A Survey of Programs Preparing Graduate Students to Teach Undergraduate Mathematics

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In the last decade there has been a concerted effort to improve the preparation of graduate students for teaching undergraduate mathematics. Now, it is important to gauge the current state of the national landscape of graduate teaching assistant (GTA) professional development for teaching (PDT) and to assess the current needs of the community. To this end, a census survey was conducted in Fall 2021 of Ph.D-granting mathematics departments in the US. The survey followed up and extended a similar survey conducted in 2014. Some survey questions were duplicated, while others probed more deeply into the depth and extent of the GTA PDT being offered. In this paper we compare some results from the surveys, comment on how the landscape of GTA PDT has changed, and highlight areas that deserve additional attention moving forward.

Keywords: teaching professional development; graduate student instructors; teaching assistants

The need to improve success, retention, and graduation rates of undergraduate students in science, technology, engineering and mathematics (STEM) is clear (e.g., Holdren & Lander, 2012; Zorn et al., 2014). Efforts of education researchers have amassed evidence of the significant roles that instructional practices play in shaping learning outcomes for such students (e.g., Freeman et al., 2014; Laursen et al., 2014). Students' experiences in undergraduate classes also impact their views of mathematics, interest in persisting in their studies, and likelihood of completing a STEM major (Hake, 1998; Seymour & Hewitt, 1997; Seymour & Hunter, 2019). Moreover, findings from education research have illuminated disparities in how instruction can impact students who arrive in our courses with different sets of experiences and backgrounds (e.g., Ellis et al., 2016; Laursen et al., 2014; Reinholz et al., 2022).

Fortunately, the education research community has generated findings to guide improvement in the teaching of undergraduate mathematics (e.g., Bressoud et al., 2015; Laursen, 2019). Of note are impacts of active, engaged student learning approaches on achievement, retention, and equity. Professional societies and other groups have amplified these findings and provided guidance and resources for implementation (e.g., Abell et al., 2018; Laursen, 2019). However, for students to benefit, instructors need professional development for teaching (PDT). It is now quite common for departments to offer PDT to graduate teaching assistants (GTAs) (Ellis, Deshler & Speer, 2016). Yet there is still much to learn about the PDT that is offered and how programs have changed over time. To explore this, we focused on two research questions: 1) What are the characteristics of current GTA PDT programs in Ph.D-granting mathematics departments? And 2) Have those characteristics changed since 2014 and if so, in what ways?

Data Collection

Description of the 2014 Survey

In 2014, a survey was sent to all 341 graduate-degree granting mathematics departments in the US. The survey was conducted jointly by two projects of the Mathematical Association of

America (MAA). The first, College Mathematics Instructor Development Source (CoMInDS), provides support to those who prepare GTAs for their teaching responsibilities, including workshops and access to materials for instructor development. The second project, Progress through Calculus (PtC) aimed to further understand characteristics associated with students' success identified by the Characteristics of Successful Programs in College Calculus project.

The survey items related to GTA PDT were designed jointly by members of the PtC and CoMInDS teams. The survey included both multiple-choice and open-ended items designed to provide insights into characteristics of programs and to reveal the interests and needs related to GTA PDT. Department chairs were encouraged to have local experts respond to portions of the survey they were most knowledgeable about. Specifically, coordinators and providers of GTA PDT were considered ideal respondents for survey questions related to GTA PDT. The survey had a 75% response rate from Ph.D-granting institutions.

Results characterized GTA PDT programs offered in mathematics departments across the US (see Apkarian et al. (2017) for a report of the full 2014 survey). A cluster analysis of these data revealed nine models of GTA PDT that varied with respect to the activities included, and the amount and timing of the PDT (Bragdon et al., 2017). Additional analysis indicated that only 19% of departments considered their GTA PDT programs to be preparing GTAs "very well," and 33% of departments reported there was room for improvement in their programs (Ellis, Deshler, et al., 2016; Rasmussen et al., 2019). One area that was identified as needing further attention was program evaluation (Ellis, Deshler & Speer, 2016; Speer et al., 2017).

Description of the 2021 Survey

To understand how things have changed since 2014, and get additional information, a survey specifically about GTA PDT (based on the 2014 design) was distributed in Fall 2021 to Ph.D-granting institutions; the response rate was 69.5%. Again, department chairs were asked to have local experts complete it. Some questions were identical or like the questions asked in 2014 while others probed more deeply to better understand the nature of the PDT. New questions were added about the providers of PDT and how they are chosen for their positions. Mixed-methods analysis of the data is ongoing.

