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# Planning and Teaching for Student Learning in Mathematics: How Graduate Student Instructors Develop and Implement Instruction

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# Dedication

To my amazing family, Aaron, Bailey, and Julianna, and to the mathematics graduate students

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# Abstract

The purpose of this study was to explore undergraduate mathematics teaching from the perspective of a graduate student serving as a first-time precalculus instructor of record. A multiple case study was designed to follow three mathematics graduate student instructors (MGSIs) through one semester of teaching to understand their goals for student learning, efforts to achieve these goals, influences on planning, and to identify challenges they encountered. For each MGSI, data collection included four interviews, three observations of teaching, weekly journal entries, and written assignments from a pedagogy course. A focus group, field notes from the pedagogy course, audio from mentor meetings, and mentor interviews also informed the data analysis.

Dramaturgical coding was utilized to arrive at common themes across MGSIs related to goals for student learning and challenges. Findings indicated MGSIs aimed to prepare students for their future, develop students' reasoning, sense making and understanding of mathematics, help students develop productive dispositions, and procedural skills. MGSIs challenges related to implementing lesson plans as intended, preparing to teach, and interpreting student's course performance and preparation. Individual case studies describe each MGSIs tactics used in the classroom, perceived lesson strengths, additional objectives, and key influences. Findings illustrate MGSIs planning, identify their needs, and may be informative for mathematics departments and individuals working to support graduate students.

# Table of Contents

# Chapter 1: Context and Problem

"The status quo is unacceptable." – Saxe & Braddy

Students often learn more and retain information better when they are active participants in the instructional process (Freeman et al., 2014). Yet any effort to improve instruction must consider the perspective of those providing the instruction. Post-secondary faculty of higher education institutions are being encouraged to incorporate "active learning," which can be defined as "classroom practices that engage students in activities, such as reading, writing, discussion, or problem solving, that promotes higher-order thinking" (CBMS, 2016, para. 1), into their instruction (Saxe & Braddy, 2015). Active learning, whose core elements are student activity and engagement in the learning process (Prince, 2004) has long been advocated as a good teaching practice in undergraduate education (Chickering & Gamson, 1987).

Despite the focus on active learning as an innovate approach to improve student learning, traditionally lecture has been the dominant teaching method used in introductory science, technology, engineering, and mathematics (STEM) courses (Lutzer, Rodi, Kirkman, & Maxwell, 2005; Stains et al., 2018). For instructors to facilitate more active learning and engage students in learning, they must develop their own teaching practice and skills. How are mathematics instructors approaching these calls for change? How can they be supported in these efforts? In order to help improve instruction in undergraduate education, a foundational understanding of the instructor's perspective is needed. What are mathematics instructors seeking to do in undergraduate mathematics

courses? Does it align well with the aims of active learning? How can they be supported in making a shift to more student-centered instruction? As of a decade ago, Speer, Murphy, & Gutmann (2009) stated “virtually no research conducted on the planning, instructing, or assessing practices (and the factors that shape them) of college teachers of mathematics” exists (p.4). This study contributes to filling this research gap by studying new mathematics instructors thinking while they are planning for and teaching with active learning methods.

### Undergraduate Mathematics Instructors

Although incorporating active learning into undergraduate service courses shows promise for improving student outcomes, there is much less known about how new instructors understand or utilize active learning instructional practices. Many mathematics instructors lack training or experience with active learning, do not have time or support to modify or improve their teaching, or draw from their own experience and success in lecture-based courses (Plush & Kehrwald, 2014). Further, learning to teach is a process. As noted by Hayward, Kogan & Laursen (2016), “the process of becoming skilled with a new teaching style like IBL [inquiry-based learning] may take years, the first steps may be shifts in instructors’ choice of instructional strategies” (p.78). Thus, despite the calls for change and potential benefits to students, changing instruction is not a trivial task.

### Mathematics Graduate Student Instructors (MGSIs)

At research universities in the United States, graduate students are often involved in teaching undergraduates. Their graduate teaching assignments can place them in a variety of roles such as grading, working in a tutoring lab, facilitating discussion groups,

leading lab or recitation sessions (weekly class meetings focused on reviewing material covered in lecture rather than presenting new material), or teaching their own course. The research literature does not always clearly define or distinguish between these roles. However, different roles create different experiences for graduate students and require different skill sets. Traditionally graduate students in all these roles have been lumped under the broad category of teaching assistants, implying they are assisting in teaching in some way. For the purposes of this research, mathematics graduate students who are the instructor of record for an undergraduate mathematics course are distinguished from mathematics graduate students serving other roles. A mathematics graduate student instructor (MGSI) is a mathematics graduate student who is serving as full instructor of record for an undergraduate mathematics course, meaning they are responsible for presenting the material, assessing student learning, and assigning final course grades. A mathematics teaching assistant (MTA) may serve as an instructor of record, but this broader term includes graduate students who also work in other roles, such as grading, tutoring, or leading recitation sessions. Thus, the term MTA includes MGSIs. While MTAs can have many teaching-related responsibilities, 35% teach their own classes as instructor of record (Belnap & Allred, 2009). This can equate to 17% to 21% of mathematics courses at doctoral institutions being taught by graduate students (Blair, Kirkman, & Maxwell, 2013), which influences a significant number of undergraduate students nationally. Prior literature does not always clearly distinguish between MTAs and MGSIs.

According to Deshler, Hauk and Speer (2015), MTAs are usually familiar with lecture-based mathematics courses, typically were successful in their own undergraduate

mathematics courses and placed out of Precalculus in college. Their own learning about mathematics includes sense-making strategies, flexibility in choosing representations, and the ability to critique reasoning; thus they "have a great deal in common with the learning opportunities we would like them to create for their own undergraduate students" (p.640). Ellis (2014) found MTAs serving as calculus instructors may differ in their beliefs, instructional practices, and student success when compared to other mathematics faculty who were instructing calculus courses, meaning both tenure track/tenured faculty and other full/part time faculty in higher education. Through analyzing survey data from a national study on calculus instruction, Ellis found Calculus MGSIs who participated in the survey "believe that technology serves as a procedural aid more than a conceptual aid" and "view their students as more capable of understanding calculus" when compared to other mathematics faculty (p.612). Further, these MGSIs more frequently report having students work together in class and having students' give presentations while they report holding whole class discussions less frequently than other faculty. Additionally, MGSIs students' switch STEM intention at a higher rate and lose confidence and interest in math at higher rate compared to other faculty.

Similar to K-12 teachers, MTAs can become isolated in their teaching; however, the professional development (PD) opportunities offered to MTAs are more limited than what is often available for K-12 teachers and MTAs relationships to both the field of mathematics and their job as teachers differ from K-12 teachers (Gutmann, Murphy, & Speer, 2005). In many ways, MGSIs differ from both other mathematics faculty and K-12 teachers. However, they play an important role in undergraduate education and are worthy of study (Gutmann, Murphy, & Speer, 2005).

**Challenges of and Supports for MGSIs**

MGSIs' are often assigned to teach "students whose expertise and experience with mathematics is quite distinct from their own" (Deshler, Hauk, & Speer, 2015, p.639) and face challenges when learning to teach that include limited teaching experience, awareness of low status of teaching at a research university, difficulties getting and interpreting feedback, working with undergraduates who bring negative mathematical experiences to their classrooms, and anxiety in dealing with these challenges (Hauk et al., 2009). According to Hauk et al. (2009), MGSIs frequently need more information on becoming a good teacher and need faculty support for becoming critically reflective of their own teaching and research.

In addition, Beisiegel & Simmt (2012) found tutoring experiences and grading assignments may negatively influence graduate students' identity as teachers. Repeatedly explaining how to solve the same problems to struggling undergraduates in the tutoring lab without getting to see growth in the students understanding or being expected to correct papers on a tight timeline following strict directions, may prevent them from viewing teaching as meaningful or rewarding. Further challenges around language, communication, and understanding cultural norms may be faced by international MGSIs' (Meel, 2009). While challenges exist, many MGSIs are interested in developing and improving their teaching (Hauk et al., 2009). Unlike K-12 teachers, there is no comparative compulsory teacher training for post-secondary faculty (Gutmann, Murphy & Speer, 2005).

Training, mentoring, and course coordination are examples of ways universities have begun to respond to the need to support and prepare MGSIs' for teaching. In a case

study of successful calculus programs, offering PD for MGSIs was one common feature of all schools considered more successful with their calculus instruction (Bressoud, Mesa, & Rasmussen, 2015). Latulippe (2009) studied how MTAs view support for good teaching and found that conventional supports such has training, textbooks, observations and feedback, awards, and coordinators were only a small part of how they perceived support. Over half their reported support came from more unofficial sources that were often casual or simple gestures such as models of good teaching, sharing ideas and tips, availability of assistance, encouragement and departmental emphasis on teaching. The growth and development of MGSIs is an emerging area of research. However, there is still limited research from the MGSIs perspective available to inform such efforts.

**Significance of Study**

Over the last decade, calls for changing instruction in higher education settings have been growing. These calls have come from multiple organizations and address a need to incorporate a variety of teaching strategies into introductory college mathematics courses. Recent examples of these calls for reform come from the Conference Board of the Mathematical Sciences (CBMS), an overarching organization consisting of eighteen professional societies including the Mathematical Association of America (MAA), focused on addressing broad concerns related to mathematical science community. They called for “time and resources to ensure that effective active learning is incorporated into post-secondary mathematics classrooms” (CBMS, 2016, para. 1). White House reports such as The President’s Council of Advisors on Science and Technology (PCAST, 2012) recommended STEM faculty use approaches that engage students in “empirically validated teaching practices” or “active learning” and emphasize the critical importance

of the first two years of college for recruiting and retaining students for STEM majors as well as preparing future teachers. Saxe & Braddy (2015) summarized the recommendations as calls to “move away from the use of traditional lecture as the sole instructional delivery method in undergraduate mathematics courses” and to “seek to more actively engage students than we have in the past” (p.19).

These calls for improving undergraduate students’ learning and experiences have been grounded in research on improving student learning, which suggests active learning improves undergraduate STEM student’s exam scores and decreases failure rates (Freeman et al., 2014). This line of research began with concerns related to students pursing and completing majors in STEM and has explored causes of underrepresentation and attrition of students (Seymour, 2001). While anchored in workforce concerns around STEM majors, the teaching practices used in introductory STEM courses became a topic of interest for research and policy. Research into students’ choice of majors, students’ experiences in introductory STEM courses, and impacts of academic supports for students helped shift attention towards a larger reform effort to improve instruction in post-secondary settings (Seymour, 2001). These concerns still have merit since undergraduate students who leave STEM fields continue to identify poor teaching as a factor in their decision (Thiry et al., 2019). Instruction is important in lower-division mathematics courses as “freshman and sophomore mathematics and statistics courses function as gateways to many majors, and they are crucial for preparing mathematically – and scientifically – literate citizens” (Saxe & Braddy, 2015).

