Mathematics Graduate Teaching Assistants' Development as Teachers: Complexity Science as a Lens for Identifying Change

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Mathematics Graduate Teaching Assistants (MGTAs) are both current and future teachers of college mathematics, but there is limited research investigating their growth as teachers. To create better professional development for training MGTAs, we first need to understand how they learn to teach. This study aims to identify why MGTAs change their teaching practices and what factors influence their development as teachers. Survey, group interview, and individual interview data from seven MGTAs at a doctoral-granting university were analyzed deductively using complexity science as a framework.

Keywords: Graduate Teaching Assistants, Professional Development, Teaching Practices

Background

Improving instruction in undergraduate mathematics courses has been a rising priority for mathematics education researchers and professional mathematics organizations. Research repeatedly shows that lecture-based teaching contributes to students leaving STEM fields (PCAST, 2012; Saxe & Braddy, 2015; Seymour & Hewitt, 1997), while active learning is linked to improved student performance (Freeman et al., 2014). In an effort to increase retention in STEM and better support student learning, college mathematics teachers are being urged by the mathematics community to incorporate active learning into their instruction. As a notable example, the Conference Board of the Mathematical Sciences released a statement in 2016 advising the adoption of active learning practices:

> We call on institutions of higher education, mathematics departments and the mathematics faculty, public policy-makers, and funding agencies to invest time and resources to ensure that effective active learning is incorporated into post-secondary mathematics classrooms. (p. 1)

In an effort to support this change in instruction, mathematics educators and education researchers have looked to Mathematics Graduate Teaching Assistants (MGTAs). MGTAs are both current and future teachers of mathematics. During their time as graduate students, MGTAs have a significant role in the teaching and learning of mathematics for undergraduate students through their work as instructors, discussion and laboratory leaders, tutors, and graders (Belnap & Allred, 2009; DeFranco & McGivney-Burelle, 2001; Ellis, 2014). After completing their graduate programs, MGTAs continue to impact undergraduate learners: in 2016, over 60 percent of new Mathematics PhDs hires were employed in academic positions (Golbeck, Barr, & Rose, 2016). Thus, MGTAs development as teachers impacts how mathematics is and will be taught.

Most graduate programs in mathematics offer some form of professional development for MGTAs (Deshler, Hauk, & Speer, 2015; Speer, Murphy, & Gutmann, 2009). There is wide variation in the duration and setting of these programs (Belnap & Allred, 2009), and most take place exclusively during a student's first year as a MGTA (Deshler et al., 2015). To develop and assess teaching training for MGTAs, mathematics education researchers have drawn from the literature base in K-12 professional development. Although researchers have been able to document a change in beliefs about teaching and learning from participating in professional

development, this alone has not been sufficient for a change in MGTAs' instruction (Belnap, 2005; Defranco & McGivney-Burelle, 2001; Speer, 2001).

Previous studies have identified multiple factors influencing MGTAs' decisions about teaching, including previous classroom experiences as a student (Deshler et al., 2015), perception of faculty attitudes about teaching (Harris, Froman, & Surles, 2009), social context of the department (DeFranco & McGivney-Burrelle, 2001), and types of teaching required (Beisiegel & Simmt, 2012). However, it is still unclear how to impart lasting changes in MGTAs teaching practices, and there is currently no consensus in the research community for how MGTAs learn to teach. In particular, a recent literature review revealed that MGTAs' "growth as teachers is a largely unexamined practice" (Miller et al., 2018, p. 2). That is, there is little research attending to MGTAs development of teaching practices over time (Beisiegel, 2017; Miller et al., 2018). If we want to provide professional development that has a lasting impact on MGTAs' teaching, we first need to understand why MGTAs teach the way they do. Thus, this study is guided by the following research questions:

1. What do MGTAs cite as reasons for changing their teaching practices?
2. What factors influence MGTAs development as teachers?

For the purposes of this research, *teaching practice* refers to the definition explicated by Speer, Smith, and Horvath (2010). That is, teaching practices are the "instructional judgments, decisions, and actions employed by instructors inside and outside the classroom" (Miller et al., 2018, p. 3).

Theoretical Framework

Complexity science has been used in previous studies of teacher learning when considering both mathematics classrooms and professional development for mathematics teachers. For example, Davis and Simmt (2003) conducted a teaching experiment in a seventh-grade classroom, viewing the class as a complex system in an attempt to foster a mathematics learning community. The authors later used complexity science as a lens for investigating the mathematical knowledge for teaching (MKT) of a group of K-12 teachers attending monthly professional development sessions (Davis & Simmt, 2006). Both studies viewed a group of learners as a complex system.

