

Who Cares About Postdocs Anyway?

Evaluating the National Science Foundation's Postdoctoral Fellowships in Science, Mathematics, Engineering and Technology Education

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Introduction

In the year 2000, there were approximately 52,000 post-doctoral researchers and fellows in the sciences and engineering in the United States (COSEPUP 2000). Although the term 'postdoc' itself is somewhat ill-defined, general trends suggest that the number of post-doctoral researchers has been increasing (COSEPUP 2000). Furthermore, while there have been recent reports which study the post-doctoral experience, the position, which dates back to the Nineteenth Century, remains largely unstudied. This paper contributes to the study of the post-doctoral experience by examining one particular post-doctoral venture, the National Science Foundation's (NSF) Postdoctoral Fellowships in Mathematics, Science, Engineering and Technology Education (PFSMETE), and three significant structural characteristics that shaped the outcomes of this program.

Background:

The foundations of the postdoctoral position lie in the European model of the research institution, brought to the United States in the 1870's when Johns Hopkins University adopted an apprenticeship model for high-level training (COSEPUP 2000). In the 1920's the Rockefeller Foundation instituted postdoctoral fellowships to provide scholars with additional time for studying the increasingly complex domain of physics. The current number of postdocs may be traced to the rapid increase in the number of doctorates awarded in science and engineering beginning in the late 1950's. With increased federal spending in the Cold War and Space Race, demands for scientists were high and the university system and federal labs were expanding (Fechter et al. 1998). The number of Ph.D.'s in science and engineering roughly tripled during the decade of the 60's to meet this growing demand. Following this increase, however, two

successive academic ‘slowdowns,’ one in the late 70’s and another in the early 90’s produced unprecedented numbers of postdocs, and changed the nature of postdoctoral positions. Postdocs in both these periods reported fewer alternatives upon graduating with a doctorate and the average length of a postdoctoral term began to increase (COSEPUP 2000).

The most significant growth in postdoctoral appointments has been in the last two decades. The Committee on Science Engineering and Public Policy (COSEPUP) and the NSF report a more than doubling in the number of academic postdoctoral appointments in the sciences and engineering in the U.S. from 1981-1998 (from 18,000 to 39,000)² (COSEPUP 2000).

Particularly relevant however, is the change in ratio of the number of Ph.D. recipients planning postdoctoral study to the number of Ph.D.’s awarded in science, mathematics and engineering. In physics and astronomy this ratio held relatively constant for the period 1980-1994, at roughly 45-55%. In more recent years, however, the ratio has dropped to roughly 40%, indicating a relative decrease in postdoctoral seekers (COSEPUP 2000). From another perspective, the same trend may be observed in the decreasing ratio of tenure track faculty to newly awarded Ph.D.’s. These trends suggest that recent Ph.D.’s are not finding their way into traditional academic posts (COSEPUP 2000). While the absolute number of postdocs is still increasing, the once ‘traditional’ route from graduate school to postdoctoral work to permanent academic posts is changing. In an ever-increasing number of cases, postdoctoral positions are becoming an end in and of themselves, rather than a means into the more traditional posts of academic world.

Recently, academics and policy makers have become interested in documenting and describing the postdoctoral experience.(AAAS 1999; COSEPUP 2000) The recent National Academies sponsored COSEPUP report, *Enhancing the Postdoctoral Experience for Scientists and*

Engineers, provides a snapshot of the current state of postdocs in the sciences in the U.S. During this year-long study (1999-2000), the Committee on Science Engineering and Public Policy gathered information from postdocs, administrators, advisors, institutions, disciplinary societies, and funding agencies in an effort to broadly study the “personal and institutional settings of that experience” (COSEPUP 2000, p. vii). The report provides detailed analysis and general features of postdoctoral experiences:

COSEPUP’s analysis of the data gathered in this report indicates that the employment conditions for postdocs, especially in universities, need to be significantly improved if the United States is to develop the human capital needed to assure a healthy research enterprise and global leadership in science and technology. (COSEPUP, viii)

The study concludes with a list of concrete action points and recommendations for each of the communities that routinely interact with postdocs. The report has been followed by two National Academies conferences: an announcement of the report (11 September, 2000) and a follow-up convocation to discuss the findings (02 March, 2001). A broader study, *Ph.D.’s – Ten Years Later* reports similar results from a larger and longer study of roughly 6000 Ph.D.’s awarded to graduate students in the United States from 1982-1985 (Nerad et al. 1999).

Defining the term ‘postdoc’:

One of the common findings of these studies is that the position or title ‘postdoctoral scholar’ is ill-defined, taking on a variety of different meanings at different institutions (AAAS 1999; COSEPUP 2000). In fact ‘postdoc’ takes on a variety of meanings within the same institution. COSEPUP refers to postdocs as “those who undertake additional research training after completing their doctoral degrees”(COSEPUP 2000). In addition to this training model, the postdoctoral experience is described as an apprenticeship and an opportunity for scholars to:

broaden and deepen their understanding of the field (COSEPUP 2000), engage in focused research activities, become recognized in a field (Vogel 1999), develop confidence (Vogel 1999), transition from one domain to another (NSF 1997a), and develop leadership skills (NSF 1997a).

From the advisor and institutional perspectives, additional definitions arise. The postdoctoral scholar is an avenue for publishing refereed journal papers, one of the few valued commodities in academic circles. Reports of one laboratory cite 51% of their (246) papers carry postdocs as the first author, while these postdocs make up only one-third of the personnel (Vogel 1999). Other reports state that the prevalence of postdocs first-authoring papers varies from 43% to nearly 100% (Vogel 1999). The postdoc may also be seen as a form of low cost labor (Mervis 1999). In addition to their own research, postdocs serve as advisors to graduate and undergraduate students, write grants, and ensure the daily operation of laboratories. Meanwhile the average salary of postdocs does not far exceed the cost of graduate students, with, in some cases, overall postdoctoral costs actually beneath that of graduate students (COSEPUP 2000).

A variety of definitions, and hence positions, arise from the perspective of funding agencies. The National Institute of Health (NIH), the largest funder of postdocs, offers postdoctoral trainee-ships and research associateships. These vary in terms of responsibility and pay. Generally, however, these postdoctoral appointments are granted by an institution that has been awarded NIH funding, a piece of which includes support for postdoctoral positions. Explicitly, since the postdoc is considered a trainee-ship by the NIH, it is accompanied with a \$26,256 (U.S.) annual stipend.³ As one of the largest funding sources of postdocs, the NIH has become the *de facto* standard, to which many PI's set their own pay-scales (COSEPUP 2000). The

National Science Foundation offers other varieties of postdoctoral support: research assistantships and fellowships. The NSF research assistants comprise approximately 95% of NSF funding for postdocs and are hired into fixed grant and institutional structures, like their NIH counterparts; alternatively, the NSF Fellows are awarded to individuals who then bring these funds and their research to an institution (COSEPUP 2000). PFSMETE Fellowships hail from this latter category. These and other varieties of postdoctoral support each carry implications as to how, where and what research a postdoctoral scholar may pursue.

Examination of the PFSMETE Postdoc Program

While the studies discussed above have examined broad trends and common themes of the postdoctoral experience by examining aggregate data and statistical analyses, another avenue for understanding the postdoctoral experience is the case study approach. Case studies (COSEPUP 2000; Vogel 1999) examine typical laboratories and postdocs to provide examples of best practices and to anchor the general trends captured in the broader studies with concrete examples. Each level of analysis (the broad survey and the individual case-study) provides useful insight into the character, quality and purpose of postdoctoral research. Our study augments these two levels of analysis, by focusing on a level of analysis *between* the micro and macro -- at the programmatic level. The following report analyzes an individual postdoctoral fellowship program, the Postdoctoral Fellowships in Science, Mathematics, Engineering and Technology Education. In the course of this analysis three characteristics of the program structure are identified and examined, shedding light on how the implicit structure of postdoctoral programs is fundamentally tied to program success.