Results: Understanding the current landscape of GTA PDT

Here we highlight some notable similarities and differences between findings from the 2014 and 2021 surveys based on our descriptive and qualitative analysis. Both surveys generated data about roles GTAs play in undergraduate instruction and whether they participate in PDT. All respondents to the 2021 survey reported that graduate students assisted with instruction and over half reported that most, if not all, GTAs serve as instructors of record at some point in their graduate education. GTAs' roles in instruction have largely remained the same since 2014 (being graders, tutors, recitation leaders, instructors of record, and assisting with in-class instruction).

There was, however, a substantial increase (from 77% in 2014 to 88% in 2021) in the percentage of Ph.D-granting institutions that reported **all** of their GTAs participate in department-based PDT. PDT may be offered in the department, outside the department within the institution or outside of the institution. Currently, over half (57%) of responding institutions reported that over 90% of the PDT was offered within the department and only 7% report that less than half of the PDT is offered within the department.

There has been a notable change in the formats in which GTA PDT is offered. A majority of departments now offer term-long courses or seminars, short workshops or orientations, and

additional occasional workshops or seminars. Table 1 shows changes from 2014 to 2021. Open responses indicate that some departments have changed their program's structure to include credit-bearing courses, regular teaching seminars, and have adjusted placement of GTAs in their teaching roles. New in 2021, institutions were asked to choose from a list of topics GTAs typically learn about in their formal preparation for teaching. Table 1 highlights the eight most frequently selected topics addressed in the PDT.

Formats offered	2014 (n=111)	2021 (n=118)	**Most addressed topics**	2021 (n=114)
Term-long course or seminar	60%	75%	University and or dept. policies	86%
Multi-day workshop	34%	48%	Grading strategies	78%
Short workshop or orientation (1-4 hours)	24%	79%	In-person classroom management	76%
Occasional seminars or workshops	16%	73%	Active learning	76%
One-day workshop	13%	39%	University resources for students	70%
Online modules	Not asked	43%	Equity and diversity in the classroom	65%
Other	13%	16%	Facilitating group work	64%
			Academic integrity concerns	64%

Table 1: Findings from survey questions: Which of the following formats are typically included in your GTA preparation program? Which of the following topics do GTAs typically learn about in their formal preparation for teaching? (Mark all that apply.)

The 2021 data allow us to better describe the community of providers of GTA PDT than was possible with the 2014 data. The providers are a mix of non-tenure track and tenure track faculty where a majority are non-tenure track. When choosing or assigning providers of GTA PDT, departments favored individuals who were willing to take on the role and were considered excellent teachers. Answers from the non-required open response questions indicated that other considerations included whether faculty work with GTAs in another capacity, like supervising or coordinating courses (40% of responses) or are involved in the graduate program (20% of responses). 25% of responses indicate that faculty were hired specifically with this responsibility.

Both surveys asked respondents to identify what additional supports are needed for providers to improve GTA PDT. In the 2021 survey, we asked "What resources would be most helpful to you, as a provider, in strengthening your GTA teaching preparation program, if desired?" Respondents were given six choices and asked to mark all that apply. Some of the results from Table 2 can be compared over time. One of the choices was "Tools for evaluating effectiveness of GTA teaching preparation"; 67% of respondents identified this as a need in 2014 and 80% of respondents checked that box in the 2021 survey. Respondents identified a critical need for the community to develop models, instruments, and methods to better understand the extent to which PDT efforts are effective and successful. This result suggests that a major effort in future work needs to be in developing tools and protocols for effective assessment of GTA PDT programs.

Most helpful to strengthen GTA PDT programs	2014 (n=91)	2021 (n=104)
Tools for evaluating effectiveness of TA teaching preparation	67%	80%
Research-based information about best practices in TA teaching preparation	74%	78%
Online library of tested resources	48%	72%
Professional development for TA teaching preparation staff	51%	53%
Online workshops for GTAs	Not asked	45%

Table 2: Findings from question: What resources would be most helpful to you, as a provider, in strengthening your GTA teaching preparation program, if desired? (Mark all that apply.)

The desire for the "Online library of tested resources" also stands out in Table 2. The CoMInDS project has created just such a library of materials to use in facilitating PDT (available via connect.maa.org). The CoMInDS Resources Suite contains materials for use in pre-term orientation sessions, semester-long seminars, periodic workshops and more. Resources, including assignments, activities, readings, syllabi, etc., are submitted and reviewed through an editorial process as the repository continues to grow. Given the existence of these resources, one interpretation of the survey finding is that the CoMInDS Resources Suite is being underutilized. Another interpretation is that folks would like a larger or differently accessible online library, or perhaps a different set of resources entirely.

