Looking beyond research in doctoral education

Steven P Campbell, Angela K Fuller, and David AG Patrick

Doctoral education in the natural sciences has traditionally focused on training students as researchers. However, this is no longer sufficient to provide students with the range of skills needed to succeed in academic and non-academic employment. Based on a review of national studies and current literature, we recommend a shift from the current model, with its focus on dissertation research, to a broader conception of doctoral education that includes training and mentoring that will be relevant to future careers. We also highlight some of the national initiatives that have made progress in these areas. Doctoral education programs cannot remain static if they are to continue to create marketable graduates. Instead, partnerships should be formed with hiring institutions, so that doctoral programs can evolve in parallel with the dynamics of the job market.

Front Ecol Environ 2005; 3(3): 153–160

Doctoral education in the US follows a long tradition of producing professionals who make important and original contributions to academic research. This is typically achieved by coupling coursework with research under the supervision of an established scientist, with the goal of training independent researchers who are able to carry out creative and rigorous scientific studies. Despite its historical success, recent surveys have shown that this model of doctoral education is no longer sufficient to prepare graduate students for the rapidly changing work environment into which they will emerge (Nyquist *et al.* 1999; Nyquist and Woodford 2000; Nerad 2002; Nyquist 2002; Wulff *et al.* 2004).

Employers are still attracted to candidates with outstanding research credentials, but many are looking for more than just research experience. For example, candidates for academic employment are increasingly being asked about their teaching experience and about their philosophy on education (Montell 2003). Non-academic employers are also seeking candidates with a broader skill base than can be obtained solely by traditional dissertation research; they are looking for collaborative ways of thinking, the ability to work in teams, problem solving skills, interpersonal skills, entrepreneurial initiative, and interdisciplinary experience (COSEPUP 1995; Nyquist and Woodford 2000). The increased expectations among potential employers, coupled with the decreasing number of traditional, research-based job opportunities and the continually increasing number of PhDs being awarded (NRC 1998; Figure1) make it clear that a more comprehensive approach to graduate education is necessary if graduates are to remain competitive in the global job market (COSEPUP 1995; LaPidus 1997).

Doctoral education has been the focus of a number of recent national studies and publications. In this paper, we review the major concerns raised by these studies, giving particular consideration to findings that apply broadly to the natural sciences and specifically to ecology. Our aim is to identify areas which, if improved, could lead to PhD programs that would better prepare graduates for the current employment market. We also highlight the progress that has been made in addressing many of these issues. This synthesis is based on our perspective as doctoral students, a perspective that is often the least represented in discussions about graduate education (Fagen and Suedkamp Wells 2004). Space restrictions prevent us from addressing all the results of these studies, so we concentrate on those findings that we perceive as being important to graduate students.

In a nutshell:

- The research component of doctoral education is often emphasized at the expense of broader training and skill development
- Connections should be established between institutions that prepare PhD students and those that hire them, to ensure that training matches job responsibilities
- Doctoral education could be improved by better mentoring, training that is relevant to future career paths, and development of interdisciplinary skills

Department of Wildlife Ecology, University of Maine, Orono, ME 04469 (steven_campbell@umit.maine.edu)

Major studies

The shortcomings of current PhD programs have been the focus of a number of studies and publications. We briefly discuss five of these.

(1) Re-envisioning the PhD: What concerns do we have?

This report by Nyquist and Woodford (2000) synthesized findings from interviews, focus groups, and surveys of

