

Postdoctoral Training Aligned with the Academic Professoriate

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Postdoctoral training in the biological sciences continues to be an important credential for academic careers. Traditionally, this training is focused on an independent research experience. In this article, we describe a postdoctoral training program designed to prepare postdoctoral scholars for the responsibilities of an academic career that balances both research and teaching. The results showed that the research productivity of the postdoctoral scholars involved in the program was not statistically different from that of a comparison group of postdoctoral scholars not in the program. The measures of productivity including scientific seminars presented, students mentored, service contributions, and engagement in professional development activities were significantly greater for the scholars in the program. Moreover, the scholars in the program obtained faculty positions at a threefold greater rate than did a national sample of postdoctoral scholars. This study demonstrates the value of a structured program that combines research and teaching opportunities and serves as a model for aligning training initiatives with specific career trajectories.

Keywords: postdoctoral scholar, postdoctoral training, teaching, minority-serving institution, diversity

There is a growing need to prepare professionals for the challenges of an academic career by aligning their educational training with the roles and responsibilities of a faculty position. Programs such as Preparing Future Faculty (www.preparing-faculty.org) are designed to train graduate students for academic careers that are focused on teaching and research; however, even fewer opportunities are available for postdoctoral scholars, with relatively few programs specifically designed to prepare them for faculty positions. In today's academic climate, an increasing number of PhD degrees are granted each year, whereas the number of tenured or tenure-track life scientist positions has remained stable (Nyquist and Woodford 2000, National Science Board 2008). As a result, obtaining a tenure-track faculty position is becoming increasingly difficult. Institutions that emphasize teaching more than research, such as primarily undergraduate institutions, expect candidates for junior faculty positions to have considerable teaching experience. These expectations encompass experiences such as being the instructor of record of a course (Fleet et al. 2006), demonstration of effective teaching skills, the ability to establish a research program that engages undergraduate students, and the potential to successfully compete for extramural grants.

Approximately half of all postdoctoral trainees hold doctorates in the biological sciences (National Science Board 2008), which indicates that postdoctoral experience continues to be an important credential as part of a career in the biological sciences, especially for those considering academic faculty positions. Traditionally, postdoctoral training in the biological sciences involves advanced, independent research experience; productivity in the form

of peer-reviewed publications; and improvement of the scholar's skills in grant writing; however, experience with other academic responsibilities is often not part of postdoctoral training. These experiences might include teaching responsibilities beyond those of a teaching assistant in graduate school (e.g., grading papers, holding office hours); contributions to departmental service, such as advising students; and serving on departmental or university committees. Many postdoctoral trainees who are interested in an academic career seek out these opportunities informally. However, devoting time to these activities can take time away from research. Moreover, the lack of a structured program to obtain additional skills of the professoriate makes it difficult to identify these opportunities. Many postdoctoral trainees who engage in informal mentoring or training of students also do not often have a tangible mechanism to demonstrate their experience or proficiency. Therefore, a niche exists in the scientific training pipeline to prepare postdoctoral trainees for academic careers that balance high-quality research, effective teaching, and the development of the professional skills necessary for the professoriate.

In order to fill this niche, the Seeding Postdoctoral Innovators in Research and Education (SPIRE) program was created to provide a different type of postdoctoral training experience. This experience emphasizes independent research and teaching experience and includes other professional development activities important for an academic career. SPIRE is one of 18 postdoctoral programs currently funded by the Institutional Research and Academic Career Development Award program through the Division of Minority Opportunities in Research of the National Institute

of General Medical Sciences (NIGMS; www.nigms.nih.gov/Training/CareerDev/MOREInstRes.htm). The goals of this program are to facilitate the progress of postdoctoral scholars toward careers in academia and to ensure that our nation's diversity is reflected in science professions by partnering research-intensive universities with one or more minority-serving institutions (MSIs). In general, these programs have a 75% time commitment focused on research and a 25% time commitment focused on teaching. However, the programs vary in expectations, activities, relative emphasis on teaching development, types of courses taught by the scholars, and areas of research emphasis, to name a few. The key features of the SPIRE program include funded, independent research training in the biological sciences and related areas; teaching opportunities as full instructors of courses for two semesters; teaching opportunities that include introductory and advanced-level courses; development of professional skills related to academic careers; a community network of current and former scholars with similar career goals; and a continuous process of program evaluation.

