The Future of Graduate Education in the Chemical Sciences: What is Really Best for Students?

by Larry R. Faulkner

This is a time when quite a few people in the chemical sciences are asking themselves about graduate education. The big issue is whether our programs are doing the most valuable things for graduate students in the most effective ways.

The questioning has gone well beyond private musing and hallway talk. The new President of the American Chemical Society, Bassam Shakhashiri, has designated a sterling group of scientists and engineers—the ACS Presidential Commission on Graduate Education in the Chemical Sciences— to examine these issues. In January, the Commission began a year-long review and will report its recommendations toward the end of calendar 2012.

President Shakhashiri charged the group to focus on two questions:

- What are the purposes of graduate education in the chemical sciences?
- What steps should be taken to ensure that programs address important societal issues as well as the needs and aspirations of graduate students?

Because Dr. Shakhashiri asked me to chair this distinguished panel, the quality of graduate education is much on my mind. The work of the Commission is highly relevant to this particular issue of *Interface*, and certainly is of interest to most members of ECS, so I would like to take a little space here to discuss the effort.

Because the Commission has just begun, it is too early for me to convey solutions. Indeed, as chair of the Commission, I have an obligation not to anticipate its decisions and recommendations. Accordingly, I will just identify the main issues—those that seem to generate the greatest concerns in the community at large—and outline some of the factors bearing on options for change.

But I also have an offer for you to engage, too.

On behalf of the Commission, I invite any reader of this article—faculty member, graduate student, postdoc, practicing scientist or engineer, or just interested party—to contribute any relevant comments. You may send them to me by email at lrfaulkner@po.utexas.edu. They will be most helpful if received by May 1, because of the schedule on which the Commission's subcommittees will be proceeding. I will see that they are brought into the process in the most effective possible manner.

In the weeks leading up to the Commission's first meeting, I had many private conversations with colleagues across the chemical community. A consistent set of concerns came to the fore.

At the top of the list is the desire to prepare students soundly for effective, rewarding careers.

Nearly everyone perceives that career paths in the chemical sciences have become much more diverse and much less predictable in recent years. Two decades ago—or even much more recently than that—practically all graduate students in our fields pursued traditional academic or industrial employment, and the latter was dominated by the plans and practices of large, well established companies. These days, the picture is very different. Graduate students in chemistry, chemical engineering, biochemistry, molecular biology, and materials science often pursue careers in directions that were pretty uncommon earlier. For example, they sometimes go into public policy, issue advocacy, scientific journalism, or patent law. Those who pursue industrial employment frequently choose smaller companies, often startups. There is also much more immediate interest among students in entrepreneurism—in starting new ventures themselves. Even on the academic side, there are more varied employment tracks than in the past. Members of our community with whom I have talked believe that this dramatically altered employment scene carries implications for graduate education—that it requires the community to rethink the academic content and experiences for graduate students.

Most of my conversations have been about doctoral programs, because doctoral education tends to dominate the world of graduate study in the chemical sciences. Inevitably it provides the main context through most of this article, but the observations and issues are largely applicable to master's programs, too.

Despite the very broad-based questioning about doctoral programs, there is still an anchoring concept. Everyone with whom I have spoken holds the view that these programs must continue to manifest traditional depth and to preserve a focus on mastery. These attributes are seen as absolutely central to the value of doctoral education, both for society broadly and in the employment markets specifically. Most observers would like to see other goals reached in doctoral education, but none of my sources desires that they be achieved by trading away depth and mastery.

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Although practically everyone believes that some change is needed, people vary significantly in the particulars. The following points are made commonly, although no point comes from everyone, and no one makes every point.

Many say that doctoral graduates need **greater technical breadth and versatility**, so that they are more adaptable in employment situations. Those who stress this point believe that the community must find ways to encourage and to achieve those attributes without sacrificing depth and mastery. People speak about this matter in three distinct ways.

Some emphasize "technical adjacencies," believing that students need fuller, more functional extension of their knowledge into technical areas that are naturally adjacent to their thesis research. The idea is for students to emerge from the thesis project with a better ability to adapt in their later work to new chemical circumstances, new materials, new techniques, new models.

Other observers see a similar need, but do not define it in terms of adjacencies. They point out that adaptation depends

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on the ability to address new technical matters in unpredictable ways, especially when considered over a whole career. These colleagues would like to see students developing their graduate educations somewhat more broadly, nurturing their own curiosities, and understanding that reasonably achievable technical breadth will pay off over a career.

There is pretty broad agreement on one other aspect of this point, which is that graduate programs need to hammer home to students that the first purpose of doctoral education is to teach graduates how to enter a new field, how to pose worthwhile problems, and how to be productive in solving those problems and generating valuable new knowledge. While the actual research results of a student's thesis project can and should have value in itself, the greater value for the student's education should be the student's developed ability to learn and to investigate new things. Commentators emphasize the desirability of building students' sure grasp of this purpose of their education, plus confidence in the broad applicability of their research skills.

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Many colleagues say that graduates in the chemical sciences need to go beyond the technical aspects of their education to achieve **greater development of allied knowledge and skills**. There is a long list of things people include in this regard. Let me quickly touch on the common ones.

