

MATHEMATICS TEACHING ASSISTANTS' REFLECTIONS ON  
THEIR FIRST YEAR TEACHING

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A Thesis

Submitted to the Graduate College of Bowling Green  
State University in partial fulfillment of  
the requirements for the degree of

Master of Arts

August 2014

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## ABSTRACT

Kimberly Rogers, Advisor

Mathematics teaching assistants (MTAs) play a critical role in the instruction of undergraduate mathematics students and may go on to become faculty members. Although the literature addressing teaching and learning of mathematics at the K-12 level is extensive, very little is known about MTAs' teaching practices, beliefs, challenges, and understandings of mathematics and teaching. The two major goals of this study were to better understand how MTAs, who were in their first year teaching expressed mathematical knowledge for teaching (MKT) and pedagogical successes and shortcomings in reflecting on their teaching practices. We coded and analyzed the weekly reflections of 21 participants for five distinct MKT categories and twenty-three pedagogical themes across the reflections. This study presents an initial investigation of mathematical knowledge for teaching at the collegiate level, has professional development implications, and suggestions for future research into this topic.

## ACKNOWLEDGMENTS

I wish to thank various people for their contribution to this project. First, I would like to express my deepest gratitude to Dr. Rogers, advisor and chair of my committee, for her expert advice, enthusiastic encouragement, and assistance in keeping my progress on schedule. My special thanks are extended to the other members of my committee, Dr. Meel and Dr. Albert. Last but not least, I would like to thank my spouse, family, and friends for their support during the past two years.

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## THE POSITION OF MATHEMATICS TEACHING ASSISTANTS

In an effort to improve teaching at the university level, mathematics teaching assistants (MTAs) have recently become subjects of investigation. Not only do MTAs play significant roles in the mathematics education of undergraduate students, but they also may go on to become faculty members. Although research has been focused more recently on undergraduate *learning*, it has not yet turned its focus to investigating undergraduate *teaching* (Speer, Gutmann, & Murphy, 2005).

MTAs play a critical role in the instruction of undergraduate mathematics students at many universities. Mathematics departments assign MTAs to a variety of roles: some MTAs have sole responsibility of teaching a course, some hold recitations that accompany large lectures given by faculty members, some work as homework graders, and some provide tutoring services to students (Speer et al., 2005). All the MTAs who participated in this study had a teaching assignment for which they were the sole instructor of a developmental mathematics or statistics course.

Regardless of major, most undergraduate students take at least one foundational mathematics course in college to fulfill a graduation requirement. Lutzer, Rodi, Kirkman, and Maxwell (2007) reported enrollment figures that indicate 21% of mathematics and 17% of statistics undergraduate students at doctoral granting institutions are taught by MTAs. These MTAs, however, often have little opportunity to learn how to teach in ways other than those they have experienced themselves or those modeled by their faculty mentors (Speer et al., 2005). Their pedagogical shortcomings can have profound impacts on learning as educational research has documented that students of inexperienced teachers perform poorly when compared to students of experienced teachers (Rivkin, Hanushek, & Kain, 2005).

In addition to their importance as MTAs, the current pool of graduate students is the source of the mathematics faculty of the future. Tabachnick and Zeichner (1984) discuss the importance of early experiences in solidifying beliefs, developing practices, and setting patterns of social learning for new teachers. Hence, the time spent as MTAs is the time during which graduate students develop teaching practices they likely will carry with them into their careers as faculty members. Therefore, it is important to offer support and professional development for MTAs to help refine their teaching skills and become more effective teachers of mathematics.

The main goal of this study is to provide initial groundwork for beginning to understand MTAs' mathematical knowledge for teaching as well as their pedagogical successes and shortcomings. It is vital to examine MTAs' knowledge for teaching mathematics and determine how to encourage MTAs, both as current teachers and as potential future faculty, to become informed consumers of texts, old syllabi and assessments, as well as shrewd investigators of student thinking and learning.

## MATHEMATICAL KNOWLEDGE FOR TEACHING

In studying teachers' mathematical knowledge for teaching, Ball and colleagues (2008) support the notion that mathematics teachers need a knowledge base that goes beyond that needed by other well-educated adults. They also promote that effective mathematics teachers incorporate both a specialized knowledge of the mathematics subject and pedagogy. Here we define *mathematical knowledge for teaching* (MKT) as “the mathematical knowledge used by teachers in the classroom to produce instruction and student learning” (Hill, Ball, & Schilling, 2008, p. 374). Although there is a large body of research related to K-12 teachers' MKT, little research has been conducted regarding MKT at the collegiate level (Speer et al., 2005).

In trying to answer the question ‘What mathematical understanding and skills are required for a person to teach mathematics?’ Hill et al. (2008) have broken down MKT into two major areas of knowledge: *subject matter knowledge* (SMK) and *pedagogical content knowledge* (PCK) as shown in Figure 1.

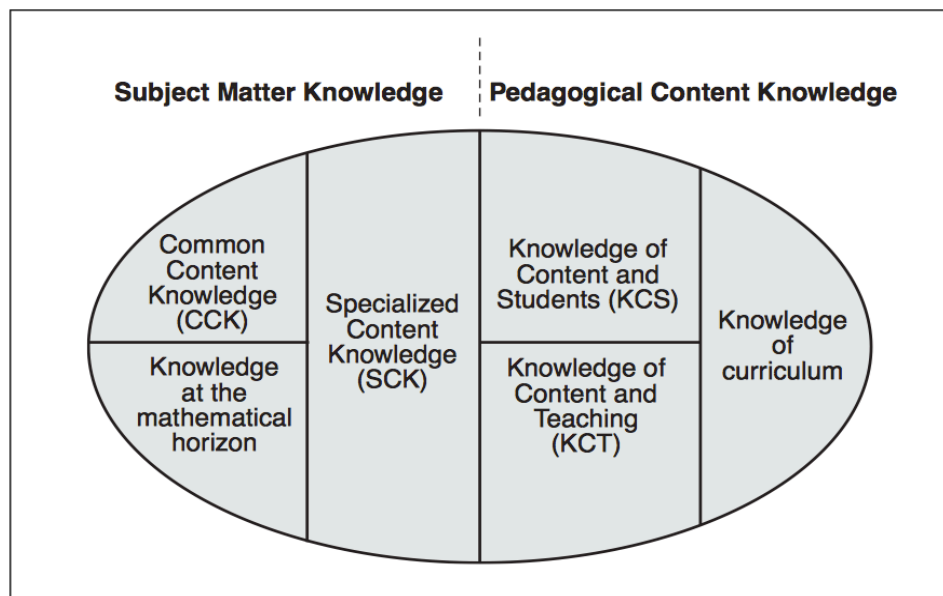


Figure 1. Dimensions of Mathematical Knowledge for Teaching (Hill et al., 2008)

Teachers' SMK focuses on teachers' knowledge of mathematics and their understanding of the discipline. The two main categories under SMK are *common content knowledge* and *specialized content knowledge*. The former is defined as the common knowledge of mathematics that any well-educated adult should have, and the latter is the knowledge of mathematics that is specific to the work of teaching. For this study, we will not distinguish between specialized and common content knowledge since it is not clear what should be regarded as common content knowledge at the collegiate level.

The third category under SMK is *knowledge at the mathematical horizon*, which is the knowledge of how mathematics topics are organized and how they span the curriculum. Since researchers have not been able to fully settle the placement of this category within SMK (Ball et al., 2008), we chose not to include knowledge at the mathematical horizon in this study.

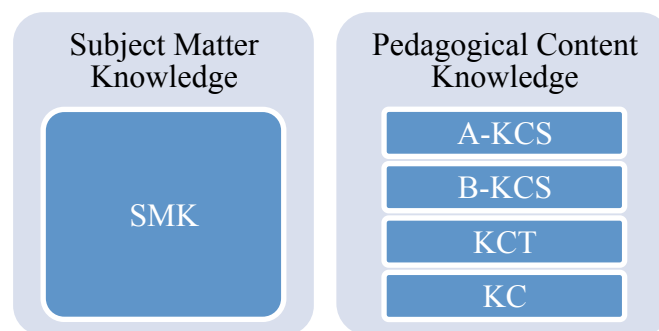
In contrast to SMK, PCK is a hybrid of knowledge of content and knowledge of teaching and learning. It incorporates the knowledge for what and how to teach mathematical content. Under PCK, we will find, for example, the concepts that are especially challenging for students, the problems that are especially helpful, misconceptions students are likely to have, and in which order certain topics are usually presented (Kung & Speer, 2009). PCK is broken into three categories: *knowledge of content and students* (KCS), *knowledge of content and teaching* (KCT), and *knowledge of curriculum* (KC).

KCS focuses on the students within the mathematical context. It represents the intersection of content knowledge and an understanding of student learning (i.e., how students think and learn, and what they may find interesting, easy, or confusing; Ball et al., 2008). For this study, we break KCS into *applying KCS* (A-KCS) and *building KCS* (B-KCS). We define A-KCS as the process of applying knowledge about students and mathematics in anticipating

students' reactions to what is being presented in the classroom. We define B-KCS as the process of building the knowledge that allows one to later anticipate those reactions. Hence, B-KCS is a precursor of A-KCS.

KCT combines pedagogical knowledge (including instructional-decisions like instructional-strategies, sequencing of examples, and appropriate representations) with content knowledge. Finally, KC is knowledge of a “full range of programs designed for the teaching of particular subjects and topics at, a given level, the variety of instructional materials available in relation to those programs, and the set of characteristics that serve as both the indications and contraindications for the use of particular curriculum or program materials in particular circumstances” (Shulman, 1986, p. 10).

The five categories of MKT that we use in this study are summarized in Figure 2.



