Revisiting Graduate Teaching Assistant Instructor Expertise and Algebra Performance of College Students

Karla Childs
Pittsburg State University

Hayley Milbourne
San Diego State University

This longitudinal study revisits a decade old study about the relationship between level of Graduate Teaching Assistant (GTA) instructional expertise, amount of GTA teaching experience, and academic performance of their college algebra students measured by course grades. The questions posed then remain relevant today. In the present study, college algebra grades for all students in classes taught by GTAs since the original experiment were analyzed. That is, data from twelve years (AY2006 – AY2017) and 168 sections (n = 6675) were examined. Noteworthy is the fact that success in lowering the drop rate in the treatment group held true for 15 years since the treatment was initiated. Included is a look at what has changed and what has remained the same since the original study.

Keywords: Graduate teaching assistants, professional development, program efficacy

"Mathematics education, unlike mathematics itself, is not an exact science; it is much more empirical and inherently multidisciplinary. Its aims are not intellectual closure but helping other human beings, with all of the uncertainty and tentativeness that that entails" (Bass, 1997, p. 21). Professional development programs for Graduate Teaching Assistants (GTAs) are becoming more common across the United States, with 81% of PhD granting institutions and 45% of Masters granting institutions reporting having some kind of department-run professional development for their GTAs (Rasmussen et al., 2016). However, it is not clear what the results of these various professional development programs are, both on teaching efficacy and student achievement.

Teachers of mathematics need both knowledge of content and knowledge of the best way to teach that content to students. Pedagogical content knowledge or subject-specific pedagogical knowledge consists of how to represent specific topics and issues in ways that are appropriate to the diverse abilities and interests of learners (Ball, Thames, & Phelps, 2008). Brown and Borko (1992) said this requires making the transition from a personal orientation to a discipline to thinking about how to organize and represent the content of the discipline to facilitate student understanding. Naturally, GTAs need support and guidance in making this transition from learner to learning to teach.

In this particular study, GTAs were given professional development to help support them in their teaching of college algebra. Results from the past 12 years since the program was implemented of the change in withdrawal rates are given. In the talk, we will further discuss changes in the grade distributions for the course.

Background of GTA Professional Development Programs

Researchers in higher education have suggested that for decades universities and colleges gave little regard to the impact of GTAs on undergraduate education (Boyer, 1990; Sykes, 1988). Sykes (1988) said that the professoriate, in pursuit of research, grants, and academic politicking, has left undergraduate students in the care of under-prepared and under-paid GTAs. During the late 1980's, in response to the sharp criticism about the practice of using graduate students as inexpensive labor, many GTA orientation and training programs were started at colleges and

universities across the United States (Bartlett, 2003). Now, as the focus is returning to the teaching of mathematics at the undergraduate level, there is renewed interest in professional development programs for GTAs. For instance, one of the seven recommendations from the Mathematical Association of America study of successful Calculus programs was to improve the professional development offered to the GTAs (Bressoud, Mesa, & Rasmussen, 2015).

Research about college student learning and development clearly shows that student learning is "unmistakably linked to effective teaching" (Pascarella & Terenzini, 1992, p.182). Furthermore, there is research to support that "good teaching" has a positive effect on the change in students' attitudes towards mathematics (Mesa, Burn, & White, 2015), with "good teaching" referring to three components: classroom interactions that acknowledge students, encouraging and available faculty, and fair assessments. However, this same study has shown that students are still citing their experiences in college mathematics as a top reason for why they are switching out of a STEM (science, technology, engineering, and mathematics) major (Rasmussen, Ellis, & Bressoud, 2015). So, more work needs to be done on how the experience in undergraduate mathematics courses can be improved.