## Problem Statement

At the undergraduate level, mathematics educators want to better prepare and support post-secondary instructors in their efforts to use more student-centered teaching methods such as active learning (Saxe & Braddy, 2015; PCAST, 2012; CBMS, 2016). However, studies related to collegiate instructors teaching practices are limited (Speer, Smith & Horvath, 2010). MGSIs are tasked with providing undergraduate instruction and are commonly assigned to teach mathematics service courses, despite being students themselves and having limited teaching experiences and access to professional development. However, there is little research *from the MGSI perspective* to assist with the design of such supports, such as professional development for new instructors. This study explores how MGSIs understand their teaching and their efforts to incorporate active learning methods into their classrooms. "Ideally, research directions will be based on the needs of TAs and TA educators, and findings will inform the design of increasingly effective preparation and development programs" (Gutmann, Murphy, & Speer, 2005, p.78). Using an instructor-centered lens to understand more about the perspective of new instructors who are working to include active learning in their undergraduate mathematics service courses could be valuable for designing professional development and policies to support their development. In addition, MGSIs perspectives can provide insight into how to encourage undergraduate instruction to continue moving towards more student-centered methods.

## Study Purpose and Design

The aim of this study is to explore, from the perspective of MGSIs, how instructors are thinking about teaching by examining reasons they give for making

various decisions when planning and teaching and identifying their perceived challenges. The MGSIs in this study were second-year graduate students teaching Precalculus for the first time. Focusing on "novice" or less experienced instructors is important as universities continually use new MGSIs to provide instruction to undergraduates. Further, efforts to support these instructors through professional development often target new MGSIs, similar to K-12 efforts to support student teachers or new teachers in their induction year of teaching.

Through a qualitative multiple case study design, this study followed three MGSIs through one semester of teaching a new service course. MGSIs were interviewed at the beginning of the semester to understand their prior teaching experience and beliefs about teaching and student learning. They were asked to select three lessons throughout the semester, roughly one each month, where they planned to seek student engagement. These lessons were observed, lesson plans were collected, and the lessons were followed by a semi-structured interview that explored the MGSIs goals for student learning, planning and lesson design, and perceived challenges. At the end of the semester, MGSIs participated in a focus group seeking to gain insight into their overall perspective on teaching the course for student learning. Other forms of data included participant observations from a methods course for MGSIs, their course assignments, and interviews with their peer mentors.

Analysis of this data utilized dramaturgical coding (Saldaña, 2016) and searched for themes in MGSIs responses. Findings seek to present MGSIs perspectives on planning and teaching, helping the field understand some reasoning of new instructors of service mathematics courses with respect to student learning. Research questions and the

methodology were designed so that this study provided some insight into how to support MGSIs in their efforts to include student-centered instruction (e.g. active learning) in their courses.

## Summary

This chapter introduced the problem of promoting active learning instruction in undergraduate mathematics courses and the need to understand instructors' perspectives related to adopting and implementing effective instructional methods, which may be counter to their experiences and perceptions about mathematics instruction. This study focused on MGSIs thinking when planning and teaching and sought to begin exploring their goals, choices, and challenges with planning and teaching for student learning. Research on teacher planning begins by considering teachers thoughts about how they and their students should spend class time together (Clark & Dunn, 1991). "Reasonable people recognize that there can be no optimal solution" (p.185) but that teachers must make decisions in complex settings while dealing with limitations of life. This study adopted a qualitative methodology to seek an in-depth understanding of MGSIs perspectives.

## Definitions

Terms and definitions in this study include the following:

*Active learning* – an instructional method that engages students in learning; "classroom practices that engage students in activities, such as reading, writing, discussion, or problem-solving, that promote higher-order thinking" (CBMS, 2016, para.1)

*Curriculum design* - intentional planning for the content and skills that students should learn

*Decision making* – a choice to implement a specific action

*Design practices* - "the plans and choices instructors make before they teach and what they do after they teach to modify and revise for the future." (Abell, Braddy, Ensley, Ludwig, & Soto, 2018, p. 89)

*Goals* – broad primary outcome; "the things that people consciously or unconsciously set out to achieve" (Schoenfeld, 2011, p. 459).

*Goals for student learning* – "desired results that establish priorities for instruction and assessment" which often include a mixture of factual, conceptual, procedural, dispositional, and expert-performance based aims; what students should know, do or understand (Wiggins & McTighe, p. 58)

*Instructional activities* – "activity structures that teachers use to organize student learning" (Speer, Smith & Horvath, 2010, p. 101)

*Instructional design* – how teachers plan to create student learning

*MGSI* - mathematics graduate student instructor – a mathematics graduate student who is full instructor of record for an undergraduate mathematics course as part of their assistantship

*MTA* – mathematics teaching assistant – a mathematics graduate student who has some role in teaching undergraduates which can include teaching their own course, leading recitation, grading or tutoring

*Objectives* – smaller goal, step towards accomplishing a larger goal

*Orientations* – "an inclusive term encompassing a group of related terms such as dispositions, beliefs, values, tastes, and preferences" (Schoenfeld, 2011, p. 29)

*Planning* - "set of basic psychological processes in which a person visualizes the future, inventories means and ends, and constructs a framework to guide his or her future actions" (Clark & Peterson, 1986, p. 260)

*Resources* – teachers' knowledge, material resources, teachers' personal and interpersonal skills (Schoenfeld, 2011)

*Tactics* – an approach or tool used towards achieving a goal

*Teaching practice* – "what teachers do and think daily, in class and out, as they perform their teaching work" (Speer, Smith & Horvath, 2010, p.99)

# Chapter 2: Literature Review

“A person’s thinking is more important than the actual event, since the event happens only once, but how he thinks about it repeats again and again in his heart and mind and is shared over and over again with himself and others” – Orrin Woodward

This chapter begins with a review of the literature supporting the problem statement in the areas of undergraduate mathematics courses, post-secondary instructor thinking, and MGSI teaching. Next it provides a discussion of some theoretical perspectives informing research on teacher thinking and reviews relevant studies. Key lines of research in this section are decision-making, teacher planning, and curriculum design. Goals are an overlapping topic in all these areas; thus, the next section reviews goals for student learning in mathematics education. The chapter concludes with a discussion of the pilot study that informs the research design and the research questions for this study.

## Mathematics Service Courses

Introductory mathematics courses are required for many majors, yet students have historically struggled in courses such as Calculus (Bressoud et al., 2012) which is often considered to be a gatekeeper for the STEM fields (Ellis, Kelton & Rasmussen, 2014). First-year courses such as calculus often act like a filter instead of a pump for STEM majors (Watt et al., 2014). Introductory mathematics courses are critical for successful completion of a STEM major, yet instruction in these courses “often leave students with the impression that all STEM fields are dull and unimaginative” (PCAST, 2012). Outside

of STEM, only about fifty percent of students earn an A, B, or C in College Algebra each year (Saxe & Braddy, 2015). High failure rates in "gateway" courses delay students from completing degrees, contribute to lower graduation rates, and disproportionally impact minorities and students from disadvantaged backgrounds (Freeman, 2007).

### *Influences on Student Achievement*

Many researchers have examined factors influencing student achievement in introductory courses. A three-year multi-campus ethnographic study with over 600 hours of interviews and focus group discussions was conducted by Seymour & Hewitt (1997) to better understand elements of the undergraduate STEM experience that might be contributing to the underrepresentation and loss of able students who choose to change majors. They found that undergraduate students who switched out of STEM majors and students who persisted in their STEM major had many similarities. Their performance, motivation and study-related behaviors were not significantly different. The majority of students in both groups reported difficulties with poor teaching and with getting help with academic problems. Fewer students reported poor math and science preparation, but at similar rates between those who changed majors and those who did not. The researchers found that the decision to change majors was almost never the result of a single concern but came from the process of dealing with these challenges over time and not being able to quickly overcome them. "Paramount among these were reports of poor teaching, and difficulty in getting help with academic problems, which was mentioned by 90% of switchers and 74% of nonswitchers" (Seymour, 2001, p. 82).

To further understand undergraduate persistence in STEM majors, the Mathematical Association of America (MAA) conducted a study to examine the state of

calculus in American colleges and universities (Bressoud et al., 2015). Their findings indicate that calculus instruction and success is a nationwide problem. Results indicated that Calculus I courses cause “significant decreases in student confidence, enjoyment of mathematics and desire to continue in mathematics” (Bressoud et al., 2013, p.686). Similar to Seymour’s study of STEM majors, Bressoud et al. (2012) focused on students who enter the Calculus sequence as a STEM major but elect to switch to a non-STEM major after completing Calculus I. Defining these students as “switchers”, they noted, “switchers are putting as much effort into Calculus I, if not more, than persisters. However, switchers report having less intellectual connection with Calculus and their instructor” (Bressoud et al., 2012, para. 26). These types of findings indicate a need to improve teaching in undergraduate mathematics courses.

***Promising Next Steps***

Efforts to address “poor teaching” have included adding various active learning teaching strategies in introductory STEM courses. Many research studies have examined the effects of such strategies and overall suggest promising results. Freeman et al. (2014) conducted a meta-analysis of 225 studies that reported on undergraduate STEM course outcomes in the form of exam scores or failure rates. They defined active learning broadly stating “active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work” (Freeman et al., 2014, p. 8413-8414). Their results indicated that using active learning boosted exam scores by 6% while lecture increased failure rates by 55%. Thus, undergraduate STEM students were 1.5 times more likely to fail if enrolled in a lecture course. This result held across all

types of STEM fields and all course types and levels. While all class sizes showed a statistically significant improvement with active learning, the greatest effect occurred in classes with less than 50 students. Further, Freeman et al. found “the effect size of active learning at the undergraduate level appears greater than the effect sizes of educational innovations in the K-12 setting” (p. 8413).