Many previous studies on postdoctoral training outcomes have been focused primarily on the number of scientific publications and on the perceptions of satisfaction within the postdoctoral research-training environment (Holtzclaw et al. 2005, Davis 2009). Although in the present study, we do investigate postdoctoral progress in these areas, we also assess multiple aspects of the training outcomes to include a range of productivity measures that are intended to more closely align with the expectations of the professoriate. Specifically, we address the following question: Does a formal postdoctoral training program, which is designed to prepare individuals for the responsibilities of an academic career, increase the probability of obtaining an academic position? We hypothesize that (a) the structured SPIRE program, which includes additional training in teaching, does not significantly hinder research productivity as compared with more traditional postdoctoral positions; (b) for those postdoctoral scholars whose career goals include a combination of research and teaching, the SPIRE program provides training aligned with the responsibilities of academic faculty positions and facilitates success in obtaining a faculty position; and (c) the program provides measurable, positive impacts on undergraduate education.

SPIRE program design

The SPIRE program is a collaboration and partnership between the University of North Carolina at Chapel Hill (UNC Chapel Hill) and several MSIs in North Carolina. This program, which was introduced in 1999 with Walter E. Bollenbacher as the first principal investigator in collaboration with faculty at MSIs in North Carolina, has been supported through the IRACDA program of NIGMS since that time. Also since its inception, SPIRE has partnered with eight MSIs in North Carolina, including Elizabeth City State University, Fayetteville State University, Johnson C. Smith University, North Carolina Agricultural and Technical State University,

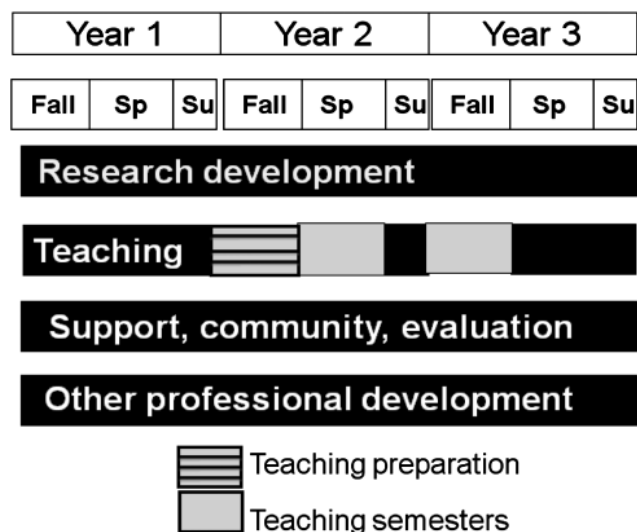


Figure 1. Structure of SPIRE training program. Abbreviations: Sp, spring; Su, summer.

North Carolina Central University, Shaw University, UNC Pembroke, and Winston–Salem State University. SPIRE is structured as a three-year funded postdoctoral training program with a 75% time commitment focused on research and a 25% time commitment focused on a mentored teaching experience with professional development activities integrated throughout the three years (figure 1). UNC Chapel Hill serves as the primary site for the research-training component, and the partner MSIs serve as the primary sites for the teaching component of the program. Therefore, SPIRE is not exclusively considered a “teaching postdoc,” since scholars engage in both research and teaching training.

Research training. Doctoral graduates accepted into SPIRE identify a research mentor within their areas of interest with the intent of gaining broader research expertise and independence, similar to traditional postdoctoral training models. SPIRE scholars have selected research mentors from a wide variety of departments, such as biology, cell and molecular physiology, chemistry, genetics, medicine, microbiology and immunology, neurobiology, and nutrition, among others. The diversity of research areas enhances the interdisciplinary nature of the program, expands the network of research expertise within the program, exposes students from the partner MSIs to many different types of research, and maximizes the range of potential course offerings at the partner institutions. The goals of the research experience are to publish in peer-reviewed journals, to present research findings at national and international conferences, and to conduct independent research that can be sustained as scholars transition into their first faculty position. Research mentors oversee the development and progress of the research project with support from the SPIRE administrative staff to ensure timely achievement of set milestones by using annual reports and research-in-progress talks.

Mentored teaching experience. The MSIs are partnered with the SPIRE program and serve as teaching sites for the scholars with the goals of supporting undergraduate science education through courses and seminars, enhancing research capacities, and inspiring students to pursue careers in science. SPIRE initially partnered with faculty in biology and the natural sciences at the MSIs and, in recent years, has expanded to include other disciplines in the biological, chemical, and physical sciences.