In reporting on the successes and failures of this novel postdoctoral training program in education research, we present the results of a survey of the 62 Fellows and their mentors who participated in this program. Our aim is to study the program's effect, achievements and limitations, by examining the program structure and the perceptions of the program by participants. As with other studies of this type, this is a mixed methodological study utilizing both case study and statistical analysis. It is a study of one postdoctoral fellowship program, which while unique, sheds light onto how the organization of postdoctoral programs might be structured to best serve each of the involved parties. We have identified aspects of this program which were quite successful, and should be adopted by similar programs, as well as categories of problems encountered by PFSMETE Fellows and mentors which may be avoided by careful organization of future programs.

Structure of the PFSMETE:

The Postdoctoral Fellowships in Science Mathematics, Engineering, and Technology Education were first introduced by the National Science Foundation in 1997. The primary objective of PFSMETE was the preparation of new science Ph.Ds for leadership roles in science, mathematics, engineering, and technology (SMET) education through the development of expertise in science education research. Recent doctorates in science were given the opportunity to transition from the sciences to science education, in an effort to bridge the heretofore separated communities of science and education (NSF 1997b). Further analysis of the program guide (NSF 1997b) suggests a number of subordinate objectives primarily related to PFSMETE research. The NSF expected that PFSMETE research would further: the communication of scientific knowledge to a variety of learners, the assessment of teaching and learning and programs, the application of interdisciplinary knowledge to curriculum development, and the use

of technology in SMET education. Several useful measures of program success are suggested, including:

development of creative teaching methods, development of innovative teaching materials for new concepts, development of quality education products (e.g. refereed publications, presentations to professional societies and end-users, educational technologies, statistical tools, evaluation, methodologies), and utility to the education community as evidenced by sponsored studies of school systems and evaluations of higher education programs. (NSF 1997b).

NSF awarded an annual stipend of \$36,000 directly to the Fellow and a research allowance of \$6000 over which the Fellow would have direct control. This annual stipend is much higher than the national average of \$28,000 (COSEPUP 2000, p 13) although no allowance was made for geographically related differences in the cost of living for Fellows. Additionally, an annual allowance of \$9000 was granted to the host institution to defray the expense of hosting the Fellow. It was also suggested, although not required, that this institutional allowance be used to cover benefits (such as health care) for the Fellow. Finally, Fellows were guaranteed two years of funding, with the option of applying for a third year, or, in the event of acquisition of a tenure track position, a starter grant (of as much as \$50,000) for science education research.

In 1997 twenty-eight Fellowships were awarded to the first cohort of Fellows in order to pursue research of their own design. In the following two years, NSF awarded thirty-five more Fellowships. In 1999, citing budget constraints, the program was cancelled, meaning that NSF would honor current awards, but offer no more Fellowships. The Fellows were distributed

around the country and represented a host of disciplines, including mathematics, physics, geology, biology, chemistry, and engineering.

PFSMETE as a new cultural setting:

The establishment of the PFSMETE program may be viewed as the creation of a *setting*, a new and sustained relationship between individuals (Sarason 1989, p. ix). PFSMETE's structure, explicit (and implicit) goals, history, and surrounding context reflected its initial intent to sustain the particular relationships developed by participation in the program. Sarason contends that in developing settings program success or failure depends upon two critical factors: the initial structure of the program and the adaptation of that structure to local conditions (Sarason 1989, p. 35, 45, 68). Using this idea of the creation of settings, we examine three key characteristics of the PFSMETE model, how these characteristics are embedded within the program structure, and how these characteristics influence the postdoctoral Fellows and their mentors. These three characteristics, identified within the data discussed below, are: 1) the level of autonomy of the postdoc; 2) the fluidity with which postdocs may cross disciplinary boundaries; and 3) the implicit goal of the program, here viewed as the creation of a cultural shift: to engage scientists in education research, practice and leadership. While these characteristics are intertwined, they are disaggregated here for purposes of classification and discussion.

Postdoctoral position: institutional support and structure versus autonomy:

A dialectic exists in the structure of post-doctoral programs. There is an inherent trade-off between institutionalized structure of the program and the autonomy of a postdoc. Within an institutionalized structure, established procedures or projects, rules, roles, and organization exist. In this model, the postdoc fits into a prescribed role with a given job description and duties.

This structure affords many opportunities; time is spent working on already defined problems and delegated roles rather than negotiating what, how, and who develops and answers research questions. However, such institutionalized structure arrives at a cost -- the roles, rules, and organization are pre-determined. Thus, the questions asked and approaches taken are constrained by the institution, rather than the postdoc. On the other hand, systems without established structures and predetermined research agendas allow for the development of new and unique approaches, roles and questions. Furthermore, if institutional boundaries are not imposed, postdocs may more fluidly move between disciplines, borrowing relevant approaches and questions from one discipline and applying them to another in a useful but locally unique fashion. Such fluidity also has its pitfalls; autonomous postdocs can find themselves intellectually isolated from established academic communities, and unsupported by local infrastructure and support (ranging from access to library facilities to health care).

One of the distinguishing features of the two main models of postdoctoral research is agency: Who is most responsible for the classification and oversight of the postdoc? The defining of agency may arrive from a variety of sources; however, agency is predominantly determined by how the position is funded. In the prevailing research assistantship model, a postdoc enters a research environment and engages in an established program with well-defined responsibilities, roles and research questions. In the fellowship model, the postdoctoral researcher is primarily responsible for defining and designing the scope and approach to the research question at-hand. This distinction is not absolute, of course. There are research assistantships that have a great deal of autonomy associated with them, and similarly, there are prescriptive fellowships. However, in general, the funding source and type of funding is strongly correlated to the type of postdoctoral position. Each type of postdoctoral position serves different roles and provides

different benefits to participants. The National Institute of Health's Research Traineeship model is in one camp; the NSF PFSMETE model is in the other. In the words of the Fellowship's request for proposals: *PFSMETE Fellows have flexibility in the design of a research plan which would be uniquely suited to their professional goals* (NSF 1997b).

Boundary crossing:

An important structural characteristic of the NSF postdoctoral fellowship is the explicit value of multi- or inter-disciplinary research. In a similar vein to the notion of a prescribed research agenda, working within a discipline enforces given and reified approaches to problems. However, some problems sit at the interface between disciplines. Whether the blending of biology and physics, or education and engineering, these cross-disciplinary inquiries require the attention of multiple fields of research. There are a variety of approaches to addressing such problems. One is to encourage people, as part of their job or training, to move between disciplines that are relevant. By having an individual work within multiple environments, research is strengthened by the alignment of these differing perspectives on the research question at-hand. The coordination of these different perspectives occurs within the individual, rather than among different individuals or groups attempting to collaborate. More detailed discussion of boundary crossing and its characteristics are presented elsewhere (Star et al. 1989; Engeström et al. 1995).

Structurally, the NSF PFSMETE program ensures a crossing of boundaries through the use and appropriation of tools from various disciplines. Doctorates in a SMET discipline are funded to engage in education research and practice. Ideally, postdocs infuse educational programs with their own scientific background and simultaneously infuse scientific disciplines with tools from

education, psychology, and other social sciences. The migration of tools from one domain to another, especially in the long term, can ultimately lead to cultural shifts both in education and in science, mathematics, engineering and technology.