One type of active learning used in mathematics education is inquiry-based learning (IBL). The key principles of IBL are students’ deep engagement with mathematics, peer to peer interactions, and instructor’s interest in and use of student thinking (Abell et al., 2018). Kogan & Laursen (2014) conducted a study on students’ course-taking patterns and grades for students enrolled in honors and upper-level mathematics courses to examine the effects of taking an inquiry mathematics course. Their study included data from over 300 hours of classroom observations and showed a clear instructional difference between classrooms using IBL and non-inquiry classes. Key differences were that students demonstrated more leadership and question asking in IBL courses and IBL courses were rated higher for “creating a supportive classroom atmosphere, eliciting student intellectual input, and providing feedback to students on their work” (p. 185). Further, IBL classes differed in the amount of time spent on student-centered instruction with about 60% of class time devoted to “activities such as small group work, student presentation of problems at the board, or whole-class discussion” while the instructor spoke in 85% of class time in non-IBL sections (p.185). Students’ course-taking patterns and grades within two years of the target course were statistically compared and results indicated modest differences. No harm was done, yet significant benefits appeared for low-achieving students.  When students with lower GPAs

participated in IBL courses, their grades in subsequent courses were higher than low-achieving students who did not enroll in IBL. Their study shows promise for using inquiry instruction in mathematics courses.

Research indicates great value in redesigning the instruction in undergraduate mathematics courses. The literature suggests students develop critical thinking skills, retain information better, and have improved attitudes toward STEM fields when active learning methods are used in their courses (PCAST, 2012). While these studies speak to the potential benefits of implementing instructional strategies in undergraduate mathematics courses, such techniques and methods are ultimately put into practice by college faculty. However, faculty and MGSIs face many potential challenges putting these techniques into practice such as expectations of content coverage, lack of time, lack of experience or training with teaching methods, departmental norms, student attitudes and resistance, class size or room layout (Henderson & Dancy, 2007; Plush & Kehrwald, 2014). Thus, the remainder of this chapter focuses on instructors' perspectives on teaching.

**Instructors Thinking**

Several studies have sought to examine how higher education faculty view these calls for more student-centered teaching methods. A national survey of abstract algebra instructors (n=129) sought to understand more about the teaching practices in advanced mathematics courses (Johnson et al., 2018). This course was selected as a best-case scenario due to limited constraints, meaning it is often taught by tenured faculty with freedom to teach as they choose in a typically small class, and wide supports in terms of available reform materials. They found 85% of respondents self-identified as lecturers yet

still report incorporating a wide range of teaching practices. The non-lecturers still used lecture, just less frequently. The authors conclude when looking at how instructors self-identify, the distinction in types of pedagogy is not clear.

Further, the most commonly cited barriers to changing methods were lack of time to redesign courses and the need to use class time to cover content. However, neither seemed to be caused by lack of departmental support. Thus "lecturers feel like they do not have the time, freedom, or supports needed to make changes. In that case, these commonly cited external constraints might actually be internalized constraints" (Johnson et al., 2018, p. 272) and appear to be more influential than departmental constraints. Results of this study indicate that instructors believe that lecture is the best way to teach. To understand how to promote greater use of reform practices, the authors argue future research can include "research into the range of instructional practices instructors would consider using, understanding what types of evidence that instructors hold as dispositive, and investigating how instructors' goals for instruction relate to the type(s) of evidence they find most persuasive" (p. 281).

In another study of faculty perspectives on teaching practices, Henderson & Dancy (2007) sought to understand the influence of dissemination efforts to use more reform physics materials. They interviewed six senior physics faculty with reputations for being reflective teachers of introductory physics. They found a "pattern of self-described practices being more traditional than self-described conceptions [which] has also been found in other studies of college faculty" (p. 6). Further, they argue "educational researchers have long been aware that conceptions are generally a poor predictor of practice" (p.10). Henderson & Dancy (2007) argue the lack of use of reform materials is

not due to instructors' traditional conceptions of teaching and learning, satisfaction with traditional instruction or lack of awareness about alternatives. Instead, faculty identified situational factors such as students' attitudes, expectations of content coverage, lack of time, departmental norms, student resistance, class size and room layouts as barriers to engaging in more reformed teaching practices.

Hora & Anderson (2012) explored norms of STEM faculty using survey (n=436) and interviews (n=56). From survey results, perceived norms for interactive teaching were weak, while interviews revealed strong evidence of a taken-for-granted norm of faculty autonomy. A unique characteristic of mathematics faculty in this study was prevalence of a fixed syllabus, textbooks, lecture notes and assessments that imposed a set of expectations on instructors that was not noticed by faculty in other STEM fields. They conclude no single policy will work for pedagogical reform and understanding institutional conditions is important to promoting instructional change among faculty.

Taken together, these studies suggest that many university faculty may be aware of and interested in incorporating student-centered instructional methods, yet many factors influence their instructional decision making. Some studies point to individual characteristics of instructors while other studies suggest departmental or institutional constraints are slowing efforts to reform teaching methods. Much of this research is still unfolding and likely varies by subject area (Speer et al., 2010). While many types of instructors work in post-secondary settings, in university settings, MGSIs are often assigned to teach service courses. This study focuses on MGSIs who are in the process of developing their teaching practices while playing an important role in undergraduate mathematics education.

## Mathematics Graduate Student Instructors

Research into collegiate teaching practice is still emerging and is at early stages of understanding MGSIs' characteristics and needs. Prior work does not consistently distinguish between MGSIs and MTAs, a term which can refer to all various teaching roles and responsibilities of graduate students. More research is needed to understand graduate students teaching experiences. As Belnap & Allred (2009) argued,

> We need a knowledge base regarding MTAs. We need to know the backgrounds of MTAs [MGSIs], the challenges they face, their instructional needs, and how they incorporate the professional development that they receive … how the MTA situation relates to the preparation of pre-service and in-service K-12 teachers (p.36).

Since then, several studies have begun to provide insight into factors influencing MGSIs teaching.

### *MGSIs Classroom Teaching*

In seeking to understand the teaching of MGSIs', it is helpful to study what they are actually doing in their classrooms. In my review of the literature, there were limited studies that examined MGSIs classroom practices. However, one possible explanation of the sparse number of studies is that research in undergraduate mathematics began in 1980's with a focus on student learning and has only recently turned towards undergraduate teaching (Gutmann, Murphy, & Speer, 2005). A few studies were found where researchers sought to study MGSIs by examining their classroom practices. For instance, Reinholz et al. (2015) focused on MGSIs ability to facilitate whole-class discussion during calculus recitations and make use of student thinking. Four MGSIs who

participated in training were observed teaching six times during a semester. While two MGSIs demonstrated changes in their teaching practice, as measured by occurrences of probing for explanations, linking student responses, students responding to one another, and student presentations, the other two showed little change in practice. The authors argue that the MGSIs who showed little change did attempt to incorporate more student-centered teaching approaches but were often ineffective when doing so. Further, interviews suggested the MGSI "has multiple goals for engaging students in such practices, which may not be consistent with one another" (p. 7). They suggested the lack of change in practice may be due to a complex mix of traditional and reform beliefs, struggles with mechanics of teaching, or being a more experienced international MGSI who easily fell into old teaching practices.

Miller (2019) provides another example of a study seeking to understand MGSIs classroom practices. She examined the decision making of six experienced MGSIs who were teaching a coordinated precalculus course, by studying the examples they chose to use and how they were presented. She identified the level of cognitive demand in the examples MGSIs used while teaching (Smith & Stein, 1998) and found about a quarter of the examples were enacted at high cognitive demand. In addition, she categorized three different roles, modeling, facilitating, and monitoring, that MGSIs took on while enacting their examples and provided detailed descriptions of their classroom teaching. While these studies described MGSIs classroom behaviors, other researchers have looked at MGSIs knowledge or beliefs.

### *MGSIs Knowledge*

Mathematical knowledge for teaching (MKT) has been studied pervasively at the elementary level. It built on Shulman (1986), whose work called attention to the role of content in teaching and established teaching as a profession whose practitioners use specialized knowledge. Ball et al. (2008) expanded Shulman's notion of pedagogical content knowledge by studying elementary teachers' practices. Their theory of MKT, built on analysis of videos of teaching practice, describes "the mathematical knowledge that teachers need to carry out their work as teachers of mathematics" (p. 4). They further categorize this knowledge into several parts: common content knowledge, specialized content knowledge, knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum. Research has shown connections between elementary teachers specialized content knowledge, the quality of instruction, and students' achievement at the elementary level (Speer, King, & Howell, 2015).

However, at the undergraduate level, there is no comparable research base. In fact, limited research exists on teaching practices at the college level (Speer et al., 2010) and it is unknown to what extent the MKT framework applies to other teachers who do not work at the elementary level. Secondary teachers have more advanced training in mathematics and college faculty have often been trained as research mathematicians (Speer et al., 2015). Thus, their knowledge of mathematics as well as the type of work they do in teaching differs from elementary teachers and there is no current "consensus in the field about the structure of secondary MKT" (p.111). Speer at al. (2015) suggest looking towards the types of mathematical knowledge used in secondary and post-

secondary classrooms such as evaluating student thinking rather than differentiating between common and specialized knowledge.

Musgrave and Carlson (2017) specifically studied MTAs meanings for average rate of change, a concept often taught in introductory mathematics courses. Their data came from 7 MTAs participants during an introductory workshop, interviews with 19 MTAs who participated in the yearlong training on Pathways Precalculus curriculum (which the authors termed the intervention) and collected written responses during the training. Results indicated that MTAs possessed a variety of meanings for average rate of change, many of which were limited in their usefulness for teaching. Shifts in meaning did occur but required “prolonged engagement” in the training that emphasized “making meaning, building coherence and communicating with precision” (p.138). However, the impact of the intervention was mixed, and some MTAs retained incorrect meanings or only slightly shifted their meanings. While it is presumed MTAs already possess strong knowledge of mathematics, the results of this study challenge the notion that PD does not need to address MTAs’ content knowledge. Their results support the arguments of Shulman (1986) and Ball et al. (2008) about the importance of content knowledge for teaching.

While not the focus of the study, the authors further noted that while MTAs spoke of new ways of thinking about mathematical ideas these “did not necessarily translate to what the participants had as goals for their student’s learning” (Musgrave & Carlson, 2017, p.148). There appeared to be some tension between their experiences as students and how the training asked them to teach. Further, MTAs with more experience and responsibility with the training more frequently mentioned “wanting students to develop

a more coherent view of mathematics" and valuing understanding student thinking (p.148).

### *MGSIs Beliefs about Teaching and Learning*

Another critical factor in understanding MGSIs practices may be their beliefs. Research in K-12 has indicated connections between teaching practices and teacher's beliefs about mathematics, teaching, learning, and students (Speer, 2008; DeFranco & McGivney-Burelle, 2001). My literature review found a few studies that approach understanding the needs of MGSIs or the influence of PD through a lens of teacher beliefs.

