Training graduate teaching assistants in the geosciences: Our practices vs. perceived needs

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ABSTRACT

In response to calls for reformed teaching practices in college STEM labs and courses, and to support graduate teaching assistants (GTAs) in their general teaching responsibilities, other STEM disciplines have recently increased their focus on GTA training and preparation. However, current practices in GTA training in the geosciences and geoscience faculty values regarding GTA teaching preparation have not been documented. In this study, survey results are used to compile the roles of GTAs in geoscience departments as well as the types and extent of training in which they participate with respect to teaching professional development (PD). Responses indicate that most GTA training depends on the instructor supervising the course (57%), with more formal GTA training coming from university or departmental requirements. Survey results suggest that some barriers to implementing GTA training are similar to those found for faculty teaching PD, including time and funding, along with unsupportive departmental culture. Responses also indicate that although faculty generally rate teaching PD as important for their GTAs, those values do not correlate strongly with the amount of training their department currently provides.

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Introduction

Graduate teaching assistants (GTAs) play an important role in teaching undergraduate geoscience courses, particularly introductory-level courses. In some research universities, GTAs teach more than 90% of laboratory sections (Sundberg, Armstrong, & Wischusen, 2005) and often teach the smaller laboratory or discussion sessions (Luft, Kurdziel, Roehrig, & Turner, 2004; Sundberg et al., 2005; Travers, 1989) that allow greater interactivity between instructor and students (Park, 2004). Therefore, GTAs have a substantial opportunity to influence student perceptions of the disciplinary knowledge, culture, and accessibility of the geosciences (Rushin et al., 1997). Effective instruction from GTAs is an important component to calls to improve student retention in STEM disciplines (President’s Council of Advisors on Science and Technology, 2012; Rosenberg, Hilton, & Dibner, 2018) and to better attract and support underrepresented student populations (Museus, Palmer, Davis, & Maramba, 2011). Many geoscience faculty are heeding the call for improved instructional approaches that prioritize reformed teaching (defined as a set of practices that place priority on student agency to promote active learning, problem solving, and critical thinking; e.g., Sawada et al., 2002) and that are aligned with improved student learning (e.g., Freeman et al., 2014). Aligning pedagogical practices in laboratory sections taught by GTAs with the practices used in lectures is equally important. Beyond their immediate impact on lab students as GTAs, graduate students are also the next generation of faculty; they have the potential to contribute to a thriving population of students in STEM disciplines.

Despite these considerations, GTAs are often insufficiently prepared to fully engage their students in ways congruent with the vast and growing literature on teaching, learning, and student success (e.g., Marbach-Ad, Egan, & Thompson, 2015; Oleson & Hora, 2014). GTAs likely begin their teaching assignments having just completed undergraduate degrees.
Importance of professional development

Teaching PD is known to improve GTAs’ teaching self-efficacy and confidence (Connolly, Savoy, Lee, & Hill, 2016; Pentecost et al., 2012; Prieto & Altmaier, 1994; Reeves et al., 2018), and increases their interest in teaching (Zehnder 2016). GTA teaching PD results in improvements in undergraduate students’ learning and retention (Chen, Kimball, Frederick, & Graham, 2013; McShannon & Hynes, 2005), as well as higher student evaluations of teaching effectiveness (Marbach-Ad et al., 2012). Reports of GTA training courses from other STEM disciplines indicate that GTAs implement new ideas from such courses and report favorably on their perceived outcomes (e.g., French & Russell, 2002).

A recent report from the American Association of the Advancement of Science (AAAS) describes that an instructor needs competency in three areas to be effective: content knowledge, general teaching knowledge (how people learn), and pedagogical content knowledge (PKD; Pallas, Neumann, & Campbell, 2005), as well as higher student evaluations of teaching effectiveness (Marbach-Ad et al., 2012). Reports of GTA training courses from other STEM disciplines indicate that GTAs implement new ideas from such courses and report favorably on their perceived outcomes (e.g., French & Russell, 2002).

Research on GTA training has grown particularly in the biological sciences (e.g., Addy & Blanchard, 2010; Becker et al., 2017; Hughes & Ellefson, 2013; Pfund et al., 2009; Shadle, Marker, & Earl, 2017; Wyse et al., 2014), partly due to the establishment of the Biology Teaching Assistant Project (BioTAP), including a nationwide survey of existing GTA programs in biology (Shadle et al., 2017). With this and other research in biology and GTA training broadly in mind, Reeves and colleagues (2016) proposed a conceptual framework to drive future research for
training biology GTAs. The framework posits that the three most important factors to examine with regard to GTA training are (a) GTA knowledge, skills, attitudes, and beliefs about teaching; (b) GTA teaching practices and undergraduate student skills, knowledge, retention, and interest in the discipline; and (c) contextual factors, GTA characteristics, and implementation variables (such as participant responsiveness). This framework was developed expressly to encourage research in each of these areas (Reeves et al., 2016).

Implementation of this conceptual framework was reported by Reeves and colleagues (2018), who examined the relationship of PD participation of biology GTAs and two of the three factors in the framework: (a) GTA knowledge, skills, attitudes, and beliefs (measured with pre- and post- PD surveys); and (b) GTA teaching practices (measured from GTAs’ student ratings). Changes in self-report data for GTAs from three universities indicated GTA self-efficacy improves, anxiety decreases, and student evaluations are interpreted to indicate increased use of teaching practices learned in PD (Reeves et al., 2018). Variations across universities and among GTAs with varying amounts of teaching experience and contact hours are suggested for future research. Other research (Gilmore, Maher, Feldon, & Timmerman, 2014) used interviews to confirm the hypothesis that GTAs are more likely to adopt reform teaching practices with mentor support, as conceptualized by Lave, Wenger, and Wenger’s (1991) ideas of novices learning from masters in communities of practice.

Beyond a single discipline, the Center for the Integration of Research, Teaching, and Learning (CIRTL) is a consortium of universities that offers evidence-based teaching professional development for faculty and future faculty (Pfund et al., 2012). Their Preparing Future Faculty (PFF) program takes a holistic approach to exposing GTAs to the diversity of responsibilities they will have as faculty, including teaching as well as research, mentoring, and service (Pruitt-Logan, Gaff, & Jentoft, 2002). Studies of specific GTA trainings cited here can be used to provide general templates or models for GTA pedagogical preparation, but because each discipline has its own body of PCK (Berry, Friedrichsen, & Loughran, 2015), implementation of teaching PD for GTAs in the geosciences requires that models are modified and tested for the disciplinary context.