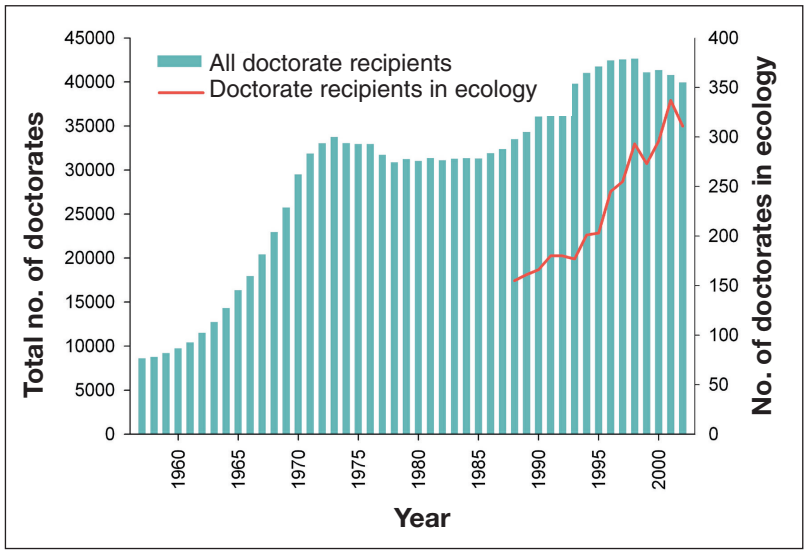

Figure 1. *Total number of doctorates earned in the US from 1957 to 2002 and the number of doctorates earned in the field of ecology from 1988–2002. Data Sources: Sanderson and Dugoni 1999; Sanderson* et al. *1999; Sanderson* et al. *2000; Hoffer* et al. *2001, 2002, 2003.*

nearly 400 individuals who were obtaining a PhD, or were training, granting, funding, and employing PhD students. These individuals represented universities and colleges, K–12 education, doctoral students, government agencies, business and industry, foundations, discipline-specific societies, and educational associations. The study was based on open-ended questions about the processes and outcomes of doctoral education.

(2) The Survey on Doctoral Education and Career Preparation

This survey assessed students' experiences during their doctoral program, students' career plans, and the effectiveness of their doctoral programs in preparing them for their anticipated career. In 1999, over 4000 doctoral students in 11 arts and science disciplines at 28 universities completed the survey. The results are summarized in the report, "At cross purposes: what the experiences of today's doctoral students reveal about doctoral education" (Golde and Dore 2001).

(3) The National Doctoral Program Survey

This web-based survey was conducted in 2000 by the National Association of Graduate–Professional Students (NAGPS 2001); it focused on current and recent doctoral students' experiences in graduate school and implementation, within their doctoral programs, of educational practices recommended by the National Academies, the Association of American Universities, and others. Over 32 000 students (646 from ecology programs), representing nearly 5000 doctoral programs at almost 400 graduate institutions in the US and Canada, completed the survey.

(4) The PhDs – Ten Years Later Study.

This study by Nerad and Cerny (1999) surveyed almost 6000 PhD recipients to assess doctoral programs in terms of career placement. The survey population included doctoral recipients in six disciplines, from 61 doctoral-granting institutions in the US, who had received their PhDs 10–14 years prior to the study. The survey focused on employment history, the job-search process, factors the respondents considered when accepting employment positions, and a retrospective evaluation of the doctoral program.

(5) Longitudinal Study of the Development of Graduate Students as Teaching Scholars

This qualitative study by Nyquist *et al.* (2001) followed 66 graduate students (19 from natural sciences programs) from three universities over a 4-year period and documented the changes that students experienced during their graduate years, how their experiences contributed to their development as teaching scholars, and the kinds of training that best prepared them for careers as effective teachers.

■ Concerns about graduate education

A number of important issues involving graduate education were identified by the five studies mentioned above as well as by other studies.

Discrepancy between doctoral education and future job responsibilities

There is a growing disconnect between the training that graduate students receive and their future job responsibilities (COSEPUP 1995; Golde and Dore 2001; Wulff *et al.* 2004). This discrepancy is rooted in the traditional model of doctoral education, which assumes that doctoral recipients will pursue research-based academic careers (Nerad 2002). However, this assumption is no longer valid, because the career goals of today's students are far more varied than those of their predecessors (Nyquist *et al.* 2004; Table 1). This discrepancy is reinforced by the fact that those primarily responsible for mentoring and training doctoral students work in research-intensive universities that are very different from non-research universities and other institutions offering jobs outside academia. Without direct knowledge of the qualifications required by other types of hiring institutions, graduate faculty lack the knowledge needed to improve the relevance of graduate student training (Nyquist *et al.* 2004).

Overemphasis on research

Individuals both within and outside academia have expressed concern that the current form of doctoral education, with its emphasis on research, does not adequately prepare students for employment (COSEPUP 1995; Nyquist *et al.* 1999; Nyquist and Woodford 2000; Nerad 2002; Nyquist 2002; Wulff *et al.* 2004). The National Doctoral Program Survey (NAGPS 2001) found that 88% of students in ecology programs felt that they were adequately trained as researchers. However, significant proportions (27–57%) indicated that other aspects of their education (eg pedagogy, professional ethics and responsibilities, and career planning) had been insufficient (Table 2). This is further supported by the diversity of primary and secondary job activities carried out by PhD graduates in the fields of environmental life sciences and biological sciences (Table 3). Graduate programs that focus only on research, to the exclusion of other skills, are therefore not preparing students for the responsibilities of the positions they will eventually fill.

