Graduate students Teaching Assistants' (GTAs') beliefs, instructional practices, and student success

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In this report I present findings from a large, national study focused on Calculus I instruction. Graduate student Teaching Assistants (GTAs) contribute to Calculus I instruction in two ways: : as the primary teacher and as recitation leaders. As teachers, GTAs are completely in charge of the course just as a lecturer or tenured track/ tenured faculty would be, although they lack the experience, education, or time commitment of their faculty counterparts. In this study, I investigate how GTAs compare to tenure track/tenured faculty, and other full/part time faculty on their (a) beliefs about mathematics; (b) instructional practices; and (c) students' success in Calculus I. Findings from this report point clearly to a need to prepare GTAs adequately for the teaching of calculus but also for further examination of the nature and implications of the differences between GTA and other instructor types' beliefs about teaching and teaching practices.

Keywords: *Graduate student Teaching Assistants (GTAs), Calculus instruction, beliefs, instructional practices, student success*

In this study I investigate the relationship between Graduate Student Teaching Assistants (GTAs) and various aspects of Calculus I instruction. Graduate student Teaching Assistants contribute to Calculus instruction in two ways: as the primary teacher and as recitation leaders. As teachers, GTAs are completely in charge of the course just as a lecturer or tenured track/ tenured faculty would be, although they lack the experience, education, or time commitment of their faculty counterparts. In the College Board of Mathematical Sciences (CBMS) 2010 report, GTAs were found to have taught seven percent of the 234,000 students enrolled in mainstream Calculus I, and 17% of all mainstream Calculus I sections at PhD institutions (Blair, Kirkman, & Maxwell, 2012). Mainstream calculus refers to the calculus course that is designed to prepare students for the study of engineering or the mathematical or physical sciences. In this report, a course was reported to be taught by a GTA only when the GTA was the instructor on record. Thus, these numbers exclude the GTAs who ran discussion or recitation sections.

GTAs can also be viewed as the next generation of mathematics instructors. Thus, in addition to their immediate contribution to the landscape of Calculus I instruction, GTAs contribute significantly to the long-term state of Calculus. The preparation GTAs receive to prepare them for teaching Calculus therefore influences both their immediate teaching practices as well as their long-term pedagogical approach. There has been much discussion about what knowledge and experiences are needed to foster excellent (or even adequate) teachers in mathematics at the K-12 level (Ball, Thames, & Phelps, 2008; Hill, Ball, & Schilling, 2008; Shulman, 1986) and instructors at the undergraduate level (Johnson & Larsen, 2012; Speer, Gutmann, & Murphy, 2005). From these discussions, it is clear that expertise in mathematics alone is not sufficient in the preparation of teachers. Professional development efforts to improve teaching are often aimed at developing teachers' knowledge, beliefs, and instructional practices in order to improve their students' success and to enculturate new teachers into the teaching community (Putnam & Borko, 2000; Sowder, 2007). However, little is known about how GTAs' compare to other instructor types along these dimensions. Accordingly, I have identified the following research question: *How do GTAs compare to tenure track/tenured faculty, and other full/part time faculty on their (a) beliefs about mathematics; (b) instructional practices; and (c) students' success in Calculus I?*

Research Methodology

To answer this question, I draw upon data coming from a large, nationwide study focused on successful calculus programs: Characteristics of Successful Programs in College Calculus (CSPCC). The first phase of the CSPCC study comprised of six surveys: three surveys given to students (one at the beginning of Calculus I, one at the end of Calculus I, and one a year later), two surveys given to instructors (one at the beginning of Calculus I and one at the end of Calculus I), and one survey given to the Calculus course coordinator. The surveys were sent to a stratified random sample of mathematics departments following the selection criteria used by Conference Board of the Mathematical Sciences (CBMS) in their 2005 Study (Lutzer et al, 2007). For the purposes of surveying post-secondary mathematics programs in the United States, the CBMS separates colleges and universities into four types, characterized by the highest mathematics degree that is offered: Associate's degree (hereafter referred to as two-year colleges), Bachelor's degree (referred to as undergraduate colleges), Master's degree (referred to as regional universities), and Doctorate (referred to as national universities). Within each type of institution, we further divided the strata by the number of enrolled full time equivalent undergraduate students, creating from four to eight substrata. Institutions with the largest enrollments were sampled most heavily. In all, we selected 521 colleges and universities: 18% of the two-year colleges, 13% of the undergraduate colleges, 33% of the regional universities, and 61% of the national universities. Of these, 222 participated: 64 two-year colleges (31% of those asked to participate), 59 undergraduate colleges (44%), 26 regional universities (43%), and 73 national universities (61%).