*Figure 2. Mathematical Knowledge for Teaching Categories for this Study*

## RESEARCH QUESTIONS

### Broad Research Question

In this study, we were interested in learning about the MTAs' MKT by examining weekly reflections they wrote on their teaching experiences.

### More Focused Research Questions

In analyzing the MTAs' reflections, we were interested in answering two questions. First, 'how was the MTAs' MKT expressed in their weekly reflections?' Second, 'how did they reflect on their pedagogical successes and shortcomings?'

## METHOD

## Participants

A total of 21 MTAs participated in this study during the 2013 fall semester. The MTAs came from different backgrounds and areas of study, including pure and applied mathematics and statistics, as shown in Table 1.

Table 1

*MTAs' Background Information*

MTAs	Gender	Nationality	Program of Study	Teaching Experience
101	male	international	Math MS	undergraduate (< 1 year)
102	female	international	Applied Stats MS	none
103	male	domestic	Applied Stats MS	undergraduate
104	male	domestic	Math MS	high school
105	male	international	Math MS	none
106	male	domestic	Math MS	tutoring (3 years)
107	male	international	Math MS	none
108	male	domestic	Math MS	secondary teaching certificate
109	female	domestic	Math MS	high school (< 1 year)
110	male	domestic	Math PhD	undergraduate (3 years)
111	male	domestic	Math MS	tutoring
112	male	domestic	Math MS	tutoring (3 years)
113	male	domestic	Stats PhD	tutoring (2 years)
114	male	international	Math PhD	undergraduate (3 years)
115	male	domestic	Math MS	tutoring (1.5 years)
116	female	international	Applied Stats MS	tutoring (< 1 year)
117	female	domestic	Applied Stats MS	tutoring
118	male	domestic	Math MS	tutoring
119	male	domestic	Stats PhD	tutoring
120	female	international	Applied Stats MS	high school (2 years)
121	male	domestic	Math MS	secondary teaching certificate

*Note.* Teaching experience summarized from MTAs' self-reported, open-ended responses. The summary categories are *none*, *tutoring*, *secondary teaching certificate*, *high school*, and *undergraduate* teaching experience. We report the highest level of teaching experience described. For example, if an MTA had both tutoring and high school teaching experiences, we recorded the experience as *high school*. If the length of the teaching experience was provided, we entered it in parentheses next to the experience.

Note that the majority of the MTAs were domestic graduate students or were enrolled in a master's program. Also, observe that only a handful of the MTAs had previously taught mathematics at the collegiate level. The commonalities and differences in MTAs' backgrounds could provide possible answers to our research questions.

All the participants had a teaching assignment for which they were the sole instructors of a developmental mathematics or statistics course. These foundational courses ranged from fundamental algebra to calculus. For the remainder of this paper, the term *MTA* refers to graduate students who are solely responsible for the instruction and assessments for a class of approximately 30 undergraduate students.

#### Procedure

During one particular semester, the participants were enrolled in MATH 5910 – Curriculum Analysis and Classroom Behaviors, a course all MTAs had to take concurrently to their first teaching assignment at the university of this study. As a requirement for this course, each MTA wrote between 10 and 13 weekly reflections that were responses to given prompts (Figure 3).

- |   |
|---|
| <p>A. This week in teaching I struggled with...</p> <p>B. The moment(s) this week that I felt most connected, engaged, or affirmed as a teacher...</p> <p>C. The moment(s) this week that I felt most disconnected, disengaged, or bored as a teacher...</p> <p>D. The situation that caused me the greatest anxiety or distress related to teaching this week...</p> <p>E. The event that most took me by surprise in teaching this week...</p> <p>F. Of everything I did this week in my teaching, what I would do differently if I had the chance to do it again...</p> <p>G. I was flabbergasted when I heard/read a student's response that said...</p> <p>H. I have to tell you what my student(s) did...</p> <p>I. A really great conversation was created when...</p> |
|---|

*Figure 3.* Prompts for Writing the Weekly Reflections

There was no specific length requirement for these reflections, but to complete the assignment MTAs were expected to write insightful, honest, and clearly explained reflections on their



teaching. Once the semester was finished, the reflections were coded and analyzed as described in the next sections.

### Weekly Reflections MKT Coding Scheme

To analyze how the MTAs' MKT was expressed in their weekly reflections (RQ 1), the MTAs' responses were coded for instances of MKT (see Appendix A for more details about the coding process). The unit of analysis was sentences written. Some sentences were coded for more than one category. Using the following coding scheme, we identified instances of SMK, A-KCS, B-KCS, KCT, and KC in the data.

#### *Coding for Subject Matter Knowledge*

Sentences that indicated an MTA was more focused on the mathematical content than on pedagogical decisions were coded as SMK. Some of the tasks related to SMK include the following (Ball et al., 2008):

- Presenting mathematical ideas;
- Responding to students' "why" questions;
- Finding an example to make a specific mathematical point;
- Linking representations to underlying ideas and to other representations;
- Connecting a topic being taught to topics from prior or future years;
- Appraising and adapting the mathematical content of textbooks;
- Modifying tasks to be either easier or harder;
- Evaluating the plausibility of students' claims (often quickly);
- Giving or evaluating mathematical explanations;
- Choosing and developing useable definitions;
- Using mathematical notation and language and critiquing its use;

- Asking productive mathematical questions;
- Selecting representations for particular purposes; and
- Inspecting equivalencies.

Whenever MTAs articulated strategies, tasks, and motivations similar to these listed tasks, they were foregrounding the mathematical content, and these statements were coded as SMK. For example, the following sentences were coded as SMK:

- MTA 105: I have done my best to simplify [the] material for this class.  
(Reflection 13)
- MTA 109: Again, this prompted my whole speech about math being a very specific language and that proper notation is important. (Reflection 6)
- MTA 110: The book has a very convoluted method, and I have [an] easier-to-understand method. (Reflection 6)
- MTA 111: In college algebra, continuity is simply defined as if a function has no breaks in its plot over an interval (that is, if it can be traced without lifting the pencil from the graph) then it is continuous over that interval, and consequently if there is a point at which the function breaks, that point is called a discontinuity. (Reflection 3)
- MTA 116: The rule is that if  $\log_a x = y$ , then  $y$  can be obtained by converting Logarithmic function to exponential function  $a^y = x$  which is easy to get the value of  $y$ . (Reflection 8)

These excerpts demonstrate the MTAs' knowledge in modifying material to be easier (MTA 105), using mathematical notation and language (MTA 109), adapting the mathematical content of textbooks (MTA 110), choosing useable definitions (MTA 111), and in presenting mathematical ideas respectively (MTA 116), and were, therefore, coded as SMK.

*Coding for Applying Knowledge of Content and Students*

A-KCS is the intersection of the MTAs' knowledge about their students' learning and understanding and mathematics. Some tasks in which instructors show the use of A-KCS include the following (Ball et al., 2008):

- Anticipating what students are likely to think and what they will find confusing;
- Predicting what students will find interesting and motivating when choosing an example;
- Anticipating what they are likely to do with an assigned task and whether they will find it easy or hard; and
- Being able to hear and interpret students' emerging and incomplete thinking as expressed in the ways the students use language.

Essential to all these tasks is knowledge of common student conceptions and misconceptions about particular mathematical concepts. To analyze MTAs' reflections for instances of A-KCS, verbs such as *anticipating* and *expecting* were particularly helpful. Some examples from the data are:

MTA 102: I thought most of them could finish in 20 minutes since those five questions were pretty standard and straight-forward questions, and I just gave them some review the day before yesterday. (Reflection 10)

MTA 115: This allowed me to throw in a bunch of fun facts that I tailored to the majors that I knew that were in the class. This included examples of the golden ratio used in music, how the human body exhibits the golden ratio in various proportions of body parts, and I even threw in how people use the Fibonacci sequence to predict the activity of a certain stock. (Reflection 2)

MTA 117: When I was preparing for this section of material (Law of Sines), I anticipated that the topic of the ambiguous case of the Law of Sines would be the most difficult for students to grasp. (Reflection 11)

The notions of expectations and anticipations of students' understanding of the content is noticeable in these examples in the following ways: MTA 102 expected students to find the assignment easy and not to take long to complete it; MTA 115 expresses how he used knowledge about students' backgrounds to come up with examples that were interesting to them; and MTA 117 anticipated that a particular mathematical topic would be confusing for students.

*Coding for Building Knowledge of Content and Students*

B-KCS represents the practice of building knowledge about students' learning and understanding of mathematics. In other words, it is the MTAs' perception of their students' understandings. To identify instances of B-KCS in the MTAs' reflections, verbs such as *finding*, *noticing*, and *realizing* were particularly useful. The contexts in which B-KCS statements were often situated involved MTAs reflecting on their interactions with their students or their students' work. Some examples include:

MTA 111: This past week, I handed back the students' second exam, and I'm not sure if the other TA's [*sic*] felt similar across the sections, but I couldn't help but think that my students did exceptionally poorly. The average score was about 59.1%, just a smidge below failing. (Reflection 8)

MTA 117: I found that my students could easily set up the triangles and gather what  $\sin x$  and  $\cos y$  were, but they could not follow the algebra that I was doing on the board. (Reflection 10)

MTA 119: I had noticed that my students had done rather poorly on a homework question about the margin of error, so I created an activity to review the topic. (Reflection 3)

In many of the sentences coded as B-KCS, MTAs discussed their students' performance on assessments (MTA 111). Thus, MTAs were interpreting and making sense of their students' work, forming a stronger understanding of students' ways of thinking about the content. MTAs also realized that the students lacked some knowledge that they had assumed students already understood (MTA 117). Another way MTAs talked about B-KCS was by describing how they learned about student misconceptions from their classroom interactions and sometimes applied that new understanding in subsequent lessons with those same students (MTA 119).

