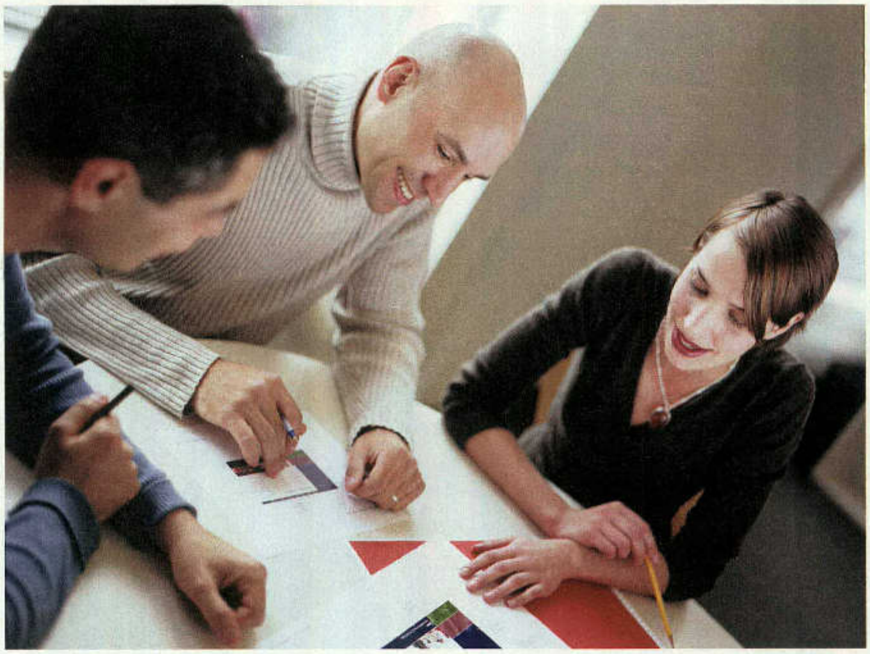
# A Professional Development Teaching Course for Science Graduate Students

*By Erin Baumgartner*

*An innovative course at the University of Hawaii provides future science professors with professional development in effective science teaching.*



Although the majority of the teaching faculty at U.S. universities is composed of people who are scientific experts, research has found that most scientists do not have information about effective teaching methods (DeHaan 2005). Traditional lecture-style college science teaching does not reflect knowledge about best teaching practices based upon research about teaching and learning (AAAS 1990). Ironically, the large lecture courses with their step-by-step cookbook laboratories in place at many universities and colleges have been suggested by some to be counterproductive to developing the real-world problem-solving strategies valued by professional scientists (Herreid 2001).

The structure of such traditional teaching practices poses a challenge to effective undergraduate instruction in science. In the late 1990s, studies found that over 50% of both minority and majority students entering college intending to major in fields in the natural sciences change their stated focus within two years of taking their first college science class (Seymour and Hewitt 1997). The negative experience created by traditional-style science courses may be a part of this phenomenon. In a control-comparison study of students in a laboratory science course, Lord and Orkwiszewski (2006) found that students in an inquiry-based lab course reported significantly greater positive attitudes about science, although their content knowledge did not significantly change compared to that of their peers in a traditional laboratory course. Beyond the issues of recruitment and retention, effective instruction in science is also needed for the majority of students in introductory science courses who are nonmajors (Bishop 2002). These students, who may not take more than one required biology course, for example, still need to gain basic understandings of the practical issues related to their environment that affect their lives (Hurd 2006).

Disconnects between types of learning experiences in K–12 and undergraduate science classrooms and a lack of awareness of current instructional research also decrease the effectiveness of undergraduate science education (NSTA 2000). McIntosh (2000) suggests that college teachers need to recognize that they are affected by reform initiatives because they are part of the team of science instructors spanning the educational experience of students from kindergarten through college.

The modeling of scientific thinking and inquiry for students should be easily accomplished by researchers, who engage in such thinking every day. The challenge is in effectively translating that thinking into the classroom setting, facilitating rather than directing learning. Many university and college instructors who were effectively trained to engage in scientific research find shifting to a learner-centered teaching model difficult (Glasson and McKenzie 1997).

