# Research Methodologies in Science Education:
## Training Graduate Teaching Assistants to Teach

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Jason, a junior faculty member in a geoscience department, has been asked by his chair to take over the training of graduate teaching assistants in the department. He was chosen mainly because he has attended a few teaching workshops and has been trying some new teaching approaches in his introductory geology course. Jason is not sure how one should structure a program to build graduate students' teaching skills. He begins with a literature search in the science education literature to find what other science departments are doing to prepare graduate students for their teaching roles. What are the key items that should be in a professional development program for graduate student instructors? He quickly finds that although many science departments have published articles describing their approach to developing graduate students' teaching skills, very few of these programs have ever been evaluated. So Jason starts a more general search through the literature focusing on teaching approaches that have some research base. His plan is to build a professional development program for graduate student instructors around research-based approaches. In this column, we chronicle Jason's progress, summarize the research in this area and highlight the areas where more research is needed.

Graduate Teaching Assistants (GTAs) play a prominent role in undergraduate education at higher education institutions. They are frequently utilized to instruct courses in a cost efficient manner, with the rationale that the experience will prepare them for careers in academia. In fact, GTAs instruct the majority of undergraduate laboratories and discussion sections at research universities (Travers, 1989). As instructors, GTAs frequently make instructional, curricular, and assessment decisions throughout their courses. They decide how information should be presented, what concepts should be emphasized, and how to evaluate student work. Unfortunately, GTAs often make these decisions with little guidance from faculty. By involving GTAs in college science education reform now, we can advance reform efforts, both in the short term, by increasing the quality of instruction in undergraduate science laboratories and discussion sections, and in the long term, when these graduates move on to permanent faculty positions and develop and teach both undergraduate and/or graduate courses.

Regrettably, GTAs are often subjected to training programs that offer limited instructional support regarding the teaching of science (Carroll, 1980; Rushin et al., 1997; Golde and Dore, 2001) and they often experience limited support for developing their teaching skills from their departments or advisors (Jones, 1993; Golde and Dore, 2001). In a recent study that surveyed over 4000 doctoral students across disciplines from 27 universities in the U.S., 83% of doctoral students responding to the survey cited enjoyment of teaching as their main reason for pursuing a faculty career (as opposed to 72% who cited enjoyment of research as the primary reason), yet most students lamented the lack of training they received to develop their teaching skills (Golde and Dore, 2001; full text of the report is available online at http://www.phd-survey.org). This comment is representative of many doctoral students in the sciences:

> "I have always considered teaching my main reason for pursuing an academic degree. I am amazed at how little preparation I am receiving in how to teach. I am still planning on pursuing a teaching position but am filling in the gaps in my education and preparation on my own time with little encouragement from my academic program" – quote from a molecular biology doctoral student. (Golde and Dore, 2001)

## Literature on GTA Training Programs in the Sciences

It is estimated that by 2014, 500,000 new professors will be teaching at American colleges and universities (Jones, 1993). Improving undergraduate education for current and future students will depend upon thoughtful and careful attention to the training of these future faculty members, especially in light of the fact that the reason many undergraduate students cite for abandoning science majors is poor teaching (Seymour and Hewitt, 1997). As universities and departments are increasingly faced with restricted budgets, creating *effective* GTA training programs is becoming even more critical. In the past three decades, there has been a large focus on how to design GTA training programs (Clark and McLean, 1979; Lawrence et. al., 1992; Druger, 1997; McComas and Cox, 1999), with the result that the majority of universities now have some form of training for GTAs (Shannon et. al., 1998). GTA training programs vary greatly among institutions; they range from half-day university-wide orientation sessions that introduce new GTAs to university policies and incorporate no department-specific training, to multi-day university-wide training as well as department-specific training, to university-wide training coupled with full-semester courses or seminars on teaching methods offered by specific departments (Rushin et al., 1997). However, very few training programs have adequate follow-up or feedback on GTA classroom practices and few studies have tracked how well these train-

ing programs actually work (Rushin et al., 1997). In addition, GTA training programs in the sciences have the added burden of addressing both classroom and laboratory teaching issues.

