

EXAMINING OBSTACLES TO MATHEMATICS GRADUATE STUDENTS' DEVELOPMENT AS TEACHERS

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As the field of professional development for mathematics graduate students evolves, there is a need for research studies that examine how mathematics graduate students develop as teachers. This study aims to fill this gap in the research by studying mathematics graduate students' experiences with teaching as they progress through their graduate programs. Mathematics graduate students were recruited from a large university mathematics department. They were responded to surveys and were interviewed semi-annually for two or more years. We analyzed their responses using thematic analysis and a framework that captured their development as teachers. In this report, we describe a framework for teachers' development and context and methods of the study. We present findings on how the framework elucidated mathematics graduate students' development as teachers and illustrate obstacles to their development.

Keywords: Professional Development; Post-Secondary Education; Affect, Emotions, Beliefs, Attitudes; Instructional Activities and Practices

As is common in most graduate programs in the sciences in the United States, mathematics graduate students (MGSs) receive funding to support the time they spend in their master's or doctoral programs. In exchange for this funding, they spend between 12 to 16 hours each week working for mathematics departments as instructors or teaching assistants. In some graduate programs, MGSs have the opportunity to teach their own courses for the duration of their graduate programs. In other programs, MGSs do not teach their own courses but instead have the opportunity to lead recitations or workshops that support larger lecture sections which are taught by faculty members. During a two-year master's degree program, mathematics graduate students might have the opportunity to teach as many as seven classes or lead as many as 24 recitations, and in a six-year doctoral program 15 classes or 60 recitations. This means that during their graduate programs, MGSs contribute to the learning experiences of hundreds, if not thousands, of undergraduate students. Their contribution to undergraduate students' learning experiences extends past their graduate programs, with more than 60 percent of new mathematics PhDs finding employment in post-secondary education settings in which teaching makes up a significant portion of their work (Golbeck, Barr, & Rose, 2016). Thus, in their roles as graduate students and later as faculty members in mathematics departments, MGSs exert a significant impact on undergraduate learners' trajectories in STEM fields (Belnap & Allred, 2009; Ellis, 2014).

Despite their contact with and impact on undergraduate students, MGSs receive very little preparation for teaching (Deshler, Hauk, & Speer, 2015; Ellis, 2014). Experts in MGS professional development have not yet reached consensus on the breadth and depth of PD programs that prepare MGSs to teach. Programs vary from a few hours, to an intensive week, to a seminar that spans a full academic year. Few programs extend beyond MGSs' first year in graduate school (Deshler et al., 2015; Ellis, 2014; Harris, Froman, & Surles, 2009; Kung & Speer, 2009; McGivney-Burrelle, DeFranco, Vinsonhaler, & Santucci, 2001). Several

researchers who aimed to change MGSs' teaching practices over an academic semester or year discovered that their professional development (PD) programs did not improve the MGSs' practices (Belnap, 2005; DeFranco & McGivney-Burrelle, 2001; Speer, 2001). Preparation for a broad scope of evidence-based teaching practices (e.g., inquiry-based learning, active learning, equitable instruction) is crucial as most MGSs' teaching practices remain rooted in lecturing, with lecture-based mathematics courses causing significant problems for undergraduate students (Deshler et al., 2015; Miller et al., 2018; Stains et al., 2018).

Prior to developing and implementing a two- to three-year PD program for MGSs, our research team sought to understand how MGSs think about teaching, what they learn about teaching, and what type of PD might be relevant at different stages of MGSs' development. We had in mind the question – how might MGSs' needs for professional development be different in their second year of teaching compared with their fourth year of teaching? Looking to the literature, we observed that little is known about MGSs' development as teachers. In an attempt to characterize the types of research conducted regarding MGSs' growth as teachers, Miller and colleagues (2018) completed a review of the literature of professional development for MGSs. The review identified 26 peer-reviewed articles since 2005 that investigated MGSs' teaching development, only 17 of which attended to growth. Thus, the authors concluded that “[mathematics teaching assistants’] growth as teachers is a largely unexamined practice” (Miller et al., 2018, p. 2) and suggested that this area of study would benefit from longitudinal studies that make explicit a model of growth.