Cultural shifts of programs:

Related to, but distinct from each of the aforementioned characteristics, the PFSMETE program attempts to induce particular shifts in local and disciplinary culture. While this program may simply be reacting to observed shifts in cultural values, the existence of these postdoctoral Fellows provides a mechanism through which such shifts can occur. By interacting in several worlds, by beginning to move elements (the tools or artifacts, material or intellectual frameworks) between these worlds, postdoctoral Fellows facilitate cultural shifts within the original cultures. What has been traditionally valued and accepted within a discipline may begin to change. Independent postdocs can begin to translate what is known in one discipline, e.g. education and cognitive science, into terms that can be accepted and valued in another, e.g. science, engineering, and technology.⁴ An example of translation is an often cited piece in physics education research, “The Implications of Cognitive Studies for Teaching Physics,” wherein Redish (1994) summarizes several key points about student learning, long known in cognitive science, psychology and education, into a language that is accessible and valued by the physics community. By bringing in tools from cognitive science, physicists interested in education are provided access to a range of ‘new’ useful tools. The use of such tools over time gives rise to shifts in the local culture. For example, physics is beginning to value education research as a fundamental pursuit of physicists themselves (APS 1999). As Sarason (1989; 1997) suggests, the creation of a new setting, one that often begins with multidisciplinary work,

necessarily affects the local, disciplinary, and interdisciplinary cultures in which the new setting is created.

To summarize, NSF had specific goals in mind in implementing this program. In the short-term, NSF envisioned the creation of teaching methods, curriculum, tools, and partnerships between scientists and educators. Additionally, Fellows were being trained to take leadership roles in science education, and were expected to become experts in discipline-specific science education. In terms of the three structural characteristics of the post-doctoral experience identified above, the PFSMETE is 1) positioned as a fellowship requiring autonomous design and implementation (as opposed to an RA); 2) designed as a method for crossing disciplinary boundaries; and 3) engaged in shifting and blending differing disciplinary cultures (in particular education and SMET).

Research Study

Three types of data were used to analyze the PFSMETE program: 1) open-ended NSF-designed broad surveys completed by each cohort, after completion of the first fellowship year, 2) Likert-scale evaluations of statements related to perceived program effects, and 3) open-ended topic-specific questions soliciting participants' opinions. These data were collected from both the Fellows and Mentors. NSF's internal plan for assessment of PFSMETE program effectiveness required mid-fellowship reviews. Fellows and mentors answered four NSF-designed questions during annual meetings. These surveys asked Fellows and mentors to comment on the helpfulness of the program, career goals and perceived roles in science education, and recommendations for the program. To gather additional data, we developed two short questionnaires, one for Fellows and one for mentors. Mentors were asked to complete a four

question, Likert-scale survey and Fellows were sent a ten question Likert-scale survey. Finally, targeted, open-ended questions were asked of both Fellows and Mentors.

The NSF designed surveys were administered to the last two groups of participants in the Fall of 1998 and Fall 1999 during NSF-sponsored annual meetings; surveys from 25 Fellows and 5 mentors were available for analysis. The subsequent survey questionnaires designed for this project were gathered in late Fall 2000 via electronic mail, after the third and final cohort of Fellows had completed the first year of their fellowship. All respondents were also asked to comment on their experiences and offer suggestions for improving the program (Appendix A). Of the 62 Fellows and approximately 40 mentors surveyed, 28 Fellows and 11 mentors responded. Responding Fellows represented all three fellowship cycles, with slightly more respondents from the final cohort.

Data were analyzed by two methods. First, Likert-scale questions were quantified, and perceived effects of the program, especially with relation to NSF's originally stated goals, are documented here. The multiple-choice questions asked of the Fellows relate specifically to Fellows' career goals, as they relate to 1) original impetus for applying to PFSMETE; and 2) PFSMETE's effect on achieving those goals. Although more difficult, these questions were also quantified. Finally, content analyses, including both thematic content analysis and quantitative descriptive analysis, were performed on all freeform responses.

Data and Discussion

The PFSMETE program's short duration prohibits a substantive look at the materials, curriculum, teaching methodologies, and other tangible products that might have resulted from participation in the program (NSF 1997a). Specifically, although such materials were indeed created by Fellows and their mentors, the longevity of these efforts is still untestable.

Additionally, the ability of Fellows to sustain their interactions within the education community, and to a lesser extent between the science and education communities, can only be ascertained after more time has passed. However, Fellows and mentors both experienced significant shifts in their thinking, as well as reported increased interaction with the education community.

Nearly all of the postdoctoral Fellows report little interaction with the education community prior to receipt of the Ph.D., although many demonstrated an interest in education through participation in small research projects or active participation in teaching. Virtually all of the postdocs surveyed indicated that their interaction with the education community increased as a result of participation in the PFSMETE program (Fig. 1). Even those Fellows who expressed minimal satisfaction with the program indicated that the program had helped them interact more closely with education researchers and practitioners. Of the three Fellows who experienced less interaction with the education community, two had moved on to other types of positions, public policy and textbook writing, since completing their fellowships, and the third had started the postdoc already with heavy ties to science education. About half of the Fellows serve on education committees, either at a university or national level, in addition to teaching or conducting education research.

Fig 1
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Fellows were overwhelmingly positive about the PFSMETE program, primarily regarding the fellowship as an opportunity to gain skills of great value to future career goals (Fig. 2). Of the

two Fellows who were only somewhat satisfied with the program, one expressed concern about their ability to transition back into science and both expressed concern over the lack of a positive relationship with their mentors. Responding mentors universally found the program to be valuable for their Fellows, but were divided as to the level of benefit the Fellows would realize from participation in PFSMETE (Fig. 2). Specifically, mentors were concerned about the instability of the program, with half of the mentors stating (in unsolicited comments) that they regretted the cancellation of the PFSMETE program.

Fig 2
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The PFSMETE program evolved as an effort to train recent science Ph.D.s in SMET education, pulling participants from the ranks of science, engineering, and mathematics. Ultimately, the program endeavored to create hybrid science educators, trained and versatile in both fields. Ideally, the postdoctoral experience was viewed as a fast-track to education; as Ph.D.s, these postdocs were capable of self-instruction and independent learning. Indeed, all of the Fellows interested in pursuing education related careers felt the program was a good job training opportunity (Fig. 3). 26 out of the 28 responding Fellows indicated that they were interested in academic careers more than careers in industry, non-profit, or the public sectors (Fig 4). However, most Fellows were somewhat concerned about the availability of job opportunities in their preferred domain (Fig 3). These sentiments confirm COSEPUP's findings: academic jobs are difficult to acquire in many fields. (COSEPUP, p 15)

Fig 3
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Within academia, Fellows were almost exclusively interested in faculty positions, although two Fellows shied away from academia completely, preferring instead government, private corporations, or non-profit positions (Fig. 4). Of those Fellows interested in academia, many were also willing to consider positions in industry, non-profit, private corporations, or K-12

teaching or administration. Several indicated that although their first choice was academia, the lack of available positions necessitates their considering other options. Fellows were primarily interested in obtaining positions within 4-year colleges and universities, and most were interested in maintaining strong ties to science departments.

Fig 4
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Institutional structure versus autonomy:

PFSMETE Fellows enjoyed the freedom that the independent research design and direct control of the research funds gave them. Sarason (1989, p. xii, 68-69, 283) articulates a need for building goals into the structure of a program, and accounting, somehow, for unexpected outcomes. Indeed, goals themselves must be fluid, if only to account for the fact that a program can never be implemented exactly as envisioned, and desired outcomes must evolve to accommodate this uncertain future. The autonomous nature of the PFSMETE program allowed postdocs a large degree of freedom and mobility that allowed them to incorporate program objectives on the one hand and adapt to uncertain local circumstances on the other.

