



Preparing Future Faculty

An Interdisciplinary, Undergraduate Science Course Taught by Graduate and Postdoctoral Teacher-Scholars

By Jessica Sales, Dawn Comeau, Kathleen Liddle, Lisa Perrone, Katrina Palmer, and David Lynn

Although the majority of graduate students pursuing doctoral-level degrees in the sciences is eventually planning for a faculty career in academics (Henderson, Clarke, and Reynolds 1996; Henderson, Clarke, and Woods 1998; Sanderson and Dugoni 1999), they leave their doctoral programs with very little experience in the broad, multidisciplinary composition of most classrooms (Austin 2002; Seidel, Benassi, and Richards 1999). Furthermore, academic hiring institutions desire applicants who are “teaching ready” (Adams 2002), yet a national survey of newly hired faculty and their chairpersons found that current graduate programs do not adequately focus on preparing doctoral students for college teaching (Seidel, Benassi, and Richards 1999). However, doctoral students who are preparing to become future faculty must develop their individual creative focus, maintain research and scientific rigor, and excel at teaching. In order to adequately prepare future faculty for these multiple roles,

To adequately prepare future faculty for their multiple roles as researchers, teachers, and colleagues, innovative teaching opportunities must be made available to doctoral students that allow them to maintain a high level of research productivity while acquiring independent teaching experience and training. A new program is developed that offers a unique teaching opportunity for graduate and postdoctoral students in the natural sciences and empowers them as independent teacher-scholars.

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innovative teaching opportunities must be created and made available to doctoral students that allow them to simultaneously maintain a high level of research productivity and acquire independent teaching training and experience.

Traditionally in the natural sciences, research consumes the majority of doctoral students' time and training, and time devoted to teaching and teacher training, if any, is usually fulfilled by becoming a teaching assistant (TA) in a few courses early in their education. Most TA positions primarily consist of grading and assisting an instructor with course logistics, and require little to no actual teaching by graduate students. The result is that graduate students leave their degree programs with almost no independent teaching experience. Thus, as Golde and Dore (2001) concluded after their survey of doctoral students, there is a three-way mismatch between the traditional structure and purpose of doctoral education, doctoral students' aspirations, and the triumvirate demands of their future careers within

academics (research, teaching, and academic service).

There are several plausible reasons for the apparent deficiency in independent-teaching opportunities for graduate students at research-oriented universities in the natural sciences. Some are institutionally driven (e.g., faculty members are already paid to instruct courses, whereas most graduate students are not), some are program driven (e.g., when graduate students' funding is based on research assistantships provided by a department, program, or external agency, students are required to conduct research for support rather than teach), while others are faculty-advisor driven (e.g., a faculty advisor may not want graduate students to be distracted from academic scholarship and research) and graduate-student driven (e.g., graduate students may not feel they have the time to devote to teaching for an entire semester). However, this paper is not a commentary on the reported mismatch between doctoral students' training and the requirements of future academic positions (Austin 2002;

Boice 1992; Golde and Dore 2001; Olsen 1993; Olsen and Crawford 1998). Instead, this paper describes an innovative program conducted at a research university that addresses and overcomes some of the perceived institutional, program, faculty-advisor, and graduate-student barriers that prevent graduate students in the sciences from engaging in independent, undergraduate teaching opportunities.

We maintained that an ideal teaching experience would allow graduate students to gain more independent teaching practice while still developing a strong research-focused agenda. Teaching must not detract from the overall missions of institutions or doctoral students' departments. Accordingly, we sought a teaching opportunity that, first and foremost, allowed doctoral students in sciences to serve as course instructors (versus TAs for other instructors), thereby providing them with independent-teaching and pedagogy-development experience. Second, to reduce the responsibility and time commitment, the course should be team-taught so that mul-

TABLE 1

Teacher-scholars and their teaching-module titles for ORDER.