During the second year of the SPIRE program, as a cohort, SPIRE scholars visit the partner MSIs to meet faculty and students, to share their research in seminars, and to discuss possible courses to teach during the teaching component of the program. The scholars also participate in a seminar on college teaching, which comprises a series of two-hour workshops held during the semester prior to teaching that include topics such as designing lesson plans and syllabi, creating learning objectives, teaching critical thinking, classroom management, implementing active-learning techniques, grading, and other relevant pedagogical skills. SPIRE scholars are placed at a teaching site by a matching process to ensure mutually beneficial experiences for both the scholars and the MSI partners. The factors involved in the placement process include the scholar's research discipline, the types of courses that the postdoctoral scholar could teach, and teaching mentorship opportunities. Once at the teaching site, the SPIRE scholars take ownership of and teach one course per semester for two semesters. Typically, during the first semester, SPIRE scholars teach an introductory-level course (e.g., general biology, cell biology). During the second semester, the scholars teach either the same course or develop and teach a course in their discipline area, which is typically a course not regularly taught at the MSI (e.g., immunology, bioinformatics, mechanisms of disease).

Professional development. Professional development activities are integrated into all three years of the SPIRE program. These targeted activities include workshops and seminars on responsible conduct of research, laboratory management, budget management, grant writing, instructional technology, and career preparation skills. The SPIRE scholars also organize an annual event, the Distinguished Scholar Seminar, in which the SPIRE scholars identify and invite an outstanding scientist–educator to provide a keynote speech, typically focused on his or her research, training, and career path. Undergraduate students from SPIRE's partner MSIs attend the event, meet the guest speaker, tour laboratories, learn about emerging scientific disciplines, and learn about postbaccalaureate opportunities in science (Price et al. 2008). The goal of this activity is to provide the SPIRE scholars with the experience of organizing an event for the academic community.

A grant-writing initiative was recently integrated into the professional development training of the program, which provides experience with writing grants. Each SPIRE scholar writes a five-page grant, following the National Institutes of Health's

guidelines. The grants are based on projects that the scholars envision establishing in their first faculty position, ideally to include undergraduate students. Each grant is reviewed by two or three faculty, who provide feedback and an overall impact score. The three highest-scored grants are awarded additional research-supply funds to develop the research project.

Community of postdoctoral scholars. The SPIRE program strives to establish a sense of cohesiveness and community. SPIRE scholars begin the program in cohorts of four to six each year. Through program activities, the scholars connect with one another as scientist–educators who have similar career goals and with the scholars and program administrators already involved in the program. This community meets together once per month to share research progress, teaching ideas, and career plans and to establish collegial relationships that further nurture future collaborations and expand professional networks. This community of SPIRE scholars helps to relieve the sense of isolation commonly experienced during postdoctoral training (NAS et al. 2000).

Study design

Since the SPIRE program is a novel approach to postdoctoral training, with additional responsibilities above and beyond research, it was critical to determine the impact of the program on the scientific productivity of SPIRE scholars as compared with postdoctoral scholars not involved in the program. To establish a comparison group for the study, an e-mail solicitation originating from UNC Chapel Hill's Office of Postdoctoral Affairs was sent annually to all postdoctoral scholars on campus, inviting them to participate in the study. Between 2007 and 2009, over 700 postdoctoral scholars contributed data for the study. A comparison group was established by combining the scholars sampled at the time points of fall 2007, fall 2008, and fall 2009, to match the group of SPIRE scholars currently in the program. Members of the non-SPIRE group had to meet following criteria: They must have been (a) an active postdoctoral scholar at UNC Chapel Hill, (b) in the current position less than four years, (c) a US citizen, and (d) placed in the same research departments as SPIRE scholars. The data presented below represent a merged data set that includes all of the participants who matched the criteria above during the study time period.

We used an online data-collection tool to allow the study participants to provide demographic data and productivity data in defined categories (box 1; Strategic Evaluations, Inc., Durham, NC; www.ibiosketch.com). The data-collection tool stores previously collected data so that each time a participant logs in, he or she needs only to input new information or update previously entered data. Chi-square tests and *t*-tests were used, where appropriate, to determine the statistical significance of the differences between the SPIRE group and the comparison group. SPSS (IBM, Armonk, NY) was used for statistical analyses. A significance level of $\alpha = .05$ was selected for all tests. In order to create a more meaningful comparison of productivity measures, a profile of typical progress for a three-year

postdoctoral position was created using regression analyses of the productivity measures of the SPIRE and non-SPIRE scholar groups. This study was approved by UNC Chapel Hill's Institutional Review Board as Study no. 08-1396.