One possible solution to the challenge of effective science instruction at colleges and universities is to provide professional development in effective instruction to the next generation of the professoriate. Graduate teaching assistants (GTAs), while focusing on their training as researchers, are being asked to effectively instruct undergraduates. Many undergraduates spend more time and connect more directly with GTAs than professors. In a com-

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prehensive study of 158 U.S. colleges and universities, Sundber, Armstrong, and Wischusen (2005) found that 91% of the biology laboratory instruction at research universities and 71% at comprehensive universities was provided by GTAs. Most universities have training programs or centers devoted to providing professional development for GTAs, but even the best GTA training programs are often very generalized to a variety of disciplines across campus (Luft et al. 2004). Effective science instruction calls for generalized teaching skills, as well as a host of very specific strategies targeted to enhancing students' scientific literacy and understanding of the nature of science. Since many of the estimated 500,000 new professors teaching students by the year 2014 (Jones 1993) will have served as GTAs, it is vital that these professors-in-training be provided effective professional development on teaching strategies in addition to their training on using audiovisual equipment, diversity awareness seminars, or weekly lab meetings that only cover the logistics of conducting labs, without targeting the strategies needed to help students think critically about the concepts that the lab work is meant to convey.

DeHaan (2005) suggests creating opportunities for educating faculty, graduate students, and others who are currently teaching science, or may do so in the future, about effective instructional techniques. Such a move would also highlight the importance of building effective teaching skills. The GTAs in a variety of scientific disciplines interviewed by Luft et al. (2004) identified a tension between the research and teaching parts of their careers. These GTAs felt the emphasis in their program was on research training, while teaching was considered to be a skill accomplishable by any graduate student with a minimal amount of effort.

An innovative course at the University of Hawaii at Manoa (UHM) offers an opportunity for science graduate students to gain expertise in teaching strategies grounded in pedagogical research that target improving instruction in the nature and process of science and learner engagement. In a recent survey, undergraduates at UHM ranked as the number one priority to improve their educational experience "improve the methods that professors use when they teach." The fourth priority item was to "make classes more intellectually stimulating" (UHM 2006). Fewer than 60% of the students surveyed agreed with the statement "Professors' teaching methods are consistent with my learning needs." Providing for the development of the teaching skills of future professors is one way to address these demonstrated student concerns.

## Course design/implementation

Zoology 619, Seminar in Science Teaching, is offered to science graduate students at UHM. I designed the course to target skills specific to effective teaching of science as both process and content, with a focus on engaging learners. Zoology 619 is in part based on the highly successful seminar provided for graduate students taking part in the NSF-funded Graduate Fellowships in K–12 Teaching (GK–12) fellowship program. This seminar was designed by myself and other UHM faculty in the College of Education Curriculum Research and Development Group (CRDG) to support instructional skills needed by the fellows to engage K–12 learners in inquiry-based science. In addition to incorporating current research-based science instruction strategies, course design for Zoology 619 also used feedback from fellows on the topics they found to be most useful in improving their teaching abilities. Following the first year of the course, students' comments and recommendations helped me improve the design and implementation of the course.

The Zoology 619 course is not targeted at improving K–12 instruc-

**TABLE 1**

**Demographic data of Zoology 619 participants.**

| Department | Degree track | Year of study | Teaching experience | Career goals |
|---|---|---|---|---|
| Zoology | PhD | 3 | None | Academic research |
| Zoology | PhD | 5 | UHM teaching assistant | Informal education |
| Zoology | MS | 4 | UHM teaching assistant | Informal education |
| Zoology | PhD | 2 | None | Undecided |
| Zoology | MS | 2 | UHM teaching assistant | College instruction |
| Zoology | PhD | 3 | UHM teaching assistant, GK–12 fellow | Undecided |
| Zoology | MS | 2 | UHM teaching assistant, nature interpreter | Informal education |
| Zoology | PhD | 2 | None | Academic research |
| Zoology | MS | 4 | UHM teaching assistant | Academic research |
| Zoology | MS | 1 | UHM teaching assistant | Undecided |
| Zoology | PhD | 10 | UHM teaching assistant, biology laboratory coordinator | College instruction |
| Zoology | MS | 1 | None | Undecided |
| Zoology | MS | 1 | UHM teaching assistant | Undecided |
| Zoology | MS | 4 | UHM teaching assistant, GK–12 fellow | K–12 education |
| Zoology | PhD | 2 | UHM teaching assistant | Academic research |
| Zoology | PhD | 6 | UHM teaching assistant | Academic research |
| Zoology | MS | 1 | UHM teaching assistant | Undecided |
| Zoology | PhD | 5 | UHM teaching assistant | Academic research |
| Cell and molecular biology | MS | 2 | UHM teaching assistant | Undecided |