**Background on barriers to GTA training**

A variety of factors influence the availability of GTA training and whether it is optional or required. Establishing teaching PD as a cultural norm is no small task and has been shown to be a significant barrier to reformed teaching for faculty (Henderson & Dancy, 2007), let alone for GTAs (Austin, 2002). Another aspect of departmental norms is whether or not faculty are themselves engaged in reformed teaching, which is often correlated with their own experiences in teaching PD (e.g., Viskupic et al., 2017). Faculty members often have experiences in graduate school that were primarily research focused and may simply “teach as they were taught” (Oleson & Hora, 2014). These faculty may not see the potential merits of their graduate students focusing on teaching PD for what they consider to be “at the expense” of research efforts (Brownell & Tanner, 2012; Connolly, Lee, & Savoy, 2018; Schussler, Gardner, Marbach-Ad, Miller, & Ridgway, 2015). However, requiring GTA programs necessitates buy-in from departmental faculty so the training will be offered consistently and so that GTAs enroll or participate in the training.

If there is departmental buy-in for the importance of GTA teaching PD, such training will need to be developed or selected. As noted previously, there is no accepted standard for GTA training in the geosciences, so development and adoption of GTA teaching PD will require time for faculty to adopt and revise or develop and implement.

**Surveys on GTA training**

Although information from other disciplines is a useful guide to developing GTA training for the geosciences, the lack of a clear summary of teaching PD available to geoscience GTAs, coupled with the notable paucity of published program descriptions and research studies on GTA training in the geosciences (Bitting et al., 2017; Kurdziel & Libarkin, 2003), inspired the development and analysis of a community-wide survey to investigate how the geoscience community prepares GTAs to teach, what geoscience faculty believe is important in such trainings, and how those practices and values manifest in training GTAs for teaching.

Other STEM disciplines, such as biology and chemistry, have conducted surveys of departments and faculty to determine if and how their GTAs are prepared for their teaching roles (Abraham et al., 1997; Shadle et al., 2017), but no such survey has previously been completed for the geosciences. The results of the geoscience GTA training survey presented here are an effort to move the geoscience community forward in understanding the state of GTA teaching PD and can
serve as a benchmark from which to develop research activities to assess and improve GTA teaching PD.

Research questions

In order to document the geoscience community’s current practices and faculty values around GTA teaching PD, we developed a survey research project intended to answer the following research questions:

1. In what kinds of teaching PD do geoscience GTAs participate?
   a. What proportion of geoscience GTAs participate in formal, department-based preparation for their teaching roles?
   b. What proportion of GTA training is related to content review and pedagogical practices?
   c. Do training characteristics correlate with GTA teaching roles and tasks?

2. How strongly do faculty value GTA training in areas of content and pedagogy?

Methods

To address these questions, we developed a survey that was distributed to geoscientists to describe GTA teaching PD in their academic departments (see final survey in the Supplementary Appendix). Survey questions address the role of GTAs in geoscience departments (Q2), the types of training available to GTAs (Q3) and topics covered (Q5), the time GTAs spend on teaching PD (Q6, 7), and the importance of GTA teaching PD to the person responding to the survey (Q4). Demographic information about the respondent’s department (Q10) and the types of resources used or needed are requested as short-answer responses (Q8, 9).

A preliminary version of the survey was first tested and revised by the authors, then distributed to 10 geoscience faculty who provided feedback about questions and answer options. Test group feedback was used to revise the survey before broader distribution. Examples of useful feedback that helped us revise the survey included adding “optional training” to Q3 and adding “Other, e.g., University resources … ” to items 3 and 4, as two reviewers indicated that university training had been important to their own TA training, and a third indicated that TAs at his or her institution only have access to university training. The order of questions was also revised to first ask what training respondents believe GTAs need (Q2) and then follow that with questions about the types of training that are offered (Qs 3–6). Reviewers suggested minor edits to clarify survey questions and response options, and to more clearly align the questions with the response options or available scale (e.g., Q2). Additional valuable feedback included that, “it was a fast survey and felt painless,” which we felt was important to maintain so respondents did not feel overwhelmed and would complete the survey.

The final GTA teaching PD survey was approved by IRBs at all three researchers’ institutions and included a consent option, which was agreed to by all survey respondents. The survey was disseminated electronically through listservs associated with geoscience organizations—including the National Association of Geoscience Teachers (NAGT), Science Education for New Civic Engagements and Responsibilities (SENCER), American Geophysical Union (AGU), Geological Society of America (GSA), Association of Women Geoscientists (AWG), the Volcano Listserv, Earth Science Women’s Network, Geocognition and Geoscience Education Research Listserv, International Association for Geoscience Diversity (IAGD) and Mineralogical Society of America (MSA)—for approximately three months in spring and early summer 2016. Our request to participants included explicit indication that we sought responses specifically regarding geoscience departments “broadly defined.” We received 120 responses, but only include data from the 113 respondents who have graduate programs in their departments. Results were compiled through Survey Monkey and converted to Excel, where quantitative scores were tabulated for analysis. A between-groups statistical comparison was conducted using SPSS version 24.

Response options to survey item 2 initially required survey participants to rank the relative importance of five areas of GTA training (grading, technology, content, pedagogy, and logistics) in comparison to one another (e.g., 1 for most important and 5 for least important). During the survey administration period, feedback from several survey respondents indicated they would have preferred to evaluate each training area independently, rather than comparing to one another (one comment was, “I really hated that question since I think some of those are really equivalent”). On the basis of the collective feedback, the format of the responses offered was modified to allow respondents to rank each item independently, so that multiple areas could be rated independently (e.g., both content and grading as “very important”; see item 2 in the Supplementary Appendix). Because this change was made after the survey had opened, only 73
respondents answered this item in the final format, resulting in a lower total number of responses for this item than for others in the survey. The data for item 2 are retained and reported here because the total number of responses to item 2 remains comparable to that of other surveys (e.g., Shadle et al., 2017).