For GTAs in science, there are few training programs that offer instructional support in physics, chemistry, geology, or biology (Rushin et al., 1997; Golde and Dore, 2001). Science GTAs need an understanding of subject matter, curricular, and pedagogical content knowledge (Shulman, 1986). Subject-matter knowledge entails knowing not only the key ideas within the discipline, but also how these ideas were developed and how ideas are interrelated. Curricular knowledge encompasses how science concepts can be taught and emphasizes instructional methodologies along with curriculum resources. Pedagogical content knowledge consists of knowing how to mediate between the existing knowledge of the student with the knowledge of the discipline. These very distinct fields of knowledge are essential in science instruction, yet no training program that addressed all three key issues was found in our literature search of existing GTA training programs.

Science laboratories are supposed to be places for enhanced student learning outside the typical lecture environment (Lawson, 1994); however, teaching in the laboratory requires a high level of skill proficiency, content understanding, and discipline-specific pedagogical knowledge. Incongruously, GTAs teach the majority of labs at most universities and colleges and the few studies that have evaluated GTA training programs suggest that the training they receive is less than 'adequate' (Jones, 1993; Rushin et al., 1997; Golde and Dore, 2001). A few studies have documented changes in GTAs' conceptions about teaching after undergoing training; conceptions moved from a content and organizational focus to a realization that knowledge of pedagogy is also valuable (Hammrich, 1996; Ishikawa et al., 2000) Nevertheless, GTAs often receive little encouragement to participate in training programs as many faculty still adhere to the notion that research is the dominant priority for all graduate students and 'teaching will interfere with research' (Jones, 1993). Additionally, Ethington and Pisani (1993) found that although GTAs perceived their role as a GTA to be important, they felt that it did not contribute to their overall professional development in the way that a research assistantship would. This perception of teaching as the lesser role mirrors the attitudes portrayed by many graduate faculty. GTAs want and need mentorship opportunities in teaching, but faculty have few incentives to take on such roles and many lack the training to act as expert mentors (Shannon et al., 1998).

A recent study that examined GTA classroom practices in inquiry-based introductory chemistry labs found that even though the GTAs had participated in two days of general GTA training offered by the graduate college, 4 days of chemistry-specific training offered by their department, *as well as* a one-credit semester long course on teaching chemistry, GTAs still experienced difficulties in implementing inquiry-based instruction (Roehrig et. al., *in press*). One of the main difficulties for GTAs arose from their prior limited or negative experiences with inquiry labs. Many were frustrated by their experiences with inquiry or simply felt that freshman were incapable of conducting scientific inquiries (Roehrig et. al., *in press*). When these GTAs were observed in their classrooms, they had restructured the lab by giving explicit instructions about what students were to do, how they should analyze their data, and what they should find. Many simply did not have the skills to teach effectively using inquiry. Although they had read about the benefits of inquiry-based teaching, these skills were never explicitly modeled for them, and the GTAs simply didn't know what to do after giving their pre-lab lecture. Many GTAs simply stood back and let students "do" the lab. They would answer student questions *if* students approached them, but what they *needed to do* was to go around to each student group and help focus, question, and challenge students. They should have been observing and asking questions about what students had done, what they were doing and why. Instead, the GTAs, who had been told not to give students the answers, and lacking any explicit modeling of inquiry-based teaching, were at a loss for what to do in the classroom. A few GTAs were observed to take equipment from students and proceed to do the lab for them (Roehrig et. al., *in press*). Obviously, modeling of effective questioning strategies may have helped some of these GTAs. Additionally, GTAs need to understand that not all undergraduate students approach the learning of science in the same way that they did.