**TABLE 2**

**Topics covered in Zoology 619, associated readings, and class activities.**

| Topic | Reading | Class engagement |
|---|---|---|
| Inquiry | Nicastro, N.H. 2005. Teaching from both sides of the desk. *Thought and Action* 21 (Fall): 57–68. | Participate in an inquiry lab and identify methods for engaging students in scientific processes and developing thinking skills |
| Constructivism | Brooks, J.G., and M.G. Brooks. 1993. *The case for constructivist classrooms* (Chapter 1). Alexandria, VA: Association for Supervision and Curriculum Development (ASCD). | View video of students describing misconceptions; identify personal misconceptions through misheard lyrics activity and describe process of correcting misconceptions |
| Differentiating instruction | Clough, M.P. 2002. Using the laboratory to enhance student learning. In *Learning science and the science of learning*, ed. R. Bybee, 85–94. Arlington, VA: National Science Teachers Association. | Revise cookbook labs into inquiry-based labs with options for differentiation and choice making by students |
| Standards—connecting science education K–16 | AAAS. 1990. *Science for all Americans* (Chapter 1). New York: Oxford University Press. | Review National Science Education Standards and participate in backward mapping exercise to link activities to standards |
| Discussion and questioning strategies | Hannel, G.I. 2003. *Highly effective questioning* (Chapter 4). Phoenix, AZ: Kismet Print Productions. | Plan questions for a lab or lecture class that emphasize critical thinking and student engagement |
| Safe and effective field studies | Niebuhr, D.H., P. Easterling, and R.A. Carroll. 2004. Put down that shark: Classroom management strategies for field based experiences. *Current: The Journal of Marine Education* 20 (2): 35–39. | Examine field-trip case studies, field-trip planning exercise to help students become aware of hazards and safety gear |
| Multiple intelligences and learning styles | McCarthy, B., et al. 1990. 4MAT article series. *Educational Leadership* 48 (2): 31–46 | Prepare personal learning styles inventories, plan an instructional sequence for multiple intelligences and learning styles |
| Multidimensional assessment | Hein, G.E. 1991. Active assessment for active science. In *Expanding student assessment*, ed. V. Perrone, 107–31. Alexandria, VA: ASCD. | Participate in five different assessments and discuss usefulness of each for different circumstances and applications |
| Technology in the classroom | Young, J.R. 2004. When good technology means bad teaching. *The Chronicle of Higher Education* 51 (12): A31. | Plan a "good" and "bad" instructional PowerPoint; discuss other educational technologies in use |
| Motivating learners | Lazzarino, C. 2004. Big risks; big rewards. *University of Kansas Alumni Magazine* 2004 (6): 25–29. | Discuss strategies for motivating and engaging large classes |
| Teaching about evolution | McMurtrie, B. Darwinism under attack. *The Chronicle of Higher Education* 12/21/2001. | Identify and plan counter arguments to intelligent design proponents |

tion, but rather the ability of GTAs to effectively teach science to learners at all levels. Thus, the course content was selected to provide instructional strategies for science teachers at all levels, particularly undergraduate instructors, and adaptations were made to topics also used in the GK–12 course to cover both precollege and college instruction in the course. For example, a session on motivating learners focused on dealing with large classes of 100 or more, which is not a problem normally faced in K–12 classrooms, but is common in many undergraduate courses.