As postdoc describe, the autonomy of this model fellowship allows for the development of new questions and approaches that may not be possible in a prescribed research program:

the open structure [of PFSMETE] ... allows [me] to attempt things that the physics department (and the education program and the outreach office) are too conservative to try.

[PFSMETE] is liberal in allowing fellows a broad range of projects to develop, rather than requiring them to fit a narrow, specific paradigm. It is financially generous enough for fellows to feel comfortable in their position

At the same time, Fellows often felt alone, cut off from each other and isolated within their respective institutions. In the few cases where a single campus hosted more than one Fellow, interactions were the rule rather than the exception. Although the PFSMETE program did not foresee isolation as a prevalent issue, it turned out to be a problem for most of the postdocs. In the words of PFSMETE Fellows:

I definitely would have appreciated the opportunity to meet with the rest of the PFSMETE fellows once per year, rather than just one time during the fellowship.

[One shortcoming of the program was that there was] not enough interaction between fellows. I believe that we all could benefit from interaction and potentially collaboration with other fellows.

My mentor was more hands off than I had anticipated, and his interests are shifting.

The mentor issue is very important - I've had two, both of whom I've gotten along with very well, and have gotten good advice, recommendations, etc. but have not really collaborated with them in any meaningful way. I can't help but feel that the experience could have been improved with a stronger and more collaborative relationship

The issue of stability within an institution is an important component of the postdoctoral experience, and PFSMETE Fellows, as autonomous researchers, provide a useful look at the need for institutional status. In general, Fellows were concerned about their status within the host institutions themselves. The highly variable ways in which host institutions dealt with PFSMETE postdocs is illustrated by the use of the PFSMETE institutional allowance. Institutional dispensation of these funds was highly variable, especially with regard to health insurance. Some institutions provided Fellows with faculty/staff insurance, although most institutions only provided Fellows with student insurance, and a few institutions viewed the allowance as independent of the Fellow and provided no health insurance. PFSMETE guidelines only provided recommendations for use of this money, rather than prescribing uses of the host funds. Clearly evident in the responses of the postdocs is a desire for more status within the host institution, as reflected by the lack of appropriate health insurance, and in a few cases, phone and library privileges. Although Fellows were not sure how to deal with this issue, it is clear that more stringent guidelines might help improve the situation. Many of these issues arose simply because the Fellows were not technically on the institutional payroll, and were therefore not viewed as part of the institution. As one postdoc explains:

To be on an NSF fellowship is an honor and privilege, but the lack of employee status at the university has meant various administrative obstacles had to be overcome

Nonetheless, in acquiring leadership roles in science education organizations, many Fellows found that this training in becoming self-advocates yielded significant opportunities. The challenge for future programs becomes a matter of balancing program-endorsed opportunities and postdoc autonomy.

Boundary crossing:

In its design, the PFSMETE program is structured to help scholars cross the boundaries between SMET and education disciplines. Specifically the program requires that individuals who are certified members in one community (individuals who are awarded Ph.D.s within a science discipline) engage in a second community (educational research and practice). In the words of the Program Announcement, the postdoc program is designed “to provide opportunities for outstanding Ph.D. graduates to develop expertise in a facet of science education research that would qualify them for the new range of academic positions that will come with the 21st century” (NSF 1997a). This explicit call for a new form of inter- or multi-disciplinary work requires that individuals move across disciplinary lines and become familiar with the cultures of each of these differing disciplines.

In the words of the postdocs themselves the PFSMETE postdoc experience:

Introduc[ed] scientists to the literature and thinking and community of science education and educators/researchers

Serv[ed] as a bridge between my narrowly focused research science training and a much larger world of education and educators (that I really knew nothing about before!)

Provides an opportunity to formally introduce and engage scientists in the world of cognitive and educational research.

Provides an academically respectable transition from pure science into science ed[ucation].

Develop[s] innovative ways to teach science by seeking input from both scientists and educators.

Overall, as shown in Figure 1, Fellows report a significant increase in their interaction with the education community. Furthermore these postdocs report significant training in their newly found discipline (Figure 3). Both by design and in practice, the program introduces postdocs to a new discipline.

Furthermore, the boundary crossing is not uni-directional, mentors (from both education and SMET disciplines) are affected by postdoc's participation in each of these disciplines. Mentors valued the impact Fellows had on both their research and teaching, reporting that the program was an unexpectedly valuable experience. All eleven responding mentors indicated that they were willing or very willing to participate in similar postdoctoral programs in the future. Additionally, mentors felt that participation in this program was a worthwhile experience, from their own perspective. The mentors clearly expressed how interacting with PFSMETE Fellows directly influenced their own teaching and research:

I have really enjoyed the diversity of subjects to which the PFSMETE has opened my interests. I was one of those who thought I knew best how to teach my subject area and my classes have benefited from my Fellow's influence.

I am an educational researcher who develops technology-supported science curricula, and the opportunity to incorporate content-area scientists into this work has been invaluable.

I was able to explore scholarly dimensions with my postdoc that I would not otherwise have had the time or resources to pursue. The results of this work...had an immediate impact on our own curriculum...

Mentors and Fellows reported interacting with the education community in ways that were unimagined when initial proposals were first submitted. It is not possible to know in the long term whether a new hybrid discipline will emerge, if these disciplines of mathematics, science, engineering and technology themselves will begin to absorb some of the cultural tools and practices of education and visa versa, or neither. However, one of the expected outcomes of such disciplinary boundary crossing is an ultimate shift in cultures of the disciplines themselves.

Cultural shifts of programs:

While Fellows spend their tenure moving across disciplinary boundary lines, from a broader or collective perspective, the PFMSTE program may be viewed as an attempt to blur these lines and help foster cultural shifts within these disciplines. In particular, the program is designed to produce a hybrid culture (if only for these postdocs), and introduce tools and practices from one domain into another. The program announcement refers to a “new range of academic positions” (NSF 1997a). Not only are postdocs being prepared for this range of posts, but in the preparation of a class of individuals with this particular skill set, the program explicitly supports the development of the new range of academic positions themselves.

While cultural change occurs over a much longer time-scale than the duration of the PFSMETE program, we may examine some of the effects of the program on the mentors who hail from and in some regards represent cultural norms of disciplines, on their impressions, and on the areas of conflict and difficulty that postdocs engage in as they participate in these cultures.

In the words of one Fellow, the program served to bridge differing cultures:

[PFSMETE] served as a structure for building ties between communities that normally would not have communicated much (e.g., ecologists and writing-center staff, science education faculty and science faculty, physicists and ecologists).

In some cases, seeds of cultural change may be seen. As one mentor observes, the program introduced broad scale change within a traditional SMET discipline:

This postdoc experience provided invaluable impact to our engineering college...and I believe it will lead to a major national impact...

However, the cultural divides between SMET and education are so ingrained that Fellows and mentors were concerned about the lack of interaction, and sometimes, negative perceptions between the science and education communities. Some Fellows felt ideally positioned to combat these issues, with several clearly indicating that they would be interested in joint appointments.

As one Fellow stated it:

Who Cares About Postdocs Anyway?

My sense is that the education community is almost entirely distinct from the scientific community in which I was working prior to PFSMETE, and we have a long way to go to bridge the two. I hope that this is a contribution I will be able to make in my career.

At the same time, mentors were concerned about the impact this fellowship might have on Fellows' career options, with the Fellowship limiting future opportunities in science. As one mentor put it,

I think if they [Fellows] stick with education-oriented programs, they will definitely benefit. If they go back to traditional research, the education research they did during their postdoc could be seen (by traditional scientists) as a waste of time.

Similarly, of those Fellows who were most interested in science research and/or research intensive institutions, most considered the PFSMETE fellowship to be somewhat of a liability:

Concentrating on education research has made me less marketable for positions at research universities; my publication record has suffered.