## GTA Training in the Geosciences

The geosciences have a long-standing tradition of using GTAs as laboratory instructors or classroom assistants. Many institutions require undergraduate students to complete a wide variety of courses regardless of major. Therefore, almost every college graduate in this country takes at least one general science course. Studies have shown that students are more likely to take geology or biology courses than physics or chemistry courses to fulfill science requirements, and this trend creates a constant demand for qualified GTAs.

Interestingly, virtually no research has been published on GTAs and GTA training programs in the discipline of the geosciences. A review of the literature reveals only two published geoscience-specific studies (Schade and Bartholomew, 1980; McManus, 2002), one special session on GTAs at the 2000 Geological Society of America annual meeting (Kohl and Coleman, 2000; Surpless et al., 2000) and one additional presentation in 2001 (Totten, 2001). Both Schade and Bartholomew (1980) and McManus (2002) based their GTA training programs on previous studies in other disciplines. McManus (2002) also made a point of designing his program around needs identified by graduate students themselves, allowing the students to have a voice in their own education. Both training programs concentrate almost exclusively on general teaching issues, with very little time devoted to the teaching of geology specific topics. For example, McManus (2002) describes an orientation session very similar to GTA orientations typically offered by institutions for all GTAs. Schade and Bartholomew (1980) describe sixteen training videos that are also very general, with only one laboratory related video that could be considered specific to the needs of geoscience GTAs. The question remains: Do teaching assistants in the geosciences, or science in general, have needs that are distinct from university GTAs in other fields?

We have analyzed the training opportunities for GTAs offered by fifty state universities in the U.S. (Figure 1). Interestingly, almost 50% of these schools either did not provide information about GTA training on their website, or offered only voluntary training opportunities

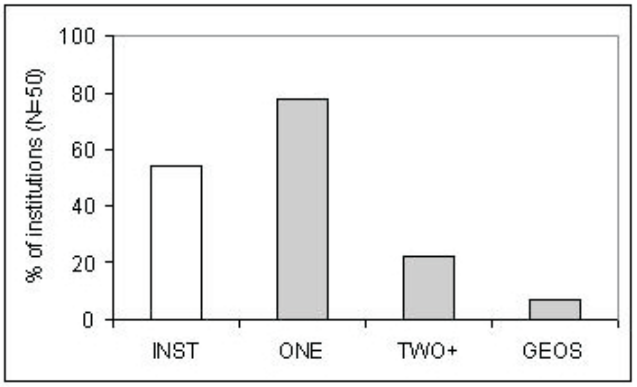


**Figure 1. Teaching Assistant training at the fifty "University of" or equivalent state institutions. Only 27 of the 50 schools explicitly require training for GTAs. 75% of these schools require training during a one-day orientation for new graduate students (ONE), with the remaining schools requiring 2-4 days of training (TWO+). These training sessions typically consist of a series of workshops on general teaching related topics. A few schools include training specifically for those teaching assistants who will be working in laboratory settings. Few geology departments made any reference to GTA training on their website, and only two had formal, departmental specific courses for geosciences GTAs. Finally, most schools offered opportunities, ranging from centers designed specifically for assisting GTAs, to coursework credit for GTAs to voluntarily learn more about teaching.**

for GTAs. Of the remaining 27 schools, most limited GTA training to a mandatory new student orientation, with the majority of orientations lasting a single day. Most schools offered additional, voluntary training for GTAs or faculty across the campus, including workshops, videotaping of courses with feedback, and web boards. Although some departments, such as Departments of English, appear to routinely offer GTA training, geosciences departments rarely mention GTAs or training on their websites. Only two of the reviewed departmental websites indicated that the department offered courses or training for departmental GTAs, although most departments offered courses in research or instrumentation methods. Of these two departments, one offered a one-credit "Topics" course listing earth science teaching methods as one possible topic, and the second offered a course called "Supervised College Teaching". In general, the issue of GTA training is a rarely discussed topic. We must then consider: How important is teaching in the scholarship of academia, and how important is it for geology departments to play a role in providing training in teaching as well as research?