I have taught the Zoology 619 course for two years, bringing the perspective of a former science GTA and that of a faculty member with CRDG in the UHM College of Education. Course participants have primarily been zoology students, but their experience in teaching and career goals range widely (Table 1). I elected to focus on general instructional skills for science to meet the needs of a diverse group of students. Readings each week provided a theoretical background for students, as well as specific examples for discussion. In addition to the reading and discussion, Zoology 619 students participated in model activities that highlighted the target strategies each week (Table 2). During and following participation, the implementation of these strategies was discussed. For example, during the session on multidimensional assessment, students took part in five types of assessments. They then discussed how each could be used effectively in a science course, and designed their own assessments for topics of their choice. Emphasis each week was on practical application of strategies and students were often tasked with modifying existing activities into more inquiry-driven, learner-centered formats. During year one of the course, I provided these activities, but in year two, students themselves provided their own activities for modification. The building of knowledge during the course was cumulative, and the instructional strategies were connected together in each session. Differentiation of instruction, for example, links closely to learning styles and multiple intelligences, which also provide pedagogical support for using multidimensional assessments.

All participants were required to complete at least one observation of a science class of their choice. Depending upon the interest of the individual, this could be an elementary, middle, or high school class at any public or private K–12 school, an outreach class at a museum or other organization, or an undergraduate or graduate course. Two class sessions at the end of the semester were devoted to sharing and discussing the techniques and strategies used in the classes participants observed, and ty-

**TABLE 3**

**Summary of course evaluations for Zoology 619.**

$n$ year one = 13; $n$ year two = 6.
1 = strongly disagree; 2 = disagree; 3 = unsure; 4 = agree; 5 = strongly agree

| Questions | Year-one average | Year-two average |
|---|---|---|
| The course content was useful | 4.86 | 4.83 |
| I will use these strategies and techniques in my own teaching | 4.86 | 4.67 |
| The course assignments were useful | 4.71 | 4.67 |
| The course requirements were useful and made sense within the context of the course | 4.93 | 5.00 |
| The course was a valuable use of my time | 4.93 | 4.83 |
| The length and scope of the course were appropriate | 4.71 | 5.00 |
| I would recommend this course to a colleague | 4.93 | 5.00 |
| The instructor was knowledgeable about the topic | 5.00 | 5.00 |
| The instructor was approachable and responsive to student needs and requests | 5.00 | 5.00 |
| The instructor was fair | 5.00 | 5.00 |
| The instructor was clear and easy to understand | 5.00 | 5.00 |
| I would recommend this instructor to a colleague | 4.93 | 5.00 |
| This course should be taught again | 4.93 | 5.00 |
| Average | 4.91 | 4.92 |

**TABLE 4**

**Combined results of concept inventory from year one and year two of Zoology 619.**

$n = 20$.
1 = I have never heard of this; 2 = I have heard of this; 3 = I know this; 4 = I know this very well; 5 = I know this so well I could teach someone else

| Concept | Average prescore | Average postscore | $p$ value |
|---|---|---|---|
| Inquiry | 1.94 | 4.39 | $p \leq 0.0001$ |
| Standards | 2.18 | 3.85 | $p \leq 0.0001$ |
| Constructivism | 1.67 | 3.63 | $p \leq 0.0001$ |
| Common curriculum | 1.87 | 3.17 | $p = 0.0016$ |
| Learning styles | 3.13 | 4.43 | $p \leq 0.0001$ |
| Motivating learners | 2.62 | 3.88 | $p = 0.0002$ |
| Differentiating instruction | 1.81 | 3.82 | $p \leq 0.0001$ |
| Understanding by design | 1.50 | 3.18 | $p \leq 0.0001$ |
| Questioning strategies | 2.06 | 4.27 | $p \leq 0.0001$ |
| Multidimensional assessment | 2.17 | 4.10 | $p \leq 0.0001$ |
| Multiple intelligences | 2.21 | 3.50 | $p = 0.012$ |
| Teaching about evolution | 2.54 | 3.89 | $p \leq 0.0001$ |
| Average raw score | 2.14 | 3.84 | $p < 0.0001$ |

ing those observations back to topics that were covered in the course. The presentation and discussion of these observations provided feedback on the ability of students to identify and evaluate the use of teaching strategies by others.