Box 1. List of categories used to measure productivity.

1. Scientific publications from current research
2. Scientific publications from prior research
3. Scientific manuscripts in review
4. Presentations at national or regional scientific research conferences
5. Presentations at international scientific research conferences
6. Scientific research seminars
7. Students mentored in scientific research
8. Publications from current education research
9. Publications from prior education research
10. Education manuscripts in review
11. Courses taught
12. Guest lectures
13. Presentations at national or regional education conferences
14. Presentations at international education conferences
15. Education seminars
16. Professional development activities
17. Service contributions
18. Job interviews and offers
19. Awards or honors received
20. Additional grants secured

Diversity of postdoctoral scholars

One important outcome of the SPIRE program has been the increase in diversity among postdoctoral scholars. The demographic data demonstrate that the SPIRE program had a statistically significantly higher proportion of female scholars (72%) than did the non-SPIRE group (60%) ($\chi^2(1) = 8.638, p = .003$; table 1). A significantly higher proportion of SPIRE scholars identified as African American (SPIRE, 16%; non-SPIRE, 3%) or Hispanic (SPIRE, 12.5%; non-SPIRE, 3%) ($\chi^2(6) = 12.403, p = .049$; table 1). One explanation for these data may be that many applicants to the SPIRE program indicate a desire to return to an MSI as part of their career path and see the SPIRE program as one mechanism to help them achieve this goal. Recruitment and training of postdoctoral scholars from underrepresented groups has been an added benefit of the SPIRE program and contributes to the diversity of scientist–educators at UNC Chapel Hill and the program's partner MSIs.

Productivity measures of postdoctoral scholars

Productivity measures are unique among professions and can vary at different points along a career track. We created a comprehensive list of productivity measures that align with measures of productivity for academic faculty (box 1). These measures encompass a broad range of scholarly activities, including scientific publications, science-education publications, presentations at conferences, courses taught, professional development, mentoring students, service contributions, and the submission and successful acquisition of grants. The primary measure of scientific research productivity is the number of research publications in peer-reviewed journals. The online data-collection system used in this study allows participants to enter publication citations

Table 1. Demographics of postdoctoral scholars.

Scholar group	Self-reported ethnic heritage											
	Female scholars		African American		Hispanic		Caucasian		Asian		Other	
	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number
SPIRE (n = 32)	72.0	23	15.6	5	12.5	4	62.5	20	6.3	2	4.0	1
Non-SPIRE (n = 67)	40.0	27	3.0	2	3.0	2	65.7	44	22.4	15	6.0	4

Table 2. Scientific publication rates, 2007–2009.

Type of progress	Group	n	Participants reporting progress		Publications per year	
			Percentage	Number	Number	SD
Scientific research publications	Non-SPIRE	67	70	47	1.17	0.10
	SPIRE	32	66	21	1.06	0.33
First-authored science research publication	Non-SPIRE	67	48	32	0.57	0.18
	SPIRE	32	47	15	0.47	0.16

from their current positions as postdoctoral scholars, as well as publications resulting from research prior to the current postdoctoral position (including doctorate work). The publication of work from graduate research typically carries over into the postdoctoral training time period and represents the ability of postdoctoral trainees to complete graduate work at the same time as they are transitioning to their new postdoctoral research. Therefore, as an indicator of overall research productivity, the number of manuscripts published during the current postdoctoral term resulting from both doctoral and current postdoctoral research was compiled in the publication rate measure (table 2). The publication rates indicate that there were no significant differences in either the number of scholars publishing or publication rates between the comparison group and the SPIRE scholar group (table 2). The average length of time in the current postdoctoral position for the comparison group was 1.85 ± 0.92 years and that for the SPIRE scholar group was 2.12 ± 1 years, which was not significantly different ($t(97) = 1.311, p = .193$) and therefore did not contribute to the differences in the average publication rates.