*Coding for Knowledge of Content and Teaching*

KCT combines knowledge about pedagogy and knowledge about mathematics. Sentences that indicated MTAs' knowledge of the design of the instruction were coded as KCT. Ball et al. (2008) describe some tasks in which instructors need KCT:

- Sequencing particular content for instruction, deciding which example to start with and which examples to use to take students deeper into the content;
- Evaluating the instructional advantages and disadvantages of representations used to teach a specific idea and identifying what different methods and procedures afford instructionally;
- Making instructional decisions about which student contributions to pursue and which to ignore or save for a later time; and
- Deciding when to pause for more clarification during a classroom discussion, when to use a student's remark to make a mathematical point, and when to ask a new question or pose a new task to further students' learning.

Central to all these tasks is a mathematical understanding and an understanding of pedagogical issues related to student learning. For example, the following sentences were coded as KCT:

- MTA 109: After sketching out the sine and cosine functions, immediately one of my students recognized the symmetry and that prompted our discussion about even and odd functions. One student then brought up the idea that sine and cosine do not pass the horizontal line test over the entire real line, so we discussed how the reciprocal functions worked in reference to sine, cosine and tangent. (Reflection 9)
- MTA 112: I paused longer when asking questions [than] I ever have prior to this lecture and gave the students breaks in between lectured topics to try and help them absorb the content. (Reflection 10)
- MTA 117: Because of the content and structure of the activity, I thought that it would be best to start with the class activity and then provide supplemental lecture notes. (Reflection 3)

The MTAs often used students' contributions to start class discussions (MTA 109). They also expressed concerns with issues of timing during the enactment of the lesson (MTA 112). Most frequently, however, the MTAs discussed instructional strategies for particular contents (MTA 117).

### *Coding for Knowledge of Curriculum*

KC is knowledge of curricula and materials appropriate and available for teaching particular topics within one grade level or course, as well as across the K-16 curriculum.

Shulman (1986) divides KC into four components:

- Knowledge of different programs and corresponding materials available for teaching the given content;
  - Knowledge of the effectiveness and implications of programs and materials for given contexts;
  - Knowledge of content and corresponding materials in other subject areas of students;
- and

- Knowledge of how topics are developed across a given program.

Whenever MTAs talked about materials and resources available for the courses, they were demonstrating knowledge of curriculum, and these statements were coded as KC. For example:

MTA 102: I have completed all the materials I need to cover this week, and we will have review sessions for the next week. (Reflection 13)

MTA 109: I am currently teaching MATH 1280 – PreCalculus, and the course is designed around the usage of MyMathLab (MML), an online program that supplements the in-class lecture. The students use MML to complete their homework, take weekly reading quizzes prior to the start of a new section and track their progress of understanding. (Reflection 1)

MTA 117: Given the limited time that I had this week (I had a midterm in one of my classes this Friday) and the fact that I was unsure if campus computers had Paint or GeoGebra installed, I searched Google and YouTube for something that I could use. I stumbled upon a video in which a teacher explained the ambiguous case of the Law of Sines by showing a series of triangles that he created in GeoGebra and that when he pivoted a side of the triangle down to the base of the triangle, it created one, two, or no triangles. (Reflection 11)

As seen in these excerpts, MTAs expressed knowledge of curriculum in various ways: MTA 102 showed knowledge about the materials covered in the semester for a particular course; MTA 109 demonstrated knowledge about the online component that accompanied the course she was teaching; and MTA 117 revealed knowledge of outside resources to use in her instruction and enhance the learning experience for the students.

#### Analysis of MTAs' MKT from Weekly Reflections

To answer RQ 1, we coded all 241 weekly reflections using the MKT coding scheme. The unit of analysis was sentences written. Reflections had as few as four sentences and as many as 35 sentences. When applicable, some sentences were coded for more than one MKT category.

We recorded the total number of sentences written by each MTA and determined frequencies of sentences coded for individual MTAs and across all participants.

Throughout this coding process, two raters conferred to refine the descriptions and procedure for applying the MKT framework. Both raters coded 21 reflections from two different MTAs randomly chosen. Agreement was reached for a majority of the codes with all disagreements resolved through discussion.

#### Analysis of Themes from Weekly Reflections

To analyze how MTAs reflected on their pedagogical successes and shortcomings (RQ 2) we used grounded theory method (Glaser & Strauss, 1967). As we read the weekly reflections, we looked for themes that could help us understand MTAs' teaching practices, beliefs, challenges, and understandings of mathematics and teaching. When new themes arose, we cycled back through the previous reflections in search of those themes. From this cyclic process, we identified 23 pedagogical success and shortcoming themes that were grouped into four broad contextual categories (Figure 4).

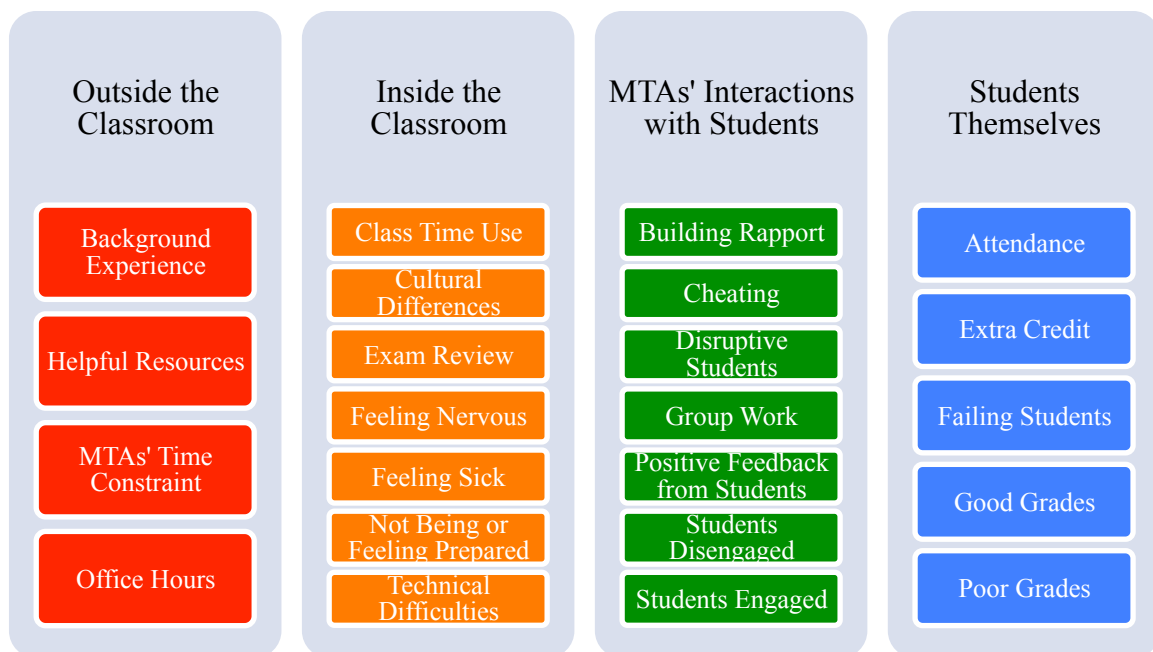


Figure 4. Themes from Weekly Reflections



Two of the broad categories, *outside the classroom* (red) and *inside the classroom* (orange), include the themes related to the MTAs as the main subject. The category *outside the classroom* includes external factors and settings, and the category *inside the classroom* concerns the activity of teaching and preparing for teaching. The other two broad categories, *MTAs' interactions with students* (green) and *students themselves* (blue), focus on students as the main subject. The *students themselves* category also include themes related to MTAs' course policies.

Using a method similar to how we coded the MKT categories, we coded weekly reflections for the pedagogical themes (Figure 4) using sentences as the unit of analysis. We recorded the total number of sentences each MTA wrote, determined frequencies of coded sentences for each MTA and frequencies across all participants.<sup>1</sup> Sentences were coded for a particular theme if the theme was present in the sentence alone. That is, we did not code a sentence from which the theme could not be identified when reading the sentence by itself. For example:

MTA 102: This week in teaching, what I feel most struggled with is that this is my first time teaching, especially in my second language. And all my students are Americans. (Reflection 1)

In this example, MTA 102's first sentence was coded as background experience since we cannot identify this particular theme when reading the second sentence by itself.

Some sentences were coded for more than one theme such as the following example:

MTA 120: I have been able to manage my time better and I believe I have learnt a lot of new strategies from discussion with peers, MATH 5910 course

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<sup>1</sup> Differently from how we coded the responses for the MKT categories, we did not keep track of the number of sentences not coded for any of the themes. Thus, we do not know the total number of sentences coded for at least one theme.

instructor's comments, and simply through the one month of experience I have had working as an instructor at BGSU. (Reflection 4)

This example was coded for both helpful resources and MTAs' time constraint.