Validity of the interpretation of results from the GTA training survey that are presented here is aligned with an “interpretation/use argument” (IUA) framework established by Kane (2013), in which claims made from results are based on known assumptions. Starting assumptions regarding the dissemination and sources of information collected include that the distribution of the survey through a variety of electronic listservs resulted in reaching a broad audience of respondents who could answer the survey items. Similarly, we assume that responses themselves are valid because respondents are well-positioned to characterize the roles and training structures of GTAs in their departments, as well as their own beliefs about teaching PD. In terms of interpreting responses, we have assumed that the topics of, and time GTAs spend in, training reflect the value of training placed by their departments. Additionally, answers to survey items that ask respondents to rank the importance of different types of GTA training (topics in item 2) can be used to measure the value each individual respondent has for each type of training. With these assumptions identified, we contend that survey responses and our interpretations are both valid and reliable.

Results

**Demographics of respondents**

Of the 113 responses, 81% are from institutions with Ph.D. and master’s programs, 19% are from institutions with only master’s programs. Eighty-one respondents (72%) are confirmed to be in geoscience-related departments (earth science, geology, geoscience education, etc.), but not all respondents included the name of their department. No further information was requested (or provided) in terms of the size of departments, number of faculty or graduate students, or other identifying information. Eighty-four respondents did provide the name of their institution, which revealed at least 37 unique institutions and 16 institutions that were represented more than once in the responses.

Answers from multiple respondents from one institution are the same or very similar for questions regarding department-level practices. For example, survey items 5 and 6 ask how much time GTAs spend on training in areas of content and pedagogy, respectively, and of the 16 institutions represented more than once, responses differed for content six times and pedagogical responses differed in seven instances. In all cases, when responses differed, responses were either “none” or “a few hours on a day just before the beginning of the semester” for content training, and six of the seven differences for pedagogical training had the same variation. The seventh mismatched pair of responses for pedagogical training indicated, “a few hours on a day just before the beginning of the semester” and “a semester/quarter-long class GTAs take prior to becoming a TA.” Because each response represents the perceptions of an individual faculty member in the department, including value and perception of GTA training, all responses are included in our data set.

**GTA teaching responsibilities**

In combination, GTAs are responsible for a range of activities, and at many institutions GTAs have multiple roles (Figure 1). Survey participants were
provided a list of possible GTA responsibilities and were asked to select as many responses as apply to their GTAs. Cumulatively, 358 answers were generated from 113 respondents and are presented here as the percentages of institutions whose GTAs are responsible for teaching lectures (at 28% of respondents), teaching laboratory sections (95% of institutions), and leading discussion sections (35% of institutions). GTAs also support instructors during lecture sections (18% of institutions) or outside of class (e.g., grading, 76% of institutions). Additional (“other”) responses include leading and organizing fieldtrips, holding office hours and tutoring sessions, teaching online courses, and managing (or helping to manage) the course Learning Management System (LMS).

**RQ1a:** What proportion of geoscience GTAs participate in formal, discipline-based preparation for their teaching roles?

Survey data indicates that some form of GTA teaching PD is required by half of respondents’ universities (50%) or by their department (45%), and 23% of institutions require training at both the university and department levels. Most responses indicate that GTA teaching PD varies according to the course instructor (57%; Figure 2). Eight respondents volunteered that their institutions have an optional teaching certificate program or “future faculty” program available to graduate students. Twenty-five respondents (4%) selected the “other” option, with 16 of those writing in that their university provides optional training for GTAs.

**RQ1b:** What proportion of GTA training is related to content review and pedagogical practices?

To determine the proportion of teaching PD allocated to different topics, we asked respondents to quantify the time spent on the different types of training (survey items 5 and 6) as:

| Code | Description                                      |
|------|--------------------------------------------------|
| 0    | none                                             |
| 1    | a few hours on a day just before the beginning of the semester |
| 2    | a multiday training workshop before the beginning of the semester |
| 3    | a semester/quarter long class TAs take prior to becoming a TA |
| 4    | semester-long training (while they are a TA)    |
| 5    | multisemester training/classes                   |

![Figure 2. Sources of GTA training (survey item 3).](image-url)

![Figure 3. Topics of training GTAs in geoscience departments (survey item 4).](image-url)
The mode of content and pedagogy responses is 0 (none) and the average is 1.0 and 1.1, respectively, which means that the “average” amount of GTA training is equivalent to a few hours on a day just before the beginning of a semester.

Elements of GTA training provided at the department level (e.g., discipline-based training) include logistical information (26% of responses), course content (18%), pedagogical training (17%), grading and use of rubrics (17%), and use of technology (e.g., clickers or LMS, 13%; see Figure 3). Additional “other” responses include safety (for the lab and in the field), dealing with cheating, and practice writing teaching statements and documenting teaching effectiveness (in preparation for applying for academic positions). Reinforcing the results above, several respondents to this question also stated that training elements vary according to the faculty member overseeing the teaching PD.

The amount of time spent on GTA content training (survey item 5; Figure 4) varies from none (40.6% of responses) to meetings just prior to the start of the semester (32.1%) or trainings before the start of the term (3.8%). Few respondents indicated their GTAs take a term-long course (18.9%), either before they start teaching (1.9%) or during the term in which they teach (17%). Only two respondents indicated that their GTAs participate in content training (beyond their required coursework as students) over the course of multiple terms.

The time GTAs spend in departmental pedagogical training (survey item 6; Figure 4) also varies, with most respondents indicating that no pedagogical training is offered (41%). Meetings just prior to the start of the semester that incorporate pedagogical training are the most common type of teaching PD offered (31.4%), followed by term-long courses (12.4%) either before (4.8%) or during (7.6%) the term in which GTAs teach. Multiday training workshops before the start of the term also include pedagogical training (8.6%). Two respondents also indicated their GTAs receive training across multiple terms. Only 3.8% of respondents did not know the amount of time GTAs spend in pedagogical training.