Teacher-scholar	Program of study	Module title
<i>Section 1: Choose Your Own Adventure (In Science)</i>		
Jason Davis	Psychology	How do monkeys deal with stress?
Piotr Habdas	Physics	What do peanut butter, silly putty, sand, and shaving cream have in common?
Steven Girardot	Chemistry/Public Health	How does air pollution affect pulmonary health?
Brenda Minesinger	Genetics	How can fungus help our understanding of cancer development?
Christine Schaner	Developmental Biology	How can worm stem cells help to heal human distress?
<i>Section 2: Size Does Matter</i>		
Kris Bough	Pharmacology	Diet and epilepsy
Denise Flaherty	Pathology	Why worms?
Wade Neiwert	Inorganic Chemistry	Chemical warfare and POMs
Lisa Rattiner	Psychology	Learning and memory
Kenneth Walsh	Chemical Biology	Origins of life

multiple graduate students share the preparation and hands-on classroom instruction for an entire semester. The reduced time commitment should remove or diminish concerns of the faculty advisor. Third, students' teaching commitments should not detract from, but rather significantly enrich, research and academic scholarship; accordingly, students should teach about their chosen research problem, bringing their passion and excitement of recent discoveries to the classroom. And finally, given that most doctoral students in the sciences are supported by research assistantships provided by either their faculty advisor, their department or program, or an external agency, the individual (e.g., faculty advisor) or department providing financial support for the graduate student should be provided with monetary compensation for graduate students' reduced hours in the research lab.

Program description

The initial experiment merging these elements was implemented

at Emory University in the fall of 2003. With funding initially provided by the Howard Hughes Medical Institute, Emory College, and the Emory University School of Medicine, we introduced a program entitled "On Recent Discoveries by Emory Researchers" (ORDER), which was offered as a freshman, undergraduate seminar. In the spring of that year, the opportunity for graduate students to teach their research was advertised across the natural-science departments through an e-mail announcement. The incentive was that each teacher-scholar selected would receive a laptop computer and their principle research advisor would receive financial compensation to be applied toward students' funding. This announcement netted 76 applicants, and a selection committee consisting of the departmental chairs of math/computer science, chemistry, biology, and physics; Pat Marsteller, the director of the Center for Science Education at Emory; Arri Eisen, senior lecturer in biology; and two undergraduate

students winnowed the applicants to 24. After presenting four-minute overviews of their proposed modules to the selection committee, 10 of the 24 finalists were appointed inaugural teacher-scholars. These teacher-scholars were divided into two equal sections designed to maximize intellectual diversity in the topics they would cover (see Table 1). Section 1, entitled "Choose Your Own Adventure (In Science)," was taught by teacher-scholars from psychology, chemistry/public health, physics, genetics, and developmental biology, while section 2, called "Size Does Matter," was taught by teacher-scholars from pharmacology, pathology, psychology, inorganic chemistry, and chemical biology.

The teacher-scholars met as a group approximately every 10 days throughout the summer of 2003 to review, to plan, and to coordinate their modules. Professor David Lynn, a Howard Hughes Medical Institute Professor, and Asa Griggs Candler, professor of chemistry and biology at Emory University,

TABLE 2

Comparison between ORDER teaching experience and other teaching experiences typically offered to graduate students in the natural sciences at Emory University.

	Graduate-student teaching experiences		
	ORDER	Independent ^a	TA ^b
Structured and supervised course preparatory work	++++	+	++
Teaching supervised by experienced faculty	++++	+	+++
Regular meetings with supervising faculty	++++	+	++
Significant independent teaching opportunities	++++	++++	+
Reasonable time commitment that does not significantly detract from research	+++	+	+++
Planned opportunity to teach same material over multiple semesters	++++	++	+
Opportunity to mentor students	++++	++++	++
Opportunity to grade/evaluate students	++++	++++	++
Opportunity to grade assignments/exams	++++	++++	++++

Note: Scale ranges from + to +++++, with more +s indicating more exposure to the corresponding aspect of teaching/teacher training.

^a Refers to independent teaching opportunities offered to graduate students.