Within the various studies done on the range of professional development programs available for GTAs, most studies can be described by three main themes: temporal, structural, and topical. In temporal studies, researchers describe the duration of the professional development and how it varies across the nation (e.g. Belnap & Allred, 2009). In structural studies, the focus is on the various ways the programs for professional development of GTAs are structured (e.g. Ellis, 2015; Palmer, 2011). In topical studies, there is an effort to create a list of standard topics and teaching practices on which the professional development programs are focused (e.g. McDaniels, 2010). Finally, outside of the three topics described above, there are a group of studies on the efficacy of particular professional development programs (e.g. Griffith, O'Loughlin, Kearns, Braun, & Heacock, 2010).

The research base on the state of professional development of GTAs is still relatively small. There have been only a handful of studies done exclusively on the state of professional development of GTAs across the nation (Belnap & Allred, 2009; Kalish et al., 2011; Palmer, 2011; Robinson, 2011). Additionally, there have been a few meta-studies conducted over the years on the state of research in the teaching of undergraduate mathematics (Speer, Gutmann, & Murphy, 2005; Speer, Smith, & Horvath, 2010). Outside of the national studies, there are also a handful of articles on particular programs at specific institutions, with a focus on the structure of the program or the efficacy of the program (e.g. Griffith et al., 2010; Marbach-Ad, Shields, Kent, Higgins, & Thompson, 2010).

During the Research in Undergraduate Mathematics Education (RUME) conference in 2017, there were five different studies presented that involved examining what GTAs learned from a particular professional development program. The study done by Pascoe and Stockero (2017) focused on the results of an intervention in which the GTAs learn about a noticing framework and how to use it while watching videos of teaching. Reinholz (2017) and Wakefield and colleagues (2017) focused on the use of reflections in the development of teaching in GTAs, with Reinholz also looking into the role of peer feedback. Each of these studies focused on a cognitive approach to learning.

Furthermore, Speer, Deshler, and Ellis (2017) presented results from a study done on the ways departments are evaluating the undergraduate student outcomes from their GTA professional development programs. With this greater focus on GTA professional development programs, ways to evaluate their efficacy is an important aspect that has not been widely studied.

Their results showed that many departments are relying on student evaluations to evaluate the teaching of their GTA's, which has been shown to be an ineffective measure of teaching (Krautmann & Sander, 1999).

The purpose of the present longitudinal study was to revisit a decade old study about the relationship between instructor participation in a GTA professional development program and academic performance of college algebra students measured by course grades (Childs, 2008). Furthermore, the relationship between algebra performance of college students in courses taught by first year GTAs and second year GTAs was reexamined.

Methods

Participants

All of the participants in the present study were enrolled in sections of MATH 113, College Algebra, taught by GTAs at a midsized Midwestern University during the spring and fall semesters over the AY 2006-17. The University remains a traditional college campus with average class size of 18 students. Approximately 7,000 students annually were enrolled in more than 200 academic programs and emphasis areas in four colleges.

College Algebra is one of three choices for all baccalaureate students to satisfy the Mathematics Area under the General Education Degree Requirements as stated in the university catalog. Enrollment for the course is approximately 700 students each academic year. College Algebra courses offered during the summer term are not taught by GTAs and not considered in this study. The students were males and females, freshman, sophomores, juniors, and seniors between the ages of 17 and 65. Participants for this study were enrolled in this course, as well as other courses, with the assistance of an academic advisor. Quantitative data was gathered from this purposive sample to examine the relationship between algebra performance among college students and instructor expertise.

Procedure

In the current study as well as the original study, there are important common components of Math 113, College Algebra, during the control and treatment years. They include course syllabi, Basic Skills Exams, final exams, and GTA instructors. These standardized conditions of college algebra during the years under investigation help control for potential group differences and allow for investigation of the treatment variable with more reliability.