The current format of graduate education, with its bias toward academic training, also fails to adequately prepare students for the responsibilities of faculty positions (LaPidus 1997; Adams 2002; Nerad 2002; Austin and Wulff 2004). The study by Golde and Dore (2001) revealed that 66% of students in ecology programs were considering a faculty job; however, only 29% of respondents felt that their program prepared them to teach lecture courses and fewer still were prepared for the service responsibilities of faculty roles. Teaching and service, while fundamental, are only two of the many non-research responsibilities of faculty. Faculty members are also expected to know how to make use of various technologies in their teaching, be aware of their ethical responsibilities, be advisors and mentors, communicate to diverse audiences, and work effectively with groups inside and outside of academia (Austin and Wulff 2004).

Table 1. Percentages of employed doctoral scientists with degrees in environmental life sciences[a] (n = 5240) and biological sciences[b] (n = 118 600) that are working in the different employment sectors

Employment sector	*Environmental life sciences*	*Biological sciences*
University and 4-year colleges	39.2	53.3
Other educational institutions	1.8	3.2
Private-for-profit	21.0	26.2
Self-employed	1.2	2.8
Private not-for-profit	5.1	4.9
Federal government	20.1	7.7
State and local government	10.8	2.0

Data taken from 2001 Survey of Doctorate Recipients (NSF/DSRS 2003).

[a]Environmental life sciences = environmental sciences, fisheries sciences, fish and wildlife, wildlife, forestry science, forest biology, forest engineering, forest management, and wood science.
[b]Biological sciences = biochemistry, biomedical sciences, biophysics, botany, cell biology, molecular biology, ecology, genetics (human, plant, and animal), microbiology, bacteriology, nutritional sciences, pharmacology (human and animal), physiology (human, plant, and animal), entomology, pathology (human, plant, and animal), zoology, biotechnology research, biometrics, biostatistics, anatomy, hydrobiology, developmental biology, endocrinology, immunology, neurosciences, parasitology, and toxicology.

Lack of mentoring and career preparation

Graduate students beginning their degrees are often unclear about what graduate education entails, what is formally and informally required of them to obtain a graduate degree, the academic culture (norms, rules, and values) of their particular discipline, and what accomplishments are necessary in order to be considered successful (Nyquist *et al.* 1999; Fagen and Suedkamp Wells 2004; Wulff *et al.* 2004). Research has shown that students who do not receive this kind of information about their program tend to interact less effectively with colleagues, to be less committed to their programs, and to be less productive (Green 1991; Bauer and Green 1994; Lovitts 2004). Furthermore, this lack of direction and inexperience on the part of the student, combined with the emphasis on research, can give students a false impression about what skills employers are seeking. This often results in students neglecting the development of a broader skill base until closer to graduation, by which time it may be too late to rectify the situation (Nyquist *et al.* 1999).

Many PhD students focus on academia as a career goal, even though a comparatively small number will go on to obtain such positions, and fewer still will fill tenure-track positions in research institutions (NRC 1998; Hoffer and Selfa 2001; Hoffer *et al.* 2003; NSF/DSRS 2003). Advisors, in part because of their own career experiences, can exacerbate this problem by emphasizing research-oriented academic careers, giving students the impression that other career paths are inferior (COSEPUP 1995; Nerad and Cerny 2000; Nerad 2002; Fagen and Suedkamp Wells 2004; Nerad *et al.* 2004). Students indicated that they were largely unaware of career opportunities outside of academia, and identified a lack of mentoring and feedback from faculty as contributing to this deficiency (COSEPUP 1995; Nerad *et al.* 2004; Wulff *et al.* 2004). Only 29% and 25% of students surveyed by NAGPS (2001) felt that they received the proper career guidance and placement assistance, respectively, for careers outside academia (Table 2), and only 29% of students surveyed by Golde and Dore (2001) were aware that a mentor other than their PhD advisor was available to give guidance on professional development. The fact that students have few formal opportunities during the course of their studies to meet with professionals in their field who work outside of research universities is probably also a contributing factor to this problem.