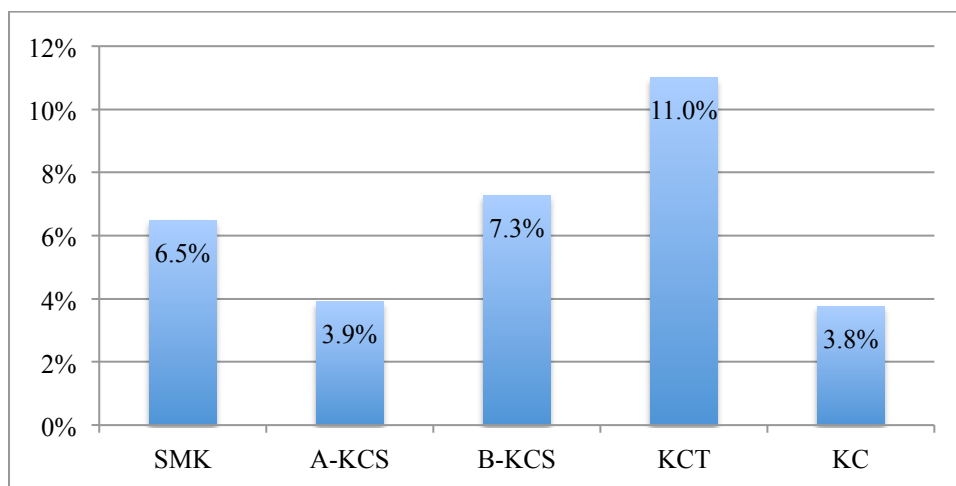
Having coded MTAs' reflections for the MKT categories and the themes, we were then interested in studying the relationship between those two groups of codes by analyzing sentences that were coded for both an MKT category and a theme. In other words, we were interested in learning about the intersection of both research questions. The results are presented in the next section.

## RESULTS AND DISCUSSIONS

To present the results from this study, we first summarize the results from coding the MTAs' weekly reflections for the MKT categories, and then we present the themes found in those reflections. We end by discussing the connections between these two groups of codes.

### Results of MTAs' MKT from Weekly Reflections

The prompts to which MTAs had to respond when writing the reflections seemed to elicit MKT responses as 201 of the 241 reflections (83.4%) had coded sentences. The total number of sentences in all reflections was 3,270 of which 1,040 (31.8%) were coded for at least one of the MKT categories. The percentage of MKT coded sentences across all 241 reflections is shown in Figure 5.



*Figure 5.* Percentage of MKT Coded Sentences out of Total Number of Sentences

The percentage was out of 3,270, the total number of sentences. Figure 5 indicates that KCT was coded most frequently. The MTAs' responses focused most often on how they taught the mathematics and usually less on the students and specific content (emphasizing KCT). We can also see from Figure 5 that KC was coded least frequently. Since for the majority of the

MTAs the 2013 fall semester was their first time teaching at the collegiate level, the MTAs' responses focused rarely on how they used appropriate materials to teach their assigned courses.

Figure 5 also reveals that the number of sentences coded as B-KCS is roughly twice as many as the number of sentences coded as A-KCS. Since all the MTAs were inexperienced teachers (those with less than five years of experience in teaching), this result is not surprising. Most of the responses focused on the MTAs' perception of their students' learning and understanding of mathematics as opposed to anticipating what students might find interesting, easy, or confusing. To see if this pattern is present within each MTA's reflections, we compared the number of sentences coded as A-KCS and B-KCS for each MTA (Figure 6).

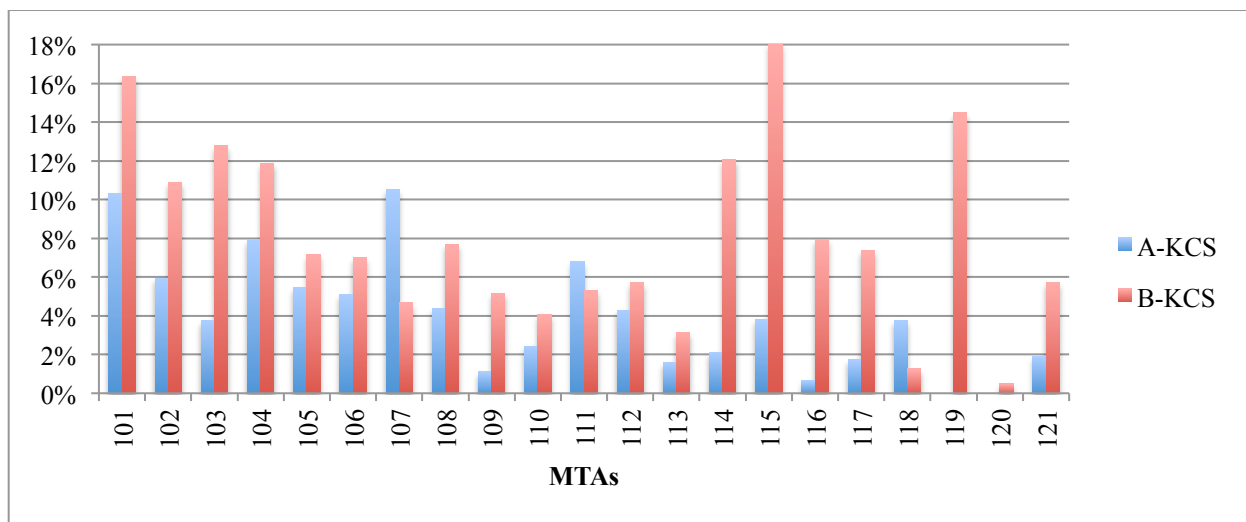


Figure 6. Percentage of A-KCS and B-KCS Coded Sentences for Each MTA

The percentage was out of the total number of sentences in all reflections for each MTA. For example, MTA 101 wrote 165 sentences (across 12 reflections) of which 17 (10.3%) sentences were coded as A-KCS and 27 (16.4%) sentences were coded as B-KCS. With the exception of three MTAs<sup>2</sup>, the reflections for each MTA had more sentences coded as B-KCS than sentences coded as A-KCS. Note that MTAs 119's and 120's responses did not demonstrate

<sup>2</sup> Although MTAs 107, 111, and 118 had no previous teaching experience, their responses had more sentences coded as A-KCS than coded as B-KCS.

any knowledge in anticipating students' reactions to what is being presented in the classroom. Many MTAs wanted to incorporate anticipations of students' difficulties but did not have prior knowledge, experience, or resources about how these students might learn, making statements such as:

MTA 111: I wasn't sure how much of the material the students were familiar with, considering this was preliminaries week. (Reflection 1)

MTA 111 had no teaching experience prior to starting graduate school, which may have affected his ability to anticipate students' thinking without access to specific pedagogical support or resources about students' misconceptions and thinking for the content he was teaching.

To investigate if the patterns noticed from Figure 5 were consistent within different types of participants, we considered the percentage of MKT coded sentences for each of the four PhD MTAs (Figure 7).

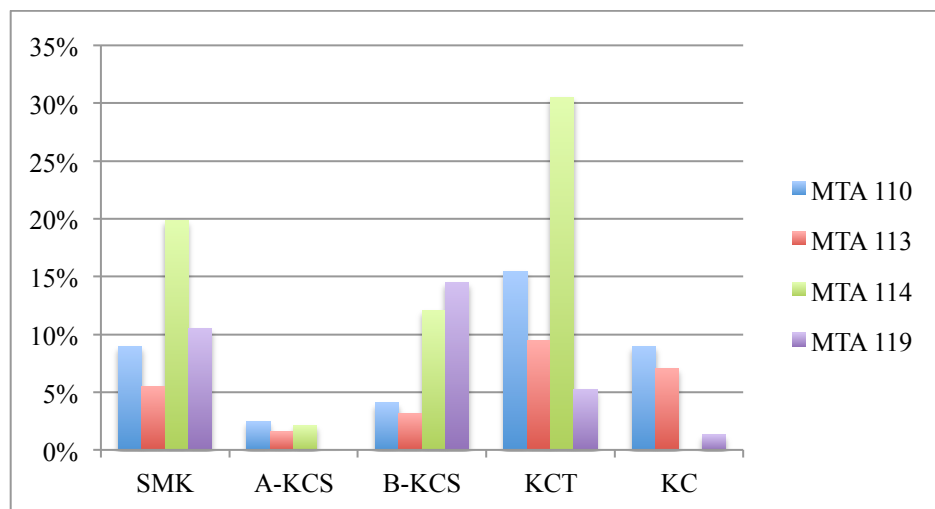


Figure 7. Percentage of MKT Coded Sentences for Each PhD MTA

Note that MTAs 110 and 114 had taught at the collegiate level for three years, and the other two MTAs only had experience in tutoring. The four of them combined wrote a total of 467 sentences of which 194 (41.5%) were coded for at least one of the MKT categories. Hence, their

percentage of coded sentences was considerably higher than the overall percentage (31.8%) of coded sentences.

The percentage for each MTA is out of the total number of sentences in the individual MTA's reflections. Figure 7 indicates that for three of the four MTAs pursuing a PhD, the responses often focused on how these MTAs presented the mathematics (KCT) and least frequently on anticipating and planning for their students' ways of thinking (A-KCS).

To continue with the investigation of the MKT differences between MTAs who were pursuing a PhD and MTAs pursuing a master's degree, we summarized the percentage of MKT coded sentences for both groups in Figure 8. The percentage for each group was out of the total number of sentences written within that group.