With this in mind, the purpose of the study described in this proposal is to investigate MGSs' development as teachers, what and how they learn about teaching, and changes in their thinking about teaching and learning longitudinally as they progress through their degree programs. The research questions that guide this study are: (1) How does an existing framework of teacher development elucidate mathematics graduate students' growth as teachers? (2) What kind of experiences do MGSs have with teaching and what impact(s) do those experiences have? (3) What features of their graduate school and teaching experiences support or hinder their learning about teaching and their development as teachers?

Theoretical Framework

Because research has not yet addressed MGSs growth as teachers, we looked to the K-12 literature, where researchers have studied schoolteachers' experiences in order to gain an understanding of teachers' growth over time. Katz (1972) described four developmental stages, which include: (1) *survival* of the first year of teaching, with particular focus on classroom management and the routines of classrooms and schools; (2) *consolidation*, in which teachers begin to understand which skills they have mastered, and what tasks they still need to master; (3) a period of *renewal*, when teachers become tired of their routines and start to think of how things might happen differently; and (4) reaching *maturity*, where teachers think more broadly about the contexts of schools and students' learning (p. 52-53). We aimed to use this lens to see whether and how MGSs might progress from thinking of teaching as lecturing (survival and consolidation) to thinking about incorporating active learning into their practice (renewal and maturity).

Context and Methods of the Study

At the beginning of the academic years in 2015-2018, participants were recruited from the mathematics department at a large, doctorate-granting institution. Approximately 5,000

undergraduate students enroll in courses such as Pre-calculus, Differential, Integral or Vector Calculus, Business Calculus, or Differential Equations each year. Most of these courses are structured as three hours of lecture with 150-250 students per class and are taught by an instructor. MGSs are generally assigned to run recitations (60-80 minute workshops each week) of smaller groups of students from the large lecture sections. MGSs are not assigned to courses based on knowledge, skill, or experience; their assignments to courses mostly depend upon scheduling.

When new MGSs first arrive to this graduate program in mathematics, they receive two to three days of professional development for their teaching assignment, with a focus on how to support active learning and student engagement in mathematics during recitations. In the first term of their graduate program, they attend a seminar for one hour each week that addresses teaching-related concerns such as grading papers, student conduct issues, and lesson planning. In the summer after their first year, they have the opportunity to teach their own course, then they return to the main MGS duty of leading recitations. Only informal mentoring happens before and during the summer sessions and into the MGSs' subsequent years.

We developed two beginning-of-the-academic-year surveys, one for new and one for experienced MGSs, and protocols for mid-year and end-of-year interviews. Surveys are used at the beginning of the year because of logistical issues. They include open-ended questions that inquire about MGSs' thoughts about teaching and learning mathematics, how they would describe a well-taught mathematics lesson, and what influenced the way they think about teaching. Mid- and end-of-year interviews allow a deeper investigation of MGSs' teaching practices, their most recent teaching experiences, whether they feel that they are receiving adequate support, and what other support they feel they need to grow as teachers. The intention of the study is to survey and interview participants for the duration of their graduate programs to study their development over time. Table 1 illustrates participation in the study.

Table 1: Study Participants

Recruitment Year	Number of Participants
2015-2016	11 new participants: 4 first year, 2 second year, 4 third year, 1 fourth year
2016-2017	11 continuing participants; 6 new participants: 4 first year, 1 third year, 1 fourth year
2017-2018	11 continuing participants; 10 new participants: 8 first year, 1 third year, 1 fifth year
2018-2019	14 continuing participants; No new participants