Of the students who intend to pursue a career in academia, few have a comprehensive idea of what it means to be a faculty member (Nyquist *et al.* 1999; Wulff *et al.* 2004). Similarly, Nerad *et al.* (2004) found that a majority of respondents in their study felt unprepared for the various tasks associated with being a faculty member (eg teaching, obtaining external funds, managing a research

Table 2. Responses to select questions for ecology programs (n = 646 students) from the 2000 National Doctoral Program Survey

Survey question	Survey response: Positive	Negative	Other
My program's curriculum is broad enough to meet my needs and prepare me for my career of choice.	0.799	0.187	0.014
My program actively encourages students to explore a broad range of career options.	0.556	0.384	0.060
My program encourages students to broaden their education through non-required activities such as coursework outside the department, internships, and workshops.	0.599	0.368	0.033
My program does a good job of preparing students for:			
a. academic careers.	0.875	0.093	0.033
b. careers outside of academia.	0.534	0.381	0.085
Teaching assistants in my program are appropriately prepared and trained before entering the classroom.	0.409	0.398	0.193
Teaching assistants in my program are appropriately supervised to help improve their teaching skills.	0.327	0.464	0.209
The teaching experience available through my program is adequate preparation for an academic/teaching career.	0.450	0.364	0.186
Doctoral students in my program receive training in professional ethics and professional responsibilities via coursework or seminars.	0.392	0.571	0.037
Doctoral students in my program receive training in professional skills such as public speaking, grant writing, and working in teams.	0.698	0.294	0.008
Doctoral students in my program receive effective career guidance and planning services for:			
a. careers in academia.	0.567	0.276	0.158
b. careers outside of academia.	0.294	0.497	0.209
Doctoral students in my program receive effective placement assistance and job search support for:			
a. positions in academia.	0.410	0.271	0.319
b. positions outside of academia.	0.254	0.384	0.362
I am learning good research practices.	0.882	0.094	0.023
Doctoral students in my program are involved in decisions relevant to their education.	0.762	0.201	0.037
Faculty in my program believe students are here primarily to help faculty fulfill their research and teaching obligations.	0.201	0.728	0.071
Overall, I am satisfied with my program.	0.796	0.190	0.014

The survey was conducted by the National Association of Graduate-Professional Students (2001). Positive responses include strong agreement and agreement, negative responses include strong disagreement and disagreement, and other responses include those that are unknown, not applicable, and left blank.

group, being an advisor and mentor, serving on committees, faculty governance). In many cases, this lack of understanding and preparation is due to the fact that the students' primary means of learning about faculty responsibilities is through observation. Students are unlikely to fully understand the range of responsibilities or to become proficient in these areas if there is a lack of explicit and systematic preparation, insufficient feedback and mentoring, little attention to faculty careers outside of tenure-track positions at research universities, and discrepancies between graduate school preparation and the realities of faculty work (Trower *et al.* 2001).

Improving graduate education: recommendations for the future

In the following section, we discuss the recommendations resulting from national studies, as well as some of our own, and briefly describe various national initiatives that are addressing the problems in the current system of doctoral education.

Establishing connections between stakeholders

Preparing doctoral students for the responsibilities that they will assume during their careers cannot be accomplished by academic institutions in isolation; they will need to collaborate with all those involved in PhD education, particularly those who fund and hire doctoral students, and those who influence doctoral education (eg professional societies, educational associations, and government boards) (Figure 2; Nyquist *et al.* 2004). Such partnerships will better ensure that the institutions preparing doctoral students are aware of the skills that students will need in their careers.

The aim of the "Re-envisioning the Ph.D." project at the University of Washington is to establish these partnerships and encourage those involved to collaboratively find ways of improving doctoral education (Nyquist *et al.* 2004). The project has generated many resources to help those interested in changing graduate education, including a website containing collections of studies and publications on doctoral education, ideas and strategies for change, examples of innovative institutional initiatives, and ongoing virtual discussions involving over 4000 stakeholders from all sectors (Nyquist *et al.* 2004).

Providing career planning and guidance

Graduate students and faculty need to be informed about the range and likelihood of employment opportunities in order to make realistic career decisions (NRC 1998). Information such as employment rates of PhD recipients from the student's department and of PhD recipients

nationwide, types of employment and employers, and the qualifications employers are seeking (eg data in Tables 1 and 3) would help doctoral students focus on a particular career path (COSEPUP 1997). These types of data are discipline specific and should be regularly updated and provided to advisors for distribution to students by their department or graduate school (Figure 2).

Students could also be helped in their career choices by the provision of more detailed information about prospective careers. University-wide seminars are a necessary but insufficient means of achieving this goal. An institution-based yet decentralized approach is required, whereby students receive more focused information. One possibility is for graduate students to meet with alumni or departmentally sponsored seminar speakers from a variety of backgrounds, to discuss their career options. These kinds of interactions can help expand the more narrowly focused career guidance that students may receive from their faculty advisor.