Gutmann (2009) interviewed seven domestic MTAs who were just beginning graduate school to examine their beliefs about the nature of mathematics and its accessibility for undergraduates. While all took different paths to graduate school, they all shared a love of mathematics and reflected on supportive but demanding role models in their own lives. He argued these factors could influence MTAs teaching in that they may have trouble empathizing with undergraduate struggles with mathematics or question their own ability to help "lower level" students succeed. In addition, their role models may influence how MTAs envision good teaching.

Other studies included MGSIs classroom practices together with teacher beliefs. DeFranco and McGiveny-Burelle (2001) conducted a study using interviews, journal entries, questionnaires, and classroom observations from 22 MTA's who were enrolled in a pedagogy course consisting of five seminars spread over a single semester. MTAs' entering beliefs were based on their own experiences as students. At the beginning of the seminar, MTAs believed effective teaching meant "giving knowledge to students" and

that students learned mathematics by “solving problems on their own” (p.685). These beliefs about teaching and learning were consistent with their described classroom practices, which used a teacher-centered approach with little classroom discussion. By the end of the seminar course, MTAs became more reflective, more willing to take risks, and differentiated between teaching and telling. DeFranco & McGivney-Burelle argue MTAs beliefs changed as they now described the goal of teaching as promoting understanding of material rather than covering material so students could memorize information. This teaching goal is related to how to promote learning; but it does not identify what desired skills, ways of thinking or understandings students should acquire through instruction.

However, despite the change in beliefs, MTAs classroom practices remained teacher-directed and included little student interaction. DeFranco and McGiveny-Burelle (2001) suggest this was because “the newly acquired beliefs adopted by the TAs [MTAs] were peripheral and held in conflict to their core beliefs about the teaching and learning of mathematics” (p.687). MTAs new belief that students need to actively construct knowledge was easier to change since it was a peripheral belief while their beliefs about the role of the teacher in the classroom were core beliefs, thus more resistant to change. Personal backgrounds of the MTAs and cultural norms of the department and university were also suggested as factors contributing to the lack of change.

Speer (2008) conducted an in-depth analysis of one MTAs practices in a calculus recitation designed to have students work on challenging problems in groups while the MTA facilitates. Concluding that clusters of beliefs were needed to understand influences of beliefs on the moment-to-moment decision making of Zachary, the MTA, Speer

demonstrated how Zachary consistently used certain beliefs as justification for his decisions. She called one key collection of his beliefs "criteria for evidence of student understanding" which influenced the frequency and types of questions he asked. For instance, as he did not believe simply producing a correct solution meant students understood the problem; he would still discuss many features of a correctly worked problem with students. The other cluster of beliefs she termed "learning and how it happens" which shaped how Zachary provided support and guidance during problem solving. As he believed learning meant making something your own, he wanted his students to make connections for themselves. She argues this level of understanding is needed to connect teachers' beliefs to their actual classroom practices.

### ***Feelings about Preparation***

Other data about MGSIs perceptions of their preparation for teaching suggests they may feel somewhat unprepared for aspects of teaching. In Hauk et al. (2009) group narrative inquiry journal entries expressed MTAs questions and conflicts related to their teaching. They asked, what is good teaching? What is student engagement? How do I deal with it when I get it? Further they expressed a desire to not be a bad teacher but acknowledged dealing with concerns about time management both in and outside the classroom. A survey of over 200 MTAs about their readiness to implement instructional techniques showed the vast majority of MTAs felt well prepared to give lectures, nearly 75% felt prepared to respond effectively to different ways students learn, yet only around half felt prepared to foster participation and engagement among students traditionally underrepresented in mathematics (Deshler, Hauk, & Speer, 2015). Effective GTAs in all fields must "master a rather daunting range of relevant competencies" including coping

with stress, setting realistic goals and priorities for themselves and undergraduate students, facilitating class discussions, and knowing how to measure and evaluate student progress (Park, 2004, p.350). Professional development can be utilized to help prepare GTAs for teaching.

***Professional Development for GSIs***

In a national survey conducted by Belnap & Allred (2009), they found the PD offered to TAs varied widely. They described two types of PD utilized by universities. One type, termed initial programs, included both those that provided only training at orientation and transitional programs which extend up to a full semester into teaching. Recurring programs, the second type of PD, include repeated opportunities for PD and can serve a variety of goals which can include developing awareness of different teaching and learning strategies and hands-on teaching practice. Overall, they concluded "departments are aware of the need to provide professional development for GMTAs [graduate MTAs] and are making efforts to support them" (p.29). Teacher PD is more effective when it includes an intensive initial experience and continues over time while including at least two of the following components: examining student thinking and work, learning teams or networks, cycles of plan-implement-assess-reflect, developing assessment, or mentoring (Deshler, Hauk, & Speer, 2015).

In a review of the literature on North America's use of GTAs across all content areas, Park (2004) noted GTA training programs work from the assumption that "teaching can be learned, practiced, and continually improved" (p.351). He summarizes literature that argues GTAs early graduate experiences are important for influencing their teaching skills, behaviors, attitudes, and job satisfaction. According to Park, efforts to

provide quality PD often include observations of teaching, active learning or constructivist learning strategies, formative evaluation, summative assessments, and strategies to create social or peer interactions. While there is no one-size-fits-all model, most training includes "generic teaching skills" (p.351). One difficulty of designing PD for GTAs is the "somewhat ambiguous niche" filled by GTAs as they are "serving as teachers and students, employees and apprentices" with PD hoping to assist GTAs with both their current and future needs (p.355).

***Instructor Summary***

The studies reviewed provide a beginning research base of how MGSIs understand and approach teaching. Speer, Smith & Horvath (2010) draw attention to the need to study the work of collegiate mathematics teaching, particularly research around what they call teaching practice. They conceptualize teaching practice as "what teachers do and think daily, in class and out" (p.99) and which "concerns teachers' thinking, judgments, and decision-making as they prepare for and teach their class sessions, each involving one or more instructional activities" (p.101). This includes planning, thinking and decision-making during lessons, and reflections on or evaluations of teaching. Studies of undergraduate teaching, including MGSIs teaching, can build on studies from K-12 in areas such as "how teachers learn to teach, how characteristics of teachers and their practices shape student learning, how culture and context shape everything, and how curriculum and methods are understood, adopted, and enacted" (Speer, Murphy, & Gutmann, 2009, p.8). Instructors' decision-making about teaching methods is an important area to research; yet there is limited literature in this area, particularly at the level of higher education. Stahnke et al. (2016) conducted a review of empirical research

in mathematics education related to teachers' perceptions, interpretations and decision-making and found 60 articles. Of these, 53.3% researched decision-making and only three were conducted in higher education. In order to explore how MGSIs think about their classroom instruction at the collegiate level, I draw upon primary and secondary mathematics education literature related to teacher thinking.

**Theoretical Perspectives on Teacher Thinking**

As the literature above suggests, teachers' practice is shaped by their knowledge, beliefs, the curriculum, as well as social and contextual factors (Speer, 2008). Much of the research on teacher planning was conducted during the 1970s through 1990s, during which studying teachers' mental processes became the focus in the 1980s (Kang, 2017).

As explained by Clark and Peterson (1986), the first attempt to describe the "mental constructs and processes that underlie teacher behavior" (p.255) was made by Jackson's (1968) book *Life in Classrooms*. Jackson distinguished between three phases of teaching: preactive, interactive, and postactive. The preactive phase occurs before teaching and is often thought of as planning. The interactive phase consists of the time spent in the classroom with students and the postactive phase includes the teacher's reflective thinking after the class. Clark and Peterson note the "kind of thinking that teachers do during interactive teaching does appear to be qualitatively different from the kind of thinking they do when they are not interacting with students" (1986, p.258). However, the distinction between preactive and postactive thinking was not retained in research. Recognizing teaching as a cyclical process, where teachers' experiences one day may influence planning for the next class, the separation of preactive and postactive thinking is not clear and is often combined under studies of planning. More recently, the

Instructional Practices Guide from the MAA defines design practices as "the plans and choices instructors make before they teach and what they do after they teach to modify and revise for the future" (Abell et al., 2018, p.89). While using the terminology of instructors as designers rather than planners, this recent definition reiterates Clark and Peterson's (1986) point that teachers' thinking during the preactive and postactive phases of teaching can be combined.

Clark and Peterson (1986) used a circular model to conceptualize teachers' thought processes in a way that reflected researchers' conceptions of teacher thinking at that time. Teachers planning (preactive and postactive thoughts), teachers' interactive thoughts and decisions, and teachers' personal theories and beliefs all influence one another. Unlike behaviors, these are not observable features of teachers and require different methods of data collection to understand. However, they urge researchers to consider both teachers thinking and behavior together, as they are also linked in the model.

This study with teachers, who in this case were MGSIs, sought greater understanding about how teachers' thinking related to their classroom behavior by trying to understand the reasons they gave for their classroom behavior. The study includes data from both their teaching (interactive thoughts and decisions) and planning (preactive and postactive thoughts) as well as classroom observations. The next section reviews theories and studies on teachers' interactive thinking, often framed as decision making, and then moves into teachers' planning.

**Teachers' Interactive Thinking as Decision Making**

Many mathematics education researchers agreed on a "definition of an interactive decision as a deliberate choice to implement a specific action" and studies of interactive teaching indicated that teachers make an interactive decision every two minutes (Clark & Peterson, 1986, p.274). The goal of this line of research is to model the decision making of teachers. While many models have been proposed over the years, a more recent goal-oriented decision-making theory informs the design of this study. Described in Schoenfeld's (2011a) book *How We Think*, this theory follows in the line of cognitive-information-processing theories and was developed through studying teaching and learning.

The three components in Schoenfeld's (2011a) model are resources (R), orientations (O) and goals (G). Resources include teachers' knowledge, material resources, and the teachers' personal and interpersonal skills (Schoenfeld, 2011b). Schoenfeld defines knowledge as "the information that he or she has potentially available to bear in order to solve problems, achieve goals, or perform other such tasks. Note that according to this definition, a person's knowledge is not necessarily correct!" (Schoenfeld, 2011a, p.25). Examples of teachers' resources used in Schoenfeld's analysis include teaching routines such as a questioning method of initiation-response-evaluation or knowledge of ways students are likely to understand or struggle with course material.

Orientations are "an inclusive term encompassing a group of related terms such as dispositions, beliefs, values, tastes, and preferences" (Schoenfeld, 2011a, p.29). This can include teachers' beliefs about mathematics, what mathematics students should learn, about teaching, about students, and how students learn. For example, believing that the

teacher is allowed to clarify or expand on student comments but not inject new material was an orientation discussed by Schoenfeld. In his study, this belief caused a student teacher to feel like he was out of options when his students did not provide the anticipated responses.