Course Syllabi. All students in the participating sections of college algebra are exposed to the same set of course topics during the semester. All college algebra classes have a common day-by-day schedule and a common syllabus of topics and skills outlined by the State Board of Regents. The Core Competency Committee, called by the State Board of Regents, determined minimum core competencies for common courses under its jurisdiction. Mathematics instructors and professors from all of the State institutions comprised the committee to develop the mathematics syllabi. To ensure this set of minimum core competencies and department approved learning goals and objectives are taught uniformly in all college algebra courses within the mathematics department, course syllabi are scrutinized by either the GTA supervisor or the department chair.

Basic Skills Exam. The Basic Skills Exam is an important formal assessment tool used in college algebra at this university. The math department requires a Basic Skills Exam for college algebra in which students must get 9 out of 11 problems completely correct in order to successfully exit the course. Students start taking this exam at the beginning of week 9 of the

semester. If a student fails the exam, he or she works one on one with the instructor and tutors and may continue to repeat versions of the exam until week 11 of the semester. If the student still does not pass the exam after week 11, he or she must repeat the course.

Every student from every section of college algebra had to demonstrate mastery of these basic algebra skills to the same high degree of accuracy by passing the standardized Basic Skills Exam during the semesters under study.

Final exam. Students in college algebra take a common comprehensive final exam that is prepared by the full-time instructor who coordinates the college algebra sections. All students in all sections of college algebra take this comprehensive final exam on the same date and at the same time. The contents of final exams during the years under investigation were analyzed for concepts tested, number of questions, and number of questions per concept. Two mathematics instructors participated in this analysis to provide inter-rater reliability and determine if there were any significant differences among the years being studied.

Each of the final exams for the 24 semesters being examined contained questions in six categories: Basics, Algebraic Operations, Solving Equations and Inequalities, Functions, Graphing, and Matrices. Just as in the original study, the contents of final exams during the years under investigation were analyzed for concepts tested, number of questions, and number of questions per concept. Two instructors participated in this analysis to provide inter-rater reliability and determine if there were any significant differences among the years being studied. The results suggest that no mean differences exist between the number of questions in each of the six categories during the control years and treatment years. In addition, there was not a significant difference in the total number of questions on the finals in the control group, AY 1999 – 2001, ($M_C = 36.6$) and the treatment group AY 2002-17 ($M_T = 37.2$). The results of the chi-square test substantiated there were no differences between the groups by content area on the final exams ($\chi^2 = 0.198$, $df = 6$, $p > .95$). The P-Value is 0.99985. The result is *not* significant at $p < 0.05$.

Treatment Procedures

Beginning in the fall 2002 semester and continuing to the present, the mathematics department implemented a coordinated program of support and professional development for its GTAs. Release time was given to a tenure-track faculty member for this assignment. Also a new course, MATH 871 Teaching Mathematics, for one-credit-hour was added and required of all GTAs.

Prior to the fall semester 2002, GTAs teaching mathematics attended a fall orientation to cover the department handbook but did not receive any further training. Under the new program, since the fall semester 2002, graduate students teaching in the mathematics department meet for a half day of professional development training before the fall semester begins and then for a one hour class each week throughout the semester. The curriculum for MATH 871 Teaching Mathematics was designed specifically to assist GTAs in their role as educators and to address the unique professional challenges and limitations they face.

The following sections describe the program and procedures of the GTA training model used in this study. They comprise information about what has changed and what has remained the same about the treatment from the original study to the current study.

Treatment that continued from the original study.

In all treatment years, pre-service training for GTAs in the mathematics department was held prior to the start of the fall semester. During this time GTAs were given their assignments,

a day by day schedule of textbook sections to teach along with unit test dates. They were provided with a copy of the textbook and ancillary materials to be used for teaching. The typical semester assignment for full-time GTAs consisted of complete responsibility for two, 3-credit-hour sections of college algebra. Both first and second-year GTAs participated in the orientation.

MATH 871 Teaching Mathematics Course Description. The course was designed to promote guidance, direction, and support for GTAs. From inception, the course goal was to encourage excellence in teaching through a program of sharing ideas, concerns, problems, and information on an ongoing basis with GTAs in the mathematics department. No one model was followed in course development. Instead, the aim was to build a unique model that drew from the research on best practices in GTA training and effective programs that fit the needs of mathematics GTAs at this university.