Similarly, MGTAs can be viewed as a complex system. A complex system is both self-organizing and adaptive. *Self-organizing* means that the group establishes norms and expectations without a specific plan or single leader. *Adaptive* indicates that the group is not rigid and can change over time (Davis & Sumara, 2001). To put these characteristics in context, consider the structure of a MGTA's work as a teacher and graduate student. MGTAs are situated within an academic department, which is also part of the larger university. Each MGTA likely has multiple supervisors, such as a research advisor and the department chair, and they may also look to a graduate coordinator or a teaching committee advisor as a point of authority. Without a central leader or specific instructions about how to be a teacher, MGTAs *self-organize* and develop an understanding of "how things are done around here." Also, as MGTAs continue their graduate programs, they learn and thus *adapt*.

Complexity science places a focus on "collective learners rather than collections of learners" (Davis & Simmt, 2006, p. 309). In the context of MGTAs, this notion implies that a MGTA's teaching development influences, and is influenced by, the growth of their MGTA peers. Previous research indicates that a change in beliefs is not sufficient for an individual MGTA to change their teaching practices. A complexity science lens views MGTAs as a group rather than

as individuals and thus offers a means of considering what they need as a collective in order to grow as teachers.

The complexity science framework presented by Davis and Simmt (2003, 2006) includes five necessary but not sufficient conditions for a complex system to learn: a balance of *internal diversity* and *internal redundancy* of beliefs, attitudes, and understandings; *decentralized control* where authority is distributed among members; *enabling constraints* that provide guidelines for behavior but space for exploration and experimentation; and opportunities for *neighbor interactions* where beliefs, attitudes, and understandings can be shared between members.

Methodology

The Mathematics Graduate Teaching Assistants (MGTAs) at a large doctoral-granting university in the United States were recruited to participate in a year-long study. Seven of the MGTAs contacted agreed to participate in the study. The participants' ages range from 22 to 36, while five of the participants are first-year graduate students and two are sixth-year students. One first-year student identifies as female, while the other participants identify as male. The MGTAs have varying trajectories that brought them to graduate school: some participants started the program immediately after completing their undergraduate degrees, while the others taught high school, worked outside of academia, or completed masters degrees before attending graduate school. One participant is an international student, while the others are domestic.

At this university, MGTAs typically serve as the instructor of record. Most classes have 25-35 students, and later-year MGTAs are frequently assigned to teach upper-division courses. Occasionally, a MGTA is assigned a grading position for a graduate course or serves as a teaching assistant for a lecture section of business mathematics. All first-year graduate students are assigned to teach a pre-calculus course during their first term of teaching. During this first 10-week quarter, the MGTAs also attend a weekly teaching seminar. There are limited opportunities for formal discussions of teaching outside of this first-year, first-term seminar.

The data collected for each participant include an entrance survey, three focus group interviews, and two individual interviews. The survey and interview instruments were designed with the intention of capturing the participants' experiences as teachers and learners of mathematics, with an emphasis on how their teaching changes over time. Although the data presented here is from one academic year, the study will repeat at the same university for a second year after another round of recruitment.

Analysis of the surveys and interview transcripts uses a thematic analysis approach (Braun & Clarke, 2006). In the initial stages of analysis, complexity science is being used as a deductive tool for identifying particular themes, namely the five necessary conditions for a complex system. Later analysis will shift to a less-structured, inductive coding approach to capture MGTAs' growth as teachers more broadly. At this stage of the study, preliminary analyses have been conducted to begin exploring how the complexity science framework captures changes in MGTAs' teaching practices.

Preliminary Results

Talking to other graduate students, a *neighbor interaction*, is frequently cited by MGTAs as a resource for making decisions about their teaching practices and for finding support. For example, MGTAs will look to their peers for support in designing assessments for their students: "When we're doing things like writing tests or whatever, I'll just go up to other people and say, 'Hey, can you look at this test and make sure it seems reasonable?' And, you know, I'll do the

same for them and that way I get ideas about what other people are doing and I get other people's ideas on what I'm doing." *Internal redundancy* helps this MGTA find reassurance that they are creating a reasonable assessment, while *internal diversity* allows them to share ideas with their peers.

Additionally, MGTAs talk about teaching as a way to find guidance and support for their teaching choices. In the words of one first-year MGTA, "I was lucky enough to have three officemates, all who have been here at least two years, and so they have experience teaching numerous classes. Anytime something comes up I don't know about, they're just like, do this, do that, and oh I had that happen, don't worry, it'll happen again, it'll be okay." A sixth-year MGTA describes a similar experience: "I do spend a lot of time talking to other graduate students about their teaching experiences. I think that definitely it helps to make sure you're on the same page as your peers." In both of these examples, finding *internal redundancy* among others helps MGTAs to feel more confident in their teaching.