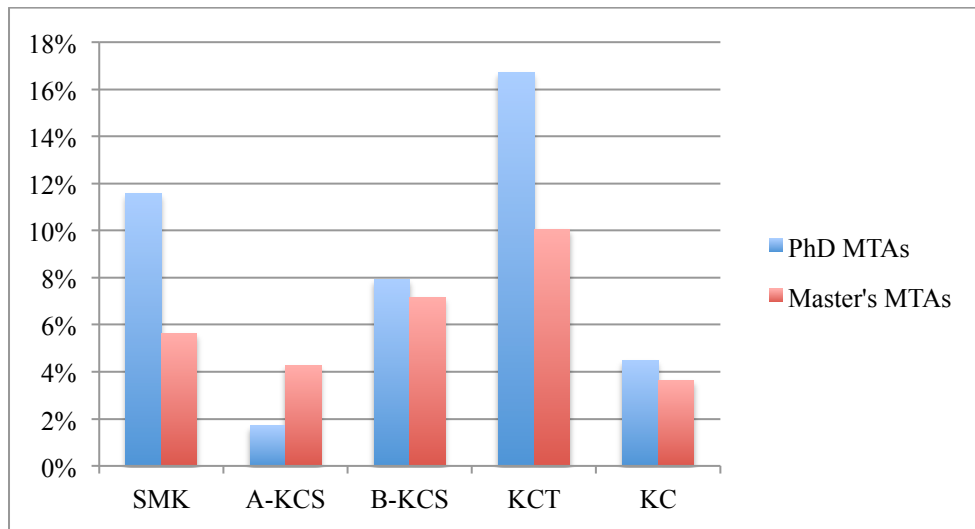


Figure 8. Percentage of MKT Coded Sentences for PhD and Master's MTAs

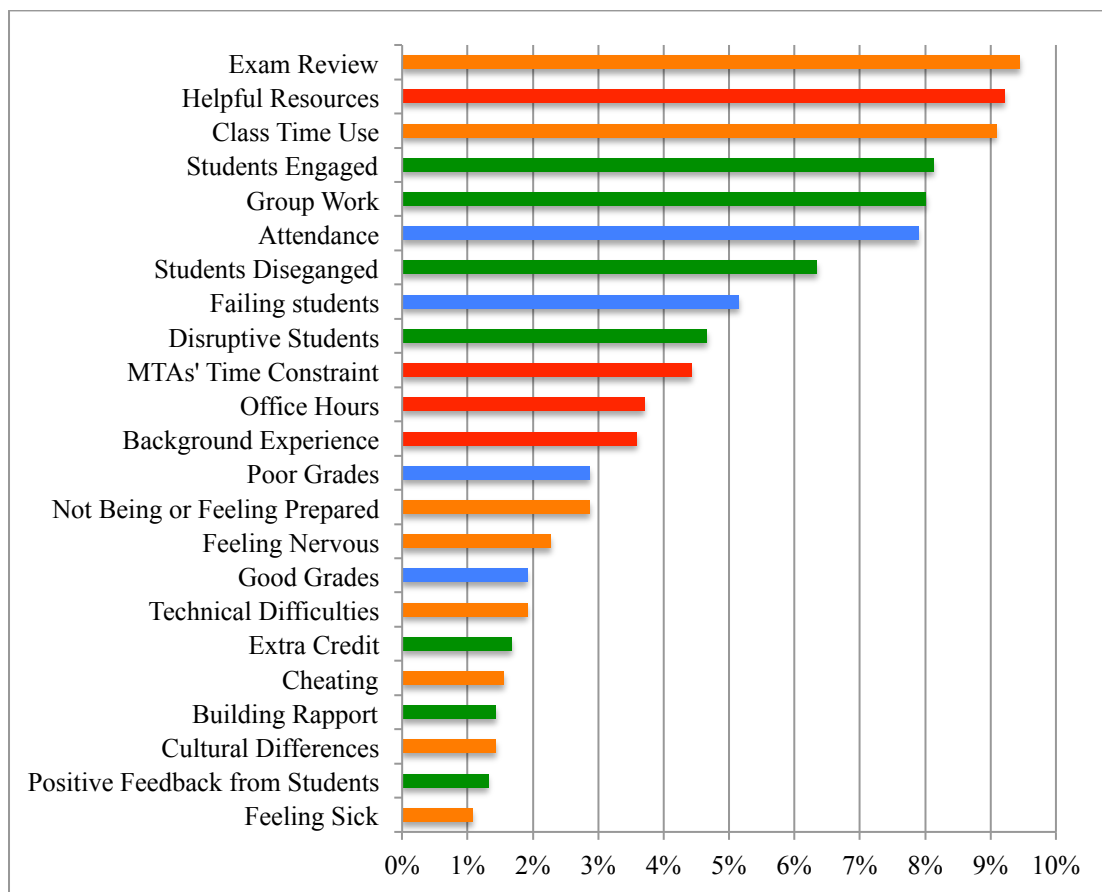
Figure 8 suggests that PhD MTAs focused more often on the subject content than the other MTAs. One interpretation of this result could be attributed to the fact that PhD graduate students presumably studied advanced mathematics longer than graduate students in a master's program. Also, Figure 8 reveals that the percentage of sentences coded as A-KCS for PhD MTAs is surprisingly lower than for MTAs pursuing a master's. One might expect that MTAs with

more teaching experience might talk more frequently about anticipating students' reactions.

Although two of the PhD MTAs had three years of experience teaching at the college level, their reflections did not focus more on A-KCS.

### Results of Themes from Weekly Reflections

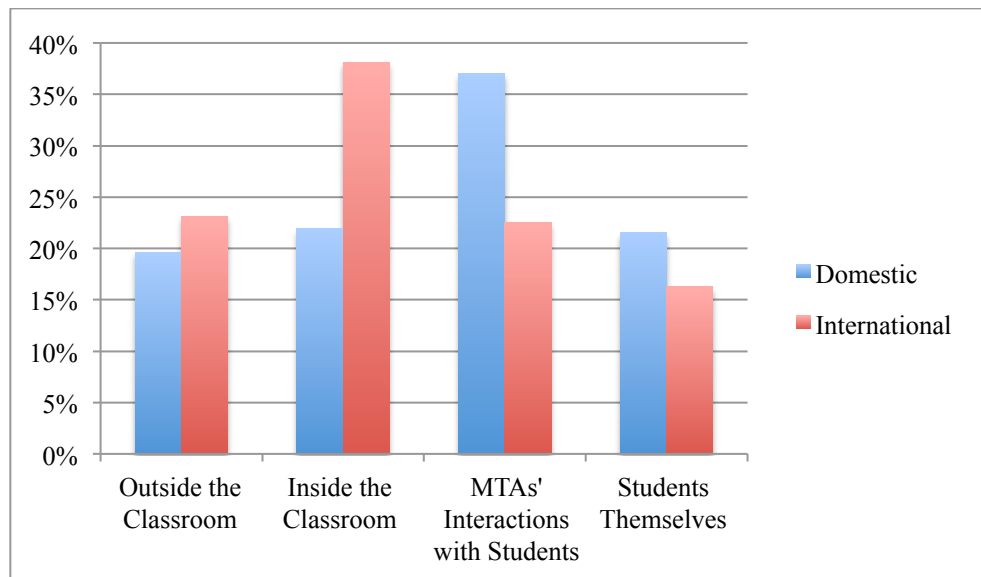
In all 241 reflections, there were 836 instances that were coded for one of the 23 pedagogical themes (Figure 4). Since some sentences were coded for more than one theme, the total number of sentences coded is less than 836. Figure 9 illustrates how those 836 instances were distributed across the different themes.



*Figure 9.* Percentage of Themes Coded out of Total Number of Instances. We used red for themes under outside the classroom, orange for inside the classroom, green for MTAs' interactions with students, and blue for themes under students themselves.

Note that the bars were colored according to the broad-level category the themes fell under. The themes are listed in descending order, from most to least frequent for the 23 pedagogical themes (Figure 9). Helpful resources (9.2%), exam review (9.4%), students engaged (8.1%), and attendance (7.9%) were the prevalent themes in their respective broad categories. We discuss these themes in more detail in the next section.

To examine potential relationships between the MTAs' background and the prevalence of pedagogical themes in their reflections, we divided MTAs into domestic and international graduate students. Figure 10 compares the percentage of coded instances for each of the four categories for both groups of MTAs. While the 14 domestic MTAs had 516 coded instances in 2,100 sentences (24.6%), the seven international MTAs had a slightly higher percentage of 320 coded instances in 1,170 sentences (27.4%). The percentage was out of the total number of instances coded for each group. For example, out of 320 coded instances, the international MTAs' reflections had 122 (38.1%) instances of themes that fell under inside the classroom.



*Figure 10.* Percentage of Themes Coded for Domestic and International MTAs in Each Category



Considering the broad categories for the domestic and international MTAs, we can see that international MTAs talked more frequently about the categories where MTAs were the subject (outside the classroom and inside the classroom) than did domestic MTAs. This scenario is reversed for the categories where undergraduate students were the subjects (MTAs' interactions with students and students themselves). Hence, international MTAs talked more about pedagogical successes and shortcomings where they themselves were the main subjects and domestic MTAs talked more about pedagogical successes and shortcomings where the students were the main subjects.

Figure 11 displays the percentage of coded instances for select themes for both groups. Since most of the international MTAs had no prior experience teaching at any level, they wrote more frequently about feeling nervous standing in front of the class or not being prepared to teach than the domestic MTAs. They also expressed more often their struggles with finding a balance between doing the work for their teaching assignments and their own graduate courses. Moreover, they repeatedly wrote about their experiences in giving exam reviews and what resources they found helpful for teaching. Two international MTAs also pointed out cultural differences between their country of origin and the U.S.