I am definitely viewed as much more qualified for science education opportunities in science dept. However, I think this postdoc has definitely made me less desirable for science positions (and since I would like to do both science and education research, this is a problem!)

My [science] degree will help me get a research job, but my postdoc probably hurts me

These comments reflect the negative attitudes that some scientists have towards science education. Indeed, the one Fellow who was completely dissatisfied with the Fellowship (Fig. 3) indicated that the prejudice against education research within the science community would probably hurt his chances to obtain a faculty position in science. This Fellow clearly identifies a problem which was essentially unaddressed by the program:

I have been hurt not so much by any weaknesses of PFSMETE, but rather by the extreme prejudice in the scientific community against science education folks. This prejudice is self fulfilling and self-propagating because all the quality minds are warned against associating with science educators. Programs like PFSMETE bring some prestige to science education, but the problem is so large that it had little noticeable effect.

This negative attitude is not unique to science, but is mirrored in some educators' views about scientists. Interestingly, one of the responding Fellows had previously nearly completed a doctoral degree in science education. This Fellow warns that science educators must be wary of accepting trained scientists as education researchers:

I don't think it is fair or profitable to exclude science education PhDs from programs like this [PFSMETE]. I also don't think it is correct for PFSMETEs to assume that their postdoc experience necessarily qualifies them for posts in education departments. There seems to be an arrogance from scientists that they can easily switch to educational fields through this postdoc. Such arrogance disrespects those trained in science education and needs to be tempered.

These sentiments express the significant rifts that still exist between the traditional SMET disciplines and the education community. Any post-doctoral training program of this type, which seeks to bridge communities must explicitly acknowledge the divide and build an infrastructure designed to help bridge the differing worlds. Several Fellows expressed concern that they were now welcome neither by scientists nor educators. As expected, few Fellows were able to offer suggestions for combating this prejudice. One Fellow suggested that the program offer additional funding for science research, so that the scientific community would be more likely to accept the Fellow as a returning member after the Fellowship was completed. Whatever the solution, it is clear that programs like PFSMETE can begin to address the issue by creating a group of practitioners who are able to speak to each of the communities (SMET disciplines and education). Further support for and within such programs, along with explicit acknowledgment that these interdisciplinary research areas are relatively new (both intellectually and culturally), will begin to combat academic prejudice and provide Fellows with a sense of legitimacy and purpose.

Conclusions

The brief tenure of the PFMSETE program proved successful both from the vantage point of achieving NSF's program goals and from the vantage point of the postdoctoral Fellows and mentors who participated in this study. Of course, there are opportunities for improvement, and agencies that look to develop postdoctoral fellowships such as this one, ought to consider the benefits (and liabilities) of providing external funding that is independent of the host institution. Furthermore, those programs that look to bridge disciplines ought to explicitly build support for this transition into structure of the program itself. PFSMETE's flexible structure allowed

Fellows to develop meaningful programs that, in general, were relevant to local context. In this regard, its structure allowed local adaptation and met with significant success. However, PFSMETE's ultimate impact on both science and education, and the bridges that connect these fields remains to be seen.

Acknowledgments

The authors wish to acknowledge the support of the National Science Foundation's Postdoctoral Fellowships in Mathematics, Science and Technology Education for support of this work. Julie Libarkin was supported on PFSMETE #9906479; Noah Finkelstein was supported on PFSMETE # 9809496. Additionally, the authors wish to express their gratitude to all three cohorts of Fellows and hosting mentors for frank and valuable comments about the program. Finally, many thanks to the program director, Dr. Sonia Ortega, and the NSF support staff for helpful discussions and additional materials.

APPENDIX: Fellow and Mentor Surveys and Responses

Questions are listed regular font, sample responses in italics and aggregate (counted) responses in bold.

I. FELLOW SECTION: 9 QUESTIONS.

There are four sections to this portion: information, education community related, research/ job related, PFSMETE specific.

PERSONAL INFORMATION:

At what institution / job are you now?

***EXAMPLE Positions:** Still in postdoc; Science education outreach;*

Science/engineering/mathematics department faculty; Director or researcher at Centers for Teaching/Learning; Academic coordinator

Where did you / do you pursue your PFSMETE?

***EXAMPLE Institutions:** Small and large, public and private universities and colleges; non-profit institutions*

For how long?

Two to three years was the common duration

PARTICIPATION IN THE EDUCATION COMMUNITY:

1. How much interaction did you have with the education community prior to PFSMETE?

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[0] 0 -N/A

[4] 1- none

[1] 2

[9] 3- individual / informal

[3] 4

[2] 5 - some / organized

[3] 6

[3] 7 - a fair amount/ paid and organized

[2] 8

[1] 9

[0] 10 - contrary to PFSMETE rules I was already in ed.

2. How much involvement do you have in the education community now?

[0] 0 -N/A

[0] 1- none

[1] 2

[1] 3- individual / informal

[2] 4

[2] 5 - some / organized / occasional conference

[6] 6

[4] 7 - a fair amount/ partially housed in ed. comm.

[5] 8

[5] 9

[3] 10 - entirely

Comment on interaction with the education community:

EXAMPLE Comments:

It is a challenge to learn the new language of mathematics education.

I'm on the Astronomy Committee of the American Association of Physics Teachers.

PFSMETE has given me time, support and status to pursue purely math education projects.

If it were explicitly part of the PFSMETE program, would have probably helped my project.

I teach an environmental science course for pre-service teachers through the School of Ed. and have regular interaction with faculty there (although my office is in a science dept) I will be teaching an on-line course for in-service teachers next semester.

RESEARCH / JOB:

4. Why did you apply for and accept a PFSMETE? (check all that apply)

23 - to get involved in education research

20 - to get involved in education practice/ teaching

5 - it seemed like something that was easy to do at the time

0 - I didn't have any other options

1 - I wasn't really sure what I wanted to do at the time

12 - to participate in a specific program/ university/ person

16 - as a stepping-stone to a clearly identified goal/ place

1 - Other: *NSF credibility for my work, better pay than other postdoc options*

5. What sort of employment opportunities did / are you headed for?

25 - academia / university

2 - 2 yr. college

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[10] - 4 yr. college (no grad program)

[14] - 4 yr. university (w/ grads)

in a:

[19] - science dept

[3] - education dept.

[2] - administration

[5] - Other: [4] *Joint appointment in science and education* [1] *K-12 Outreach*

[1] - K-12 system / teaching (_____)

[2] - Gov't

[2] - Industry

[4] - private / consulting (non-profit organization)

[2] - Other: *possibly someplace like SRI;*

large non-profit contract research organization, with education technology

R+D group

6. Is this what you had originally envisioned when you started PFSMETE?

[0] 0 -N/A

[0] 1- not at all

[1] 2

[1] 3

[0] 4

[6] 5 - somewhat

[0] 6

Who Cares About Postdocs Anyway?

[6] 7

[1] 8

[5] 9

[8] 10 – totally right on

7. Has PFSMETE made you more competitive/ better trained for the job you reported in #5?

[0] 0 -N/A

[1] 1- not at all

[0] 2

[0] 3

[0] 4

[2] 5 - somewhat

[0] 6

[7] 7

[3] 8

[4] 9

[11] 10 – yes, absolutely!

8. There are lots of job opportunities in my chosen field (#5):

[0] 0 -N/A

[1] 1- not true at all

[1] 2

[6] 3

[1] 4

[8] 5 – if I squint

[2] 6

[6] 7

[3] 8

[0] 9

[0] 10 – I get lots of unsolicited offers

Comments on your research pursuits and job prospects:

EXAMPLE Comments:

it's going to be hard to transition this from post-doc to faculty with too few engineering pubs for the engineers and too few education pubs for the education folks

I'm going to be the faculty ecologist at a small college...and I will be the Director of Community Outreach. Lots of teaching and plan on continuing the education research and doing science research as well.