A regression analysis was used to predict a typical profile of productivity outcomes to create a more meaningful comparison between the SPIRE and the non-SPIRE scholar groups. Table 3 summarizes the regression analyses performed across the progress measures for both groups. The values for each cell are the result of substituting three years for the “time in postdoctoral position” variable in each regression equation. The results are truncated to the nearest whole number. For example, 1.8 publications would be truncated to 1 publication, given that 0.8 publications is not a practical value. As the results indicate, the predicted productivity characteristics of the number of publications and attendance or the number of presentations at national scientific conferences varied, but these differences were not statistically significant between the SPIRE and the non-SPIRE scholars (table 3). In other outcome measures, regression analyses predicted that the productivity rates of the SPIRE scholar group would be significantly higher than those of the comparison group in the categories of the number of scientific research seminars presented, the number of students mentored, the number of courses taught, attendance and the number of presentations at education conferences, service contributions, and participation in professional development opportunities (table 3). The productivity rates in the categories of awards or honors and grants secured were insufficient in the two groups to be compared statistically and were not included in the analysis.

Since 2000, in collaboration with its partner MSIs, the SPIRE program has collected data on the impacts on undergraduate education made by the program, which include over 150 courses taught, with more than 2500 students served. These courses included introductory-level courses, new courses, and revised laboratory courses. In addition, the SPIRE scholars had mentored over 50 students in research experiences at UNC Chapel Hill and at the partner MSI campuses and had provided students with guidance on

Table 3. Predicted progress for a three-year postdoctoral position.

Measure of progress	Non-SPIRE (n = 67)	SPIRE (n = 32)
Number of scientific research publications	4	3
Number of scientific research conferences attended	2	5
Number of presentations at national scientific research conferences	1	5
Number of scientific research seminar papers presented	1	3*
Number of undergraduate and graduate students mentored	0	3*
Number of courses taught	0	1*
Number of education conferences attended	0	2*
Number of presentations at education conferences	0	1*
Number of science-related or professional service contributions	0	4*
Number of professional development activities	1	2*

Note: These numbers were computed on the basis of each group's linear-regression equation.
* $p < .05$

career options in science. Although it is not a main goal of the program, some SPIRE scholars have engaged in the scholarship of teaching and learning, which has resulted in broader impacts on undergraduate education. Examples of these impacts include changes in course structure; engagement of students in research-based courses and inquiry-based teaching; the introduction of technology in the classroom (i.e., the use of student-response systems, “clickers”); and the development and assessment of learning tools, such as case studies (Rybarczyk 2002, Baines et al. 2004, Walton 2005, Key 2007, Rybarczyk et al. 2007, Casper 2008).

Career trajectories

On the basis of the program's design and goals, it is anticipated that SPIRE scholars will aspire to transition to careers at academic institutions, ideally into tenure-track faculty positions. Prospective postdoctoral scholars self-select SPIRE, because they identify the program as an intended step toward an academic career. Career-placement data were analyzed for all SPIRE scholars since the program's inception ($N = 52$). Since data about career placement were not available from a comparison group of postdoctoral scholars exiting UNC Chapel Hill specifically, published national data was used as a comparison to determine the career trajectories of SPIRE scholars in relation to a traditional postdoctoral experience (National Science Board 2008). As was predicted, a majority of previous SPIRE scholars (85%) are currently employed at academic institutions; the national rate was 47% (table 4).

Table 4. Career outcomes of SPIRE scholars and non-SPIRE scholars.

Position after postdoctoral training	SPIRE (percentage; n = 52)	Non-SPIRE ^a (percentage)
Position at academic institutions	85	47
Tenure-track faculty position	62	13, 20
Private institution position	8	37
Other position	8	7

Note: The two values for the non-SPIRE tenure-track faculty positions cell are for those with one to three years of postdoctoral experience and those with four to six years of postdoctoral experience, respectively.

^aFrom published national data (NAS et al. 2000).

Of those at academic institutions, 62% are in tenure-track positions or have already earned tenure; the national rate is 13% for one to three years of postdoctoral experience and 20% for four to six years of postdoctoral experience. An unanticipated outcome of the SPIRE training is the transition of nine SPIRE scholars (17%) into faculty positions at SPIRE's MSI partner institutions. This demonstrates potential long-term impacts on undergraduate education at these institutions, since it is tangible evidence that partner MSIs value the expertise of the SPIRE scholars. As faculty, former SPIRE scholars continue to use their skills in teaching and engaging undergraduate students in research endeavors. Follow-up studies and data are required to further demonstrate these long-term impacts, including documentation of curricula changes, implementation of effective teaching strategies, and publication of research involving undergraduate student participation. Only 16% of the SPIRE scholars chose other areas of employment (i.e., industry, science writing); compare this to the national rate of 44%.

