Chapter 1

A New Vision of Graduate Preparation for Science and Mathematics Faculty

New faculty members in most institutions of higher learning are expected to be effective teachers, active researchers, and good academic citizens who contribute to the betterment of their departments and campuses. They are expected to be able to teach and advise a student body diverse not only in race, ethnicity, gender, and other demographic qualities, but also in terms of intellectual skills, motivation, and learning styles. Faculty and administrative colleagues expect new faculty to be able to employ powerful new strategies of teaching and learning, including collaborative, experiential, and technological approaches, and to assist with campus initiatives, such as writing across the curriculum, assessment of student learning, and strong general education curricula. These challenges face all new faculty, but they are more critical in the sciences and mathematics, where many undergraduate students lack adequate background, fear their own inadequacies, and seek to avoid these subjects altogether. Indeed, one of the greatest challenges facing colleges and universities today is preparing all students to live and function in a new era, a world where technology and unprecedented scientific advances, representing both promise and peril, have proven their capacity to both connect us and shock us.

Further, a substantial reform movement exists in the sciences and mathematics to help students learn about the natural and living worlds. It involves such diverse initiatives as using problem-based learning to teach calculus, analyzing important community issues such as AIDS and pollution by means of biochemical concepts, finding engaging ways to teach non-scientists in all disciplines, assessing scientific learning and quantitative reasoning, and making scientific fields attractive to underrepresented groups. (Seymour 2002; Wubbels and Girgus 1996.)

Where in their graduate programs do aspiring faculty learn about these matters and acquire capacities to make these improvements? The answer is that too often they do not, at least not in any systematic manner. It is true that some doctoral students may become teaching assistants, and some may even discover significant talent as teachers. But the reality is that large numbers of graduate students do not have an opportunity to be teaching assistants, and many teaching assistants are not given much training or support. Many teaching assistants are relegated to low-level assignments, such as supervising laboratories, grading papers, or leading discussion sections, and don't have opportunities to grapple with the serious intellectual and practical challenges of teaching, learning, and service within an institution of higher education. The academy faces the challenge of raising the quality of faculty preparation, because teaching and professional service are frequently not components of doctoral education.

Many faculty members and administrators in doctoral education assert that American graduate education in science is the envy of the world, and they believe that all is well with their programs. And yet, after a thorough review of undergraduate education, the advisory committee to the National Science Foundation's Directorate for Education and Human Resources (1996, iii) pointed to a serious deficiency:

> Despite the observation that America's basic research in science, mathematics, engineering, and technology is world-class, its education is still not. America has produced a significant share of the world's great scientists while most of its population is virtually illiterate in science. Undergraduate SME&T [science mathematics, engineering, and technology] education is typically still too much of a filter that produces a few highly-qualified graduates while leaving most of its students 'homeless in the universe.'

If undergraduate science is to be improved, doctoral students preparing for academic careers will have to learn to address this problem. New faculty will have to learn to be effective teachers, invent curricula, devise instructional strategies, and construct programs that engage students in learning.

The Preparing Future Faculty program, known familiarly as PFF, sets forth a vision of graduate preparation for new science and mathematics faculty that equips them to be leaders of twenty-first century science education. In 1998, academic departments in the biological and life sciences, chemistry, computer science, mathematics, and physics embraced the vision, and—led by their disciplinary societies—embarked on a collaboration to infuse PFF concepts into the preparation of the future professoriate.

What is PFF?

PFF is a configuration of ideas designed to promote expanded professional development of doctoral students who aspire to an academic career. It embraces the doctoral degree's traditional emphasis on research, but it also brings knowledge about the diverse colleges and universities that constitute the higher education landscape—particularly those primarily serving undergraduate students—into doctoral preparation. For those interested in a faculty career, PFF introduces students to the academic profession and to the diversity of institutions with their different missions, student bodies, and expectations for faculty. PFF gives graduate students an opportunity to experience faculty life in a protected educational context at a variety of colleges and universities, allowing them to decide if they really do want an academic career, and if so, to determine what kind of institution is right for them.