All GTAs attended an hour-long class once a week with the GTA supervisor. During the entire time period of the study, the researcher served as the GTA supervisor. Both new and returning GTAs participated in class activities with second-year GTAs acting as mentors for new GTAs.

Treatment new to this study.

Peer Observations. Peer observations were instituted starting in Fall 2012. GTAs were given opportunities to provide feedback about teaching, not just receive it. It was hypothesized that they may learn as much from providing feedback as receiving feedback. The process started with peer conferences. In this meeting GTAs were encouraged to discuss specific behaviors that they were interested in receiving feedback on. Following the peer observation, a second conference allowed students to discuss their feedback and analyses. Peer observations provided an additional learning opportunity for the GTAs, beyond only receiving feedback from a supervisor.

Journals. During the AY 2003-05 journal entries were required and submitted weekly. During the years of the current study, AY 2006-17, GTA's had a choice of a weekly face-to-face conference with the supervisor or a weekly journal submission. Both options were used as a way for the GTA supervisor to have continuing dialogue with individual GTAs and as a vehicle for GTAs to reflect on their own experiences and growth. From time to time a specific prompt activity was assigned. Regardless of the means, graduate teaching assistants were encouraged to regularly reflect intelligently on the work they were doing.

Teacher Noticing. A lesson about Teacher Noticing was added to the content of the GTA training course in AY 2014. GTA's were assigned research articles to read about this relatively new field in education and a GTA class meeting was devoted to discussion and question/answer dialogue about Noticing. The goal of introducing these student-centered pedagogies was to help GTAs to attend to and respond to student thinking in their classrooms.

Portfolios. All GTAs during the treatment years of the original study maintained teaching portfolios that documented their accomplishments during the semester. Portfolios during the treatment years of the current study were recommended by not required. This change was made help alleviate the many demands for their time.

Results

To assess the effectiveness of GTA training and the influence of GTA experience, course grades in college algebra were used as the dependent variable in this analysis. Students who finished the course were assigned grades of A, B, C, D, or F by their instructors. For the purpose

of analysis, these grades were assigned numeric values (e.g., an "A" was assigned a value of 4; a "B" was assigned a value of 3, etc.). Students who withdrew from the course were assigned a grade of W. Of the 6675 participants, 4826 (73.4%) completed college algebra and 1849 (26.6%) withdrew from the course.

Table 1: Percentage of students who received each grade in the course broken down by semester.

AY	Semester	A	B	C	D	F	W
06	SP	30.4%	15.6%	8.0%	8.0%	6.3%	31.6%
	WF	21.5%	21.5%	16.8%	4.4%	7.7%	27.9%
07	SP	29.6%	21.3%	19.2%	4.5%	3.8%	21.6%
	WF	24.7%	18.8%	15.3%	9.0%	5.9%	26.4%
08	SP	40.2%	14.5%	14.1%	3.9%	4.3%	23.0%
	WF	24.2%	23.9%	13.8%	8.0%	3.1%	27.0%
09	SP	25.0%	17.3%	16.5%	5.0%	6.9%	29.2%
	WF	24.2%	15.9%	13.6%	5.5%	7.1%	33.8%
10	SP	19.9%	18.8%	10.8%	8.3%	7.2%	35.0%
	WF	18.8%	19.6%	19.0%	9.7%	6.3%	26.7%
11	SP	22.1%	17.2%	13.1%	4.5%	7.4%	35.7%
	WF	25.4%	20.6%	9.8%	6.0%	5.8%	32.4%
12	SP	23.5%	20.5%	14.0%	9.2%	5.1%	27.6%
	WF	46.8%	16.4%	8.8%	3.2%	4.5%	20.3%
13	SP	47.1%	15.8%	12.9%	4.0%	3.7%	16.5%
	WF	30.8%	17.8%	14.9%	5.5%	6.3%	24.6%
14	SP	25.3%	16.6%	18.4%	3.7%	8.8%	27.2%
	WF	24.1%	22.2%	13.8%	6.8%	4.6%	28.6%
15	SP	18.5%	19.8%	11.3%	7.2%	7.7%	35.6%
	WF	32.8%	25.5%	12.1%	6.6%	5.3%	17.7%
16	SP	15.2%	20.6%	15.5%	8.3%	8.3%	32.1%
	WF	34.6%	22.6%	12.1%	4.2%	6.8%	19.7%
17	SP	31.3%	18.8%	11.6%	5.8%	6.7%	25.9%
	WF	34.2%	22.7%	12.3%	5.1%	6.4%	19.3%