^b Refers to teaching assistantships offered to graduate students.

coordinated these meetings, challenging students to identify the unique features of their disciplines and their specific research discoveries, to select central themes that resonated across the modules, and to design a course that was more than a series of individual modules from a variety of disciplines, but rather one that generalized and unified the process of research across a larger intellectual community. The summer provided sufficient time to develop a complete five-unit course that introduced scientific research as an intellectual continuum (for a detailed description of the modules developed, course layout, and syllabi for the course, contact the authors).

As for the course itself, each class was limited to 15 freshmen students and each section was offered during both the fall semester of 2003 and the spring semester of 2004, meeting twice a week for 75 minutes each session. Over the course of one semester, teacher-scholars independently taught their research discoveries—an area of their unique expertise—over the span of five class sessions. Professor David Lynn attended and supervised all class sessions and offered assistance and feedback to the teacher-scholars throughout both semesters.

Two classes in the beginning of each semester were used to explain the course structure and overarching course theme, and to personally introduce the teacher-scholars, who reviewed their backgrounds, discussed their pathways to selecting a scientific discipline, and provided overviews of their research discoveries. Class time included a trip to a laboratory to test whether UV light was damaging to yeast, use of Magic Sand and household detergents to demonstrate the forces created by entropic ordering, and use of sand to demonstrate the properties of non-Newtonian fluids. One particularly instructive experiment, devised by Steven Girardot, was based on the fictitious statement that Emory University was considering eliminating

all parking on campus to reduce pollution levels. To test the university's proposed solution, three-person student teams were provided with several diffusion tube samplers to measure atmospheric nitrogen dioxides and instructed to place these samplers in areas that would allow them to assess the impact of automobile emissions on campus air quality. Each team had to justify sampler placement, evaluate the data collected (samplers were analyzed in the Rollins School of Public Health, Department of Environmental and Occupational Health), and argue for or against the university's proposal. This exercise proved enjoyable and motivational, nicely demonstrated the scientific method and, most importantly, connected with Steven's experimental model, which evaluates the impact of local pollution on distant locations such as the Great Smoky Mountain National Park. Many of these experiments were successful enough to be covered by the local National Public Radio affiliate, WABE (see www.cfkeep.org/HHMI).

In addition, one class period was reserved mid-semester for students to present their own research questions to their peers. Teacher-scholars selected three principle advisees and mentored these students as they developed their own National Science Foundation-style research proposals, which students presented in written form and defended orally at the end of the semester. Teacher-scholars served as both intellectual role models and near-peer process mentors, facilitating access to electronic databases, library resources, and other experts across the campus.

Overall, the ORDER program provided teacher-scholars with a better option for gaining a well-rounded, independent teaching experience than the teaching opportunities generally available to graduate students in the natural sciences at Emory University (see Table 2).

Measuring success

We hoped to provide graduate students in the sciences with an opportunity to gain independent instructional experience by teaching their discoveries—the area where each is the world's expert—while collaboratively introducing the concepts and procedures of their field. Second, we hoped to provide graduate-student teacher-scholars with an opportunity to play a central role in the university's intellectual mission by exposing entering freshman undergraduates to the diverse research conducted at a research university (see Sales et al., forthcoming, for analyses of the ORDER program's impact on undergraduate students' scientific thinking). Finally, we hoped that the ORDER experience would enrich teacher-scholars' appreciation of their own research when placed in the larger context of the intellectual pursuits across the institution. To measure the success of ORDER in achieving the three goals, we surveyed participating teacher-scholars about their experiences both prior to and after their participation in ORDER.

Method

Emory University's Institutional Review Board (IRB) approved the surveys given to teacher-scholars, and neutral individuals were appointed to administer the surveys, evaluate the efficacy of the collected data, and remove all identifying information. Pre- and postparticipation surveys were completed by 7 of the 10 teacher-scholars.

Both pre- and postparticipation surveys consisted of open-ended questions about teacher-scholars' reasons for applying to the program, perceptions of their roles within the university, benefits and challenges of participation, as well as any impact the course had on their future career plans. (Several questions on the survey were specifically about course logistics and therefore irrelevant to this paper. Thus, only selected questions are discussed here; the

complete surveys are available from the authors upon request.) Three questions were directly relevant to examining the impact of the ORDER program on graduate students' teaching roles within the university and future career plans: (1) Why did you apply for the Howard Hughes Medical Institute ORDER program? (2) What role do you as a graduate student play in the university? and (3) Has this experience helped you draw any conclusions about teaching as part of your career?