**Figure 4.** Time and format of GTA training in areas of content and pedagogy (survey items 5 and 6, respectively).

**Figure 5.** Amount of GTA content training (6a) and pedagogical training (b) provided by geoscience departments for GTAs who teach lectures and those who teach only laboratory sections (survey items 5 and 6).
Of the respondents who indicated “other” to the amount of content or pedagogical training their GTAs get, 14 wrote that their GTAs are asked to attend a weekly preparation/organizational meeting. However, in one case, a respondent noted that some GTAs have begun a “rebellion” and refuse to attend such organizational meetings because they are not paid for their time to attend (Respondent 2534). Additional “other” responses include working with the lead professor and periodic observations of GTAs as they teach. Three respondents indicated that GTAs in their programs do not need content training because they have degrees in the content areas in which they teach (Respondents 0183, 1019, and 3782). GTAs in the three programs with this response either attend a semester-long course (Respondent 0183), have a few hours of training before the start of the course (Respondent 3782), or have no training (Respondent 1019).

**RQ1c:** Do training characteristics correlate with GTA teaching roles and tasks?

Mann-Whitney U-tests were used to examine potential correlations between types of teaching PD provided to GTAs who teach labs as compared to GTAs who may teach lectures as well. On average, GTAs who teach lecture sections are only slightly more likely than GTAs who only teach labs to receive any training, and this difference is statistically insignificant. Of GTAs who teach lectures, 28% get no teaching PD, and 35% of GTAs who teach only labs get no teaching PD. Regardless of the teaching assignment, most GTAs who do participate in teaching PD do so in a few-hour session prior to the start of the term (e.g., an orientation), which respondents report includes both content and pedagogy (Figures 5a, 5b).

GTAs who teach a lecture section do not participate in more or different kinds of teaching PD than GTAs who teach a lab section (RQ 1c; Figures 5a and 5b; \( p > .05 \)). In fact, a smaller percentage of GTAs who teach lecture sections have required university or departmental training (56% and 47%) than GTAs who teach lab sections (69% and 61%). Seventy-nine percent of GTAs who teach labs get teaching PD from the main instructor of the course for which they are teaching (e.g., instructor-determined), but the style, timing, and content of such trainings are not known.

### Table 1. Number of responses to levels of importance of GTA Training Topics (survey item 2). Gray bolded cells are those with the largest number of people reporting the level of importance of each training topic.

| Ranking: | 5: Very important | 4: Moderately important | 3: Neutral | 2: Not very important | 1: Not at all important | Average scores |
|----------|-------------------|-------------------------|-----------|----------------------|------------------------|---------------|
| Pedagogy (n = 66) | 32 | 17 | 10 | 2 | 5 | 4.0 |
| Content (n = 60) | 11 | 20 | 16 | 9 | 4 | 3.4 |
| Grading (n = 71) | 11 | 20 | 17 | 10 | 13 | 2.1 |
| Logistical (n = 59) | 16 | 8 | 8 | 15 | 12 | 2.0 |
| Technology (n = 65) | 2 | 5 | 10 | 25 | 23 | 2.0 |

### Figure 6. Comparison of time spent on pedagogical training and the importance ranking for pedagogical training (based on survey items 6 and 2, respectively). The size of each bubble and labels within bubbles represent the number of responses in that category. A total of 53 responses are shown, based on the number of respondents to the final version of survey item 2, as described in the text.
Many GTAs are trained in the content of upcoming lab activities through weekly organizational meetings, but pedagogical training is not cited by respondents as associated with these meetings. Respondents who selected “other” training indicate that teaching PD includes lab and field trip safety, or that training varies by the needs of the course or is determined by individual instructors.

**RQ2:** How strongly do faculty value GTA training in areas of content and pedagogy?

Respondents rated the importance of five areas of teaching related information: logistical, pedagogical, content, technology, and grading/use of rubrics (survey item 2 in the Supplementary Appendix). The number of responses for each area is provided in the first column of Table 1; this number is lower than for other survey items reported because only 73 respondents were asked the question in the final format. Data reported are from respondents who were asked to rate their value for each area independent of the others (e.g., the areas were not rated in comparison to one another but according to the independent importance of each). Respondents used the Likert scale ratings of 1 = not at all important; 2 = not very important; 3 = neutral, not important but not unimportant; 4 = moderately important; 5 = very important. Based on averaged ratings, the highest regarded area (highest average scores) for GTAs training was pedagogy, followed closely by course content, grading, logistics, and finally technology (Table 1).

Of the 32 respondents who gave pedagogical training the highest value ranking, the mode of responses regarding amount of time spent on teaching PD on that topic is 0, which corresponds to “none.” The average response for this group is .92, which corresponds most closely to “a few hours on a day just before the beginning of the semester,” which is slightly lower than the overall average amount of time indicated by all respondents. As a result, there is very poor correlation between the Likert scale ranking of the importance of pedagogical training and the amount of time their GTAs spend on pedagogy in training \( (R^2 = .0058, \text{ Figure 6}) \). The GTAs in departments with faculty who have the highest value for such training still may receive very little (Figure 6).

Mann-Whitney U-tests were also used to examine whether faculty reported specific types of training as being equivalently important at schools where GTAs teach labs as compared to those where GTAs may teach lectures as well. These tests indicate that the perceived needs for training on content (Mdns 0, 2; \( U = 872; \ p = .0066 \)), logistics (Mdns 0, 1; \( U = 947; \ p = .029 \)), and technology (Mdns 0, 3; \( U = 929; \ p = .022 \)) were as great at schools where GTAs teach labs as compared to those where GTAs may teach lectures as well. These tests indicate that the perceived needs for training on content (Mdns 0, 2; \( U = 872; \ p = .0066 \)), logistics (Mdns 0, 1; \( U = 947; \ p = .029 \)), and technology (Mdns 0, 3; \( U = 929; \ p = .022 \)) were as great at schools where GTAs teach labs as well as labs.