Examination of Grades of Students Who Completed the Course

Of the 6675 participants, 4826 (73.4%) completed college algebra with an average grade of 2.73 (approximately C+). The course grade data for students who finished the course were entered into an analysis of covariance with Math ACT scores as the covariate. Covariates are influential variables that affect the dependent variable but do not interact with any of the other factors being tested at the time. Therefore, since prior mathematics knowledge was present during the study, using Math ACT scores as a covariate in the analysis allowed for control of its influence.

The results of the analysis of covariance revealed that there were no main effects or interactions involving Year of Teaching. The only main effect was that of Math ACT, $F(1,4826)$

= 166.72, $p < .0001$. The results of this analysis indicated that students' math abilities (MACT) explained the variability in course grades rather than the GTAs' experience.

Examination of Withdrawals Only

Of the 6675 participants in the current study, 1849 (26.6%) withdrew from college algebra. In the original study, of the 2,198 participants, 670 (30.5%) withdrew from college algebra and for those who withdrew, 60.5% withdrew from classes taught by GTAs who were not trained and 39.6% withdrew from classes taught by GTAs who were trained. Upon examination of the frequency of withdraws by year of teaching, there were slightly fewer withdraws (48.2%) from classes taught by GTAs who had two years of teaching experience than had one year of teaching experience (51.8%). This result is in contrast to the finding from the original study where the results indicated that GTAs who had been trained and were in their second year of teaching had significantly fewer withdraws from their courses.

Discussion

A noteworthy finding is the fact that success in lowering the drop rate in the treatment group held true for 15 years. Of the 6675 participants in the current study, 1849 (26.6%) withdrew from college algebra. In the original study, of the 2198 participants, 670 (30.5%) withdrew from college algebra.

Furthermore, the results of this analysis indicated that students' math abilities (MACT) explained the variability in course grades rather than the GTAs' experience. This result corroborates with the findings in the original study.

Upon examination of the frequency of withdraws by year of teaching, there were only slightly fewer withdraws (48.2%) from classes taught by GTAs who had two years of teaching experience than had one year of teaching experience (51.8%). This result is in contrast to the finding from the original study where the results indicated that GTAs who had been trained and were in their second year of teaching had significantly fewer withdraws from their courses. A possible reason for this difference is the new treatments within the GTA professional development program. The result that the withdrawal rates are no longer significantly different based on the number of years the GTA has been teaching provides evidence that the new treatments may be helping to reduce the withdrawal rates starting in their first year of teaching.

Finally, the pass rates (receiving an A, B, or C in the course) for the students since the change in the professional development program for the GTAs are 58.7% on average. This average pass rate is higher than that of the national average for college algebra, which is 50% (Saxe & Braddy, 2015). So, there is some evidence that shows the students in these college algebra courses with GTAs who have had additional support may be doing better in the course than the national average.

With the increase in professional development programs for graduate teaching assistants across the nation, large data sets are needed to gain an understanding of the impact the support may have on student success. This study provides evidence of the impact a professional development program can have on student pass rates in college algebra and adds to the literature base on the efficacy of professional development programs.

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