Conclusions

In the basic- and biomedical-science fields, postdoctoral training is often considered a key transition period between earning a doctoral degree and becoming an independent researcher and educator in academia. The SPIRE program addressed a need for the preparation of scientists interested in academic careers by providing a training experience that combines both research and teaching excellence. The program is structured to align with expectations of the professoriate and is not necessarily a prescription for all postdoctoral training but, rather, serves as a model for designing postdoctoral training programs that target specific career outcomes. To capture a more comprehensive representation of the outcomes of postdoctoral training, we measured several areas of scientific productivity, professional activities, and educational contributions that align with the expectations of the professoriate. The results support the hypothesis that the SPIRE program does not negatively affect the research productivity of the postdoctoral scholars involved in the program when they are compared with postdoctoral

scholars not in the program. This result was indicated by similar rates of scientific research publication and presentation at scientific conferences. As was hypothesized, the results also indicate that the training provided by the SPIRE program results in significantly higher rates of progress in areas such as the number of courses taught, the number of students mentored, the number of service contributions, and participation in professional development activities. The program also results in a different outcome profile than that of traditional postdoctoral positions (table 3) and prepares postdoctoral scholars for successful transition into academic positions, which was indicated by career-placement data (table 4).

A strength of the design of this study is the method of data collection. The online data entry system accommodates new, incoming participants into the study population in both the comparison and SPIRE groups and does not rely on long-term compliance of individual subjects as would a subject-matched control approach. Thus, this approach addresses the issue of attrition, since a new comparison group can be generated at each data-collection time point on the basis of the subject-selection criteria outlined previously. A potential limitation of our study is that higher rates of entry of SPIRE scholars into academic or tenure-track positions reflects, in part, the career aspirations of those scholars who apply to SPIRE. We acknowledge this limitation, and with future data collection for non-SPIRE scholars, we will attempt to address career goals at the time of entry into a postdoctoral position.

Manuscript publication rates arising from postdoctoral research alone does not represent a complete picture of postdoctoral scholar productivity. Our data represent a publication rate that includes manuscripts published during the postdoctoral scholar's current training period, as well as those publications originating from previous graduate or postdoctoral positions. We propose that this pooled publication rate is a more accurate measurement of overall productivity at this career stage, since manuscripts resulting from dissertation work are typically submitted toward the end of the PhD completion process but are often published during the postdoctoral training phase. It is also important to recognize that postdoctoral scholars will often continue to complete publications resulting from prior postdoctoral or graduate work while they are in their current position. Although there are not published data to support this statement, a common concern expressed by research mentors and postdoctoral scholars is the difficulty of or delay in completing research papers related to graduate work after exiting a lab. Therefore, we believe that the ability to effectively take prior research to publication while pursuing new postdoctoral training is a valid component of overall research productivity. In the future, a measure of the rate of productivity from the specific SPIRE training time is desirable, but to do this, we plan to measure manuscript publication rates a year or more after the end of the postdoctoral training in order to accurately account for the lag time between submission and publication of research in peer-reviewed journals.

Although all of the present study's participants were from the same research-intensive university, there are confounding factors that cannot be controlled for in such a study. Some confounding factors not addressed in our analysis include (a) whether a postdoctoral scholar transitioned into a different research area than his or her doctoral research area; (b) the publication rates in different types of research and disciplines (i.e., animal studies usually take years to produce data, whereas other types of research may require less time), which may influence research progress and productivity rates (Davis 2009); and (c) the quality of publications. One measure proposed as an indicator of quality is a journal's impact factor; however, impact factor is an indicator of the quality of the journal itself, not the importance of its constituent articles. Therefore, using impact factors to compare the quality of articles published between the two groups in this study would be problematic. Comparing impact factors within a discipline may provide useful indicators; however, with such diverse disciplines represented in both of the study groups, comparing journal impact factors across different disciplines becomes even more problematic.

The comprehensive approach taken in this study to track the progress and outcomes of postdoctoral scholars has already been adopted by other postdoctoral programs and has been adapted to various graduate and undergraduate training programs. With this data-collection approach, other questions related to measuring the outcomes of scientific training can be investigated in a more quantitative and comprehensive manner. The data can be used to guide improved programmatic structure and implementation and to improve the overall postdoctoral training experience.

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