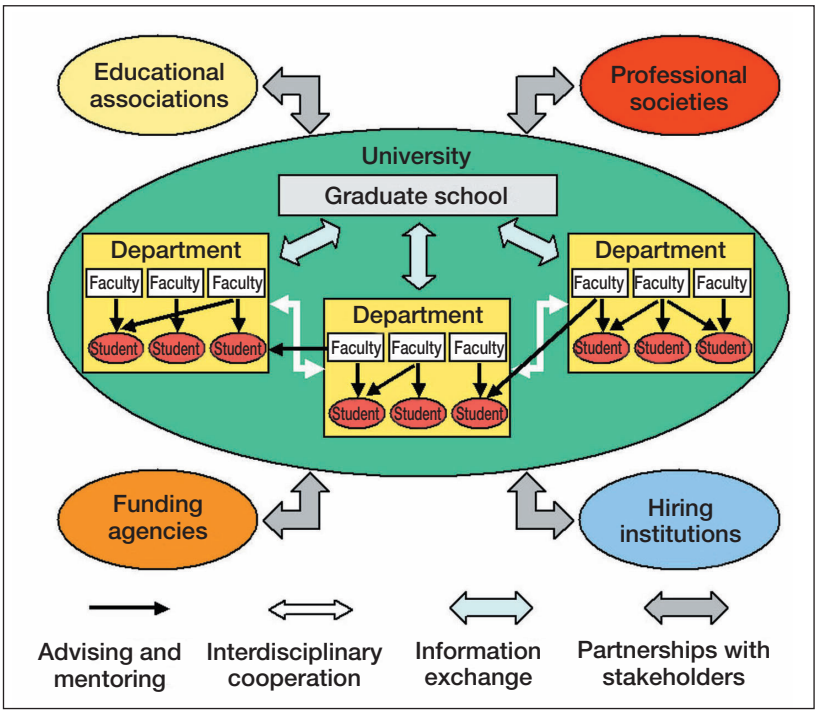

Figure 2. *Relationships inside and outside of universities that will help to improve doctoral education.*

Departments, advisory committees, and in particular advisors, need to work with individual students to explicitly identify their mutual goals and expectations during the degree program and the students' career goals following the receipt of their PhD. Such conversations will enable the student's goals to be balanced against the requirements and expectations of the department (Wulff and Austin 2004). To ensure that students are meeting those goals, advisors and students should routinely discuss these issues, track progress towards the agreed goals, and provide the department with periodic assessments on progress toward the degree (AAU 1998). As with any management plan, monitoring is a key component in ensuring a successful outcome.

Broadening training for careers outside academia

The rapid pace of societal change is constantly creating new requirements for PhD graduates (Nyquist 2002). Participants in the "PhDs – Ten Years Later" study called for greater educational relevance to the changes occurring inside and outside academia and better labor market preparation, such as teaching and practical, hands-on experiences (Nerad *et al.* 2004). Thus, graduate education needs to be broadened from its research focus to include a wider range of training for the careers students are pursuing and to reflect the versatility needed to work in an increasingly global job market, where collaboration between industry, universities, and government agencies is the norm rather than the exception (COSEPUP 1995; Fagen and Suedkamp Wells 2004). To do this, doctoral students and the institutions training them need to identify what this wider training entails and continually adapt their degree programs to fit.

Interdisciplinarity is becoming a key requirement for many jobs. This can be encouraged in graduate programs via minors or collections of courses developed in areas related to the student's major field of study and via multidisciplinary research seminars organized to discuss real-world problems (Figure 2; LaPidus 1997). The National Science Foundation (NSF) initiated the Integrative Graduate Education and Research Traineeship (IGERT) program in 1997 to foster such links between disciplines. The IGERT program, which currently comprises 125 award sites, aims to establish innovative new models for graduate education and training based on collaborative

Table 3. Percentages of employed doctoral scientists with degrees in environmental life sciences[a] (n = 5240) and biological sciences[b] (n = 118 600) whose time is devoted to the different primary and secondary work activities

Primary or secondary work activity	*Environmental life sciences*	*Biological sciences*
Research and development	70.7	70.1
Applied research	59.2	35.0
Basic research	12.3	43.6
Development	10.0	7.7
Design	4.1	2.2
Teaching	27.8	30.7
Management, sales, and administration	46.6	39.0
Computer applications	8.0	6.7
Professional services	11.0	15.3
Other activities	4.5	5.1

[a,b] See Table 1.
Data taken from 2001 Survey of Doctorate Recipients (NSF/DSRS 2003).