Our research team analyzed participants' responses to survey and interview questions in two rounds of coding using thematic analysis (Braun & Clarke, 2006). Thematic analysis has six stages which include: (1) familiarization with the data; (2) coding interesting features of the data in a systematic way and collating data that is appropriate for each code; (3) possibly combining codes into themes and collect data for each them; (4) reviewing the themes and supporting data for each theme; (5) continuing to analyze the themes, generating a clear definition for each; and (6) producing the report of the themes with selected data to provide evidence of each theme. In the first round of coding, we applied a deductive approach (e.g., using a pre-existing coding frame) where we looked for instances of the participants' experiences that could be elucidated

with Katz's (1972) four-stage model of teacher development. In the second round of coding, we used an inductive approach that focused on codes we developed through the first round of analysis, when we observed issues that either provided explanation for the stages or weren't captured by Katz's framework. These codes included what had an *impact on their views about teaching* (graduate course work, their students, the instructor they are assigned to, the course they are assigned to, their previous experiences as learners, office hours, their MGS peers, and the resources they use for teaching), *issues of identity* (being a teaching assistant versus being an instructor, resignation), and *teaching* (descriptions of their teaching practices, the transitions they have made in their teaching, what changes they would make to their teaching, and what is important for their teaching).

Findings

Using Katz's Framework to Elucidate MGSs' Development as Teachers

We have found Katz's (1972) framework to be a useful lens to view MGSs' development as teachers. First-year MGSs struggled to survive as they adjusted to their roles as teachers. In the quote below, a first-year MGS described his initial experience teaching:

By that point the quarter [midterms], it was just getting really hectic and I wasn't able to plan as much as I usually like to plan for courses. Sometimes I was looking at the material for about two hours before I started that day whereas usually I like to look at it the day before or during the weekend or something. And so sometimes, though, the classes that I went to where I was kind of doing it on the fly, where I was literally looking at it like an hour or two before class. A lot of times it's just more like get the notes done, go in, and do it.

We discovered that after they gained some experience teaching, MGSs could reflect on their teaching and think about how their teaching might evolve:

I think previously, I was more focusing on, "I just want to survive my first teaching experiences." So, now that this is my fourth time [leading a recitation], I feel a little bit more comfortable trying to incorporate more active learning in my classroom, and trying non-traditional techniques whereas previously, when I taught, for example, my first time teaching my own class and I taught Calculus, I did mostly lecture because I just wanted to do what I felt most comfortable with – what I felt I could be successful at.

We found that a few MGSs reached the *renewal* stage after a couple of years of leading recitations and were ready to grow their teaching practices:

Because I've already gone through three years now teaching. So I'm already comfortable with coming up to class and writing things down and grading things in a reasonable enough fashion and in good time. But, yeah, it would be really great to be able to like just take it another step further.

A participant in their third year of the graduate program acknowledged that they could now better understand what active learning meant: "maybe even if I heard the same thing, it would carry more weight now. It might be good to hear [about active learning] in the context of now having three years' experience. I would have a better understanding for the context it would fit in." We observed that a small number MGSs began to think about incorporating active learning strategies in their third and fourth years of teaching.

Out of 38 study participants, we observed that only a few reached the *renewal* stage, and only

one or two of the MGSs spoke of teaching in ways that Katz (1972) would categorize as *maturity* even in their sixth year of teaching. Most MGSs appeared to be stuck in the *consolidation* stage and their descriptions of teaching were remarkably unchanged year after year. We have also found that MGSs do not pass through Katz's (1972) developmental stages linearly. In fact, they sometimes returned to the *survival* stage if their new teaching assignment varied significantly from their prior teaching assignments. Based on these findings, we investigated further what was having a significant impact on the study participants development as teachers.