Orientations help shape goals, which "are the things that people consciously or unconsciously set out to achieve" and individuals' will select resources that help them accomplish their goals (Schoenfeld, 2011b, p.459). Teachers often have different levels of goals operating at the same time. Their goals can be overarching broad content or social goals, for example help students understand where algebraic notation and procedures come from, or they can be specific to a lesson or problem. These three components are deeply intertwined in understanding teacher decision making.

The main theoretical claim of Schoenfeld's book is that "people's decision making in well-practiced, knowledge-intensive domains can be fully characterized as a function of their orientations, resources, and goals" (Schoenfeld, 2011a, p.182). This theory posits meaning orientations shape what an individual sees as relevant and what resources they need to achieve a goal. As the individual implements the routine, either it will work as expected or a decision will be made on how to proceed based on evaluation of possible outcomes. The theory allows analysis of all sizes of decisions from macro, (e.g., organization of an agenda), to micro (e.g., analyzing individual actions or words). According to Schoenfeld (2011a), "the notion of orientation/resource/goal clusters is a lens through which teacher activity can be examined – and studies of coherence and change along these dimensions could be very interesting and useful" (p.194). While Schoenfeld often uses his model to explain teachers' in-the-moment decision making, I

believe it should also be useful for teacher planning. During planning (preactive and postactive phases of teaching), teachers have time to analytically select and consider goals and instructional methods; thus, they are still engaging in decision-making.

***Expert vs. Novice Decision Making***

Some studies of teachers' decision making have contrasted differences between expert and novice teachers. For instance, a study of five elementary student teachers (novices) and their cooperating teachers (experts) revealed differences in the ways these teachers integrated their knowledge, responded to student behavior, and differences in how they made decisions during the three phases of teaching (preactive, interactive, and postactive) interacted (Westerman, 1991). The expert teachers thought about learning sequentially and could use the curriculum as a foundation on which they adapted to meet their own goals. During teaching, experts could integrate current topics with students' prior knowledge, clarify connections, use formative assessment, summarize key points, and use a variety of classroom management techniques to respond to student behaviors. Their decision making during all three phases of teaching was highly connected. They used information about the curriculum, subject matter and student interest to arrive at lesson goals. Their interactive teaching was "driven by the goals they formulated during planning" and they evaluated their lessons in terms of how well they achieved their goals (Westerman, 1991, p.298). Further, expert teachers were able to flexibly move towards their goals as they modified preactive decisions to respond to students during interactive teaching while still moving towards overall lesson goals.

In contrast, novice teachers in this study lacked information about the overall curriculum and student characteristics. They relied more heavily on prescribed

curriculum objectives and used them more literally. Their decision making involved a linear process; they planned, then taught, and then evaluated the lesson based on how well they achieved the given objectives and how well the students behaved. Interestingly, learning objectives shaped the interactive decision making of both experts and novices. The ability to see learning from the students' perspective "was a hallmark of expert teachers' decision making in both planning and teaching" (Westerman, 1991, p.302) while "tailoring lesson plans to accommodate student needs is what many novices cannot do" (p.300).

This finding is similar to results from another study that in the United Kingdom that followed 36 secondary English, math, and science teachers through student teaching and the first two years of classroom teaching. Using data from that study, Mutton et al. (2011) studied the learning of 17 of the teachers. They found that during student teaching, beginning teachers stuck tightly to their lesson plans or "scripts." The researchers described how the teachers were still learning to plan during their first years of classroom teaching meaning they were "developing [an] understanding of the relationship between the pre-active and the interactive phases of teaching… [as they] came to realize (sic) that planning was the anticipation of what might happen rather than the determination of what would happen" (p.408). Thus, the role of their plan evolved from a "script" to a more flexible plan that could respond to student needs. The researchers suggest due to limited experiences, beginning teachers are "much more dependent than experienced teachers on detailed planning, both in terms of a decision-making process (determining what to do in the lesson), and as a form of rehearsal (playing through sections of the lesson in their

mind)" (p.261). No studies were found that directly examined how MGSIs planning relates to their interactive teaching.

***Studies of Mathematics Teacher's Interactive Thinking***

Decision making has been used to describe teachers thinking during the interactive phase of teaching. Some studies have examined the interactive thinking of mathematics teachers, highlighting the multiple goals and values that instructors often simultaneously possess. Thomas and Yoon (2014) studied Adam, a secondary mathematics teacher in his second year of teaching who despite believing that student-centered teaching approaches were effective, choose to engage in teacher-centered approaches during a calculus lesson. Their analysis used Schoenfeld's (2011a) framework of resources, orientations, and goals (ROG), to illuminate the conflict between a teachers' beliefs and practice. Adam experienced conflict between his goals of wanting to use student-centered learning as much as possible and wanting to prepare students for success in future tasks. The conflict was caused by constraints of time, his concerns about covering all the curriculum so students would be prepared for final assessments, as well as a desire to respect cultural differences. These factors ultimately led Adam to choose teacher-led demonstrations over student discussion.

Paterson et al. (2011) analyzed segments of two mathematicians' lectures. Also using the ROG framework (Schoenfeld, 2011a), they identified multiple goals and orientations that simultaneously influence an instructor's thinking, which in their examples led to internal conflict between a mathematician and a teacher. They described how an instructor can "contain competing goals each inspired by a teacher's various orientations (and) suggest that, unlike most schoolteachers, lecturers are both research

mathematicians and teachers bringing differing, at times conflicting, orientations into play" (p.986).

Zimmerman (2015) sought to understand the goals and concerns, or practical intentions, of six middle or high school algebra student teachers while they were teaching a lesson. He had them watch a recording of their teaching and stop it to discuss their thoughts, feelings, and intentions during the lesson. His analysis identified four types of practical intentions. The two teacher-centered intentions were maintaining lesson momentum and achieving lesson objectives and academic goals while the two student-centered intentions were supporting student needs and affective goals and fostering independent thinking. Zimmerman found that practical intentions overlapped and both teacher and student-centered intentions occurred simultaneously over 70% of the time. Thus, beginning teachers are frequently dealing with potentially conflicting interests during their interactive teaching. The next section turns to studies more focused on teachers' thinking when they are not interacting with students, which is during planning.

**Teachers' Planning**

Teachers' planning is "challenging to study because it is both a psychological process and a practical activity" and these two conceptions of planning are both frequently used in research studies about planning (Clark & Peterson, 1986, p.260). Differences in how researchers approach planning has led to a wide range of what study results report and discuss. Clark and Peterson (1986) define the two major conceptions of teachers' planning as either a "set of basic psychological processes in which a person visualizes the future, inventories means and ends, and constructs a framework to guide his or her future actions" which draws from cognitive psychology or "the things that

teachers do when they say that they are planning" (p.260). In this study, the first conception of planning as mentally visualizing the future will be used.

### *MGSIs Planning*

Two studies were found that examined elements of MGSIs planning practices. The first study adopts Clark and Peterson's (1986) second notion of planning as what teachers do when they say they are planning. Noting that MTAs do not always directly follow provided lesson plans, Winter et al. (2009) studied the planning procedures and resources used by seven MTAs. All MTAs were teaching precalculus in a setting with a common syllabus, common exam, were provided ready-made lesson plans, and had participated in PD. Results of the study found while "all MTAs consulted the suggested lesson plans … very rarely were these plans literally followed" (p.107). While planning, MTAs often consulted other resources, worked out the problems to ensure their own understanding of the content and to assist with time management planning, modified the provided explanations, wrote out their own lesson notes, outlines or annotations on the provided plans, and adjusted the provided schedule to meet the needs of their class. All MTAs consulted the provided plans and textbook as resources, yet only three drew upon their own knowledge or experiences as learners when planning. Time management and specifying learning objectives were rarely focuses of these MTAs planning.

Yee et al. (2016) studied two groups of MGSIs who participated in a lesson study project over a two-week period. The MGSIs planned a lesson together, then implemented, revised, retaught, and reflected on the lesson. In creating their lesson, MGSIs had to select measurable goals for the lesson and reflect on how they knew their goals had been met. Both groups chose to utilize active learning in the form of group

work during their lessons. The analysis focused on revisions that MGSIs made to their goals and tasks after they had the opportunity to observe student work. The researchers found evidence of each group engaging in mathematical teaching practices advocated by the National Council of Teachers of Mathematics (NCTM). Practices used consistently throughout both lessons were establishing mathematical goals to focus learning, implementing tasks that promote reasoning and problem solving, and eliciting student thinking. While both groups revised their lesson plans based on the first teaching episode, their revisions focused on modifying tasks, adding examples or adjusting the pacing of the lesson. Both groups maintained their goals and general activity structure of the lessons.

### *Teachers' Planning Decisions*

While several studies reviewed above address aspects of teachers' planning, this section discusses further findings from studies of secondary teachers and post-secondary faculty planning that highlight the role goals play in teachers' planning. A study in the United Kingdom followed 36 secondary English, math, and science teachers through student teaching and the first two years of classroom teaching. Using data from that study, Burn et al. (2000) focused on two post-lesson interviews with 27 of those secondary teachers seeking to understand how inexperienced teachers made sense of their practice. They studied the reasons, or "aims," given by student teachers for decisions made both before and during lessons as well as the teacher's reflections of the lesson in terms of their evaluations or assessments and described the focus of teachers' concerns about the lesson which they termed "factors."

The “most striking finding is the seriousness with which they [student teachers] appeared to regard pupil learning. Across both sets of interviews, those [codes] concerned with pupil achievement accounted for 57% of statements” (Burn et al., 2000, p.266). The researchers coded 790 statements related to aims and found the majority of the teachers (n=23) discussed aims related to student achievement. Their aims for pupil outcomes included cognitive processes, such as understanding or acquiring a concept, developing learning strategies or practicing skills, as well as aims related to covering content or creating a product such as a poster or notes. The next most common aims mentioned by 21 teachers related to aims for students’ affective states such as enthusiasm, interest or confidence. However, these made up only about 20% of the statements. Other much less common types of aims were related to pupil action meaning general behavior or instructions, assessing prior pupil knowledge, self-learning, ingredients of what makes a good lesson, and other aims. Interestingly, 86% “referred to aims formulated some time before the lesson as part of the planning process” (p.264). They noted some evidence of interactive thinking such as emphases added but overall, the teachers “did not decide what they wanted to achieve as the lesson developed. They had planned the lesson in advance and remained essentially dependent on that plan” (p.264).