Concentrating on education research has made me less marketable for positions at research universities; my publication record has suffered. Of course, I made the decision knowing this was true.

I would not have been hired had I not also chosen to do traditional physics research, but my education research did help; -- the market is improving, but it's still very tight

It would have been extremely difficult without PFSMETE. I feel I have gotten an extremely valuable training experience which will make me uniquely qualified for many of the positions for which I will be applying.

I am definitely viewed as much more qualified for science education opportunities in science dept. I recently interviewed at an annual meeting for several jobs and got a very positive

response from the science ed position interviewers. However, I think this postdoc has definitely made me less desirable for science positions (and since I would like to do both science and education research, this is a problem!)

I think that without PFSMETE, I never would have been in the position to find out about my current job, and wouldn't have known what to do to get it.

PFSMETE SPECIFIC QUESTIONS:

9. PFSMETE has been a valuable program:

[0] 0 -N/A

[0] 1- not at all

[0] 2

[0] 3

[0] 4

[2] 5 - somewhat

[0] 6

[2] 7

[1] 8

[4] 9

[19] 10 – yes, absolutely

10. Would you opt for MORE or LESS in the way of

__[18]__ _____ gatherings

__[15]__ _____ [1] resources (eg. job listings, networking)

__[19]__ _____ collaborative research

Who Cares About Postdocs Anyway?

__[2]__ _____ Other

More support at start-up; more opportunities to share projects/findings

What role do you believe PFSMETE serves?

EXAMPLE Comments:

For me, it was allowing someone with background in science pursue an interest in education, and I'm not sure who else would have taken that chance on me.

I think it provides an opportunity to formally introduce and engage scientists in the world of cognitive and educational research.

From an institutional standpoint, it served as a structure for building ties between communities that normally would not have communicated much (e.g., ecologists and writing-center staff, science education faculty and science faculty, physicists and ecologists).

Provides an academically respectable transition from pure science into science ed. Provides time and generous support.

Please reflect on some of PFSMETE's strengths:

EXAMPLE Comments:

It provides a fellow a lot of freedom to pursue interests, develop educational research skills, and make connections with others in their discipline who are also interested in science education research.

Great stipend, resources, critical area of interdisciplinary work.

the freedom to choose projects and generous allocation of resources to acheive our goals is wonderful.

Recognized prestige of receiving a fellowship from NSF.

The program encourages vital interactions between the science and education communities.

It is liberal in allowing fellows a broad range of projects to develop, rather than requiring them to fit a narrow, specific paradigm. It is financially generous enough for fellows to feel comfortable in their position, and it is responsive...to fellows' various needs. It also allows budding scientists, passionate about education, to meet and network.

Please reflect on some of PFSMETE's weaknesses:

EXAMPLE Comments:

My impression is the level and quality of mentoring varied greatly from fellow to fellow; in part becomes someone coming out of science into education doesn't necessarily know how to identify a good mentor.

I do not have much interaction with my mentor, and it seems that this is true of the majority of fellows. I believe the program would work best if each fellow had true mentors both in education (or an allied field) and his/her scientific discipline.

Little communication—probably because not enough time to develop it before the program ended.

insufficient opportunities to network and interact with fellow PFSMETE's is a minus. this is reflected in the 10 minute talks at the end-of-year-1 meeting.

Health care issues, Taxes, Institutional hassles because PFSMETE is not on institutional payroll

This isn't necessarily a weakness of PFSMETE, but as much as I love education, I really miss doing science. I don't know how to solve that problem without giving up the postdoc.

I definitely would have appreciated the opportunity to meet with the rest of the PFSMETE fellows once per year, rather than just one time during the fellowship.

The fact that fellows get paid directly by NSF turned out to be a real problem, especially when it came to getting health benefits (my first institution wouldn't even give me a phone without an argument because I technically had no status at the university). I think that NSF could definitely require more of these institutions (especially since NSF is such a major funding institution); why can't NSF require that institutions give fellows normal postdoc status (and analogous benefits) as a requirement of hosting the fellows (which would cost nothing since NSF provides an allowance)?

It stinks that institutions don't have to provide health insurance with some of the funds they receive from NSF

PFSMETE perhaps doesn't pay adequately, especially in communities with higher costs of living. And there have been some particular challenges to overcome with regard to using the institutional support funds to pay for health insurance. To be on an NSF fellowship is an honor and privilege, but the lack of employee status at the university has meant various administrative obstacles had to be overcome.

My institution did not care one bit about me or my fellowship (in fact they tried to cut off my health insurance more than once) and provided very little assistance with the logistics of my proposed project (which is why I never got to test half of the materials I developed). But overall, the funding and the loose structure of the fellowship allowed me a great deal of freedom to learn and meet people, and that was an opportunity that I would not have otherwise had, and for which I am very grateful.

I have been hurt not so much by any weaknesses of PFSMETE, but rather by the extreme prejudice in the scientific community against science education folks. This prejudice is self-fulfilling and self-propagating because all the quality minds are warned against associating with science educators. To be fair, I have been disappointed with the average level of

competence among science education presentations and research projects I've seen at conferences. Programs like PFSMETE bring some prestige to science education, but the problem is so large that it had little noticeable effect...at least in chemistry.

Overall comments about PFSMETE and this survey (eg. mentor relations, institutional support, NSF's role, structure of funding, etc):

EXAMPLE Comments:

I think it would be valuable for all SMETE fellows to have both education and science community input. I have a mentor in both areas. of the two, the education person is the most critical to supplement my weaknesses (lack of knowledge) Science educators can introduce us to the pedagogy and provide connections with the education research world.

It's a shame that it's being dismantled. Math education needs more actual math doctorates working on it full-time and not as dilettantes. Without this program I wouldn't have considered becoming a math ed academic and probably would have worked for educational think-tanks, industry or non-profits.

The links to education community need only be nominal, because there is very little structure imposed in the program. In my case for example, I didn't really talk with educators or education research folks until the PFSMETE meeting this year. My mentor was more hands off than I had anticipated, and his interests are shifting.

Increased opportunities for collaboration with other PFSMETEs would be valuable. I know we all have our own research agendas, but I've collaborated with 2 other PFSMETEs on my campus on a topic that was peripheral to my own research and it was one of the most positive experiences I've had.

This program has been absolutely imperative in allowing me to move my career in the direction I wanted it to go, and in providing me with a rich, intensive experience that has broadened my science horizons. I think the PFSMETE program provides unique opportunities of inestimable value for young scientists, and shows foresight and thoughtfulness on the part of NSF.

I was surprised at the annual meeting to find so many fellows engaged in practice (teaching, minor curriculum development) rather than research (assessment, evaluation). I would have expected more research from people interested in going into academia. I also wish there were a way to engage in science research during the postdoc; perhaps explicitly allowing fellows to engage in science research (as it is I have been doing science in my spare (ha) time). I'm very grateful for the experience!

Of course, I am very disappointed that the program has been terminated. It was working quite well and the cutting of the program seemed arbitrary and short sighted.

II. MENTOR SECTION: 4 QUESTIONS

Please rank questions 1 and 2 from 1-10, where 1= strongly disagree and 10=strongly agree

Who Cares About Postdocs Anyway?