To extrapolate common themes and general information from the survey responses, two independent coders read through all responses to gain a general familiarity prior to systematically assessing themes and common responses for each question. An iterative process of incorporating emergent themes was employed, followed by clustering these themes in logical groupings, and then summarizing in text the patterns that emerged.

Results

The teacher-scholars' responses are summarized below. The responses to each of the three target questions are presented separately.

Why did you apply for the Howard Hughes Medical Institute ORDER program?

Teacher-scholars gave multiple reasons for applying to the ORDER program. Strikingly, however, all teacher-scholars stated that they had applied to the ORDER program to gain teaching experience. Specifically, four applied because they only had the opportunity to be a TA in their departments. Gaining independent teaching experience was particularly important to two of the teacher-scholars because they were actively trying to decide whether or not to pursue a career in academia. Those who had taught previously expressed a desire to gain more experience, in one case because of the desire to secure a faculty position at a liberal arts

college. These experienced teachers also perceived the program as an opportunity to teach in a different way and emphasized their interest in teaching a course about their own research, having greater flexibility in the classroom, and being able to use real-life examples.

Compensation was also commonly mentioned as a factor that led graduate students to apply. Specifically, three teacher-scholars indicated that the compensation, in conjunction with the teaching experience, attracted them to this teaching opportunity. A number of other factors received a single mention: the reasonable time commitment, the opportunity to work with an "intellectually stimulating group," the opportunity to work with interdisciplinary researchers, and the desire to better understand their own research.

What role do you as a graduate student play in the university?

Teacher-scholars answered this question both before and after their involvement with the ORDER program, allowing us to examine how they perceived their roles changing over time. When questioned about the roles of graduate students in the university prior to the beginning of the program, most teacher-scholars highlighted their roles as researchers. They discussed their own research, but particularly emphasized their work in university research labs. Some characterized the graduate-student population as the "workforce" of university research, the people who do the "grunt work" and provide "cheap, experienced labor for the labs." Additionally, they indicated that through these positions, they assisted with generating grant income and recognition for the university. Several perceived their presence in the labs as a benefit both to themselves and to their faculty advisors in terms of research quality and productivity.

Several teacher-scholars noted that opportunities for teaching and

mentoring exist within these lab-based research positions. Teacher-scholars reported training lab personnel, mentoring undergraduate and other graduate students, and serving as a link between faculty and undergraduate research assistants. However, they emphasized that apart from these experiences, few opportunities to teach in a classroom setting exist for graduate students in the sciences.

Postparticipation responses revealed that ORDER helped teacher-scholars broaden their roles in the university. For many teacher-scholars, the program was their first experience with independent teaching. One in particular explained that graduate students can feel isolated from the rest of the university, and this teacher-scholar discussed finally having a role in the university that wasn't just within the graduate school. Another said, "I didn't feel like a grad student while teaching." This person appreciated the chance to think about their research independently of their advisor's influence. At the same time, this teacher-scholar acknowledged the challenge of transitioning into the role of instructor and learning to communicate scientific information to undergraduates without relying on scientific jargon. Another appreciated the chance to share knowledge with others across the university.

For teacher-scholars who had contact with undergraduates in the classroom prior to participating in ORDER, responses indicated that the program broadened this contact. In particular, two teacher-scholars noted that teaching in a freshman seminar was a good opportunity because most interactions graduate students have with undergraduates are with upperclassmen and restricted to lecture-based courses. One respondent stated that this program "should be required of all graduate students," noting that combining teaching with research raises the level of both and is "more fun."

Has this experience helped you draw any conclusions about teaching as part of your career?