The goals of these surveys were to gain an overview of the various calculus programs nationwide, and to determine which institutions had successful calculus. *Success* was defined by a combination of student variables: persistence in Calculus as marked by stated intention to take Calculus II; affective changes, including enjoyment of math, confidence in mathematical ability, interest to continue studying math; and passing rates. These variables will be used to discuss student success. The instructor surveys address various components of instructors' knowledge, espoused beliefs, and instructional practices. The course coordinator survey addresses programmatic qualities that can be used to situate the individual GTAs within their institutions as well as to gain a topical understanding of the training and support structures available to GTAs, as stated by their course coordinators.

There were 535 instructors who responded to one of the surveys linked to 6306 students, coming from 136 institutions. As shown in Table 1, 30% of the instructors came from a large national university (over 20,000 students) and taught 35% of the students, 30% from a small national university (less than 20,000 students) and taught 30% of the students, 10% from a regional university and taught 6% of the students, 18% from a undergraduate college and taught 22% of the students, and 13% from a two-year college and taught 6% of the students. As shown in Table 2, 46% of the instructors reported being tenure track or tenured and taught 40% of the students, 37% reporting to be "other full or part time faculty" and taught 48% of the students, and 17% report being GTAs who taught 12% of the students. GTAs only taught at national universities, with 67% at large national universities.

Table 1. Number of instructors and students from each institution type.

Institution Type	Instructors	%	Students	%
Two-year colleges	68	12.7	365	5.8
Undergraduate colleges	96	17.9	1381	21.9
Regional universities	54	10.1	377	6.0
Small national universities (<20,000)	156	29.2	1940	30.8
Large national universities (>20,000)	161	30.1	2243	35.6
Total	*535*		*6306*	

Table 2. Number of instructors and students from each instructor type.

Instructor Type	Instructors	%	Students	%
Tenure track/ Tenured faculty	246	46.0	2477	39.3
Other full or part time faculty	197	36.8	3052	48.4
Graduate teaching assistant	92	17.2	777	12.3
Total	*535*		*6306*	

I answer the research question by conducting descriptive analyses to determine differences between instructor types (tenure track/tenured faculty and other full/part time faculty) across a number of variables, addressing knowledge and beliefs about mathematics, instructional practices, and student success.

Results

Beliefs about doing, teaching, and learning mathematics

The first dimension of teaching practice that I compare between tenure/ tenure track faculty, other full and part time faculty, and GTAs is their beliefs about doing, teaching, and learning mathematics. As shown in Table 3, there were significant differences between the types of instructors for three of the reported beliefs about teaching mathematics: "graphing calculators or computers help students understand underlying mathematical ideas (1) or find answers to problems" (6) [$F(2, 516) = 4.193$, $p = .016$], and "all students in beginning calculus are capable of understanding the ideas of calculus" [$F(2, 389) = 3.112$, $p = .046$], and "if I had a choice, I would continue to teach calculus" [$F(2, 385) = 5.969$, $p = .003$]. For all other beliefs about doing teaching, or learning mathematics, there were no significant differences between reported frequencies based on instructor type.

Post hoc comparisons using the Tukey HSD test indicated that the mean response to the prompt "graphing calculators or computers help students understand underlying mathematical ideas (1) or find answers to problems (6)" was significantly different between tenure track/ tenured track faculty (3.62, 1.62) and GTAs (4.17, 1.55), but there were no significant differences between the other types of instructors. The mean response to the prompt "all students in beginning calculus are capable of understanding the ideas of calculus" was significantly different between tenure track/ tenured track faculty (3.63, 1.52) and GTAs (4.15, 1.27), but there were no significant differences between the other types of instructors. Finally, the mean response to the prompt "if I had a choice, I would continue to teach calculus" was significantly different between tenure track/ tenured track faculty (5.19, 1.04, 1.68) and GTAs (4.66, 1.25), and between other full or part time instructors (5.14, 1.09) and GTAs, but not between full or part time instructors and tenure track/ tenured faculty.