Analysis of the 1675 references to factors teachers considered again reinforced the importance of the teachers’ preactive decision making, as 69% of the factors were mentioned as part of pre-lesson planning. The takeaway from these findings was the surprising wide range of factors the teachers considered. Factors included pupils, content, phase in series, time available, curricular/exam, student teacher, resources, phase in lesson, teacher conditions, material conditions, time, routines, and other. On average,

each teacher considered over eight factors when planning a lesson. Finally, all teachers' evaluations of the lessons included some reflection on what they themselves had done as well as their students. Overall, they found the teachers were "more likely to regard pupil outcomes in a positive light, and to take a more critical view of their own actions and planning" although they generally discussed a balanced perspective (Burn et al., 2000, p.274).

Kang (2017) studied the planning practices and quality of instructional tasks used by eight secondary science student teachers. She interviewed the preservice secondary science student teachers (PST) to understand how they designed instructional tasks, as well as their mentor teachers and university methods course instructors to understand the interactions between the educators. Studying patterns in the cognitive level of demand used in their introductory tasks, Kang categorized the PSTs into two groups. The disciplinary practice group progressed to using high cognitive demand tasks while the content group consistently used low cognitive demand tasks focused on either content or process. Most PSTs had multiple goals in mind when designing tasks and she noted differences in the resources used by the two groups and how they adapted the curriculum. Moreover, the pedagogical reasoning of the two groups differed in terms of their instructional goals, lesson scenarios, and framing of problems.

The disciplinary practice group framed their goals broadly and their goals included disciplinary practices and thinking skills in addition to specific content goals. When designing tasks, this group considered big ideas and students' thinking. Finally, while both groups mentioned challenges with students' willingness and ability to engage in the lessons, the disciplinary practice group worked to build scaffolds into their lessons

to overcome these challenges. In contrast, the content group, as their name implies, focused their goals on specific content. They tended to follow traditional science storylines or given ordering of curriculum topics rather than student thinking when constructing lessons and attributed challenges with students to a lack of willingness or ability on the part of the student.

Kang (2017) notes, “consistencies and changes observed in the PSTs trajectories suggest that framing instructional goals is a dynamic, responsive, and contentious process shaped by their social and professional interactions in contexts” (p.65). She suggests PSTs who view science as either content or process may similarly frame their goals as “either a piece of content or process in a lesson” (Kang, 2017, p.65) and argues that professional development should support PSTs in planning for big ideas and including disciplinary practices into their goals for instruction.

Another study examined the beliefs and values of introductory physics faculty to better understand dissemination efforts of reform physics materials. Yerushalmi et al. (2010) conducted an artifact-based structured interview with 30 physics faculty from a variety of institutions of higher education. Instructors were given five variations of a problem and asked to make judgments about the problems features and discuss how the problems related to ones used by the instructors in their classes. The analysis described valued problem features, instructor’s goals, and the extent to which features were used in classes. Instructors described two types of goals: one type related to student learning and the other to their own teaching. The two most common learning goals were for students to develop an understanding of physics and to develop the ability to plan and explore solution paths. Teaching goals related to motiving students, monitoring student thinking,

and leading or not leading students through a problem. There was considerable disagreement around this last goal as to whether or not instructors should lead students through a problem solution.

Results of this study indicated “instructors will use problem features that run counter to their instructional goals” (Yerushalmi et al., 2010, p.8). This included omitting problem features they value and using “features they believe hinder the achievement of their own goals” such as breaking a problem into parts (p.10). Over half the reasons given for this decision related to exam situations where instructors wanted to avoid stressful situations for students; thus, they avoided the use of novel problems even though doing so conflicts with their goals. In addition to reducing student stress, instructors also recognized the need for clarity, and both concerns were related to fairness of exams. Yerushalmi et al. recommend efforts to change instructors’ practice address conflicts between learning and teaching goals in addition to instructors’ values of reducing stress and clarity of presentation.

Another faculty interview study examined the goals, approaches to teaching, perspective of the course, and reflections on challenges and successes of 10 instructors of mathematics content courses for preservice elementary teachers (PST). The instructors’ struggled with balancing wanting to improve PSTs mathematical proficiency and content knowledge while also addressing teacher beliefs and attitudes towards mathematics. This led to an analysis of the “tension related to instructor’ efforts to balance their affective and cognitive goals for their students” (Oesterle, 2012, p.660). The results described three instructors who each managed this tension by “staying true to the course syllabus and covering the material” (p.665). One hoped to improve affect by developing stronger

cognitive skills, another saw students' low affect as a barrier to them achieving cognitive aims, while the last emphasized affect but acknowledged her students may not be prepared for teaching. While this study primarily concerns PST preparation, it also highlights how conflicting goals present challenges for collegiate faculty.

Taken together, the studies reviewed here suggest that teachers' goals are an important aspect of their planning. Goals are also recognized as centrally important in instructional design. Abell et al. (2018) conceptualize design practices as "thoughtful planning" (p.89) involving both assessment and classroom practices. Essentially a design is a plan; studying planning and design work are two closely related concepts. Research in curriculum design assumes that curriculum materials can "serve as facilitators of pedagogical reform; that is, that could influence *how* teachers teach" (Remillard, Reinke, & Kapoor, 2019, p.101). Thus, researchers in this area also pursue questions about how teachers plan, yet with a focus on teachers' curriculum use. In addition to decision-making theory, a theory of curriculum design will also be used to inform this study. Theory and studies on curriculum design will be reviewed next.

**Curriculum Design**

According to the Merriam-Webster dictionary (n.d), the verb design means "to conceive and plan out in the mind" or "to have as a purpose". The Oxford English dictionary (n.d) defines design as "to have purposes and intentions; to plan and execute." Thus, designing involves purposeful decision-making. Curriculum "refers to the specific blueprint for learning that is derived from desired results" (Wiggins & McTighe, 2005, p.5). Curriculum design involves intentional planning for the content and skills that students should learn. Various models of curriculum design exist. Following

recommendations by Abell et al. (2018), this study draws on the theory of backwards design as explained by Wiggins and McTighe, who assert, “teachers are designers. An essential act of our profession is the crafting of curriculum and learning experiences to meet specified purposes” (p.13). Similarly, teachers could also be called instructional designers as they are designing instruction for students.

Wiggins and McTighe (2005) model of backwards design includes three components that must be in alignment: identifying desired results, determining acceptable evidence, and planning learning experiences and instruction. The authors acknowledge that design work is messy and iterative, thus it does not necessarily follow the linear steps described below. What matters is the logic and coherence of the final design. Anderson (2005) argues that curricular alignment, the relationship between objectives, assessment, and instruction, is important to understanding the effects of instruction on student learning and is essential to educational accountability efforts.

In step 1, identify desired results, Wiggins and McTighe (2005) prompt instructional designers to establish goals by considering big ideas for students to understand, essential questions to ask students to consider, and knowledge and skills students should learn. By establish goals, they mean “formal, long-term goals, such as state content standards, district program goals, departmental objectives, and exit-level outcomes… [which] typically refer to a complex mixture of academic aims: factual, conceptual, procedural, dispositional, and expert-performance-based” (p.58). Next designers should consider what evidence, such as performance tasks or traditional assessments, will allow students to demonstrate achievement and understanding. Finally in step 3, designers select the experiences and instruction that will enable students to

achieve the desired results. In this model, “the specifics of instructional planning – choices about teaching methods, sequence of lessons, and resource materials – can be successfully completed only after we identify desired results and assessments and consider what they imply. Teaching is a means to an end” (p.19). Consistent with Anderson’s arguments (2005), an important conclusion from this model is that

> different types of aims require different instructional and assessment approaches. How people develop and deepen their understanding of an abstract concept differs fundamentally from how they become proficient in a skill. Similarly, students do not learn factual information in the same way they acquire habits of mind and control of big ideas over time; understandings have to be inferred from well-designed and well-facilitated experiences, whereas a good deal of knowledge can be learned from readings or lectures. The distinctions in the template remind the designer that different pedagogies are called for as the logical consequences of the aims, not because of some ideological assumptions about “good teaching” (p.60).

Thus various teaching methods should align with various objectives.

Weak educational design involves two kinds of purposelessness, which Wiggins and McTighe (2005) call the “twin sins” of traditional design. Activity-oriented design occurs when designers think their job is only to engage learners. Rather than recognizing learning comes from considering the meaning of the activity, they see the activity itself as learning and may only accidently lead to insight or achievement. The second design problem, generally more common in secondary and collegiate settings, can be called “coverage” or “teaching by mentioning it” (p.21). In this context, teachers aim to move

through all the material and check off the content but in a way that suggests no overarching goals.

***Studies on Elementary Teachers Curriculum Use***

Following the assumption that teachers are curriculum designers, Davis et al. (2011) studied two elementary teachers decision making as they adapted reform science curricular materials. This study was unique in that the two teachers were part of a project where they would write narratives to be included in textbooks with the intent of helping guide other elementary teachers in adapting materials. The study framed the basis for curricular adaptions of these teachers in three categories: knowledge and beliefs, experiences, and resources. One teacher's modifications centered on attending to students and her changes were in line with the intentions of the curriculum developers. However, the other teacher's changes were harder to describe. She had goals of helping students learn organization while wanting them to develop creativity. While still emphasizing important content and including some inquiry practices, her adaptions dismissed some curricular resources that offered different opportunities for student learning because "her learning goals, which, in addition to being in tension with one another, were not well-matched with those" in the materials (p.807). This study provides more evidence "that teachers' learning goals and their knowledge of their students play important roles in influencing how a teacher adapts curriculum materials" (p.807).

Another study provided similar findings when examining the selection and enactment of mathematics textbook problems by three elementary school teachers (Son & Kim, 2015). They found variation in how teachers enacted the problems and in the associated cognitive demand of the tasks. They identified the critical issues of how

teachers' chose their adaptions to be related to the match (or mismatch) between teachers' beliefs and goals of the textbook, teachers' views of the textbook, interpretation of state curricular framework and assessment, and teachers' knowledge and orientation toward student thinking.

Seeking to understand how curriculum can be better written so that teachers can guide students towards the mathematical point of a lesson, Remillard et al. (2019) studied eight elementary teachers' use of four different curriculums. They follow a framework that views the teacher as the critical agent who enacts written curriculum through a process influenced by personal, curricular and contextual factors. This study found variation in the elementary school curriculum materials as to what counted as a mathematical learning goal, the number of goals used, and "how goals are articulated and connected to instructional activities" (p.106). In the curriculum materials, learning goals were called a variety of terms including objectives, focus points, and key concepts and skills. Learning goals also included both understandings and skills. Goals varied in both scope and specificity. The most common way to orient instructional activities towards goals was linking, meaning connecting goals and tasks by "restating or paraphrasing the goal" (p.105). Teachers in this study typically steered towards two or three goals per lesson and followed a "pattern of steering toward a subset of the many goals identified by the curriculum authors" (p.113). The variety of terms used to describe learning goals illustrates the challenges with studying a seemingly important yet not well-defined term.