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The most fundamental idea characterizing PFF is that the doctoral experience for those interested in an academic career should include: a) increasingly independent and varied teaching responsibilities, b) opportunities to grow and develop as a researcher, and c) opportunities to serve the department, campus, and community. More specific concepts include the following:

1. Apprenticeship teaching, research, and service experiences should be planned so that they are appropriate to the student's stage of professional development and progress toward the degree. Doctoral students assigned as teaching assistants, for example, tend to be viewed as "covering a course section" rather than developing professional expertise benefiting themselves and students. Future faculty should be given progressively more complex assignments, more responsibility, and recognition associated with increased professional capacities.

2. Doctoral students should learn about the academic profession through

exposure to the range of professional responsibilities in the variety of institutions that may become their professional homes. Becoming aware of the variety of institutions enables them to find a better "fit," providing them with context as they seek to match their own interests and competencies with the needs of departments and institutions.

3. Doctoral programs should include a formalized system for mentoring in all aspects of professional development. Just as students have a mentor to guide their research, they also would benefit from an ongoing relationship with an experienced faculty member as they develop their teaching and service repertoire. Indeed, students can benefit from multiple mentors. A teaching mentor may be at a different institution, perhaps one with a mission that is distinctly different from that of the research university.

4. Doctoral experiences should equip future faculty for the significant changes taking place in the classrooms and curricula of today. For example, future faculty should be competent in using technology and in addressing issues presented by increasing heterogeneity among students, sophisticated about general education and interdisciplinary curricula, and capable of using the newer, active, collaborative, technological, and experiential approaches to teaching and learning.

5. Professional development experiences should be thoughtfully integrated into the academic program and sequence of degree requirements. Unless leaders of doctoral education are intentional about these matters and structure these new experiences into their programs, PFF activities are likely to be added on to an already full program and may increase time to degree. Careful integration overcomes the tendency to add new elements without modifying existing expectations which could avoid lengthening time to degree.

6. Where high-quality teaching assistant orientation and development programs are available, PFF programs should build upon them. PFF is consistent with the best practices of teaching assistant development, while also advancing another, more comprehensive level of preparation. While teaching assistant development programs can be valuable preparation for certain faculty roles, PFF programs broaden preparation by including teaching experiences at different institutions, providing mentors for coaching and feedback, and engaging students in professional service and governance responsibilities of various sorts.

The other key element in the implementation of the PFF program is the "cluster," a new form of institutional collaboration that brings the "consumers" of Ph.D.s together with the "producers." A cluster is a formal, cooperative arrangement involving doctoral-granting universities—anchors—with a range of other institutions or departments—"partners" in our terms—in a joint working relationship. Specifically, the cluster leadership:

- decides what is needed in new faculty (and it is always more than specialized knowledge in a discipline);
- gives students opportunities to experience faculty life in multiple institutional settings; and
- increases awareness among faculty in both the doctoral university and partner institutions about the expectations for faculty and the ways faculty roles are changing in various institutions.

The idea is to develop PFF programs that produce students who are well prepared to meet the needs of institutions that hire new faculty.

Making the Case for the PFF Concept

In recent years a good deal of empirical study has documented the need for this new concept. Studies of graduate students (Golde and Dore 2001; Lovitts 2001; National Association of Graduate and Professional Students 2001; Nyquist, et al. 2001) support the need for more information about potential careers, greater attention to teaching, more mentoring, and a closer relationship between doctoral preparation and the realities of faculty work. Similarly, studies of new faculty point to the need for better graduate preparation and clearer expectations about the nature of faculty work (Rice, Sorcinelli, and Austin 2000; Trower 2001; Sorcinelli 2001). Studies of doctoral recipients several years after receiving their degrees, including those employed both in the academy and outside it, also support the need for new approaches represented by PFF ideas (Nerad and Cerney 1999; Nerad and Cerney 2000; Smith and Pedersen-Gallegos 2001). A summary of these studies can be found on the PFF Web site at www.preparing-faculty.org.

Why PFF and Disciplinary Associations?