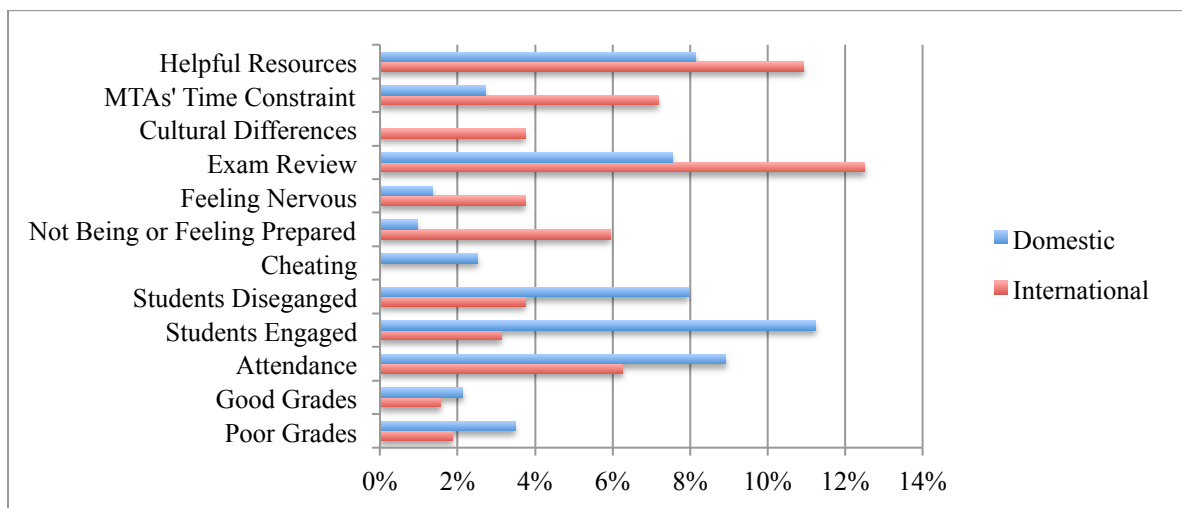


Figure 11. Percentage of Select Themes Coded for Domestic and International MTAs

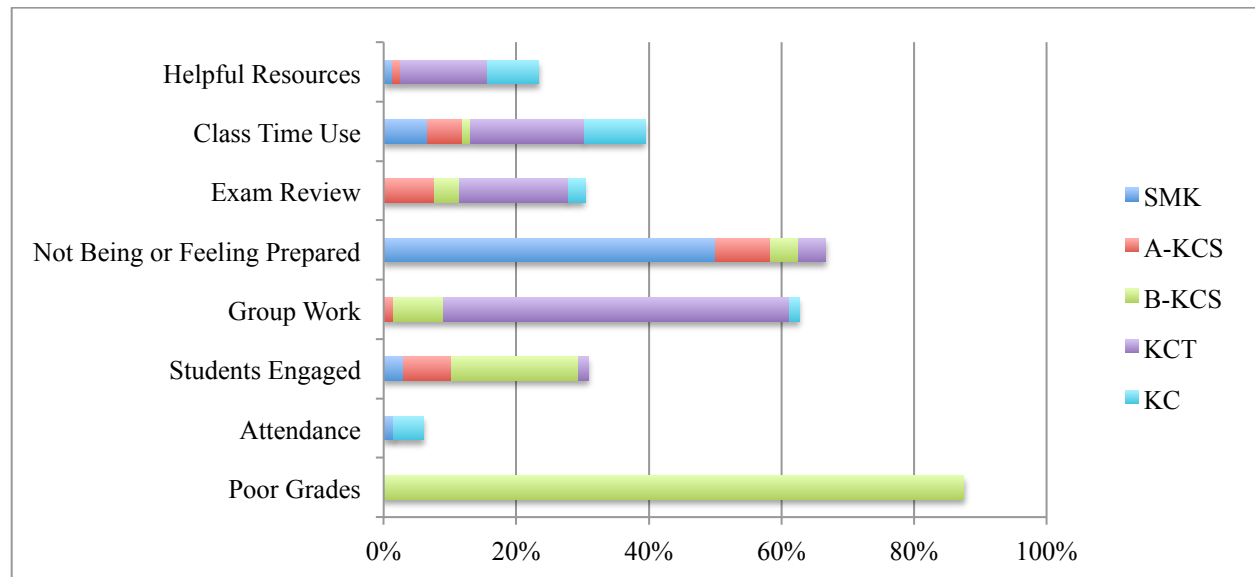
The domestic MTAs, on the other hand, wrote more frequently about their interactions with students than the international MTAs. Their responses often focused on describing students' engagement in the classroom and on discussing students' attendance or grades.

#### Results of MTAs' MKT and Themes from Weekly Reflections

Now that we have presented separately the results of the MTAs' MKT and the themes from the weekly reflections, we are ready to discuss the connections between these two analyses.

#### *MTAs' MKT from Pedagogical Themes*

As a starting place, we chose the predominant pedagogical themes in the four broad categories to investigate what percentage of the instances coded for those themes were also coded for the MKT categories (Figure 12).



*Figure 12.* Percentage of MKT Coded Instances for Select Themes. The percentage was out of the total number of instances coded for a particular theme.

For example, of the 76 instances when MTAs talked about class time use, five (6.6%) instances focused on SMK, four (5.3%) attended to A-KCS, one (1.3%) was about B-KCS, 13 (17.1%) addressed KCT, seven (9.2%) were about KC, and the remaining 48 (63.2%) instances were not about MKT categories. Note that the sum of all percentages in this case is greater than

100% because some instances talked about more than one MKT category. We chose not to include the non-coded MKT percentages in the graph in light of a more visually appealing figure.

We can see from Figure 12 that often when MTAs talked about helpful resources they also talked about KCT and KC. It is evident from their responses that the MTAs frequently sought help from their course coordinators, faculty members, or experienced MTAs to improve their teaching as in the example from MTA 107.

MTA 107: When I consulted with my course coordinator, I realized I was not supposed to interrupt students during the activity; I should have let my students make progress themselves; my job was just [to] answer questions. (Reflection 4)

They often applied many of the ideas learned from the Curriculum Analysis and Classroom Behaviors course to their own classrooms. For example:

MTA 109: My idea actually came from MATH 5910. I had everyone push their desks to the perimeter of the class so that we were all in one large semicircle facing the board. I then put a verification problem on the board and instructed everyone to work on the problem quietly and independently at their seats. (Reflection 9)

The MTAs occasionally wrote about the helpfulness of some of the materials available for teaching their courses, characterizing KC, as MTA 101 describes:

MTA 101: I realize I should read more this kind of notes from experienced instructor when I prepare the new class, try to understand why and how they design like that and what strategy I should give next time. (Reflection 3)

When MTAs discussed class time use in their responses, there were instances coded for each of the MKT categories as already stated. In few occasions, the MTAs dismissed class early because they were confused with the content of the material they were teaching (emphasizing

SMK). At other times, they finished class early because they underestimated how long it would take students to complete a task. For example:

MTA 115: In reality, my students exceeded my expectations and flew through the problems so I ended class fifteen minutes early because I had not entertained the idea that they would get done early. (Reflection 1)

In most of the instances coded as class time use, the MTAs expressed struggle with time allocation for each activity in their instructions as exemplified below.

MTA 107: I was frustrated to [*sic*] my lack of sense of time. I focused too much on stopping my students during the activity to make sure every group is at the same pace. (Reflection 4)

Figure 12 reveals that frequently when MTAs talked about exam review they also talked about KCT. MTAs usually wrote about their instructional strategies when describing their exam review sessions as shown in this excerpt from MTA 118's reflection:

MTA 118: During my class this morning, I was reviewing for the exam that my students are going to be taking on Monday. I gave a brief overview of [the] material that I thought was most important for the exam and then mentioned some things that I noticed on a homework they had just turned in. (Reflection 3)

Some of the instances coded as exam review focused on how students think and learn. Because the majority of the developmental courses had at least three exams throughout the semester and most of the MTAs held review sessions before each of them, the MTAs were able to use the information they gathered about their students' understanding in the first review sessions to improve future ones. For example:

MTA 101: Previously, exam time took place after I gave them review section on the same day. I found students felt hard to digest what I just said in the review section. Hence, I wanted to give that in advance this time. (Reflection 12)

In this example the MTA describes what was discovered about students' learning from a previous review session and, by taking that knowledge into consideration, the MTA adjusts the current review session accordingly (emphasizing both B-KCS and A-KCS).

Often when the MTAs reflected on their lack of preparedness for teaching they expressed confusion about certain topics as in the example below:

MTA 120: That day was not one of my lucky ones and I ended up not quite finishing my preparation. On top of that, I did not quite understand one section of Chapter 21, a topic concerned with repeated sampling. (Reflection 12)

It is clear the focus of the second sentence is on the mathematical content, depicting SMK.

Similarly to the exam review instances, many instances coded as group work were also coded as KCT. When the MTAs reflected on their group work activities, they most likely described the design of their instructions as in the next example. All three sentences were coded both as group work and KCT since the MTA is relating an instructional strategy.

MTA 117: I began each class this week by asking students to get in their usual activity groups. I began lecturing and completed some examples on the board. Then, I wrote a few similar problems on the board and asked students to work in their groups to complete them. (Reflection 9)

Figure 12 shows that often when the MTAs wrote about students being engaged, they also wrote about what they thought students found interesting as in the example below:

MTA 115: I think that the students really enjoyed this activity because they were really engaged in the discussion. (Reflection 13)

Although the MTAs' responses frequently addressed students' attendance, they were not focused on any of the MKT categories in particular. Occasionally the MTAs wrote about changing their grading policy to include attendance in order to motivate students to go to class as in this next case.