Limitations and Future Directions

In the 2021 survey, 96% of institutions responded "yes" to the question "Do graduate students in your department participate in any formal preparation for their teaching responsibilities?" In any survey with less than a 100% response rate one should consider the effects of unit nonresponse bias (Bose, 2001). A response rate of 69.5% for a survey of this kind is very high. However, intuitively, one might suspect a higher response rate from departments with programs than from those without. It is likely that fewer than 96% of the non-responding institutions have a GTA PDT program, though it is difficult to quantify.

Another concern was whether there was a "CoMInDS summer workshop bias." At these multi-day workshops (running each summer 2016-2021) participants designed or revised GTA PDT programs. The workshops have served 203 participants from almost half (87) of the Ph.D-granting mathematics departments in the U.S., in addition to some masters-degree granting institutions (Bookman & Speer, 2021). Institutions that sent participants to a CoMInDS summer workshop might have been more likely to respond to the survey than those that did not. 73.6% of workshop-participating institutions responded compared to 65.4% of non-participating institutions. A 2x2 chi-square test revealed no statistically significant differences at the .05 level in those response rates ($p=0.223$). In future work, we may examine effects of differences between 'early' respondents to 'late' respondents and the effect of item non-response.

In both surveys, we collected data about the formative and summative feedback given to GTAs about their teaching and about how well providers feel their program does at preparing new GTAs. Analysis of these questions is ongoing, however the mixed-methods analysis of the 2014 survey data revealed that most programs used student evaluations of teaching (SETs) to evaluate the teaching of graduate students in their department and there were limited efforts undertaken to evaluate the effectiveness of the programming (Speer et al., 2017). From

preliminary analysis of the 2021 survey data, it appears that SETs are still the most common method of formally evaluating GTAs' teaching (91% of institutions reported doing so).

As of 2021, graduate students in 88% of Ph.D-granting mathematics departments have opportunities to participate in PDT that is offered by their department. Although that certainly indicates that many GTAs are receiving preparation for their teaching-related responsibilities, programs vary in terms of enrollment. As a result, we do not know what percentage of all mathematics graduate students are participating in PDT. If the large Ph.D-granting programs are represented in the 88% then person-level participation may be even higher. However, if the 88% primarily includes small-enrollment programs, then the actual person-level participation rate may be lower. Knowing more about the size of the programs represented in the response sample could inform strategies used to increase the reach of efforts to departments that are currently not offering programs. On-going analysis will further examine this issue via other data provided on the survey as well as publicly available data from the CBMS survey of programs.

We anticipate that further analysis of responses to open-ended prompts will provide additional insights. Several comments highlighted major changes that have been implemented to GTA PDT programs, including hiring a GTA PDT provider and/or dedicated course coordinators. Course coordinators may be well-positioned to take on the role of providing PDT for GTAs (Martinez et al., 2021), and future analysis of the survey data could shed light on the ways coordinators are complementing existing GTA PDT programs.

Conclusions

The mathematics community has responded to calls for increased attention on professional development for those new to teaching. Now, 88% of departments offer PDT to graduate students whereas in 2014 only 77% did so. The scope and content of those programs has also changed and now better reflect what is known from research about effective design of PDT. The K12 education community has recognized that development of teaching practices and knowledge requires sustained engagement (Blank & de las Alas, 2009). In 2014, 60% of departments offered a term-long course or seminar and today, 75% of departments do so. Such courses or seminars may represent as little as 10-15 contact hours (for a 1-credit course) or as much as 30-45 contact hours (for a 3-credit course). This falls short of the 100 hours that is regarded as necessary for impact (Banilower et al., 2006), however, when taken together with other changes we see, the shifts since 2014 are encouraging.

We also see that current programs are focusing on issues of importance to the broader mathematics community (e.g., active learning, collaborative groupwork, and diversity/equity/inclusion, see Table 1). We lack comparison data but the presence of such topics in the majority of programs suggests that those involved in program design are well-informed about current needs of the mathematics community and findings from education research.

Those involved in GTA PDT continue to request tools to better understand the impact of their programs on teaching and learning. In 2014 this was expressed by a majority (67%) and today, 80% say this is something they need. While some of this increase may be a result of trends about assessment and evaluation seen throughout the mathematics community, the finding points to the need for ways of examining the impact of PDT on instructors (which also requires tools for assessing and evaluating instructional practices). This creates opportunities for increased collaboration among those with expertise in PDT programs for GTAs, research on the teaching and learning of undergraduate mathematics, and program evaluation.

References

Abell, M., Braddy, L., Ensley, D., Ludwig, L. & Soto-Johnson, H. (2018). *MAA Instructional Practices Guide*. The Mathematical Association of America.

