INVESTIGATING MATHEMATICS GRADUATE STUDENTS' GROWTH AS TEACHERS: THE UNIQUE CASE OF EMMA

Mary Beisiegel
Oregon State University
mary.beisiegel@oregonstate.edu

Claire Gibbons
Pierce College
cgibbons@pierce.ctc.edu

Alexis Rist
Oregon State University
delonga@oregonstate.edu

The need for research-based professional development programs for mathematics graduate students is significant, yet few studies have investigated their development 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. Participants 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 the developmental stages for teaching and context and methods of the study. We present general findings on the experiences that mathematics graduate students did not move past a certain developmental stage and we present specific findings about one mathematics graduate student who experienced significant growth in her teaching.

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

At graduate institutions in the United States, mathematics graduate students often receive funding from mathematics departments to support their time working on master's or doctoral degrees. In return, they teach courses as instructors or they work as teaching assistants, supporting faculty instructors of large lecture courses by leading weekly, small-group recitations. Over the course of their graduate programs, mathematics graduate students contribute to the learning experiences of hundreds of undergraduate students. Their contribution to undergraduate students' learning experiences extends beyond 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, mathematics graduate students exert a significant impact on undergraduate learners' trajectories in STEM fields (Belnap & Allred, 2009; Ellis, 2014).

Despite the amount time they interact with undergraduate learners, mathematics graduate students receive little professional development (PD) for their teaching (Deshler, Hauk, & Speer, 2015; Miller et al., 2018). The PD they do receive varies greatly across institutions – programs range from a few hours, to an intensive week of PD, to a seminar that spans a full academic year (Deshler et al., 2015). The field of mathematics graduate student PD is relatively new and experts in the field have not reached consensus on the depth and breadth of PD programs that prepare mathematics graduate students to teach. This lack of consensus might be due to the fact that mathematics graduate students' growth "is a largely unexamined practice" (Miller et al., 2018, p. 2). Miller and colleagues (2018) suggest that this field of study would benefit from longitudinal studies of mathematics graduate students' growth as teachers.

Our primary long-term goal is to develop an extended PD program for mathematics graduate students. Prior to developing and implementing such a program, our research team sought to understand how mathematics graduate students think about teaching, what they learn about teaching, and what type of PD might be relevant at different stages of their development. We

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wondered – how do mathematics graduate students develop as teachers? What are salient, transformative experiences and what are experiences that might hinder mathematics graduate students' growth as teachers? In this report, we describe a longitudinal study of mathematics graduate students growth. We focus on one specific participant who illustrated significant growth in her teaching.

Theoretical Framework

Because research has not yet addressed MGTAs growth as teachers (Miller et al., 2018), we looked to the K-12 literature, where researchers have studied schoolteachers' experiences in order to gain an understanding of their 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). Based on the literature, we posit that mathematics graduate students' teaching practices in the survival and consolidation stages will be lecture-based, and in the renewal and maturity stages, more focused on teaching practices that support student engagement in mathematical work during class time (e.g., active learning, inquiry).

Context and Methods of the Study

Our study takes place in a mathematics department in which mathematics graduate students receive two to three days of professional development when they first arrive, as well as a year-long, introduction-to-graduate-studies-in-mathematics seminar part of which is focused on teaching. Mathematics graduate students are most often assigned to teach recitations for large lecture courses, but they also have the opportunity to teach their own courses. Sometimes they work as a grader for upper-division or graduate courses. Mathematics graduate students were recruited for the study in 2015, 2016, and 2017. They are asked to complete a beginning-of-the-year survey, a mid-year interview, and an end-of-year interview. Three mathematics graduate students have participated in the study for its duration (currently in its fourth year), five have participated for three years, and other mathematics graduate students in their second year of participation in the study. We are using the six steps of thematic analysis (Braun & Clarke, 2006) as a method for analyzing surveys and transcripts of interviews.

Findings

We have found Katz's framework (1972) to be a useful lens to study mathematics graduate students' growth. We have observed that mathematics graduate students do not pass through Katz's (1972) developmental stages linearly. They sometimes returned to the *survival* stage if a new teaching assignment varied significantly from their prior teaching assignments. Most mathematics graduate students appeared to be stuck in the *consolidation* stage and their descriptions of teaching were remarkably unchanged year after year. In addition, out of the nine mathematics graduate students who have participated in the study for three or more years, only two of the participants spoke of teaching in ways that Katz (1972) would categorize as *maturity* – and none so profoundly as one participant, Emma (pseudonym).

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Focusing on Emma's Growth as a Teacher

Emma began participating in the study in 2015 as a second year graduate student. Emma has had several different teaching assignments over the years of the study. She has worked as a teaching assistant in both in-person and on-line courses, as a grader for graduate courses, and as an instructor for a course. These positions were determined by the department based on Emma's schedule. Early in the study, Emma expressed her belief that a goal of teaching mathematics is to impart knowledge – not only mathematical knowledge but also "the knowledge of how to gain more knowledge, how to be a student, how to be a mathematician, how to think like a mathematician." Whether and how she felt she had an impact on students (in their learning and what they thought about mathematics) was very important to Emma. Her role as a teaching assistant made her feel that she had very little impact on students.