These results indicate that GTAs believe that technology serves as a procedural aid more than a conceptual aid when compared to tenure/tenure track faculty, that GTAs view their students as more capable of understanding calculus than tenure/tenure track faculty, and GTAs are slightly less interested in teaching calculus than all other types of instructors. These results also indicate that GTAs report holding similar beliefs about doing, teaching, and learning mathematics for all others beliefs questions.

Table 3. Beliefs about doing, teaching, and learning mathematics by instructor type.

Belief about doing, teaching, or learning mathematics:	**Tenure track/ Tenured faculty**	**Other full or part time faculty**	**Graduate teaching assistant**
From your perspective, in solving Calculus I problems, graphing calculators or computers help students:** *(1=understand underlying mathematical ideas; 6=find answers to problems)*	3.62 (1.62)	3.81 (1.45)	4.17 (1.55)
All students in beginning calculus are capable of understanding the ideas of calculus.** *(1=strongly disagree; 6=strongly agree)*	3.63 (1.52)	3.70 (1.51)	4.15 (1.27)
If I had a choice, I would continue to teach calculus.** *(1=strongly disagree; 6=strongly agree)*	5.19 (1.04)	5.14 (1.09)	4.66 (1.25)

Note.* = $p \leq .10$, ** = $p \leq .05$, *** = $p \leq .001$; Standard deviation in parentheses.

Instructional Practices

As shown in Table 4, there were significant differences between the types of instructors for four of the reported instructional activities: having students work with one another [$F(2, 404) = 6.084$, $p = .002$], holding a whole-class discussion [$F(2, 403) = 2.495$, $p = .084$], and having students give presentations [$F(2, 400) = 3.927$, $p = .020$]. For all other instructional activities, there were no significant differences between reported frequencies based on instructor type.

Post hoc comparisons using the Tukey HSD test indicated that the mean frequency for having students work with one another was significantly different between tenure track/ tenured track faculty (2.80, 1.68) and other full or part time faculty (3.24, 1.73), and between tenure track/ tenured track faculty and GTAs (3.59, 1.86). The mean frequency for holding whole class discussion was significantly different between other full or part time faculty (3.20, 1.76) and GTAs (2.69, 1.26), but there were no significant differences between the other types of instructors. Finally, the mean frequency for having students give presentations was significantly different between tenure track/ tenured faculty (1.46, .96) and GTAs (1.87, 1.25), but there were no significant differences between the other types of instructors.

These results indicate that GTAs report having students work together significantly more frequently than tenure track and tenured faculty, holding whole class discussion significantly less frequently than other full and part time faculty, and have students give presentations significantly more frequently than tenure track and tenured faculty. Taken together, these results indicate that GTAs report different instructional practices than tenure track tenured and other full and part time faculty.

Table 4. Instructional practices by instructor type.

During class, how frequently did you:	Tenure track/ Tenured faculty	Other full or part time faculty	Graduate teaching assistant
(a) show students how to work specific problems?	5.18 (1.14)	5.28 (.99)	5.14 (.97)
(b) have students work with one another? **	2.80 (1.68)	3.24 (1.73)	3.59 (1.86)
(c) hold a whole-class discussion? **	3.13 (1.69)	3.20 (1.71)	2.69 (1.26)
(d) have students give presentations? *	1.46 (.96)	1.68 (1.23)	1.87 (1.25)

Note.* = p ≤ .10, ** = p ≤ .05, *** = p ≤ .001; Standard deviation in parentheses.

