of the College of Arts and Sciences or the College of Engineering. CAER currently hosts ~20 Ph.D. students who are involved in CAER-based research projects.

Students are encouraged to participate in the intellectual property development process, and trained in the recognition, description (patent writing), and protection of intellectual property. At CAER, chemistry and chemical engineering students collaborate on projects and share in the traditional, strong interactions that CAER provides with federal agencies, national labs, and industry.

I would encourage more interactions like this one for other groups both internal and external to the University of Kentucky. The synergy that is derived from the expertise of the researchers and the enthusiasm of the students is impossible to engender in any other setting.

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