To help me evaluate the ability of students to incorporate teaching strategies into their own instruction, all participants were also required to develop a lesson plan to teach about a topic from their own research or from a course that they were responsible for teaching. Lesson plans were required to be grounded in relevant education research discussed in the course, and include strategies for assessing student learning. As part of their lesson plans, participants described their personal philosophies of science teaching and built their lesson plans to reflect those philosophies. Lesson plans also had to account for assessment of student learning.

I used student comments from year one to help refine the course during year two. One of the most common suggestions made by first-year students was to increase the course meeting time from one to two hours. I did so in year two, allowing for increased time for activities and more extensive coverage of topics, also a common request of first-year students. Second-year students did not make any comments about the limited time for topic discussion (which nearly all first-year students identified as a challenge in the course), and one second-year student even felt too much time was spent on some topics.

Students also recommended that the lesson-plan assignment begin earlier, be developed throughout the course, and perhaps even taught to other students in the course for feedback. In response to this request, the lesson plan was assigned at the beginning of the semester. Most students did not begin their work on it until later in the class, perhaps due to time needed to gain comfort with the material. There was not an opportunity for students to teach their lesson plans because they were mostly completed near the final day of class, but students in the second year of the course were encouraged to take a more active role by bringing in lessons from courses they had taught or were currently teaching. These activities were used as models for using course content to modify lessons to enhance learner engagement and facilitation of scientific inquiry. This strategy also made the course more directly useful to participants, as they could more immediately address current teaching challenges. Second-year students were also provided with a class day to work on their lesson plans and meet independently with the instructor for assistance, although none of them

took advantage of this opportunity.

Even with the modifications to the material selected for use from the GK–12 program, some year-one students felt that there was still too much emphasis on strategies for younger learners. The addition of another hour to the weekly meeting time allowed for more time to spend on undergraduate and graduate teaching issues, and the use of model lessons from undergraduate courses being taught by the GTAs also enhanced the higher-level teaching aspect of the course. Finally, both K–12 teachers and university instructors were invited to sit in on various sessions to help round out the course and to accommodate requests from first-year students that more educators visit the course to share their expertise. This strategy was embraced by second-year students who identified the anecdotes and real-world experiences shared by practicing educators as one of the most valuable aspects of the course.

## Assessment of impact

Assessment of impact targeted the usefulness of the course to the GTAs. Because the course is not useful to the GTAs if they don't find it enlightening, enjoyable, or valuable, I examined their attitudes about the course, as well as their awareness of the emphasized teaching practices. This awareness included their ability to use learned strategies to evaluate the teaching abilities of others via observation and to synthesize and incorporate new strategies into their own practice through development of a lesson plan. Although individual GTAs reported on the undergraduate responses following their implementation of course material, I did not specifically examine undergraduate attitudes or performance in courses taught by GTAs from either Zoology 619 cohort.

Following participation in the course, students were asked to complete an anonymous survey to rate aspects of the course and my instruction using a 5-point Likert scale (Table 3). Overall, student response was very positive with all responses averaging 4.70 or above. When asked if the course should be taught again, year-one and year-two students reported average responses of 4.93 and 5.00, respectively. When asked if they would use strategies from the course in their teaching, year-one and year-two students reported average responses of 4.86 and 4.67, respectively. This part of the survey also asked students to provide specific comments about the course. These responses were also very positive and described many perceived benefits to the participants, as well as suggestions for course improvement. The results of the survey indicated that the course was enjoyable and had perceived value to the participating GTAs.