Difficulties of Being a Teaching Assistant Instead of Instructor (Survival, Consolidation)

Like many participants in the study, Emma found the role of teaching assistant to be "less than ideal" because she did not have control over the classroom dynamic or over the work the students were assigned. This feeling continued into the third year of the study, where Emma described the instructor of the course as the decision-maker who has the biggest impact on student learning. Emma explained that the instructor chooses the content for recitation, which meant that she had "No power over what happens in the recitation hour" which made her feel ineffective: "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?" Because she saw the instructor as having total control over both the lecture and her own work with students, Emma felt like she had "such little power to actually impact [students'] learning."

Eventually, her role as teaching assistant began to have a negative impact on how she saw herself and what she felt she could contribute to students' learning:

> 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 from going to anybody's office hour.

Teaching Her Own Course for The First Time (Consolidation With Hints of Renewal)

When Emma had the opportunity to teach her own course, she very much wanted to have an impact on students and aimed to do so through detailed, planned lectures. She spoke in detail about how she planned for her lectures:

> So I worked so hard on that class. Oh, my God. It was a full-time job for me. I was preparing lectures, and I supplemented the text in all these ways, and I spent boatloads of time coming up with awesome examples and activities. So I spent all this time and energy into the activities, and I do think that I had a big impact on people's enjoyment of it, and I got personal notes from students saying as much.

Even though Emma emphasized lecturing, we observed evidence that the message of active learning was having an impact on Emma. She described "full on lecture" as "easier" than leading recitations. But she also remarked that she wanted to include both group work and direct instruction. She vocalized some uncertainty of how successful she would be: "Having never done this before, I don't know how effective it's going to be."

In the interview following her first experience teaching her own class, Emma reported using strategies that supported student engagement in mathematical work. She lectured during most

class periods, but had students working on problems three or four times per class. Her goal was to talk for no more than several minutes before letting students work on an example:

> I would introduce a concept, try to put it in the big picture. This was my whole thing, was like, "Okay, fundamental theorem of calculus. Let's put it in the big picture. Why am I even talking about this? 'Why is it called fundamental'? What makes this worth studying?" And then instead of doing example, I would do a simple example on the board, and then I would make them do an example on their own.

Unfortunately, Emma saw students' exam performance as the most important measure of her impact as a teacher and she reflected on her lecturing:

> But my students got the exact same average on the midterm as every other instructor who was teaching this course over the summer. That made me think, "Maybe I'm not having as big an impact as I thought." […] I would like it to be, "I just nailed all of my lectures," and I want that to have a measurable impact on student performance. I think [lecturing] doesn't have as big an impact as I used to think it did.

In a later interview, Emma remarked: "I have started to see the in-class lecture as a colossal waste of time, and not as big an impact."

Emma's Move Away from Lecturing (Renewal, Maturity)

Recently, we observed Emma reach the renewal and maturity stages through a unique experience in which she had the opportunity to design and teach a course. With some advice from the department, she chose the curriculum, lesson formats, and assignments. She incorporated many things that were important to her about mathematics, including a focus on deep mathematical reasoning (e.g., *Why* would a mathematician think about a problem in a particular way?). She made the choice to not lecture and instead had students engage in mathematical activities. When asked about her transition from lecturing to active learning and whether it was difficult, Emma admitted her love of "performing" and stated, "I like being center of attention and look like I know everything." Reflecting on her choice to not lecture, Emma said, "It bums me out because I like lecturing. I think I'm good at it. But now, I'm convinced that people don't learn by lecturing." She later said, "So I did feel a sense of loss at first. And then by the end of that class, it totally changed me. I maybe got more out of the class than the students did because I got to the end of that class and I said, 'I am never ever lecturing again, ever.'"

Conclusion

What can we learn from Emma's experiences and her growth as a teacher? What prompted Emma to make the changes to her teaching practices? Emma noted that some events in the mathematics department influenced her. For example, the department that had selected a few courses to be more focused on active learning and Emma had exposure to an active learning classroom in her first year as a graduate student, a visiting colloquium speaker provided examples of active learning and some of her peers were incorporating active learning into their classes. However, we acknowledge that not all mathematics graduate students will have the same exposure to active learning and opportunities to grow in their teaching practices. Thus, we see as Emma's desire to feel that she had an impact on students and how she reflected on her own learning experiences for more guidance critical to her growth as a teacher. We suggest that PD programs be designed such that mathematics graduate students understand the contributions they make to students' learning. We also propose that PD programs include a reflective component

that prompts mathematics graduate students to consider their most meaningful learning experiences. Our study will continue and it remains to be seen whether Emma will continue to develop as a teacher after this unique experience. What might happen to her views about active learning should she be assigned to an instructor who wants her to lecture mathematics to students and/or if she feels that her role does not allow her to contribute to student learning?

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