## Discussion

**Diversity of GTA training in the geosciences**

**GTA teaching PD**

GTA training in the geosciences is varied, and ranges from none offered (7% of respondents) to required courses for teaching PD, offered either by the university or department (Figure 2). Required GTA training occurs in approximately 73.5% of geoscience graduate programs surveyed, but not quite half (45%) of those surveyed say GTA teaching PD is required in the department, which means a significant portion of GTAs in the geosciences are not getting pedagogical training specific to the discipline. In comparison to other disciplines, department-based GTA training in the geosciences is slightly lower than that required in other disciplines (Table 2). A survey of chemistry departments indicates that, of 203 institutions, 63% offered GTA training and 56% required formal training at the department level (Abraham et al., 1997). A similar survey of 153 biology departments in 1997 found that 44% required some GTA training (Rushin et al., 1997), but a more recent nationwide survey of

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**Table 2. GTA training in teaching professional development for geosciences compared to that reported for other disciplines.**

| Discipline          | % institutions with required teaching PD for GTAs | % departments that require departmental teaching PD | Year data was collected | References and notes (note superscripts connect data to references in same discipline (row) in table) |
|---------------------|-------------------------------------------------|---------------------------------------------------|-------------------------|----------------------------------------------------------------------------------|
| Geosciences         | 73.5%                                           | 45%                                               | 2016                    | This work                                                                         |
| Biological sciences | 44%\(^\text{a}\)                                 | 96%\(^\text{b}\)                                  | 2019                    | Rushin et al. (1997)                                                             |
|                     | 51%\(^\text{c}\)                                 | 73%\(^\text{d}\)                                  | 2013\(^\text{e}\)       | Schussler, Gardner, et al. (2015) \(^\text{f}\) = % programs that require a pre-term course-specific orientation |
| Chemistry           | 63% provided (not required)\(^\text{m}\)         | 56%\(^\text{a}\)                                  | Dates unknown\(^\text{m, a}\) | Marbach-Ad et al. (2012)                                                         |
| Psychology          | 83%                                              | 48% required                                     | Dates unknown           | Mueller et al. (1997)                                                            |

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biology departments from 71 institutions determined that this has increased to 96% of respondents with some form of required training for their GTAs (Shadle et al., 2017). Furthermore, 51% of biology departments require training from the department, and 73% of respondents specify that they require a preterm course-specific orientation for the course(s) a GTA will teach (Shadle et al., 2017). Interestingly, this recent analysis of biology GTA training reveals that by 2015, the proportion of GTAs required to complete teaching PD had gone up significantly from 1997 (Rushin et al., 1997). Although not a discipline in the physical sciences, a survey of 108 psychology departments reveals that 65% offer departmental GTA training, and that training was required in 48% of those departments during the 1990s (Mueller, Perlman, McCann, & McFadden, 1997).

Source of GTA teaching PD

Considerable discussion has addressed the merits of disciplinary teaching PD that can occur at the department level for GTAs versus more general PD they may encounter from a university-wide program such as a teaching and learning center (e.g., Hadré & Burris, 2012). University-level professional development is likely to provide GTAs with general pedagogical skills as well as university-level rules and expectations for GTAs (e.g., Pfund et al., 2012). Disciplinary training that GTAs would get from their departments is better suited to address PCK that prepares GTAs to teach specific skills and topics encountered in geoscience courses but may not be necessary in other disciplines (e.g., geospatial reasoning or interpretation of large-scale variations of time and space; Hammrich 2001; Healey 2000; Nicklow, Marikunte, & Chevalier, 2007).

As previously noted, teaching requires competencies not just in the content area and general pedagogical knowledge but also in the disciplinary-specific PCK (e.g., Pallas et al., 2017). A large proportion of psychology faculty (79%) believe that GTAs learn the most from department-level training (Mueller et al., 1997). Departmental training for geoscience GTAs most commonly focuses on logistics and content (75.5% and 50%, respectively), with 51.6% of respondents indicating that content-specific training is needed for their GTAs. The geoscience GTA training survey did not specifically ask about the need for PCK, so the extent to which such training is included in programs is not clear. Content and PCK training provided for GTAs by departments may be especially important for new instructors who, like the students they teach, gain expertise along a scale from beginner toward expert (e.g., Chi 2006; Kober, 2015). As such, GTAs would benefit from disciplinary training that helps them develop their PCK, particularly when training models the instructional practices that will be valuable for them to use (e.g., Hammrich 2001; Marbach-Ad et al., 2015). Recent work has shown that faculty members who attend teaching PD that is specifically aligned with the content of their courses are statistically more likely to teach student-centered classes than when professional development is not topically related (Viskupic et al., 2017). The same pattern is likely to be true for GTAs, which means that training by departments is an important component of a GTA training package (Healey, 2000; Lueddeke, 2003).

Some respondents in departments that do provide department-level teaching PD used comments to indicate that such training does not necessarily include pedagogical GTA training. For example, one survey response (Respondent 0329) noted:

[The] university requires one training for each new GTA position, but it only goes over the basic logistical information (don’t date students, be on time, etc.) The department has a TA meeting at the beginning of the year, but it basically just repeats this information. Certain instructors in the department have weekly meetings/etc. with the TAs to go over the course materials. There is NO training on how to be an effective teacher though.

This is an important reminder of the need for providing a complete suite of training that includes all three components of content, general teaching knowledge, and pedagogical content knowledge for GTAs in the geosciences.

Characteristics of GTA duties vs. types of training

Survey results confirm that, as in other STEM disciplines, GTAs in the geosciences have a diverse array of responsibilities, ranging from teaching entire courses to teaching laboratory sections to grading and logistical support (Marbach-Ad et al., 2012; Shadle et al., 2017). In comparison, duties reported for psychology GTAs are similar to those in the geosciences (Figure 1): Grading, conducting discussions or review sessions, and teaching labs were the most common tasks reported, but there is no indication they also teach lecture sections (Mueller et al., 1997).

Time

Content and pedagogy are the two areas of GTA training ranked most important and are generally
included in teaching PD programs provided by departments. Geoscience departments with a short GTA training session just before the beginning of a term report approximately the same amount of time is spent on content and pedagogy (Figure 4). There is no clear indication that longer trainings lead to greater likelihood that GTAs will be exposed to more pedagogical training. Multiday workshops before the start of a term have slightly more pedagogy, but the average time spent on content is greater than on pedagogy for a whole term course. This mixture of responses leaves no simple generalizations for the training GTAs receive in preparation for (or during) their teaching activities. The lack of generalities supports the observation that GTA training in the geosciences varies widely, as has been the case in many disciplines (Diamond & Gray, 1987).