## Jason's Training Program – One Possible Path

After sifting through this literature, Jason decides to proceed cautiously. He decides to have geoscience GTAs attend the general GTA training offered by the graduate college at his university to get information about university policies such as academic dishonesty, sexual harassment, and general topics such as how to use Powerpoint or web based grade management tools. Jason attends these sessions to find out exactly what will be covered, as this will prevent the duplication of material in the departmental GTA training program. He decides to develop a five-day departmental training session that will be offered prior to the beginning of fall semester that all new GTAs must take before they start teaching. He knows from his literature survey that most new GTAs want to know how to motivate students and how to fairly assess student work (Nyquist and Wulff, 1996). Jason has been reading about professional development for teachers (especially useful were the books by Loucks-Horsley et. al., 1998 and Bransford et al., 2000) and from that literature, he knows that teaching, like research, is a skill that is best developed over time, with practice and guidance provided at each stage. The other valuable lesson that Jason has learned from this literature is that you must first meet the GTAs' immediate needs before you can go further. Jason realizes that the needs of GTAs are likely to be different from the needs of beginning teachers, and lacking any GTA training program that has been demonstrated to be effective, he proceeds slowly. He develops a survey (using questions from the Nyquist and Wulff, 1996 book) that all incoming graduate students complete to gather information on the most pressing questions GTAs have about teaching. He plans five half-day sessions that will address the immediate needs of the GTAs and he plans to model some specific techniques: how to work with a diverse student population, different learning styles and how to address them, active learning strategies, using collaborative groups in labs, questioning strategies, addressing common misconceptions in geology, and how to assess student work. Jason then plans to offer a series of short workshops throughout the coming year on these and related topics; all GTAS will be required to attend about one workshop every month or two. He plans to cover several topics in the first year (assessing student writing, exploring new assessment methods, critical thinking, problem-based learning, how brain chemistry and development affect learning by college students, using the 5E approach) and to add more advanced topics (such as developing a new course, advising and mentoring students, employing a varied pedagogical repertoire) for more experienced GTAs in future years. Jason found the following three websites especially useful for identifying possible topics to include in teaching workshops:

http://www.collab.org/
http://bingweb.binghamton.edu/~biogrant/Workshop/Default.html
http://www.preparing-faculty.org/

One particularly applicable program, the "Preparing Future Faculty" program, funded in part by NSF, involves 43 doctoral-granting institutions that have programs in place to help graduate students learn about the various roles and responsibilities –teaching, research, and service– of faculty members (see Figure 2). The "Preparing Future Faculty" program is the most comprehensive program for reforming how we train graduate students for future roles as faculty and several assessments of this program should be released this year, but are not yet available according the official web site for the program ("preparing-faculty" URL above). The State University of New York at Binghamton web site

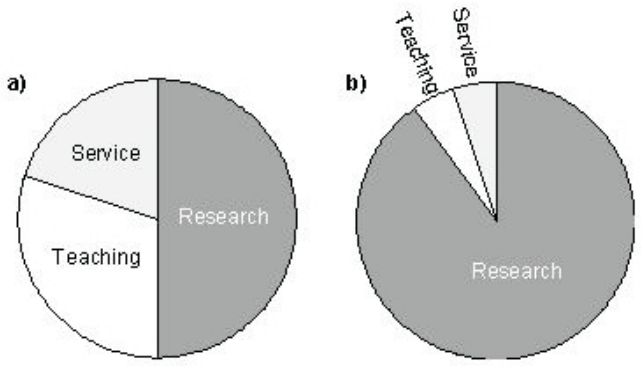


**Figure 2. a) Typical distribution of time spent on various activities by geosciences graduate students (from collective experiences of graduate students in the geosciences that we informally polled). Research generally dominates, although the demands of undergraduate curricula for both majors and non-majors require significant investment of time in teaching. Many students also perform service for departments, institutions, or national organizations. b) Priorities placed on graduate student activities by many science faculty and/or departments (Golde and Dore, 2001). Notice the disparity between activities and priorities; this disparity is mirrored by the lack of GTA training programs in the geosciences (see Fig. 1).**

("bingweb" URL above; see Stamp and Pagano, 2002 for details) even has complete scripts for conducting workshops on several topics.