Participation in the program affected graduate students' career aspirations and research plans. One teacher-scholar reported wanting to pursue a career in teaching and research, rather than just research. A second individual is now considering doing outreach education and feels more confident about being able to communicate with a general audience. A third said, "I didn't think I'd be good at teaching," but is now considering staying in academia after participating in the program. Additionally, teacher-scholars indicated that having the opportunity to teach developed their skills and teaching confidence. Some respondents also appreciated learning about how to use new teaching approaches. In particular, one noted the importance of discussions and class assignments in student learning, while another said the experience "confirmed my enjoyment of teaching" and reinforced the importance of linking concepts to students' experiences.

The experience of teaching their discoveries provided unexpected benefits. The process of preparing for classes and expressing ideas to undergraduate students led some teacher-scholars to conceptualize their research differently. Having feedback from both students and each other helped teacher-scholars to better understand how others view their research. Specifically, the multidisciplinary perspective offered by their peers was reported to be particularly helpful. Some teacher-scholars found that the process helped them to achieve greater focus with their research and broadened their ideas about how to present research effectively. One respondent explained that the program "reminded me of how interested I am in my research" and "showed me that people outside think my research is interesting." All of the teacher-scholars' surveys reiterated the importance of linking

teaching and research. For example, one respondent acknowledged the importance of incorporating research into the classroom, while another asserted that "research and teaching shouldn't be separate" because they each help improve the other.

Discussion

Overall, the ORDER experiment reinforces previous findings for the need to provide graduate students in the natural sciences with independent teaching opportunities. The talents of research and teaching are not separated in academic faculty—both are considered in their hiring and evaluation for promotion, and the interest in the ORDER program suggests that graduate students already recognize the requirements of the academic positions they pursue; why maintain such separation in their training? The results suggest that ORDER is an important initial step toward better preparing graduate students for academic careers.

As indicated previously, several barriers confound independent teaching opportunities for graduate students in the natural sciences (i.e., perceived institutional, program/departmental, faculty-advisor, and graduate-student barriers to teaching). Teacher-scholars' responses when asked why they applied to the program illustrate how ORDER overcame many of these obstacles. Specifically, in line with Golde and Dore's (2001) findings, graduate students' awareness that they lacked teaching skills and their desire for independent teaching experience led them to apply to ORDER.

The funding provided to faculty advisors to supplement graduate students' stipends provided another strong motivator to participate in the program. However, this monetary incentive for the most recent class of teacher-scholars was significantly decreased and the number of applicants remains

high. Therefore, modest support appears to provide sufficient incentive and a program like ORDER may be successfully implemented and maintained with limited monetary overhead. The reasonable time commitment involved in this teaching opportunity, the interdisciplinary nature of the course, and the chance to teach their research were other motivators specifically noted by teacher-scholars.

ORDER also provided graduate-student teacher-scholars with an opportunity to play a central role in the university's intellectual mission. Teacher-scholars' responses when asked what role they played in the university demonstrate that the ORDER program broadened that role from merely student and researcher to include teacher and scholar, as well. Specifically, participating teacher-scholars reported that multiple roles made them feel more integrated into the larger university community rather than feeling isolated within their specific discipline. Additionally, they noted that combining research and teaching made both more enjoyable.

Moreover, teacher-scholars proved to be effective teachers. Our postcourse evaluations of the undergraduates who participated in the ORDER classes indicated that graduate-student teacher-scholars successfully increased freshman students' critical-thinking abilities and science-related skills, such as formulating research questions and communicating scientific information, and, perhaps most importantly, teacher-scholars stimulated many undergraduate students to pursue research-related interests in the future (see Sales et al., forthcoming, for a detailed description of the ORDER program's impact on undergraduate students enrolled in the course).

Finally, teacher-scholars' responses demonstrated that the ORDER program was successful at exciting graduate students about teaching, as well as giving them the

confidence to pursue careers in academics. When asked whether the experience helped them draw any conclusions about teaching as part of their careers, teacher-scholars indicated that the process of teaching their research, particularly in an interdisciplinary setting, allowed them to refine their thinking about their own research and gave them skills for effectively presenting research findings to a diverse audience. However, the most prominent theme that emerged across all the teacher-scholars' responses was that linking teaching with research was fundamentally important because one improves the other.