> *I am a lot more confident that my ability to teach well isn't going to be something I either have a knack for or don't—I think the ideas and tools we talked about will make a big difference.*

Participants completed concept inventories self-reporting knowledge of strategies prior to participation in the course (retroactively in year one, and prior to the course in year two) and following participation in the course (Table 4). Two concepts that were not specifically targeted within the course were included: Common curriculum and understanding by design were not specific topics addressed during the course, but were included within the concept inventory to help validate student responses. I compared pre- and post-results using a two-sample paired $t$-test. Self-reported knowledge of concepts related to science instruction increased significantly for all concepts, although no concept was recorded at a 5-level, with most falling between 3.80 and 4.30 on average. Although students felt that they had a greater awareness of concepts related to science instruction, they were not yet comfortable enough with these concepts to feel that they could teach them to someone else. As for the increase in rank of concepts that were not specifically addressed in the course, their increase suggests that the results of the concept inventory should be treated with caution. It also suggests that some of the GTAs may be overestimating their teaching skills following course participation.

> *We didn't spend much time practicing what we learned, but I'm sure it will be easy since we have such a good foundation.*

Assessment of the classroom observations and lesson plans submitted by students also suggests that students need time to find a comfort level with the teaching strategies. Assessment of these assignments was by rubric, with indicators linked to the successful incorporation of different concepts from the course. All students were able to successfully identify both the presence and absence of strategies from the classes they observed, indicating they were aware of the strategies when used by others. However, only a small group of students spontaneously made suggestions on their observation forms for how the instructor they observed could more effectively incorporate absent strategies, suggesting a lower level of comfort with actual incorporation of the strategies.

With a few exceptions, the implementation of teaching strategies within the first-year lesson plans was fairly superficial. The majority of strategies were touched on briefly, but not well embedded in the plans. Although awareness increased, it appears that for most students a solid working knowledge of research-based strategies for improving science instruction was not fully achieved. During the second year, when the weekly sessions were expanded from one to two hours, improvements in the depth and consistent application of teaching strategies were seen in the lesson plans. All but one of the second-year lesson plans addressed selected individual topics in more depth than had the first-year lesson plans. These tended to center on only one or two specific topics that were identified by students as important and were

well embedded in their plans. As a personal teaching philosophy usually favors certain approaches, the focus on one or two strategies by students in their lesson plans is not necessarily an unfavorable result.

GTA behavior demonstrates the benefits of awareness, even with limited facility. I observed one of the more gratifying results of the course in the efforts of students to incorporate some of the ideas conveyed in the course into their teaching. In place of a lesson plan, one student developed an entire syllabus for a course that she taught the following year to student acclaim. Another reported offering to work with a UHM zoology professor to help revamp an existing zoology course to provide an increased inquiry focus. A third student reported weekly on her efforts to incorporate ideas from the course into the lab class she was teaching, and into her work as an informal educator at a state park. All three students requested additional assistance to aid them in their efforts. As increasing awareness is the first stage in an important shift in teaching practice, these results are promising. They support the findings from groundbreaking programs at institutions like Stanford and Arizona State University that good teaching practices are often transmitted beyond the initial contact (HHMI 1997).

*Teaching is an important part of the realm of communication and the skills learned can be applied to lecture classes, seminars, conferences, etc.*

## Summary

The response of students participating in the course was overwhelmingly positive. The average response both years to the course surveys was high, with a very slight positive shift in average responses from 4.91 in year one to 4.92 in year two (this is not significant, probably because the first-year responses were so high). The demographics of the course participants, and their overall positive response to the course, suggest that this is a useful course for a range of graduate students with varied teaching experience and career goals.

*Really enjoyable, well worth my time. I think this course should be a requirement for grad students—well, at least it should be highly recommended.*

Of the twenty students who participated in the course during the 2005 and 2006 spring semesters, seven have reported successful attempts to incorporate strategies from the seminar into their own undergraduate teaching, and two have reported working with the professors supervising their teaching assistantships to incorporate strategies into the larger lecture courses. In addition to increasing awareness of appropriate teaching strategies and perceived ability of GTAs to use those strategies in their own teaching, they have also been able to leverage their knowledge to improve general course instruction by aiding their supervising professors. The promise of these young professionals to improve scientific instruction in their future tenure as professional scientists is already being borne out.

*I've learned a lot more about teaching philosophies and techniques, information that I hope to apply to future classes that I instruct.* ■

### Acknowledgments

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