In developing the third phase of the PFF program, the national PFF leadership in 1998 initiated partnerships with selected disciplinary societies in several academic disciplines as a way to gain the support of more graduate faculty and their departments. In the first phase of PFF, graduate deans received grants to organize university-wide programs. They created clusters of diverse institutions to develop model programs based on PFF concepts (see Table 1). A subsequent grant, the second phase, allowed deans to further institutionalize PFF programs, assess results, disseminate findings, and spread the PFF vision to other institutions. This strategy was successful in building a broad base of support for PFF ideas among graduate deans and within a limited

Table 1. PFF Project History

PROJECT PHASE	DATES	GOAL	FUNDING	PARTICIPANTS
I	1993-1997	Develop model programs	The Pew Charitable Trusts	17 anchor institutions and 68 institutional partners
II	1997-2002	Institutionalize and spread programs	The Pew Charitable Trusts	15 anchor institutions and 119 institutional partners
III	1998-2002	Develop model programs in the sciences and mathematics	National Science Foundation	19 departments and 92 departmental partners
IV	1999-2002	Develop model programs in the humanities and social sciences	The Atlantic Philanthropies	25 departments and 130 departmental partners

number of disciplines, notably the humanities and social sciences. Thus graduate deans led the early initiatives.

Despite this support, the total number of graduate faculty involved was limited, and academic departments did not develop a significant sense of ownership for the PFF program. Too few faculty members were aware of the changing expectations for new faculty, the current job market, and the potential benefits of PFF programs for their graduate students.

Thus, in the third phase, PFF joined with the following disciplinary societies to develop model PFF programs in academic departments of their disciplines:

- American Association of Physics Teachers;
- American Chemical Society;

- American Mathematical Society jointly with the Mathematical Association of America; and
- Special Interest Group on Computer Science Education of the Association for Computing Machinery.

Originally, a society in the biological and life sciences was included, but it withdrew because it reported little interest in PFF among its members. The national PFF office subsequently served as a surrogate for the biology association in soliciting proposals and found significant interest within universities. Appendix I provides information about graduate student enrollment, doctoral degrees awarded, and posdoctorate positions that places this PFF project within the larger context of graduate education in each discipline.

The initiative to collaborate with disciplinary societies was based on the assumption that by focusing on challenges and opportunities facing the disciplines, the societies could entice graduate faculty and their departments to look carefully at the diverse world of higher education in which new assistant professors work, and to enrich their doctoral programs accordingly. Doctoral education is a powerful socialization experience in which academic departments play primary roles. It is through doctoral education that scholars in a field of specialization educate future practitioners and cultivate their capacities to make advances in the field. These disciplinary societies have embraced PFF as an important direction for the future of doctoral education in their fields. In so doing, society leaders discovered that PFF creates synergy with other national agendas pursued by the societies, such as efforts to diversify the faculty, provide seminars on teaching for new faculty, encourage social and community engagement, and explore the scholarship of teaching and learning.

The National Science Foundation (NSF) supported this project for several reasons. The Division of Undergraduate Education awarded the grant, with an ultimate aim of improving undergraduate science education. Furthermore, a major NSF goal is to better balance research and education in the sciences, mathematics, and engineering (NSF 1996), and it saw PFF as one way of re-balancing these roles among faculty. NSF also sought to broaden the participation of underrepresented groups with respect to gender, race, ethnicity, and disability in science and mathematics. In addition, NSF wanted to encourage disciplinary societies to take more responsibility for teaching and academic citizenship roles of faculty and to develop better balance in their own programming between research and education.

A fourth phase of PFF, funded by The Atlantic Philanthropies, was undertaken to work with disciplinary societies in the social sciences and humanities. The structure of the project is similar to that of the third phase; societies in communication, English, history, political science, psychology, and sociology are supporting the development of model PFF programs in their fields. A report on phase four will be published in late 2002.

What Did the Disciplinary Societies Do?

Each of the societies conducted a national competition in spring 1999 to award academic departments in their fields matching grants to create model PFF programs. In addition, they provided technical assistance to those departments, assisted with the assessment of these innovative programs, highlighted PFF programs in their regular meetings and publications, and generally promoted PFF as a beneficial way to educate future faculty in their disciplines. The national PFF office coordinated activities on these initiatives among the disciplinary societies and also served as the surrogate disciplinary society for the four life sciences clusters that became involved in PFF.