In another case, a MGTA explains the benefits of hearing differing ideas and how it helps inform their decisions about how they want to teach:

> Just like, hearing other people's perspectives on things and how they deal with certain situations. I mean, sometimes it's positive things, like, "Oh, that's great. I should be doing more of that." And also sometimes, even though you might not say it to their face, it's kind of like, "Eh, I don't know. I don't know about that." I think the more you can hear and see, the more you can kind of decide for yourself what you think is right and what you think is wrong. And so that has been really good for my development.

This MGTA is relying on both *neighbor interactions* and the presence of *internal diversity* to hear multiple perspectives and then make their own judgment. Both when the MGTA is skeptical about someone's decision and when they would like to adopt a particular teaching practice, it is the diversity of the ideas from the MGTAs own that make the interaction impactful.

However, not all MGTAs are having conversations about teaching that they feel are productive or helpful to their growth. As one MGTA describes in a Fall term group interview, "It'd be nice if we had more venues for productive discussion about teaching. Cause right now, at least for me, it's mostly sort of Band-Aid kinds of things." They reiterate this again the following term, stating, "Most of the shop talk is just kvetching about students, which is cathartic but not useful." Here, examining these *neighbor interactions* illustrates that not all talking about teaching is impactful for MGTAs teaching practices. It seems that having *internal redundancy* in a conversation may make it seem more cathartic than useful. Instead, MGTAs perceive conversations that rely on *internal diversity* as more productive for their teaching development.

In an individual interview at the end of the year, a first-year MGTA recalls that they had shown up late to one of their graduate courses because they were finishing lecture notes for later that day. The instructor of the course approached them after class and said that while preparing for teaching is important, it was disruptive to come in late. From this, the MGTA felt conflicted about how they were expected to balance their coursework and their teaching duties:

> I have studies, but I also have 30 people who I am responsible for. And you can't have a class of 30 students absolutely learning nothing. What are our priorities here? Am I lecturer, or am I not? I don't understand. If it is a second priority, then tell me that up front, "Hey, if your studies are lacking, then procrastinate on your lecturing." Oh, okay. I will do that, if that is from the top the message. But if we are going to get contradictory messages, I'm going to do what I feel is right. If I'm told you need to study and you need

> to be good at lecture, then I'm going to do what I feel is right. And my obligation to those 30 students takes priority.

In this case, the MGTA was not experiencing *enabling constraints*. The MGTA believed they were doing something wrong by prioritizing preparing for lecture, and they felt restricted in how they should spend their time. However, the MGTA also did not know where to find guidance about how to balance their studies and their teaching, and so this constraint was not enabling to them. It also seems that the *decentralized control* of the system was too present; the MGTA was looking for a message "from the top" to provide directions about how they should manage their time and thus felt the absence of a central leader and explicit instructions.

The sixth-year MGTAs both discuss the amount of freedom they were given when teaching their own classes. As one MGTA explains, "After the first year, like starting the second year, I thought it was almost comical how little direct oversight there is of us. I was just like, I can't believe they give me this much trust to do this. I feel like I'm just let free." The sixth-year MGTAs appreciate the space to make their own decisions about teaching, but they also acknowledge that more involvement would have been valuable for their development: "It's nice that they're kind of hands off. You have some room to kind of explore and have some academic freedom to figure out how you want to do things. But I wouldn't have minded a little more check-in over the years." Having freedom in their teaching is *enabling* for the MGTAs because it offers them space to try different teaching methods and gives them, as one MGTA puts it, "free rein to fail." However, it does not serve as any type of *constraint*, thus leaving the MGTAs wanting more feedback. For example, a MGTA describes their concern that the lack of direction is negatively impacting the quality of teaching in the department:

> I've been observed once. More than once every six years would be nice. I don't mind that they're not observing me, because of course I care and am trying to do a good job. But if I didn't, and wasn't, there'd still be no oversight. And so I don't know. It seems a little irresponsible. It's not hurting me, but I think it's hurting some graduate students.

The MGTA has identified that having their teaching observed would be a helpful *enabling constraint* for them, and they also believe that it would be beneficial for other MGTAs.

Discussion

The five necessary conditions of the complexity science framework were helpful in identifying some areas where MGTAs are missing support for their teaching. Additionally, complexity science highlights how MGTAs are influenced by their peers and the context of the department they work in. However, it seems that there are some factors for change that were observed in the data but are not captured by the framework, such as MGTAs changing how they structure class time based on observations of their class while teaching. This prompts the following questions for discussion:

1. Can the complexity science framework describe changes a MGTA makes to their teaching that are influenced by the individual rather than the collective?
2. How might the results of this study be effective for informing professional development for MGTAs? Are the results applicable in other departments' contexts?
3. What types of professional development are fitting for supporting each of the necessary conditions?

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