Always a Teaching Assistant, Never a Teacher

The role of teaching assistant stood out as significantly problematic for the research participants. Some of the participants felt that being an instructor and a teaching assistant were very different things, with a second-year MGS stating, "Because [working as a teaching assistant] is totally different than teaching. And I didn't realize that until I got in there." She did not think her work as a teaching assistant (helping individuals or groups of students during class time) did not count as teaching:

I guess I don't feel like I've taught yet. Right now in [instructor's] class where I just walk around and answer individual questions. And so I don't really feel like I've taught yet but I have ideas for what I'd want in my own classroom. But as a teaching assistant, like you can't tell them no cell phones. Really it's up to the instructor. And so it kinda sucks when you get super frustrated that all these students are on their cell phones and you can't do anything about it. Or you wanna be able to say, you have a week to turn in late work instead of everyone handing you stuff in the final week of classes and you have to take it because that's the instructor's policy. So, stuff like that I don't really have control over.

Several of the MGSs expressed dissatisfaction at the amount of communication they had with the instructors of the courses they were assigned to. One participant said: "I just had like zero interaction with the instructor. So, it just would have been nice to be on the same page about things that the students were learning and things that he wanted, that kind of thing." This lack of communication led to feelings of uncertainty about what mathematics they should offer students:

I mean I'm often happy to or at least, you know, I've always taken the approach that if the instructor wants something done I'll just do it their way. Which can sometimes be hard. I guess with you know with giving concepts I go back and forth on you know if you're teaching a concept should you teach it the same way the teacher does to reinforce thinking about it a certain way. Or should you teach it in the way that you think about it so a student can see these two different ideas and maybe they'll pick up one instead of the other. And I think I have a tendency to follow the instructor if I know what they're doing and not if, well if I don't know what they're doing then it's a tossup.

Others experienced a sense of ineffectiveness in the role of teaching assistant, with little input into or control over the class:

But I have no power over what happens in the recitation hour. There is a quiz that was written up, there's an activity that was written up. That's nice, because I appreciate the standardization, and I know that the people who were making these things care a lot, or think a lot about it. So I'm not grumpy about that, necessarily. It's the instructor's course. That's fine. But it means I'm not choosing any of the problems, or anything like that. So what can I do?

Some MGSs' experienced some detachment, disinterest, and frustration in what happened in the role of teaching assistant:

But I haven't, you know it's not my problem I didn't put it together. I didn't it just. Yeah. I don't know I'm just less invested and then it's coupled with the material just being very difficult and the students struggling. It's hard to, it can be a lot to overcome. You know just when you just have a very small window.

The perceived lack of contribution to students' learning led some MGSs' to feel as though it didn't matter who they were:

For the impact on their learning, I think I'm interchangeable with all the other graduate students. Every once in a while, there'll be a problem that everyone's asking questions on, and I'll be like, "Okay, let's review something that you all might enjoy having a small review of." And that's fine, but they could get that in the tutoring center. They could get that from going to anybody's office hour.

One MGS expressed the pain that resulted in being a teaching assistant and feeling forced to work with students in ways she didn't agree with: "When I am forced to overwhelm my students or otherwise have no freedom in teaching and consequently get cruel reviews... I take things personally... negative feedback is painful."

A MGS in the fourth year of his graduate program had started to see the value in teaching mathematics in ways that he felt most comfortable with, and that he might even become assertive in his thinking about the recitations he would lead:

Things that I learned? Probably just re-emphasizing that I should probably be a little bit more assertive about how I think the class should go. Because to some extent, now that I think about it, it probably depends on me as a leader for that recitation. Rather than just you know the instructor wants it done a certain way. If there's a way that I'm comfortable doing it probably works better than what someone else would do.

Discussion and Conclusion

Given the obstacle that the role of teaching assistant played in MGSs' development as teachers, we propose that mathematics departments reconsider how the role is portrayed to MGSs and instructors. Specifically, we recommend that departments fully define the role and make explicit how teaching assistants are valued and how they contribute to students' learning. We also recommend that instructors are offered their own professional development in what and how they communicate with their teaching assistants (e.g., valuing their contributions, providing space for MGSs to contribute to the course, helping MGSs to learn about teaching). Finally, we recommend that professional developers keep in mind the obstacles to MGSs' growth as teachers that we have described in this paper. In particular, professional development programs that aim to teach MGSs about teaching should inform and empower MGSs in their roles as teachers.

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