Figure 3. *A graduate student conducts hands-on science activities with junior high school students as part of the NSF Graduate Teaching Fellows in K–12 Education Program.*

research that transcends disciplinary boundaries.

The Responsive PhD Initiative of the Woodrow Wilson Foundation is collaborating with 19 major doctoral-granting institutions with the goal of re-conceiving the training of doctoral students from one that largely produces discipline-specific professorial replacements to one that produces interdisciplinary scholars capable of applying their expertise in the broader society. Institutions work together as well as with representatives outside of the academic community to derive, implement, and gauge the effectiveness of new practices that improve doctoral education, and the institutions act as models and demonstration sites for these practices (Weisbuch 2004). A similar project has been launched by the Carnegie Initiative on the Doctorate, which is a multiyear research and action program that is supporting 85 departments from 45 institutions to conceive, experiment with, evaluate, and disseminate ideas and practices designed to strengthen and improve doctoral education. The improvements in doctoral education are aimed at creating high quality researchers who are able to convey information to diverse audiences and across disciplinary boundaries (Walker 2004). This initiative, like the Responsive PhD Initiative, advocates a much broader conceptualization of doctoral education than the current model, which focuses almost solely on research.

Another program that is successfully broadening the training of students beyond their doctoral research experience is the NSF Graduate Teaching Fellows in K–12 Education Program (Figure 3), which provides fellowships for graduate students and advanced undergraduates in science, technology, engineering, and mathematics to work in K–12 classrooms and enrich the learning of K–12 students with their expertise in a particular field of study. The benefits for the graduate fellows include improved communication, teaching, and collaborative skills. Since its inception in 1999, 126 programs have been established at 110 universities in 42 states.

Preparing students for faculty careers

PhD students who seek faculty careers should be given a realistic view of what it is like to be a faculty member. A greater involvement of such students in departmental faculty meetings and in faculty search committees, as well as topical monthly discussions between faculty and PhD students would be a good first step. Students, under the supervision of a professor, could be given an opportunity to teach their own course, or the course of a faculty member on sabbatical. They should be trained to teach in a variety of roles, such as classroom instructors, one-on-one tutors, project managers, and mentors (Nyquist and Wulff 2001). Students also need to be made aware of the responsibilities that different types of faculty have (Nyquist and Wulff 2001), since the faculty roles that students observe in research universities will differ from those in other types of institutions (Austin and Wulff 2004).

The Preparing Future Faculty (PFF) program of the Council of Graduate Schools (CGS) and the Association of American Colleges and Universities is designed to prepare PhD students for teaching careers; this program was established with the goal of creating faculty that are competent in teaching and service in addition to research. PFF programs are based on collaborations between a doctoral degree-granting university and multiple, primarily undergraduate institutions (Pruitt-Logan and Gaff 2004). Graduate students experiencing these different institutional settings gain a broad understanding of faculty careers. The program was established in 1993 and involves 45 doctoral degree-granting universities and 300 partner institutions. Grants for these programs have expired, but new PFF programs can receive administrative support from the CGS.

The inclusion of pedagogical training in graduate education does not have to be at odds with research training. For example, the Carnegie Academy for the Scholarship of Teaching and Learning has helped to initiate projects in which faculty conduct research on their own teaching activities and on students' learning (Hutchings and Clarke 2004). When graduate students collaborate with faculty on such projects, they improve their skills as researchers, provide valuable findings about education in their university and beyond, and learn about teaching and learning processes (Hutchings and Clarke 2004).

Mentoring

The terms "advisor" and "mentor" are often used interchangeably, but are not necessarily the same thing.

Mentoring, unlike advising, is not just a professional relationship; it is also a personal relationship, developed to advance the specific educational and personal goals of the student (COSEPUP 1997). It is this flexibility that is often missing from student/advisor relationships; a one-size-fits-all policy is often used, which can lead to advisors producing carbon copies of themselves. Mentoring involves giving advice, sharing experiences, acting as a source of information and support, and providing an example of correct ethical and scientific conduct. Good mentors help students to optimize their educational experiences, become familiar with the norms and values of their discipline, build a network of contacts, and obtain suitable employment (COSEPUP 1997). It is unlikely that one mentor will be able to fulfill all these different roles, so ideally graduate students should have a network of mentors, each able to contribute his or her advice, skills, and experience (Figure 2; COSEPUP 1997; Nyquist and Wulff 2001).