1. PFSMETE fellows will benefit from participation in the program, regardless of their chosen career path.

5: [2] 7: [1] 8: [4] 9: [1] 10: [3]

2. I would participate as a mentor in a similar postdoctoral program in science education again.

8: [1] 10: [10]

3. Compared to other postdoctoral programs, participating in the PFSMETE program as a mentor was/is _____ valuable.

[2] 0 - N/A

[0] 1 - much less

[0] 2

[0] 3 - less

[0] 4

[2] 5 - as

[1] 6

[4] 7 - more

[1] 8

[0] 9

[1] 10 - much more

4. Compared to other postdoctoral programs, PFSMETE is

[1] 0 - N/A

[0] 1 – the same as any other

Who Cares About Postdocs Anyway?

[0] 2

[0] 3

[0] 4

[1] 5 – somewhat unusual

[1] 6

[3] 7

[0] 8

[1] 9

[4] 10 - totally unique

Please comment on your experiences as a mentor. Do you have any suggestions for the PFSMETE or similar program?

EXAMPLE COMMENTS:

It has been personally rewarding to see the professionalism develop in the post-docs as they design and execute something entirely of their creation.

I have really enjoyed the diversity of subjects to which the PFSMETE has opened my interests.

I was one of those who thought I knew best how to teach my subject area and my classes have benefited from my Fellow's influence. I would very strongly recommend participation in such a program to all my colleagues who teach and am very disappointed that the program has been discontinued.

There were definitely a lot of gaps in background to fill, but this is to be expected when someone essentially switches fields, in this case from traditional research to educational research.

I am an educational researcher who develops technology-supported science curricula, and the

opportunity to incorporate content-area scientists into this work has been invaluable. For the fellows, it has clearly been an extremely valuable opportunity to learn about and contribute to education.

I was greatly disheartened that the program was discontinued before it had a chance to prove itself. The fact that this communication network among fellows and mentors continues to exist is a testament to the importance of this program.

Notes:

1. The quote continues, “*Funding agencies also need to recognize the value of the postdocs to our nation both for the work that they are doing now and the work that they will do in the future when they become the great scientists and leaders of US science*” -- Maxine Singer, President, Carnegie Institute of Washington, and Chair, Committee on Science Engineering and Public Policy, COSEPUP Convocation 3/2/2001 - -- 5:00 - 5:40 in closing remarks
2. The remainder of the 52,000 are in government or industrial postdocs. More than fifty percent of all postdocs are foreign citizens (COSEPUP 2000).
3. In 1999 - 2000. Until October of 1998, stipends began at \$19,000 per year.
4. This value is evidenced by the dramatic increase in studies by physicists using established social science methodologies. For instance, preconception studies using appropriate context and techniques have increased five-fold in the past fifteen years (Kurdziel et al. 2001)

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Figure Captions:

Figure 1. Interaction of fellows with education community before and after participation in the PFSMETE program. Notice that almost all fellows experienced an increase in interaction (gray circles) as a result of the program. Squares indicate a decrease in interaction (gray) or no change (open). The bisecting line divides regions of negative change (below) from regions of positive change (above).

Figure 2. Perceived value of the PFSMETE program, from both fellow (gray) and mentor (white) perspectives. On horizontal scale, 1 is not at all valuable, 5 is somewhat valuable, and 10 is highly valuable.

Figure 3. Fellow perception of PFSMETE as a job training opportunity, as well as perceived availability of jobs. On horizontal scale, 1 is not at all, 5 is somewhat, and 10 is definitely. Notice that although fellows felt the program was a useful training opportunity, they are skeptical about the availability of jobs in their chosen domain, specifically academia.

Figure 4. Career paths of fellows. a) The majority of fellows (25/29) are interested in academic jobs; these and the remaining fellows are split between governmental, industry, private sector, and K-12 outreach positions. b) Type of academic institution (gray) and department (white) desired. Of those fellows interested in academic positions, most preferred positions at 4-yr colleges and universities. Most fellows were interested in obtaining positions with science departments or joint between science and education.

Who Cares About Postdocs Anyway?

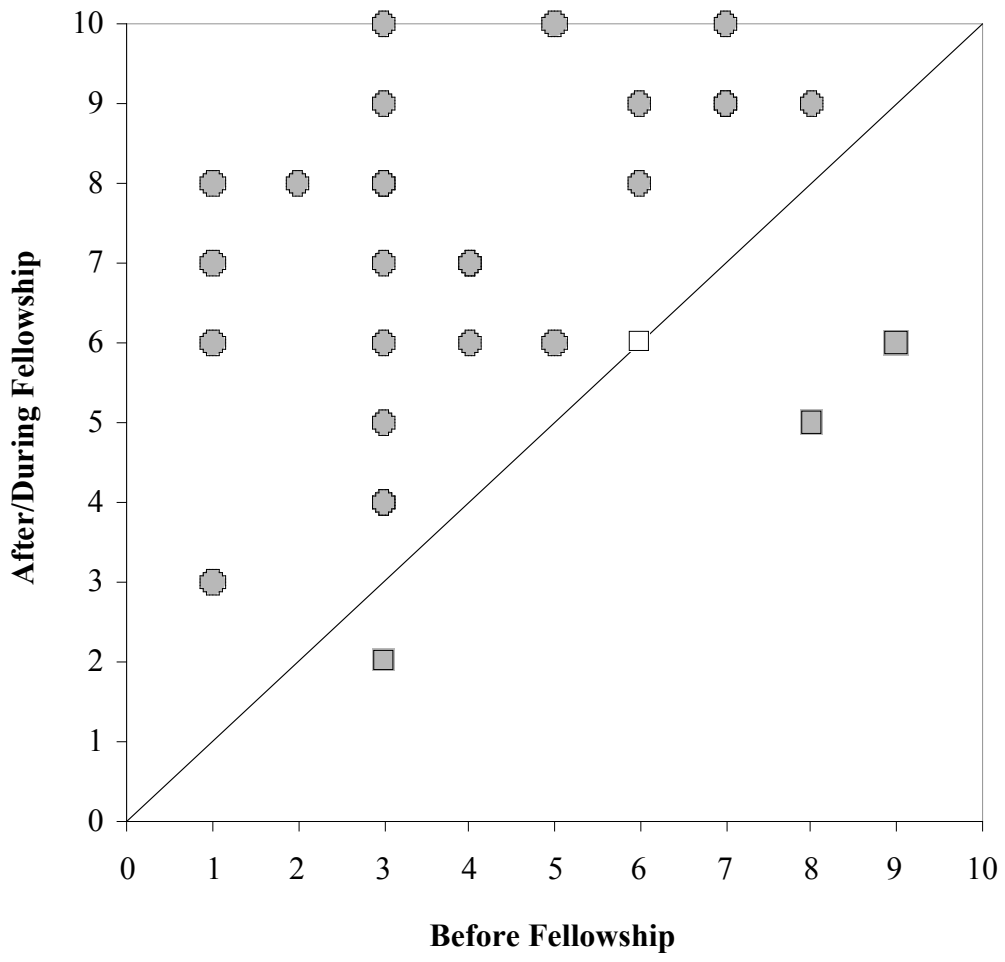


Figure 1

Who Cares About Postdocs Anyway?