**Topics**

More detailed information on GTA training is known in other disciplines, such as in chemistry, where, of the 56% of departments with required training, topics include safety (98%), grading (83%), review and analysis of lab activities (75%), pedagogy (72%), and how to deal with difficult students (55%; Abraham et al., 1997). A more recent survey of biology GTA training programs indicates that most programs include rules and guidelines (91%), content information (82%), and pedagogical strategies (77%; Shadle et al., 2017). The near-equal proportions of content and pedagogy are consistent among geosciences, chemistry, and biology GTA training programs, but more detailed studies are needed to assess the efficacy of this balance, in the context of multiple programs in multiple disciplines. Although self-report data from surveys such as this one and that of Shadle et al. (2017) provide a broad overview, more comprehensive assessments of GTA programs would provide useful information on the utility of topics used in GTA training programs.

**GTA roles compared to GTA training**

Training for GTAs for the array of duties they might encounter in the geosciences is quite variable (Figure 3), and there is no obvious correlation between GTA teaching roles and responsibilities (e.g., lectures vs. lab sections) and the extent of training they receive. This is despite the fact that faculty have higher expectations for the need for training on content, logistics, and technology at institutions where GTAs teach lecture sections. Even when those expectations are higher, there is no difference in the amount or type of required training based on roles GTAs play within a department. There does appear to be some variation (Figure 5) that may be lost in grouping the roles of GTAs as either teaching “labs, no lectures” or teaching “lectures and labs.” Individual GTAs who teach lectures may still have more training required of them within a department, but those requirements may not be for all GTAs in that department. Our expectation was that graduate students who are asked to take responsibility for an entire course (lecture) would be more fully supported with training than those who teach the laboratory component of a course, in which they might interact with peer GTAs as an informal form of training. Although our survey does not address this more fully, anecdotal discussions with peer faculty suggest that GTAs (particularly doctoral students) may be perceived as equivalent to course lecturers or adjunct faculty, who in some cases have master’s degrees, but who also receive little or no training (e.g., Forbes, Hickey, & White, 2010; Webb, Wong, & Hubball, 2013).

**Inconsistent value for and topics of GTA training**

Respondents generally expressed that they believe content and pedagogy are both important components of GTA training (survey item 2). This may reflect a sampling bias, in that faculty who are most likely to take time to respond to a GTA training survey also are more likely to have a strong interest in, or high intrinsic value for, GTA training (see Limitations). However, the very poor correlation between the Likert scale rankings of the importance of pedagogical training (“value,” item 2) of the respondents and the time their GTAs spend on pedagogical training (item 6; R² = .0058; Figure 4) suggests that an individual’s values are not enough to sway a department’s choice to require a certain amount of training. Disparities between beliefs about GTA training and the training provided by a department are not unique to the geosciences. Most psychology faculty indicated they believe that GTAs learn the most from department-level training (78%), but only 48% of departments in the same survey require department-level GTA training (Mueller et al., 1997).
receive, nor does the survey request information regarding the reasons why GTAs are trained in the topic or amount of time currently in use. Voluntary comments from respondents raise the idea that a variety of barriers exist that prevent departments (or individual respondents) from offering more or different types of training. For example, responses to item 8 (“What types of resources are you still looking for to help with GTA training?”) included comments that are consistent with barriers to making change in a faculty member’s own teaching practice (e.g., Brownell & Tanner, 2012) and are similar to barriers for implementing GTA training in the biological sciences (e.g., Shadle et al., 2017), both of which include time, funding, and training. More specific comments cite that time and funding are needed to support faculty in the development and implementation of GTA training programs and the need for release time from teaching to mentor GTAs (e.g., Respondent 0894). Another respondent suggested the need for financial support of GTAs, to “allow them to take pedagogy and teaching courses PRIOR to becoming a TA” (Respondent 3379).

Departmental culture
Some survey responses indicate a lack of expertise (one’s own or throughout the department) in the areas of research-based pedagogical practices prevents implementation of GTA training. Others cite the need for department buy-in. For example: “The primary problem is NOT need for training of TAs but a change in attitude of the TAs and many faculty. The faculty view teaching as a distraction from research to be minimized. The TA’s adopt this attitude over time from the faculty” (Respondent 0894). This comment is well aligned with research that suggests that in some research-intensive universities, departmental culture may discourage STEM graduate students from pursuing teaching PD (Addy & Blanchard, 2010). For example, there is a perception that additional coursework in teaching PD may add to already-demanding graduate programs (e.g., Hadre & Burris, 2012; Offstein, Larson, Mcneill, & Mjoni Mwale, 2004) so may be perceived to come at the expense of other coursework or research expectations. However, recent research has shown that evidence-based teaching PD results in GTAs having increased confidence in their research and communication, and is not in conflict with their research productivity (Shortlidge & Eddy, 2018), and that trained GTAs who taught inquiry-based labs reported positive impacts on their research, including improved understanding of the process of science and improvement in their ability to communicate their results (French & Russell, 2002).

Because both faculty and graduate student identities are built around scientific discipline, if teaching PD is required and provided by departments, it may have a greater impact on GTAs in that they perceive that such training is a component of professional norms and expectations (e.g., Austin, 2002; Brownell & Tanner, 2012). In addition, Marbach-Ad and colleagues (2012) suggested that teaching PD is a form of building community for graduate students, an important component of improving doctoral education. However, such change in academia requires significant time, effort, and buy-in from a variety of participants (e.g., Corbo, Reinholz, Dancy, Deetz, & Finkelstein, 2016), which in this case includes GTAs but also faculty with varying commitment to their own teaching practices. That said, making changes in one’s teaching practice has been shown to be facilitated when done within a group of one’s disciplinary peers (or within the disciplinary culture; Manduca et al., 2017).

Another component of department culture revolves around the commitment to reform teaching to enhance student learning (e.g., Freeman et al., 2014). If department faculty members are committed to student-centered learning, revising and reforming parts of courses (e.g., just the lecture sections) without addressing sections taught by GTAs is an incomplete transformation. As such, GTA training not only serves to prepare graduate students to succeed in the classroom but also enhances student learning, which is an important component of departmental commitments to teaching. Without departmental norms that reinforce and support its value, teaching PD for GTAs may seem superfluous to a graduate student’s goal of finishing his or her research to graduate. But as graduate students develop their professional identities, teaching PD as part of their graduate training can help establish that careers in academia include research and teaching, which can be supported (or contradicted) by departmental culture (Brownell & Tanner, 2012).