Figure 4. *PhD students from the Department of Wildlife Ecology at the University of Maine meet informally with faculty members to discuss issues pertaining to professional development and career goals.*

Faculty members are constrained by a host of factors, including the policies of granting agencies, the teaching and research needs of their institution, and the pressure to publish and to obtain external funding. It is therefore not surprising that mentoring is not their first priority. Universities can help to establish a better balance between research training and guidance by affirming the importance of faculty mentoring through policy, incentives, and inclusion as a criterion in faculty evaluations (COSEPUP 1997; AAU 1998). Faculty members may not have the necessary experience or skills to be effective mentors, so departments or graduate schools should provide guidelines, based on current research on effective mentoring practices (eg NAS 1997; King 2003; Nyquist and Wulff 2001). At the very least, departments can create opportunities for graduate students and faculty to discuss professional development issues and career goals (Figure 4; Nyquist and Wulff 2001) and perhaps establish a distinguished graduate mentoring award to recognize faculty for outstanding mentoring.

Conclusions

Clearly, academic policies designed 80 years ago cannot be expected to achieve the same success today in providing a properly trained workforce (Trower *et al.* 2001). While research is, and will continue to be the basis of the PhD program, doctoral education has become too focused on this one aspect, resulting in graduates who are not well prepared for the array of responsibilities their future careers will entail (Golde and Dore 2001; Nerad 2002). There needs to be a greater emphasis on preparing students for their future careers, many of which will not be in academia (Table 1), and most of which will require many more skills than those related to research (Table 3).

Many universities are already addressing, to various extents and with varying success, some of the problems we have identified. The success of many of the initiatives to improve doctoral education relies heavily on the participation and commitment of graduate administrators and faculty. Success will also require the involvement of graduate students. We hope that this paper raises awareness among graduate students and encourages them to collaborate with their faculty to help effect some of the changes we are suggesting.

Acknowledgements

We thank the Department of Wildlife Ecology at the University of Maine for initiating a graduate mentoring program for PhD students, and RJ O'Connor for his valuable insights and role as facilitator of the program. We also thank ML Hunter, Jr, and SG Delcourt for reviewing our manuscript. SP Campbell was supported by the NSF Graduate Teaching Fellows in K–12 Education Program at the University of Maine.

References

AAU (Association of American Universities). 1998. Graduate education report and recommendations. www.aau.edu/reports/GradEdRpt.html. Viewed 30 Mar 2004.

Adams KA. 2002. What colleges and universities want in new faculty. Preparing Future Faculty Occasional Paper, Number 7. Washington, DC: Association of American Colleges and Universities.

Austin AE and Wulff DH. 2004. The challenge to prepare the next generation of future faculty. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Bauer TN and Green SG. 1994. Effect of newcomer involvement in

work-related activities: a longitudinal study of socialization. *J Appl Psychol* **79**: 211–23.

COSEPUP (Committee on Science, Engineering, and Public Policy). 1995. Reshaping the graduate education of scientists and engineers. Washington, DC: National Academy Press.

COSEPUP (Committee on Science, Engineering, and Public Policy). 1997. Advisor, teacher, role model, friend: on being a mentor to students in science and engineering. Washington, DC: National Academy Press.

Fagen AP and Suedkamp Wells KM. 2004. The 2000 national doctoral program survey. In: Wulff DH and Austin AE (Eds). An online study of students' voices. Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Golde CM and Dore TM. 2001. At cross purposes: What the experiences of doctoral students reveal about doctoral education (www.phd-survey.org). Philadelphia, PA: A report prepared for The Pew Charitable Trusts.

Green SG. 1991. Professional entry and the advisor relationship: socialization, commitment and productivity. *Group and Organization Studies* **16**: 387–407.

Hoffer TB, Dugoni B, Sanderson A, *et al.* 2001. Doctorate recipients from United States universities: summary report 2000. Chicago, IL: National Opinion Research Center.

Hoffer TB, Dugoni B, Sanderson A, *et al.* 2002. Doctorate recipients from United States universities: summary report 2001. Chicago, IL: National Opinion Research Center.

Hoffer TB, Sederstrom S, Selfa L, *et al.* 2003. Doctorate recipients from United States universities: summary report 2002. Chicago, IL: National Opinion Research Center.

Hoffer T and Selfa L. 2001. Academic employment of recent science and engineering doctorate holders. Arlington, VA: National Science Foundation NSF 01-332.