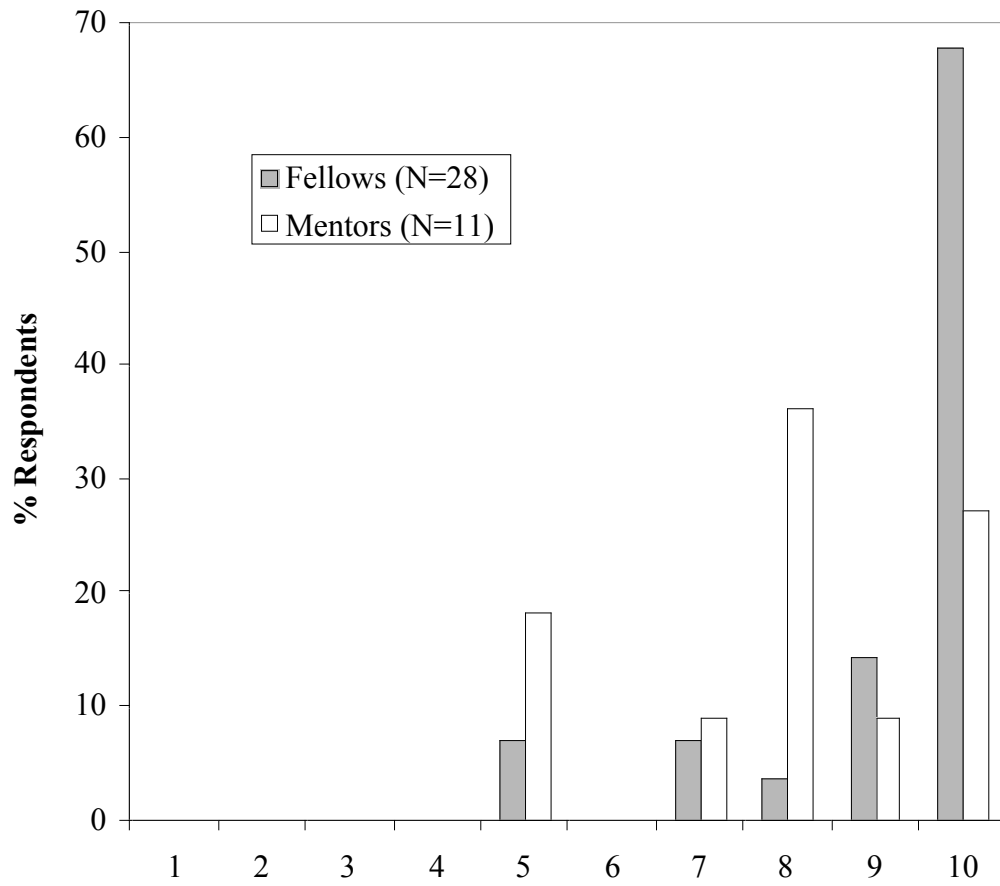


Figure 2

Who Cares About Postdocs Anyway?

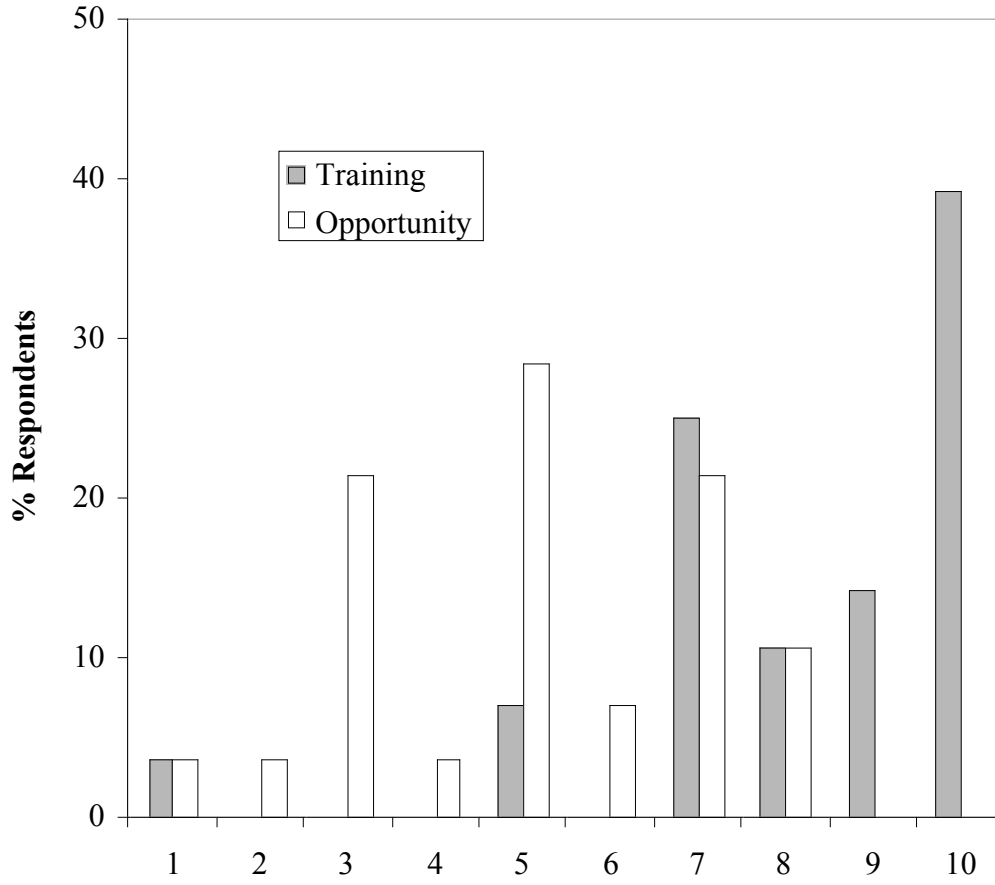


Figure 3

Who Cares About Postdocs Anyway?

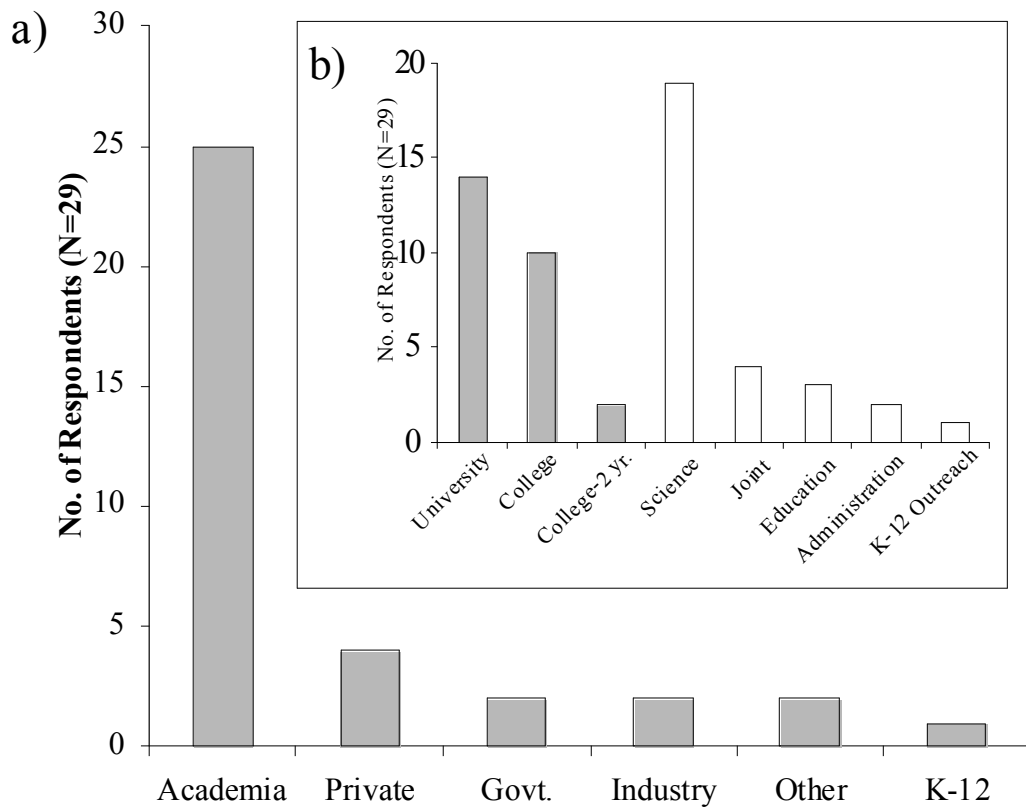


Figure 4