Apkarian, N., Kirin, D. & Progress through Calculus Team. (2017). *Progress through calculus: Census survey technical report*. http://bit.ly/2xcbZTV

Banilower, E. R., Boyd, S. E., Pasley, J. D. & Weiss, I. R. (2006). Lessons From A Decade Of Mathematics and Science Reform. *A Capstone Report for the Local Systemic Change Through Teacher Enhancement Initiative*, 1–100. papers3://publication/uuid/90FCBAD8-8291-42B9-BAC0-AD5886961D3B

Blank, R. K. & de las Alas, N. (2009). Effects of teacher professional development on gains in student achievement. In *Meta-Analysis Study of the Effects of Teacher Professional Development with a Math or Science Content Focus on Improving Teaching and Learning*. Council of Chief State School Officers.

Bookman, J. & Speer, N. (2021). CoMInDS: Supporting faculty who provide professional development for teaching to the next generation of college mathematics instructors. *MAA FOCUS*, *41*(3 (June / July), 22–25.

Bose, J. (2001). Nonresponse Bias Analyses At the National Center for Education Statistics. *Proceedings of Statistics Canada Symposium*, 1–9.

Bragdon, D., Ellis, J. & Gehrtz, J. (2017). Interaction, activities, and feedback: A taxonomy of GTA professional development. *Proceedings of the 20th Annual Conference on Research in Undergraduate Mathematics Education*, 502–510.

Bressoud, D., Mesa, V. & Rasmussen, C. (Eds.). (2015). *Insights and recommendations from the MAA National Study of College Calculus* (MAA Notes). Mathematical Association of America.

Ellis, J., Deshler, J. & Speer, N. (2016). Supporting institutional change: A two-pronged approach related to graduate teaching assistant professional development. In T. Fukawa-Connelly, N. Infante, M. Wawro & S. Brown (Eds.), *Proceedings of the 19th Annual Conference on Research in Undergraduate Mathematics Education* (pp. 729–735).

Ellis, J., Fosdick, B. K. & Rasmussen, C. (2016). Women 1.5 Times More Likely to Leave STEM Pipeline after Calculus Compared to Men: Lack of Mathematical Confidence a Potential Culprit. *PLOS ONE*, *11*(7), 1–14. https://doi.org/https://doi.org/10.1371/journal.pone.0157447

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H. & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410–8415.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*(1), 64–74.

Holdren, J. P. & Lander, E. S. (2012). *Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics*.

Laursen, S. L. (2019). *Levers for Change: An assessment of progress on changing STEM instruction*. American Association for the Advancement of Science.

Laursen, S. L., Hassi, M.-L., Kogan, M. & Weston, T. J. (2014). Benefits for Women and Men of Inquiry-Based Learning in College Mathematics: A Multi-Institution Study. *Journal for Research in Mathematics Education*, *45*(4), 406–418. https://doi.org/10.5951/jresematheduc.45.4.0406

Martinez, A. E., Gehrtz, J., Rasmussen, C., LaTona-Tequida, T. & Vroom, K. (2021). Course Coordinator Orientations Toward their Work and Opportunities for Professional Development. *Innovative Higher Education*, *0123456789*. https://doi.org/10.1007/s10755-021-09579-1

Rasmussen, C., Apkarian, N., Hagman, J. E., Johnson, E., Larsen, S. & Bressoud, D. (2019). Brief report: characteristics of precalculus through calculus 2 programs: insights from a national census survey. *Journal for Research in Mathematics Education*, *50*(1), 98–111.

Reinholz, D. L., Johnson, E., Andrews-Larson, C., Stone-Johnstone, A., Smith, J., Mullins, B., Fortune, N., Keene, K. & Shah, N. (2022). When active learning is inequitable: women's participation predicts gender inequities in mathematical performance. *Journal for Research in Mathematics Education*, *53*(3), 204–226. https://doi.org/10.5951/jresematheduc-2020-0143

Seymour, E. & Hewitt, N. (1997). *Talking About Leaving: Why Undergraduates Leave the Sciences*. Westview Press.

Seymour, E. & Hunter, A.-B. (2019). *Talking about Leaving Revisited: Persistence, Relocation, and Loss in Undergraduate STEM Education*. Springer.

Speer, N., Ellis, J. & Deshler, J. (2017). Evaluation of Graduate Student Professional Development and Instruction by Mathematics Departments: Results from a National Survey. In A. Weinberg, C. Rasmussen, J. Rabin, M. Wawro & S. Brown (Eds.), *Proceedings of the 20th Annual Conference on Research in Undergraduate Mathematics Education* (pp. 1442–1448).

Zorn, P., Bailer, J., Braddy, L., Carpenter, J., Jaco, W. & Turner, P. (2014). *INGenIOuS Project: Report on July 2013 Workshop*. http://www.ingeniousmathstat.org/pdfs/INGenIOuS-report.pdf