When GTAs are not supported with teaching PD, once they achieve the goal of being hired to a tenure-track academic position, they arrive with little training in teaching (e.g., Diamond & Wilbur, 1990; Marbach-Ad et al., 2012; Rushin et al., 1997) and experience a disconnect between their research-based training and significant teaching expectations for which they are hired (Austin, 2002; Brownell & Tanner, 2012). The aforementioned barriers to GTA training are well-aligned with barriers to making change in a faculty member’s teaching practice, such as inadequate
resources, lack of accountability or reward structures, and ideas that teaching PD competes with time for doing research (Schussler, Gardner, et al., 2015).

**Costs of GTA training**

The cost of department-level training may be an underreported barrier to department-level GTA training. Although time to develop and teach GTA training courses is often cited (e.g., Brownell & Tanner, 2012), the issue of time may be equated with costs. For example, reassigning a faculty member from a disciplinary course to teach a GTA course may result in costs associated with paying for an instructor to cover the disciplinary course. University-level training may therefore be more cost efficient than departmental training, resulting in more generic teaching skills at the expense of training GTAs in their disciplinary PCK (e.g., Park, 2004). In one engineering study, the authors pointed out that teaching engineering requires “unique teaching skills beyond those of other disciplines,” so teaching PD for engineering GTAs needed to be done in the department (Nicklow et al., 2007). However, the financial costs of this specialty department program inspired the authors to conclude that more general training from the university teaching and learning center would be appropriate. Additional costs may also include paying GTAs for time spent in training, as in the case of one previously mentioned group of GTAs who began a “rebellion” and refused to attend training because they are not paid for their time to attend (Respondent 2534).

**Need for GTA training materials in geosciences**

More than half of respondents (57.5%) suggested ideas for resources that would help them with GTA training. Four respondents asked for “any” resources, and one person indicated, “Literally anything would help our department” (Respondent 7418). Specified needs are dominated by pedagogical training (26 respondents), followed by need for departmental buy-in (10), training GTAs in the logistical information (nine), and course content (six). Development of such resources is clearly an area of need in the geosciences.

In anticipation of the need for such resources (similarly encountered by the authors), we included a question in the survey that could be used to help compile a list of resources that might already exist that are perhaps well-known but unpublished. Item 7 asks, “What resources have you found helpful in graduate student TA training? (Specific responses will be most helpful.)” There were 72 responses to this question, and the most common type of materials used are those developed in-house (19 responses). Because we did not provide prompts for descriptions of such materials, we cannot determine the emphases of content, general teaching knowledge, PCK, logistical and safety information, grading, rules and regulations governing TA behavior, and other topics. A study of in-house training materials would be an important contribution to characterizing GTA training in the geosciences.

Other respondents refer to informal interactions among GTAs (19) and faculty (12) as part of GTA training in their geoscience programs, use of more general university resources (e.g., teaching and learning centers and their workshops; 15 responses), or online resources (e.g., NAGT, 2018), but there is no widely known manual or resource used for GTA training in the geosciences.

In comparison to in-house resources for GTA training, it is more likely that university resources (workshops and teaching and learning centers) that are developed by instructional developers are founded in best practices for teaching and learning. However, as noted previously, such resources are likely quite broad (e.g., Luft et al., 2004; Rushin et al., 1997) and do not address geoscience-specific areas of learning such as spatial reasoning or systems thinking or areas of discipline-specific PCK. Based on the diversity of GTAs’ responsibilities and the stated lack of expertise in our respondent population, GTA training materials must cover a wide range of topics of content and pedagogy that are consistent with, and address, disciplinary best practices. The number and types of specific resources, such as webinars and online pedagogical materials, that were suggested by respondents (survey item 8) constitute a clear call for their development and distribution. Such a collection of resources might prove useful for use across the geoscience community, much like collections of geoscience instructional activities that exist through the NAGT (NAGT, 2018) or that incorporate results from existing research in other disciplines (e.g., Roehrig et al., 2003). The development and dissemination of GTA training materials would not only be a resource to support faculty in GTA training but also for faculty, who can benefit from review and use of the materials, which may impact their own teaching practice.

**Need for more research on GTA training in geosciences**

In some cases, survey respondents who indicate a need for “off-the-shelf” GTA training materials specify
the need for resources that have been assessed and can demonstrate their efficacy and methods for assessment and feedback for GTAs. A similar call to action in biology suggests that randomized studies are sorely needed to demonstrate the effects of GTA training programs and to determine which models are most effective in changing GTA characteristics, teaching practices, and student outcomes (Reeves et al., 2018). Existing resources provide broad advice on working with GTAs in the geosciences (Bitting & Cook, 2016). Publications citing best practices in GTA training in the geosciences are sparse (Bitting et al., 2017), and there is no clear standard by which GTAs in the geosciences are currently trained; nor is there evaluation data available with regard to the efficacy and long-term impact of that training on GTAs’ teaching practice. GTA training is an important emerging field in other disciplines (e.g., the NSF-funded BioTAP project; Shadle et al., 2017) and is a critical component of pressing GER questions such as how best to support geoscience instructors’ continual growth and what roles different types of professional experiences play in instructor learning (Bitting, Teasdale, & Ryker, 2018; St. John, 2018), making the timing of research targeting GTA training in the geosciences key now, too.

Reports of GTA training from other STEM disciplines describe types of teaching PD such as the use of constructivist teaching methods (Etkina, 2000), instructional design (Hardré & Burris, 2012), lesson study (Dotger, 2011), the use of weekly preparation meetings as GTA PD (e.g., Luft et al., 2004; Wyse et al., 2014), semester-long courses (e.g., Baumgartner, 2007; Lockwood, Miller, & Cromie, 2014; Schussler et al., 2008), practice-based training (Becker et al., 2017), and the use of active learning strategies (Ebert-May et al., 2015; Gibbs & Coffey, 2004; Ho, Watkins, & Kelly, 2001; Meyers & Prieto, 2000; Pfund et al., 2009). Inquiry-based labs themselves have also been used as a type of professional development to encourage GTAs’ use of student-centered teaching in labs (Ryker & McConnell, 2014). GTA teaching PD that incorporates some of these elements may be transferable for GTA training programs in the geosciences.