MTA 106: Note that, to be precise, I didn't truly change the policy (which would require creating a new syllabus), but rather I'm just using the points I control in the class to go toward attendance. (Reflection 11)

Note that in nearly every circumstance where the MTAs reflected on their students' good or poor grades they learned about their students' understandings and misconceptions, which is part of the definition of B-KCS. For example:

MTA 105: I felt frustrated because no more than four students can give a correct answer for Question 1 in Quiz 2. (Reflection 4)

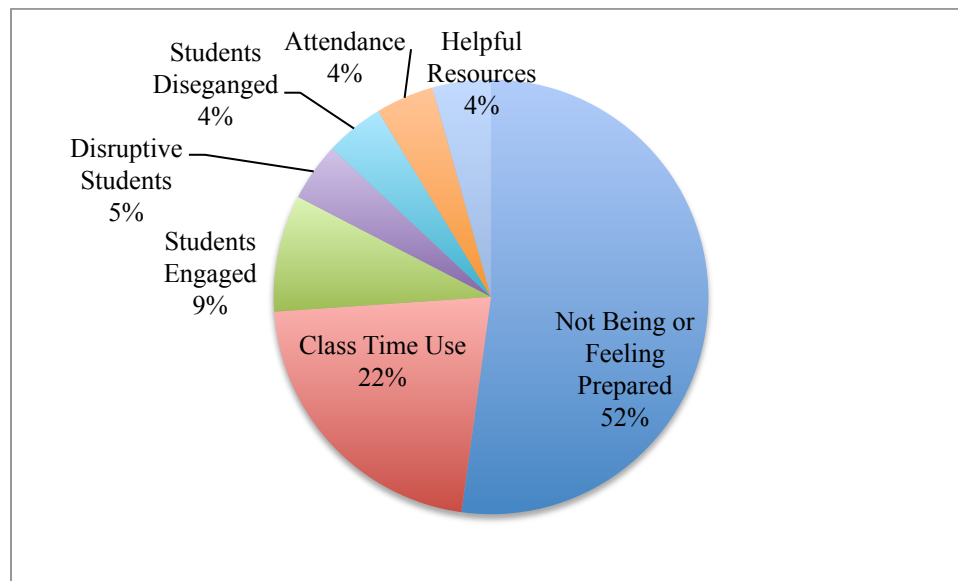
Here MTA 105 learns what issues students have with a particular topic (emphasizing B-KCS).

#### *Pedagogical Themes from MTAs' MKT*

To further examine the relationship between the MTAs' MKT and the pedagogical themes, we present in the next five figures the themes found in the MTAs' responses when the focus was on SMK, A-KCS, B-KCS, KCT, and KC in this order. Although some statements fell under certain MKT categories, they did not help us understand the MTAs' successes and shortcomings. So these instances did not get a thematic code and were not included in the figures that follow. The percentage in each figure was out of the total number of instances coded for pedagogical themes under each MKT category. For example, out of the 232 SMK coded sentences, there were 23 pedagogical thematic instances.

We can see from Figure 13 that for most of those 23 SMK instances the MTAs expressed not being or feeling prepared for teaching as a consequence of not feeling comfortable with the

topic. They sometimes wrote about not using the class time effectively and dismissing students early because they felt confused with the mathematical content during their instructions.



*Figure 13.* Themes Found under SMK

Figures 14 and 15 show what themes MTAs chose to write about when the focus of their responses was on applying knowledge of students' learning of mathematics to anticipate their reactions and on building that knowledge, depicting A-KCS and B-KCS respectively. As we already discussed, the MTAs often built knowledge in the first review sessions of what instructional strategies engage students, and then applied that knowledge when conducting future exam review sessions. This observation is clear from Figure 14, where 32% of the theme-coded instances under A-KCS were coded as exam review and 26% as students engaged.

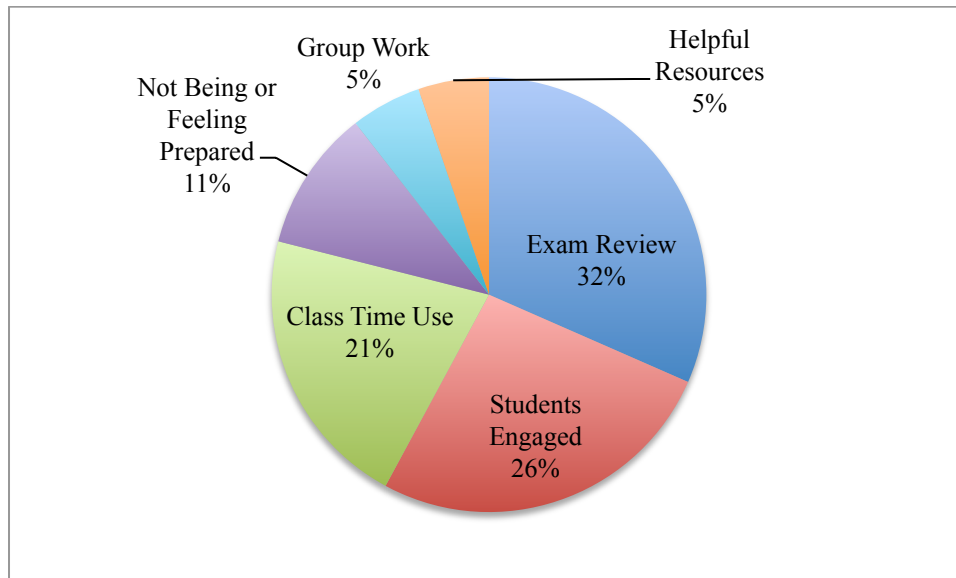


Figure 14. Themes Found under A-KCS

Figure 15 confirms what we had showed earlier in Figure 12. Often the MTAs built knowledge about students' understanding of mathematics by interpreting the students' assessments.

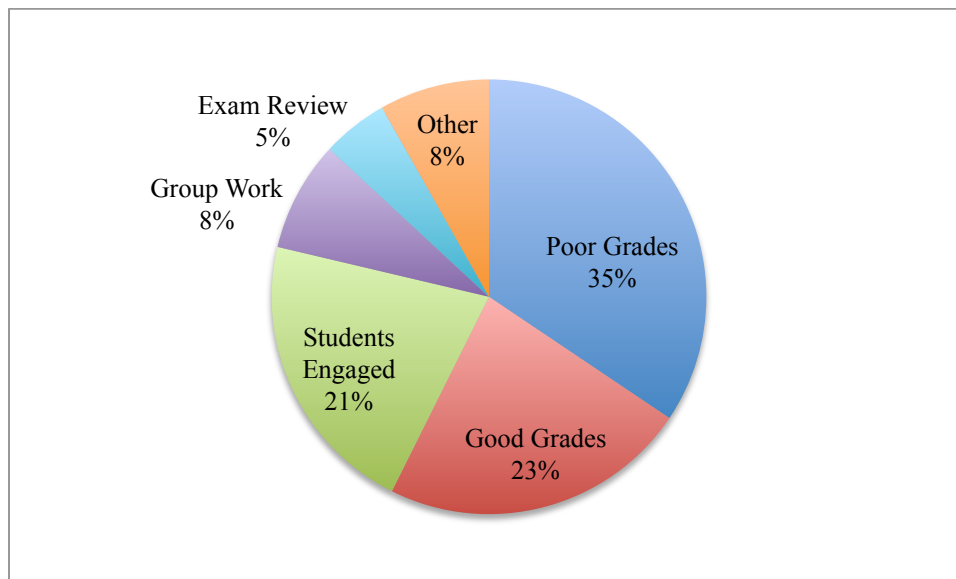


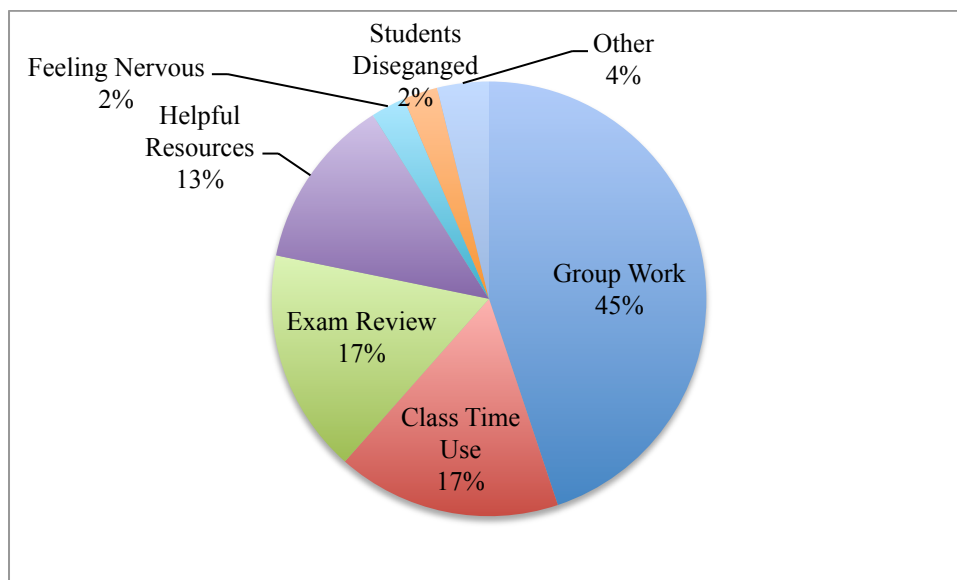
Figure 15. Themes Found under B-KCS

As argued by Speer and Kung (2009, p. 148), "reflection on the grading process creates opportunities to build knowledge of both how students typically think about the ideas as well as



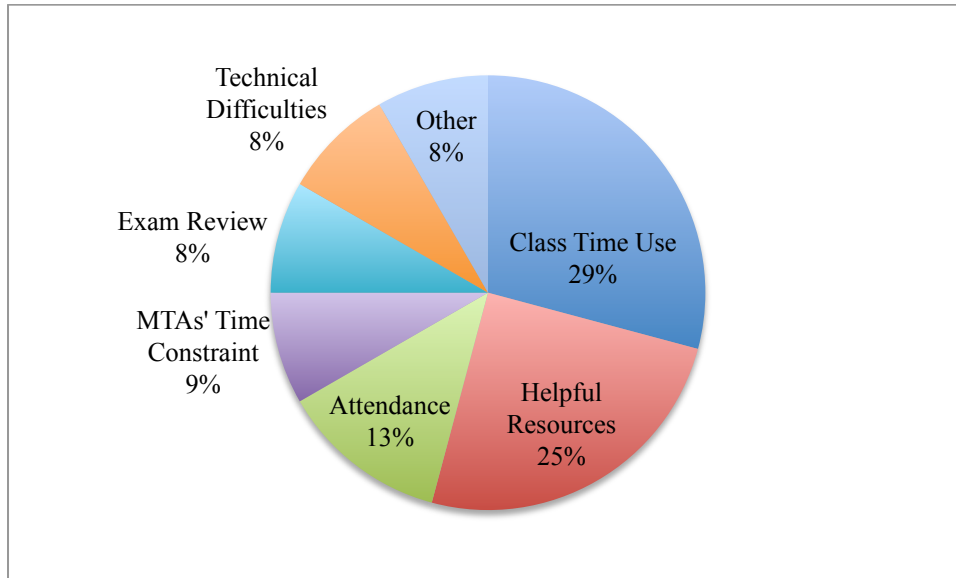
the typical difficulties that students have while learning these topics.” Out of 61 theme-coded instances under B-KCS, 58% of them focused on the students’ grades. The MTAs also discovered what examples students found interesting and motivating by observing when students were engaged in classroom discussions.