Hutchings P and Clarke SE. 2004. The scholarship of teaching and learning: contributing to reform in graduate education. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

King M. 2003. On the right track: a manual for research mentors. Washington, DC: Council of Graduate Schools.

LaPidus JB. 1997. Doctoral education: preparing for the future. Washington, DC: Council of Graduate Schools. www.cgsnet.org/pdf/doctoraledpreparing.pdf. Viewed 8 June 2004.

Lovitts BE. 2004. Research on the structure and process of graduate education: retaining students. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Montell G. 2003. What's your philosophy on teaching, and does it matter? *The Chronicle of Higher Education:* Chronicle Careers. March 27.

NAGPS (National Association of Graduate-Professional Students). 2001. The 2000 national doctoral program survey. http://survey.nagps.org/. Viewed 12 May 2004.

NAS (National Academy of Science). 1997. Advisor, teacher, role model, friend: on being a mentor to students in science and engineering. National Academy Press, Washington, DC.

NRC (National Research Council). 1998. Trends in the early careers of life scientists. Washington, DC: National Academy Press.

NSF/DSRS (National Science Foundation, Division of Science Resources Statistics). 2003. Characteristics of doctoral scientists and engineers in the United States: 2001. Arlington, VA: National Science Foundation NSF 03-310.

Nerad M. 2002. The PhD in the U.S.: criticisms, facts, and remedies. Proceedings of Science, training, and career: changing modes of knowledge production and labor markets workshop; 21–22 Oct 2002; The Netherlands. University of Twente: Center for Higher Education Policy Studies.

Nerad M, Aanerud R, and Cerny J. 2004. "So you want to become a professor!": lessons from the PhDs – Ten Years Later study. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Nerad M and Cerny J. 1999. Postdoctoral patterns, career advancement, and problems. *Science* **285**: 1533–35

Nerad M and Cerny J. 2000. Improving doctoral education: recommendations from the PhDs – Ten Years Later study. *Council of Graduate Schools Communicator* **33**: 6.

Nyquist JD. 2002. The Ph.D.: a tapestry of change for the 21st century. *Change: The Magazine of Higher Learning* **34**: 12–20.

Nyquist JD, Austin A, Sprague J, and Wulff D. 2001. The development of graduate students as prospective teaching scholars, a four-year longitudinal study: final report. Seattle, WA: University of Washington, Center for Instructional Development and Research.

Nyquist JD, Manning L, Wulff DH, *et al.* 1999. On the road to becoming a professor: the graduate student experience. *Change: The Magazine of Higher Learning* **31**: 18–27.

Nyquist JD and Woodford BJ. 2000. Re-envisioning the PhD: What concerns do we have? Seattle, WA: University of Washington, Center for Instructional Development and Research.

Nyquist JD, Woodford BJ, and Rogers DL. 2004. Re-envisioning the PhD: a challenge for the twenty-first century. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Nyquist JD and Wulff DH. 2001. Recommendations from national studies on graduate education. http://www.grad.washington.edu/envision/project_resources/national_recommend.html. Viewed 9 Jan 2005.

Pruitt-Logan AS and Gaff JG. 2004. Preparing future faculty: changing the culture of doctoral education. In: Wulff, DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Sanderson A and Dugoni B. 1999. Summary report 1997: doctorate recipients from United States universities. Chicago, IL: National Opinion Research Center.

Sanderson A, Dugoni B, Hoffer T, and Myers S. 2000. Doctorate recipients from United States universities: summary report 1999. Chicago, IL: National Opinion Research Center.

Sanderson A, Dugoni B, Hoffer T, and Selfa L. 1999. Doctorate recipients from United States universities: summary report 1998. Chicago, IL: National Opinion Research Center.

Trower CA, Austin AE, and Sorcinelli MD. 2001. Paradise lost: how the academy converts enthusiastic recruits into early-career doubters. *AAHE Bulletin* **53**: 3–6.

Walker GE. 2004. The Carnegie initiative on the doctorate: creating stewards of the discipline. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Weisbuch R. 2004. Towards a responsive Ph.D.: new partnerships, paradigms, practices and people. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Wulff DH and Austin AE. 2004. Future directions: strategies to enhance paths to the professoriate. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

Wulff DH, Austin AE, Nyquist JD, and Sprague J. 2004. The development of graduate scholars as teaching scholars: a four-year longitudinal study. In: Wulff DH and Austin AE (Eds). Paths to the professoriate: strategies for enriching the preparation of future faculty. San Francisco, CA: Jossey-Bass.