The studies of elementary teachers' use of curriculum and theory of backwards design speak to the significance of learning goals in teachers' practice. The theory of backwards design is important to consider considering the earlier discussion in the

problem statement about the use of active learning in undergraduate courses. Teaching is more than just methods, and the methods used in a course should align with goals and assessments used in the course. Theoretically, learning will be most effective when these three elements are in alignment. Thus, to consider how to facilitate instructors' use of student-centered teaching practices, the instructors' goals and their association with various instructional activities should also be considered. This thinking is acknowledged by Abell et al. (2018) as they state, "key aspects of course and lesson design are identifying goals for student learning, selecting instructional strategies to achieve those goals, and choosing methods to assess student learning" (p.89).

**Goals for Student Learning**

Goals and objectives have been discussed and debated throughout the history of curriculum theory. Even Wiggins and McTighe (2005) acknowledge the theory of backwards design has its roots in theorists from the 1950's and 60's such as Ralph Tyler, who advocated that educational objectives were essential to curriculum planning. As reviewed in Flinders and Thornton (2013), Tyler was a leader in adopting a rational approach to the study of schooling. He argued for considering four fundamental questions when developing curriculum and plans for instruction. The first was: What educational purposes should the school seek to attain? (as cited in Flinders & Thornton, 2013, p.59). His other questions built on these aims by asking what educational experiences further these purposes, and how should educational experiences be organized and evaluated to achieve these purposes? Tyler placed education purposes at the center of efforts to improve education stating, "All aspects of the educational program are really means to accomplish basic educational purposes. Hence, if we are to study an educational program

systematically and intelligently, we must first be sure as to the educational objectives aimed at" (as cited in Flinders & Thornton, 2013, p.60).

W. James Popham emphasized the need for measurable learning objectives for purposes of effective instruction and evaluation. However, he acknowledges for instructional purposes, some goals may currently be non-measurable but still worth pursuing. He urged evaluators to be aware that a reasonable proportion of time and effort will go to important objectives that cannot be assessed. Other important efforts to assist in assessing objectives during this time came from the work of Benjamin Bloom and David Krathwohl who created taxonomies or classification schemes for cognitive and affective goals.

A few theorists such as Elliot Eisner questioned whether objectives could really be specified in advance of teaching and cautioned "educational objectives clearly and specifically stated can hamper as well as help the ends of instruction" (as cited in Flinders & Thornton, 2013, p.109). He argued teaching is also an art and not all objectives are known in advance but may emerge in the complex process of teaching. Further, they need not be known before organizing and selecting content or student activities. This perspective was acknowledged by Wiggins and McTighe (2005) as they advocated not for the linear completion of their three steps of design but rather for the congruence of the three constructs of goals, evidence, and learning experiences. Eisner claims the outcomes of teaching are too many to be specified and that not all goals are measurable. His critique of the rational approach to school reform efforts acknowledges the role that specifying intended outcomes has taken in holding teachers accountable for achieving

these results. He cautions holding strictly to this approach can send the wrong message to students by overvaluing test scores and hiding deeper problems in schooling.

The role of objectives, purposes, or goals in education is extensively debated in theory and still influential in policy and practice. In research, “teachers’ learning goals have typically been included under a broad umbrella describing teacher’s beliefs about teaching her or his subject matter, and those beliefs are also identified as central influences on curricular adaptions” (Davis et al., 2011, p.807). Several studies reviewed above addressed teachers’ goals in various ways although they were never the direct construct under study. According to Schoenfeld (2011), goals are distinct from orientations and resources in decision making. This study sought to use MGSIs goals for student learning as a way for MGSIs to share and reflect on their teaching practice. Agreeing with Eisner, these goals may be emerging for new MGSIs, not always known in advance of teaching a lesson or at the outset of the course.

### ***Mathematics Standards***

The ideas of Tyler and others like him have continued to shape the teaching and learning of education today. Tyler contended that objectives are choices or value judgments made by school leaders and that no single source of information can provide enough wisdom to determine objectives for a school. He argued that multiple sources such as the learners’ themselves, contemporary problems, and content specialists’ knowledge of their subject should be considered when specifying educational objectives as they all bring valuable information useful for thinking about educational purposes. He insisted that subject specialists should ask what their “subject [can] contribute to the education of young people who are not going to be specialists in your field; what can

your subject contribute to the layman, the garden variety of citizen?" (as cited in Flinders & Thornton, 2013, p.64). Mathematics education has made some strides in trying to answer this question.

Until the 1950's, learning mathematics "successfully" meant being able to perform computational procedures (NRC, 2001). The "new math movement" shifted this understanding of learning mathematics to be defined "in terms of understanding the structure of mathematics together with its unifying ideas, and not just computational skill" (p.115), which was followed by a pendulum swing towards "basic skills" and computational proficiency. This debate over what learning mathematics means repeated itself in decades that followed, but sparked efforts to articulate and agree on goals for what learning mathematics should look like.

One significant document seeking to describe mathematical proficiency is *Adding It Up*. Focusing on K-8 schooling, this book describes five strands, interwoven like braids, which are necessary for students to successfully learn mathematics and "provide a framework for discussing the knowledge, skills, abilities, and beliefs that constitute mathematical proficiency" (NRC, 2001, p.116). They call for students to develop both conceptual understanding, described as comprehending concepts, operations, and relations, as well as procedural fluency, being able to carry out procedures appropriately and accurately. The third strand is called strategic competence which is defined as forming, representing, and solving problems. The last two strands are adaptive reasoning, meaning logical thinking and the ability to justify and explain that thinking, and productive dispositions. Productive dispositions refer to students' affective learning

domain and are defined as “habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy” (p.116).

Within K-12 mathematics, standards have been developed to reflect key goals of the discipline. The term “mathematics standard” has been used in multiple ways and its meaning can vary from identifying essential knowledge in a field to measurable goals for student learning to mechanisms for encouraging dialogue and consensus building in a field (Blair, 2006). The “Standards movement” began in 1989 with the National Council of Teachers of Mathematics (NCTM) release of Curriculum and Evaluation Standards for School Mathematics. This document reflected a constructivist view of learning and called for more focus on problem solving and understanding of concepts. It was a seminal document in mathematics education, seeking to advocate for greater equity and beginning to define what quality mathematics teaching and learning may mean and what skills or abilities students should develop.

About a decade later, it was followed up by NCTM’s Principles and Standards for School Mathematics (2000) which laid out principles for equity, curriculum, teaching, learning, assessment, and technology. This document also included content standards, which described strands of content students should learn, and process standards. The five process standards, problem solving, reasoning and proof, communication, connections, and representations, are “ways of acquiring and applying content knowledge” (NCTM, 2000, p.3). Other documents and recommendations have since followed along these same lines, continuing to seek to define and describe learning goals for students and effective practices for teaching mathematics. For instance, the Common Core State Standards, an effort to provide focus for K-12 mathematics curriculum, are adapted from the

recommendations above and identify eight mathematical practices for students. The mathematical practices are: make sense of problems and preserve in solving them, reason abstractly and quantitatively, construct viable arguments and critique the reasoning of others, model with mathematics, use appropriate tools strategically, attend to precision, look for and make use of structure, look for and express regularity in repeated reasoning (NCTM, 2014).

While most of the work on mathematics standards has been done at the K-12 level, the American Mathematical Association of Two-Year Colleges (AMATYC) produced their first standards document in 1995. Similar to the NCTM recommendations, Crossroads in Mathematics: Standards for Introductory College Mathematics before Calculus articulated standards for intellectual development, standards for content, and standards for pedagogy (Blair, 2006). Their standards overlap with the recommendations developed for K-12 but are intended to focus on student learning during the first two years of college. While this frequently applies to community college students, it also includes lower-division service courses at universities. The coursework taught by many MGSIs tends to be at the lower level and can overlap with community college coursework.

In 2006, AMATYC published Beyond Crossroads which added implementation standards and reaffirmed their standards for intellectual development. Their eight standards for intellectual development, described as “desired modes of student thinking and goals for student outcomes” (Blair, 2006, p.5) are:

1. ***Problem solving.*** Students will engage in substantial mathematical problem solving.

2. ***Modeling.*** Students will learn mathematics through modeling real-world situations.
3. ***Reasoning.*** Students will expand their mathematical reasoning skills as they develop convincing mathematical arguments.
4. ***Connecting with other disciplines.*** Students will view mathematics as a growing discipline, interrelated with human culture, and understand its connections to other disciplines.
5. ***Communicating.*** Students will acquire the ability to read, write, listen to, and speak mathematics.
6. ***Using technology.*** Students will use appropriate technology to enhance their mathematical thinking and understanding, solve mathematical problems, and judge the reasonableness of their results.
7. ***Developing mathematical power.*** Students will engage in rich experiences that encourage independent, nontrivial exploration in mathematics, develop and reinforce tenacity and confidence in their abilities to use mathematics, and be inspired them to pursue the study of mathematics and related disciplines.
8. ***Linking multiple representations.*** Students will select, use, and translate among mathematical representations—numerical, graphical, symbolic, and verbal—to organize information and solve problems using a variety of techniques.

The literature discussed above related to teachers' thinking, decision making, and planning, as well as theories of curriculum design, all speak to the importance of a teachers' goals for student learning. Agreeing with Clark and Dunn (1991), "we cannot hope to understand fully why teachers act as they do until we learn more about their own

intentions and goals" (p.186). The standards movement in mathematics education has worked to identify key long-term goals for student learning from a policy perspective. As this study seeks to understand the teaching in introductory mathematics service courses, the theories above suggest the intentions and goals of instructors, which include MGSIs, should be explored. However, another source of theory comes from the thinking of MGSIs themselves. Their thinking is important because they can provide real insight into their own teaching as they have real experience to speak from (Maxwell, 2013). Thus, this chapter concludes with a discussion of a pilot study as the final source theory before concluding with the research questions.