In Figure 16 we notice that frequently when the MTAs’ responses focused on instructional strategies, the MTAs were discussing their experiences in doing group work activities. Class time use and exam review (17% each) were also popular themes under KCT.



*Figure 16.* Themes Found under KCT

In Figure 17 we can see what themes MTAs wrote about under KC. Often they expressed knowledge of what content had to be covered in a particular week. In some circumstances where they knew they were ahead of the schedule, the MTAs dismissed class early. Helpful resources (25%) was another common theme under KC.



*Figure 17.* Themes Found under KC

## CONCLUSIONS AND IMPLICATIONS

### Outcomes and Implications

The two major goals of this study were to better understand how the MTAs expressed their MKT as well as their pedagogical successes and shortcomings in reflecting on their teaching practices. We conducted an analysis of the weekly reflections of 21 MTAs of whom only four had previous experience teaching at the collegiate level (Table 1). Adapting the dimensions of the MKT framework described by Ball and colleagues (2008), we combined the categories under SMK and divided KCS into two new categories (A-KCS and B-KCS), and then we coded the reflections following a cyclic coding scheme.

Overall, the MTAs made statements related to their KCT most frequently and KC least frequently. This pattern, however, was not consistent across all different types of MTAs. Surprisingly, the PhD MTAs focused least frequently on A-KCS than on any other category. This result might be justified by the lack of experience in teaching of two of the four PhD participants. We also saw that the PhD MTAs' responses had more instances describing their MKT, in particular SMK, than the other MTAs' responses. One might conclude that because the PhD MTAs had been studying advanced mathematics longer than the other participants, their reflections were greatly focused on the mathematical content.

With the exception of three MTAs, the participants tended to focus more often on B-KCS than on A-KCS in their weekly reflections. They often wrote about their perceptions of their students' work and what they learned students found interesting, easy, or confusing. However, because for most of the MTAs the fall 2013 semester was their first time teaching at the collegiate level, they regularly expressed concerns about increasing their abilities to anticipate students' difficulties and incorporating common student misconceptions in their instructions.

Most of the MTAs' ideas for teaching were developed from their own experiences as students in traditional mathematics classrooms where inquiry-based instruction is rarely adopted. Since these MTAs were successful at learning in this type of classroom environment, there is little internal motivation to change their teaching styles to incorporate anticipating how students may learn the material best. The results from this study can have professional development implications. An important direction for future work is to consider these results to integrate opportunities for MTAs to discuss and learn about teaching strategies, common student misconceptions, and lesson planning techniques and resources. For example, MTAs could videotape their teaching and find specific time points where they anticipated students' reactions. Incorporating small-group or whole-class discussion involving those video clips could provide opportunities for the MTAs to discuss, collaborate, and benefit from others' teaching experiences.

By coding the MTAs' weekly reflections for pedagogical themes, we were able to analyze how they expressed their pedagogical successes and shortcomings in their responses. We identified 23 salient themes that were common, some more than others, across the different MTAs, and we grouped those themes into four distinct categories. Exam review, helpful resources, class time use, students engaged, group work, and attendance were the most predominant themes and they constituted more than half of the thematic coded instances.

The MTAs expressed their pedagogical successes in several ways (Figure 9). They frequently wrote about what resources helped them with their lessons (e.g., the instructor of MATH 5910, course coordinators, experienced MTAs, and street sidewalk chalk), what instructional strategies worked best with their students when conducting exam reviews (e.g., horseshoe desk arrangement), and what examples and activities motivated students and engaged

them in classroom discussions or group work (e.g, examples related to students' majors). On the other hand, the MTAs expressed their shortcomings in more ways than their successes (Figure 9). They often wrote about their struggles with finding a balance between doing the work for their own classes and the work required from teaching. They also expressed concern using the class time efficiently and to its fullest, dealing with disruptive students, finding ways to engage students, keeping students from missing class, and handling failing students.

These shortcomings suggest the potential benefit for mentoring relationships between pairs or small groups of MTAs teaching the same course. Mentoring could provide the new MTAs with opportunities to learn from more experienced MTAs and mathematics faculty how to deal with some of those issues. For example, the pairs or small groups could work together to find better ways to use class time, engage students, and deal with the stress of graduate school. Thus, MTAs could incorporate ideas from their colleagues and faculty instead of only relying on their own understanding of the mathematics and experiences teaching or learning the content.

#### Limitations and Future Directions

Some limitations of this study are worth mentioning as they also indicate additional areas of future study or some research methods researchers could consider for future studies of mathematics teaching at the collegiate level. First, since the participants here only represent part of the population of MTAs at the university of this study, we cannot generalize these results for all MTAs in the mathematics and statistics department. New studies could investigate how intermediary and experienced MTAs express MKT in reflecting on their teaching practices.

Second, the weekly reflections were not anonymous when they were submitted as an assignment for the Curriculum Analysis and Classroom Behaviors course. These reflections only became anonymous later for the purpose of this study. So the MTAs might not have shared some

of the experiences that they felt uncomfortable with or that they felt could have compromised their teaching assistantships. To encourage MTAs to reflect without reservations, future studies could implement a system that keeps the writers unidentified.

Third, the MTAs' responses might have been coded more often as B-KCS than A-KCS because the MTAs found the former statements more interesting to write about than the latter ones. It is likely that the MTAs felt more compelled to write about what their students did that surprised them than they did to write about other topics that would have elicited A-KCS. Possibly, more direct prompts about anticipating students' thinking could have stimulated additional A-KCS responses.

Fourth, it is possible that certain prompts may have privileged different types of responses from the participants. Knowing the research questions before assigning the weekly reflections would have made possible designing more direct prompts. For example, a prompt such as "today I expected/did not expect my students to..." might have elicited more responses related to the MTAs' knowledge of mathematics and students learning (emphasizing A-KCS). Unfortunately, the MTAs did not always make clear which prompts they addressed when writing their reflections. In a future study, one could ask the participants to indicate the prompts in their responses and analyze those prompts to find which elicit responses that are more frequently of particular MKT categories.

Finally, one of the main goals of this study was to investigate the usefulness of using the adopted MKT framework for examining teachers' content knowledge and pedagogical content knowledge at the collegiate level. We found that it is possible to apply this framework to identify if the MTAs' responses were one of the five categories. Recall that we did not divide SMK into its components as in the original framework by Ball and colleagues (2008) because it is unclear

how to effectively differentiate between the subcategories of SMK effectively at this time. Specifically differentiating between these three components (common content knowledge, specialized content knowledge, and knowledge at the mathematical horizon) for MTAs is an area of further study.

In this study we endeavored to find themes related to the work of teaching to identify areas related to MTAs' mathematical content knowledge and pedagogical content knowledge about which MTAs expressed their pedagogical successes and shortcomings. This study serves to identify current MTA thinking about mathematics teaching, and identifies some focal areas for future professional development opportunities for MTAs.

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## APPENDIX A

## MTA 108'S THIRD REFLECTION CODED FOR MKT

A really great conversation was created when I gave what I thought to be a simple quiz on Tuesday. The very first question gave a relation as a set of three ordered pairs,  $\{(2,4), (0,2), (2,6)\}$ , and students were asked to give the domain and range in set notation and decide if it was a function or not. Most students correctly answered that it was a function, which made me glad, but there were some recurring problems with their answers for domain and range. I had many students, perhaps as many as 2/3, give the domain and range as  $(0,2)$  and  $(2,4,6)$ , respectively. Obviously, this has all the right numbers with all the wrong notation. So first thing Thursday, I got to leave behind the supervised group work that is usually done and give a mini-talk about the necessity of being precise with mathematical language. I explained that it is something that I still get corrected on by my professors, so it is a continual learning experience for all of us, but it is important to have a standard way of talking about a set versus an interval. While the efficacy of my talk has yet to be determined, I was glad for the opportunity to leave the script behind and just talk about mathematics in a broader sense than usual for 1220.

## Description of Coding Procedure

Using highlighting and the 'comment' feature, sentences were coded for describing an MKT category as long as their response coincided with the description explained in the coding scheme. We used red for SMK instances, yellow for A-KCS, green for B-KCS, blue for KCT, and purple for KC instances. For the sentences that depicted more than one category, we used the 'comment' feature to record the additional categories. We recorded the total number of sentences coded into a worksheet for each MTA for his or her reflections, and then we totaled and recorded the number of sentences coded across all MTAs into a new worksheet.