Overall, this study suggests that ORDER, a unique, collaborative teaching opportunity offered to graduate students in the natural sciences, was successful at overcoming multiple barriers that typically hinder graduate students in the sciences from gaining independent teaching experience during their doctoral training. Moreover, the program was well received by the teacher-scholars who participated, as well as by graduate students across the sciences, with 76 graduate students and postdoctoral fellows applying to participate. Furthermore, the program helped integrate graduate students into the larger university community, and allowed participants to more accurately understand what an academic position entails. Perhaps the most striking finding was that after gaining some independent teaching experience, graduate students felt inspired and empowered to pursue academic positions. Indeed, all of the teacher-scholars have pursued academic jobs, with 6 of the 10 teacher-scholars currently in postdoctoral training positions, and four who have already successfully obtained academic positions. ■

Acknowledgments

We are grateful to the Howard Hughes Medical Institute, both for allowing this experiment to take form and for

nurturing its development, and to Dean Hilary Ford for running the selection committee. We also gratefully recognize support from Emory College, the Graduate School of Arts and Sciences, the Emory College Faculty Science Council, the Emory University School of Medicine, and the Departments of Biology, Chemistry, Math/Computer Science, Pharmacology, Physics, and Psychology. Finally, we are most grateful for the undergraduate students at Emory University who took a chance in this experiment and the teacher-scholars whose creative energies made it all possible. The latter are: Kristopher Bough, research fellow in physiology at Emory; Denise Flaherty, research fellow in pathology at Emory; Wade Neiwert, assistant professor of inorganic chemistry at Bethel College; Lisa Rattiner, research fellow at Yerkes National Primate Center; Kenneth Walsh, assistant professor of chemistry at University of the South; Jason Davis, research fellow in biology at the University of Washington; Steven Girardot, adjunct assistant professor in the School of Earth and Atmosphere Science at Georgia Institute of Technology; Piotr Habdas, assistant professor of physics at St. Joseph's University; Brenda Minesinger, research fellow at Massachusetts Institute of Technology; Christine Schaner, research fellow at the University of Virginia; and Nikki Khana of the Department of Sociology at Emory.

References

Adams, K.A. 2002. What colleges and universities want in new faculty. *Preparing Future Faculty (PFF) Occasional Papers*. Washington, DC: Association of American Colleges and Universities.

Applegate, J.L. 2002. Engaged graduate education: Seeing with new eyes. *Preparing Future Faculty (PFF) Occasional Papers*. Washington, DC: Association of American Colleges and Universities.

Austin, A.E. 2002. Preparing the next generation: Graduate school as socialization to the academic career. *Journal of Higher Education* 73: 94–122.

Boice, R. 1992. *The new faculty member: Supporting and fostering professional development*. San Francisco: Jossey-Bass.

Golde, C.M., and T.M. Dore. 2001. *At cross-purposes: What the experiences of today's graduate students reveal about doctoral education*. Philadelphia: Pew Charitable Trusts.

Henderson, P.H., J.E. Clarke, and M.A. Reynolds. 1996. *Summary report 1995: Doctorate recipients from United States universities*. Washington, DC: National Academic Press.

Henderson, P.H., J.F. Clarke, and C. Woods. 1998. *Summary report 1996: Doctorate recipients from United States universities*. Washington, DC: National Academic Press.

Olsen, D. 1993. Work satisfaction and stress in the first and third year of academic appointment. *Journal of Higher Education* 64: 453–71.

Olsen, D., and L. Crawford. 1998. A five year study of junior faculty expectations about their work. *Review of Higher Education* 22: 39–54.

Sales, J.M., D.L. Comeau, K. Liddle, N. Khanna, L. Perrone, K. Palmer, and D.G. Lynn. Forthcoming. Bridging the gap: A research-based approach for teaching interdisciplinary science to undergraduate freshman. *Journal of College Science Teaching*.

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

Seidel, L.F., V.A. Benassi, and H.J. Richards. 1999. College teaching as a professional field of study: The New Hampshire model. Unpublished manuscript. Quoted in Adams 2002.