Student success

The final dimension that I compare GTAs to other instructor types on is their students' success. In order to measure student success in Calculus I, I used five variables: persistence onto Calculus II, expected pass rate, and three affective measures – change in confidence in mathematical ability, change in enjoyment in doing mathematics, and increased interest in taking mathematics. These measures of success were chosen because many students enter Calculus I pursuing a STEM degree and change their major away from a STEM field because of a decreased interest or enjoyment in mathematics. Research into the reasons students switch out of STEM majors consistently points to the calculus classroom environment as the underlying commonality (Rasmussen & Ellis, 2013; Seymour & Hewitt, 1997; Thompson et al., 2007). As shown in Table 5, there are significant differences in the success of GTAs' students when compared to tenure track/ tenured faculty's students and other full or part time faculty's students. Specifically, GTAs' students switch STEM intention at a significantly higher percentage than both other types of instructors', and their students lose confidence and interest in mathematics at heightened frequencies when compared to both other instructor types.

Table 5. Student success by instructor type.

Measure of student success:	Tenure track/ Tenured faculty	Other full or part time faculty	Graduate teaching assistant
Percentage of STEM intending students who decided not to pursue Calculus II***	13.9%	9.8%	20.1%
Percentage of students expecting to pass.	96%	95.9%	96.9%
Student change in confidence	-.389 (1.06)	-.440 (1.12)	-.515 (.961)
Student change in enjoyment**	-.255 (1.06)	-.356 (1.09)	-.419 (1.12)
This class has increased my interest in taking more	3.94 (1.40)	3.72 (1.42)	3.58 (1.40)

mathematics.***

Note.* = p ≤ .10, ** = p ≤ .05, *** = p ≤ .001; Standard deviation in parentheses.

Discussion

The above results indicate that in many ways, GTAs are different than other types of Calculus I instructors. They express different beliefs regarding the role of calculators, are more optimistic about their students' capabilities, and are less interested in teaching calculus than tenured/ tenure track faculty and other types of full and part time faculty. Additionally, GTAs report different classroom environments than other types of faculty: students working together more, holding less whole class discussions, and having students give more presentations. While these results indicate some differences between GTAs and other instructor types regarding their beliefs and instructional practices, the most striking differences between GTAs and other instructors lies in their students' success. The students of GTAs decide to not take Calculus II after originally intending to do at much higher frequencies and lose significantly more confidence and interest in mathematics than the students of other instructor types.

These results point clearly to a need to prepare GTAs adequately for the teaching of calculus but also for further examination of the nature and implications of the differences between GTA and other instructor types' beliefs about teaching and teaching practices. Why do GTAs hold a procedural perspective on the role of calculators in the classroom? How does this affect their teaching, and how can we prepare them to explore the conceptual advantages of calculators? Why do GTAs engage their students in more group work and presentations but less whole class discussions? How is this related to their students' decreased interest in studying calculus?

Beyond these questions examining the connections between the above results and student success, are questions regarding the broader implications to teacher preparation at the post-secondary level. In order to teach Calculus at the secondary level in California (a state with some of the most stringent requirements), one must obtain a Bachelor's Degree (or higher) from a credited university, complete a teacher preparation program involving student teaching, and demonstrate subject matter knowledge by passing the California Subject Examinations for Teachers (CSET) or by completing specified mathematics content courses. In order to teach Calculus at the post-secondary level, one must obtain a Bachelor's Degree and be enrolled in a graduate program at the institution, obtain a Master's Degree and teach as an adjunct or obtain a Doctorate and teach as a professor. The difference between these requirements is attention to pedagogical training, which demonstrates differing assumptions on what knowledge is needed to teach mathematics: at the secondary level, content knowledge, pedagogical knowledge, and often pedagogical content knowledge are all prerequisites; at the post-secondary level only strong content level is deemed as sufficient to teach.

Due to this implicit assumption, often the only form of training an instructor receives is as a Graduate student Teaching Assistant (GTA). As such, the training of GTAs is one of few ways to alter the way post-secondary mathematics is taught, and thus the nature and emphases of these training programs are of high significance to the future landscape of post-secondary mathematics. The work described here is the beginning of a large project seeking to respond to the questions outlined above, as well as build a model for GTA training programs that can be used for development of new programs and evaluation of existing programs.

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