Based on the GTA training survey, specific geoscience-based GTA training materials and resources are not known to the community (item 8), and a thorough review and compilation of existing resources would be a significant contribution to the geosciences community. Survey results presented here also provide the first stages of compiling a needs assessment to assemble information on the timing, types, and requirements for teaching PD that already exist for GTAs in the geosciences, as well as the types of materials faculty would like to have access to. These results, and the practices used in other disciplines, can help guide future research focused on assessment of individual programs or components of programs, which can then be transferred to other geoscience programs.

Based on the needs of faculty involved in training GTAs, it is important for the geoscience education research (GER) community to work with practitioners to develop assessment strategies for new and existing geoscience GTA training materials, along with integration of assessment of resources used in other STEM disciplines. The shortfall of GTA training resources identified by survey respondents provides a clear call to action for the GER community to develop evidence-based resources that can guide the community forward.

Future GER that addresses professional development for GTAs’ teaching practice can be modeled after research in other STEM disciplines. For example, in the context of Vision and Change in Undergraduate Biology (American Association for the Advancement of Science, 2011) and other curricular redesign movements, biology departments and biology education researchers (BERs) have developed research programs to study GTA training (e.g., Shadle et al., 2017). The conceptual framework for future research in biology (Reeves et al., 2016) is also a useful framework to drive future research for training geoscience GTAs. This framework posits that the three most important factors to examine with regard to GTA training are (a) GTA knowledge, skills, attitudes, and beliefs about teaching; (b) GTA teaching practices and undergraduate student skills, knowledge, retention, and interest in the discipline; and (c) contextual factors, GTA characteristics, and implementation variables (such as participant responsiveness). The BER community is beginning test components of this framework (e.g., Becker et al., 2017; Reeves et al., 2018; Shortlidge & Eddy, 2018), and recent research on GTA training in chemistry and for GTAs across science disciplines (Gardner & Jones, 2011; Marbach-Ad et al., 2012; Pentecost et al., 2012; Sandi-Urena & Gatlin, 2013; Wheeler et al., 2015) suggest that discussion of such higher-level structures is well-timed to produce transferable results and to help guide research questions in the geosciences.

**Research limitations**

Limitations of this project start with the nature of the survey questions, in that we cannot fully characterize
GTAs in all respondents’ departments with primarily multiple response questions in a short survey without follow-up questions or interviews to get clarification of responses. The number of questions was intentionally limited to minimize the time required for respondents, with the expectation that a shorter time commitment would result in a larger number of completed responses (e.g., Schussler, Read, Marbach-Ad, Miller, & Ferzli, 2015). Distribution of the survey was for an intentionally limited amount of time (three months) through a series of listservs, which will have confined dissemination to people who receive those emails. Respondents were self-selected in that they chose to read the email inviting them to participate and took the time to respond. This potential self-selection likely has a strongest effect on item 2, which in its final version asks participants to use a Likert scale to rate the importance of five different areas of GTA training. Answers to this item are likely biased toward the opinions of those who care more about GTA training than is representative of the general population of geoscience faculty.

The sample size of 113 respondents is similar to the number of respondents reported for other disciplines in Table 2, which range from 71 to 153, so although we would have preferred a larger sample size, this work is comparable in size to previous work. Item 2 had a smaller sample size (73 responses), which is still within the range of responses of other studies cited in Table 2, but was able to capture the importance of different areas of GTA training independently, rather than as a ranking system of the five areas. Increasing the reach of future surveys would more accurately represent the geoscience community’s ideas of GTA training. In not asking for department information, we cannot determine the exact number of departments represented in our sample; nor can we gauge the size of departments or the number of faculty or GTAs in a department, which might be a factor in the ability of a department to provide GTA teaching PD.

Implications

Results of this GTA training survey reveal that GTAs in the geosciences have important roles and diverse responsibilities in geoscience departments, most of whom teach labs but many who also teach lecture sections of courses. Because GTAs play such a large role in facilitating student learning in lectures and in lab sections while graduate students, and in the future as faculty members, their preparation to be effective instructors is an important departmental effort. Sources of GTA training are split among requirements of the university, and less so from departments, but training is most often done at the discretion of lead instructors, so is inconsistent within our discipline. Departmental requirements for GTA training are not as commonly required as in other disciplines, such as biology. Geoscience faculty members generally recognize the value of teaching PD for their GTAs, but there is poor alignment with whether such training is provided in their departments. Respondents volunteered a variety of barriers to providing teaching PD to their GTAs, including a departmental culture that does not support GTA training, time and funding to develop training programs, and expertise needed to develop such materials.

No clear resource (or set of resources) was identified by survey respondents as useful in informing GTA training. This is consistent with the lack of published research that could support development of discipline-based education research (DBER) GTA training materials in the geosciences (Bitting et al., 2017). We see future research activity investigating best practices for GTA training with a geoscience context as a clear call to action for the GER community. Geoscience-specific research can build on efforts in other discipline areas (e.g., Shadle et al., 2017) that have established projects examining research on GTA training with an eye to developing resources founded in DBER. DBER that investigates the components of teaching PD—such as learning theory, belief, and motivation—integrated with GTA teaching practices will be important contributions for use in developing GTA training.

In addition to investigating best practices in training GTAs and developing resources for teaching PD, responses to the GTA training survey reinforce the idea that providing GTA training is bigger than the training materials themselves but also involves departmental cultures and dynamics. Although beyond the scope of results of this survey, we recognize that individual faculty beliefs have important impacts on departmental decisions on whether or not GTA training is implemented, how much is provided (or required), and the means by which it is delivered. However, we also acknowledge that long-term systemic change in training future generations of geoscience faculty requires administrative support (e.g., Henderson, Beach, & Finkelstein, 2011), and systemic change in pedagogical training and cultural dynamics will also be essential to improving training of GTAs.
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