Jason recognizes assessment as a needed component of GTA training, and plans to assess how GTAs perceived the university training, the five-day departmental training, as well as each the teaching workshop given throughout the academic year. Jason has also asked the teaching center staff on campus to visit each GTA's classroom at least twice during the year to videotape the class and provide critiques for each GTA. Jason realizes that GTAs need more feedback on their teaching than just the student evaluations at the end of the course and knowing that he cannot possibly observe every GTA and carry out all his other responsibilities, he looks for help from the teaching center; most campuses have teaching centers with knowledgeable staff that can provide valuable services. At the end of the year, Jason plans to analyze the data received from surveys, from the observations by teaching center staff, and from feedback from GTAs and undergraduate students and revise his training program accordingly.

## Preceptors – a classroom assistant for faculty or GTAs?

In addition to the traditional model of paying graduate students to act as teaching assistants, some departments across the country are moving towards using undergraduates as peer teachers in the classroom. Nursing schools have traditionally used peer teachers, or preceptors, as a means for advanced students to assist entry-level students in navigating a new field of study. Science departments have only recently adopted a similar model. Although undergraduate-only institutions may pay preceptors, many institutions provide course credit and training for undergraduates who assist in the classroom (e.g., Allen and White, 1999). Institutions generally offer such credit on a departmental basis, although a few schools have begun to receive funding to implement peer teaching across the curriculum (e.g., Libarkin and Mencke, 2001). Those institutions that do consider preceptors as a viable method for providing teaching support to faculty also tend to have more developed training for GTAs. However, the lack of information on the effectiveness of GTAs and preceptors, the disparity across institutions in time and effort spent on GTA and preceptor training, and the overall lack of resources for GTAs at all levels indicates that significant work remains to be done.

## Future Directions

There are few research studies on GTA training programs that evaluate how well existing training programs actually work. There is a great need for more studies in this area. Several pressing questions remain:

I. What are the essential knowledge and skills that science GTAs must have to be effective teachers?

> Researchers are still determining whether GTAs can be effective teachers without significant background in pedagogy, science of teaching and learning, and advanced content skills. In the geosciences, we have very little evidence of the impact of training programs on teaching effectiveness. In particular, the trade-off between time and training must be addressed, and the question of university versus departmental training is central to this issue. What do "one-shot" (one or two day training) GTA training programs accomplish?

II. How should GTA training programs be structured? Should they emphasize the unique qualities of each discipline? Or should a general science GTA program be developed?

> Unfortunately, the research base in GTA training in the sciences is limited, and is significantly lacking in the geosciences. We need to assess the unique qualities that the geosciences have, the unique needs of the geology classroom, and the unique potential inherent to teaching from a geologic perspective. In addition, the needs of geoscience GTAs must play a significant role in the training that is developed. Specifically, the structure of GTA training programs should reflect the experiences of typical geoscience graduate students, address the concerns and barriers faced by these students in the classroom, and expose students to research in education that impacts and informs teaching in the Earth Sciences.

III. Which research efforts would be most beneficial to answering the question of how to best train GTAs for both immediate duties and future potential as effective teachers?

> Significant research is currently being conducted to analyze the effectiveness of GTA training

programs in non-scientific disciplines (e.g., Ethington and Pisani, 1994), although geoscience departments lag far behind in this research effort. The geosciences community needs to investigate the types of GTA training that exist across the country and internationally, the effect of this training on both GTA classroom practice and the learning of undergraduate students, and the impact this training has once GTAs transition to academic positions.

Finally, the geosciences as a community must decide how important teaching is to the discipline, and the relative priority of teaching in the education of graduate students must be reassessed. Without adequate training, is it possible for geoscientists to rise to the needs of future generations of students? We hope to see the geoscience education community addressing some of these issues in near the future.

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