A total of nineteen academic departments were selected to participate in this project: five in chemistry, four each in biological and life sciences, mathematics, and physics, and two in computer science. The departments and the name of a contact person for each are listed in Appendix II. Each department organized a cluster of departments in its discipline, and each cluster, by design, represents the variety of higher education institutions likely to hire new faculty. A total of eight departments were located on campuses with existing university-wide PFF programs, and eleven were on campuses without a centralized program. Although science and mathematics faculty and graduate students had been involved in two earlier PFF projects—PFF phases one and two— this volume is based largely on the experiences of these societies and the departmental clusters with which they worked during phase three.

NSF also sought to broaden the participation of underrepresented groups.

During phases one and two, graduate deans took various steps to engage graduate faculty and to secure a sense of departmental ownership for PFF. They identified certain departments as loci for creating PFF programs, recruited key faculty to participate, and obtained departmental approval for students to participate. In phase three we reversed the process by having disciplinary societies name faculty members as principal investigators. The principal investigators worked to involve their departmental colleagues and gain the support of graduate and academic deans. To this end we required a letter of support from university administrators as part of the application process.

Table 2. Distribution of institutions participating in phase three PFF by discipline

Type of Institution	Chemistry	Physics	Computer science	Mathe-matics	Biology/Life Sciences	TOTAL
Doctoral	5	13	2	5	4	29
Masters	7	5	4	6	11	33
Baccalaureate	15	2	3	3	6	29
Associate	5	5	0	3	5	18
Specialized	0	1	0	0	1	2
TOTAL	32	26	9	17	27	111

We also required the university to match grant funds, suggesting that funds might come in part from the offices of the graduate or academic deans. If the university had a centralized PFF program, we urged departments to take advantage of these resources as well, in the belief that doctoral education works best when the department, the university, and other institutional partners work together to support a broader education for doctoral students.

Table 2 summarizes the types of colleges and universities participating in this third phase of PFF. Across all disciplines, 74 percent of the institutions were non-doctoral granting, which nearly mirrors the fact that 64 percent of the faculty in higher education are employed at non-doctoral institutions (American Council on Education 2001). The clusters reflect the rich diversity of American higher education, and they expose graduate students to quite different institutional missions, histories, campus cultures, and student bodies—and hence, different expectations for faculty.

How Do PFF Programs Operate?

Campus leaders have been encouraged to develop PFF programs that are both in keeping with PFF concepts and reflect their particular needs, interests, and circumstances. PFF programs concentrate activities in three different loci: the university, because some learning is general and appropriate for all PFF students; the department, because some learning is particular to the disciplines; and the partner institution, because some learning is dependent on the institutional context.

Typical activities at the *university* level include a course on the general topic of college teaching and learning, forums on faculty life and careers, discussions of faculty governance issues, and development of professional portfolios documenting student expertise in teaching, research, and service.

Departments typically offer a course on the teaching of their discipline, provide sequences of supervised teaching experiences, host discussions in which faculty members from different institutions describe their careers, and sponsor talks by alumni in which they discuss how their graduate programs did and did not adequately prepare them for their jobs.

Partner institutions often assign a teaching mentor to work with doctoral students, invite students to attend department or faculty meetings, include them in faculty development activities, and offer supervised teaching opportunities.

The specific kinds of program elements developed by the science and mathematics departments in this project are discussed in Chapter 3.

What Lessons Have Been Learned From the PFF Initiative?

Numerous assessments have been conducted since PFF programs began. Here is a brief summary of the major lessons learned.

- PFF programs do function largely as they were conceived.

- Doctoral students and alumni are enthusiastic about the benefits of their PFF programs.
- Faculty members from partner institutions enjoy working with doctoral students and derive benefits for their own professional development.
- Graduate faculty members learn about faculty life in different institutions and appreciate the professional development their students receive through PFF programs.
- Virtually everyone involved in PFF programs says that they would recommend them to others.
- Benefits to academic departments and universities include better recruitment and placement of graduate students.
- These benefits outweigh the modest investments of time and money that are required.