Practically universally, commentators emphasize communication skills, both oral and written. Some mention "presentation skills" as a distinct category. Professionals in the chemical sciences, almost to the person, confess how very important they have found communication to be in so many aspects of their careers. The world is full of words, and it is just essential for any new professional in the chemical sciences to be able to provide efficient, informative, and interesting messages to colleagues. Essentially everyone recommends that our community find ways to teach these things more effectively, and to raise standards for them, during the course of graduate education.

A closely related matter is better development of the ability to teach. Of course, quite a few graduate students seek teaching careers. Many observers believe that we ought to find more thoughtful and effective ways to equip them for that service. Success along that line would, in fact, benefit all students, whether bound for a career in teaching or not, because the skills for effective teaching are the skills for effective explanation and presentation—all very valuable these days in practically any career.

There is widespread comment that students should emerge from graduate research with a much better grasp of safety and related best practices.

Community members having extensive connections with industry often suggest that graduate students would benefit from a better understanding of intellectual property and its management.

There is also a sizable lobby for helping students to gain a rudimentary grasp of the economics of technical business, including real costs and how to look at economic practicality of proposed new materials or processes.

Entrepreneurial skills are mentioned fairly commonly, too. Certainly included in this domain would be the two topics just identified: intellectual property and technical economics, but there are other things, too, such as financing options and the establishment of robust business plans. Of course, the driver for this suggestion is the reality that more students now are actually pursuing entrepreneurial paths, so many observers would like to see better access for students to this kind of professional development. Most, however, see this package as a potential option in graduate education, rather than as a universal element.

Quite a few commentators also emphasize that graduates could benefit from some **opportunity to gain a more global perspective, in both geographic and cultural senses**. Science has, of course, been global for a long time, so this is not a new theme for our community; however, the recent globalization of business and culture have greatly increased the likelihood that any new graduate will be working collaboratively across national and cultural boundaries and, for more than a few, even *within* a different society. Perhaps it is practical to design experiences into a graduate program that can build relevant knowledge and skills for students. They need to become comfortable with the reality that there are several, or even many, valid ways to do most things in a society, and they could benefit mightily from learning more about how to engage a new culture constructively and how to adapt quickly.

Most observers who have commented on this theme also hasten to note that such development cannot be a central element of graduate education in the chemical sciences; even so, they believe that our community can be more cognizant of the need and take more systematic advantage of opportunities for students.

Time-to-degree is another sizable concern among the people with whom I have spoken. Quite a few believe that the average for achieving a PhD in the chemical sciences is much too long; others do not agree with that judgment, but are apprehensive about tendencies toward lengthening. Most are comfortable with a term between four and five years for a conscientious, effective student pursuing a doctorate from the baccalaureate level without interruption. They understand the opportunity cost for students implied by a longer term, and they believe that very long or completely unpredictable times-to-degree tend to push

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very talented baccalaureate graduates out of our fields toward professional options with shorter, or at least more predictable, post-graduate phases.

The undeniable desire in the community is to keep time-to-degree from lengthening—indeed to shorten it, if possible. A corollary is that it is impractical to generate educational breadth along the lines discussed above by adding time to graduate programs. If any of those things is to be accomplished, we will have to be smarter—to make better use of the time and experiences for students while they are in graduate school. People seem interested in how some of the elements mentioned above might be addressed as degree options or in compact packages, such as courses of short duration, perhaps even a day or a week.

Many commentators believe that faculty members in graduate programs need **to advise students more fully and more competently about diverse career options**. People also spoke often about fostering a more supportive atmosphere for students who are inclined toward careers outside academia.

More than a few observers see destructive tension between the **mechanisms for student support**, which are so rooted in individual research grants, and effective educational outcomes in graduate degree programs. They are interested in alternatives, but the community is wary about moving toward portable awards to students, largely because of the risk that such a practice would feed faddishness.

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Over the next six to eight months, the Commission will digest what it has already heard in the areas discussed here. It will hear much more through listening sessions, correspondence, and its own topical working groups, which include many contributors beyond the members of the Commission. The task is like looking into a kaleidoscope. The pieces can produce many different patterns, indeed, a continuous range of patterns. How can we find the most coherent, most functional part of that spectrum, best supporting the long-term well-being of our graduates? Imagination, thought, and sound judgment will surely be required.

About the Author

Larry R. Faulkner is President Emeritus of The University of Texas at Austin. He recently retired from Houston Endowment, a private philanthropy, after six years as President. He previously served on the chemistry faculties of Harvard University, the University of Illinois, and the University of Texas. At Illinois, he was also department head, dean, and provost. From 1998 into 2006, Dr. Faulkner served the University of Texas as its 27th president. He now serves on the board of Exxon Mobil and was previously on the boards of Temple-Inland, Sandia National Laboratories, and Internet2. He is a past president and Honorary Member of The Electrochemical Society, and has received The Society's Edward Goodrich Acheson Medal and Norman Hackerman Award. He is a member of the American Academy of Arts and Sciences. He may be reached at lrfaulkner@po.utexas.edu.

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