**Pilot Study**

In order to understand how MGSIs were thinking about teaching, a pilot study was conducted during fall 2018 to inform the design of this dissertation. The study was approved by IRB, involved three participants, and generated valuable data which provided insight into how MGSIs spoke about their classroom teaching. Each participated in a background interview designed to understand their prior teaching experiences and beliefs about teaching, while building rapport between the researcher and participant. At the conclusion of the interview, each MGSI was asked to choose a lesson in which they planned to incorporate some form of active learning. The day before teaching the lesson, they provided a written lesson plan and participated in a pre-lesson interview where they discussed their plans and anticipated strengths and challenges of the lesson. I observed the lesson and then facilitated a post-lesson interview where MGSIs reflected on their teaching. After the first MGSI completed this process, adjustments were made to the interview protocols and then the study continued with two other MGSIs. These two

participants were second-year male graduate students teaching for the first time as an instructor of record and both were assigned to teach College Algebra. In addition to the individual interviews, I attended and participated in most sessions of a weekly pedagogy course (MATH 792) designed to support second-year mathematics graduate students learning to teach. All pilot study participants had either taken or were currently taking the course.

***Pilot Study Analysis***

The six interviews from the last two participants were transcribed and coded multiple ways to inform the design of this dissertation. Analytic memos (Saldaña, 2016) were written to reflect on the research process throughout the analysis of pilot study data. Efforts to analyze the pilot study data helped inform the design of this dissertation through focusing analysis on MGSIs goals for student learning, discovery of a coding scheme to use with future data, as well as writing of the research questions.

Participant responses and data analysis from interviews suggested that these instructors had reasons for trying various teaching techniques in their classroom. For instance, when asked in the post-lesson interview about the purpose of asking various questions to students in class, Chris (a pseudonym) explained,

> So later on, when they're looking at these problems, they can be like, oh, its growth, it's growing. I remember, I remember thinking about this. It's growth. It's not because he said growth equals because that's what’s hard. If you, if someone tells you a definition, you only remember it because that's the thing he told me it must be defined this way, but if you can come to it yourself… So [that] they can

make the connections they can, in their own brains, so that they can remember. In my mind, it helps them retain it better.

Chris described his reason for asking specific questions in terms of what he wanted students to remember or learn.

In the pilot study, MGSIs described ideally what they wanted students to take away from their classes and what they hoped would happen in their classrooms; thus, they expressed goals for student learning. Some statements included vague references to goals such as while explaining what he thought lecture was and how he tried to engage his students, Chris stated, “I guess my goal is to help them learn the material.” MGSIs were also aware that their ideas may not always work as planned and frequently indicated obstacles they had encountered with implementing their plans. However, they described these goals for student learning as a basis for explaining why they were making choices about teaching. Consistent with Schoenfeld’s goal-oriented decision-making theory, in seeking to understand the instructional decision making of these instructors, their goals, or in this case goals for student learning, were useful for explaining their actions. Thinking about the interview data in this way began with efforts to code the pilot study data.

Various coding cycles were tried for analysis of pilot study data. This included using Schoenfeld’s decision making framework to code for resources, orientations, and goals as well as trying first-cycle coding methods such as emotion coding and values coding (Saldaña, 2016). While all these schemes produced lots of codes, some were more useful than others. When exploring the codes for goals Chris discussed in his background interview, it was noticed that some codes related to what the MGSI wanted to do himself,

such as improve group participation, dispel students' fear of "looking stupid," show interesting mathematics, give definitions or provide problems. Other codes for goals related to what he wanted students to do, such as "work together" or learn math concepts. Thinking about why he wanted to use specific teaching methods or how he explained his interactive teaching also contributed to focusing analysis on what he wanted to help students learn. Other coding schemes did not seem to help with productively understanding what the MGSI was trying to do in the classroom or how he was accomplishing it. For instance, the resources codes were a long list of knowledge and various methods or materials the MGSI tried to utilize such as group worksheets, undergraduate professors, question posing, and officemates, which were not as helpful to answering the developing research questions. The process of coding and thinking about what the codes suggested began to provide some focus for a way to talk about how MGSIs think about teaching. In addition, it suggested future coding schemes could incorporate the idea of the MGSI working towards meeting a learning objective or goal.

It was difficult to figure out how to relate the codes to the research questions, which at that time sought to understand what active learning methods MGSIs were using and the reasons MGSIs gave for these decisions. This struggle makes sense given Saldaña's reminder that "coding is not a precise science; it is primarily an interpretive act" (p.217) and I was trying to interpret what the MGSI had said. One way to interpret why MGSIs were using various methods while staying grounded in their own justifications of their decisions, was to focus on their goals for student learning. Thus, the process of analyzing the pilot data helped shape the focus for this study. With a focus on understanding MGSIs teaching as trying to help students achieve objectives while

encountering struggles along the way, the choice was made to use dramaturgical coding. This proved to be a productive cycle of coding with the pilot data and will be discussed further in chapter three.

Another influence of the pilot study appears in the wording of one research question which seeks to understand more about how MGSIs achieve their goals. Initially I wanted to understand more about the instructional activities MGSIs were using in their classrooms. During his background interview, Brandon (another pseudonym) stated, "because the goal of teaching is you need to understand the material. And I don't care if you didn't know it at the beginning, I care if you know it by the end." This quote again illustrates the use of the vague goal "understand the material" but is referring to Brandon's strong ideas about assessment. When asked if there was anything else he wanted to share about his teaching, he discussed his ideas about grading by using what he called mastery learning. He spoke at length about his assessment strategies and wanting students to demonstrate mastery of a conceptual concept by solving a novel problem by the end of the semester. He sought to use his assessment strategies to help students grow mathematically. Realizing that my focus on instructional practices would omit this MGSIs idea about assessment, I broadened my initial focus from instructional practices to design practices, as this includes both assessment and classroom practices. Finally, in continuing to explore the analysis on MGSIs goals, the question evolved to asking how MGSIs aimed to achieve their goals. In this way, the study was able to freely explore and present MGSIs ideas.

Finally, the pilot study confirmed that this is a good setting to conduct research on MGSIs teaching and planning. These MGSIs enrolled in a yearlong sequence of courses

(MATH 791 and MATH 792) that sought to encourage MGSIs to reflect on their teaching and provided some exposure to ideas from mathematics education research. Noticing an overlap between Brandon's responses and course content, I wanted to explore whether Brandon was just repeating what he himself had been taught or possibly saying things because he thought I might want to hear a certain answer. Brandon clarified his perspective on MATH 792 during the post-lesson interview,

> The same way that mathematics works in that you, you think about these things and they're in the back of your head, but then you develop the language and now that you have the language you can do more things. And so, I think that [Math 792] class is great for that too. You know, when I would teach, I would think about these things. I didn't really know a good way to talk about them and I didn't know how to put them into practice. But then his class gives you the language to speak about them and then once we have the language to speak about them, then you can develop new ideas and so on and so forth… Now I can develop new ideas because I have the language to speak about these things and now I kind of understand, oh these are the types of things I should avoid; these are the types of things I should emphasize or strive towards.

It appears that the participation in Math 792 does influence MGSIs ability to think and speak about their teaching, perhaps both in positive and potentially challenging ways. Yet the fact that these MGSIs seem comfortable reflecting on their teaching and were able to discuss their goals and challenges made a good setting for a study on MGSIs thinking.

More examples of pilot study data are provided in chapter three. It is discussed here to provide an understanding of how the pilot study shaped the focus of this

dissertation and the research questions for this study. The importance of the student learning goals was suggested by the pilot study. At times the goals were not very specific such as wanting students to understand the material. In addition, the relationship between these goals and teaching methods was not well understood in the pilot study. Thus, this study sought to better unpack what goals for student learning MGSIs were actively trying to achieve and how they relate to MGSIs interactive teaching. This may be valuable because it may inform PD efforts seeking to build on MGSIs thinking as they shift into more student-centered instruction and give insight into how goals for student learning are related to classroom instruction in new instructors teaching practice.

**Research Questions**

This study aimed to explore, from the instructor's point of view, what is going on in a mathematics service course and why. The instructors for this study were MGSIs who were first time instructors of record for Precalculus. In seeking to understand their perspective, this study asked questions about the instructor's thinking and followed a cognitive information-processing approach to research. According to Clark and Yinger (1979) this approach "is generally concerned with the mental processes that are thought to underlie behavior" (p.8) and makes the assumption that "what teachers do is rational and sensible" (p.27).

This study focused on MGSIs' goals for student learning for several reasons. First, research on decision-making (Schoenfeld, 2011) and design (Wiggins & McTighe, 2005) suggests goals are a key component of teachers' thinking. Second, goals are a key piece of the standards movement in mathematics education reform efforts and little research has been conducted in this area with respect to MGSIs. Finally, pilot study data

suggests MGSIs are aware of and can speak about their goals. Other than the lesson study where MGSIs were asked to select measurable student learning goals, no studies found have examined the goals of MGSIs.

In order to investigate this area, I posed the following research question: During their first semester teaching a new undergraduate mathematics course, how do MGSIs plan (design and reflect) and implement their plans, with a focus on their goals for student learning? To address this broad question, four sub-questions were created.

a. What goals do MGSIs aim to achieve for student learning?
b. In what ways do MGSIs seek to achieve their goals for student learning?
c. In what ways, if any, did MGSIs describe external factors as influential to their goals for student learning or planning practices?
d. What challenges do MGSIs describe as they reflect on their planning and classroom instruction?

The third sub-question was added during the data analysis process and is explained in chapter three.

A key term used throughout this study is MGSIs goals for student learning. In chapter one, this was defined from a curriculum design perspective as “desired results that establish priorities for instruction and assessment” (Wiggins & McTighe, 2005, p.58) which often include a mixture of factual, conceptual, procedural, dispositional, and expert-performance based aims. In other words, it’s what students should know, do or understand. Many types of goals for student learning can exist and it was not known what types of goals MGSIs would express. The phrase “instructors’ goals for student learning” was used to address whatever aims the MGSI perceived they were actively seeking to

help students achieve in their classroom. As anticipated, these reached beyond goals tied to a specific mathematical piece of content knowledge. For instance, helping students convert between a growth factor and a growth rate is an example of a goal given by an MGSI during a lesson used in the pilot study. This would be considered a content goal while a broader goal of connecting mathematical concepts would be a goal for student learning used in this study that also emerged in the pilot study data. Further, these were not just ideas MGSIs believe would theoretically be good for undergraduate students to know or do but skills, ways of thinking or being that MGSIs were attempting to develop in their students through some design on the part of the MGSI. Arguably goals are often shaped by beliefs (Schoenfeld, 2011). In this way, a goal is distinguished from a belief in that it is considered an aim that involves a MGSI taking some action to try and achieve rather than just a belief that something should or should not be done. Further they are goals for student learning, thus describing in some way what students can do, think, or know.

Thinking about how to support instructors in using more student-centered teaching approaches requires an understanding of where the instructors themselves are coming from. Just as teachers use knowledge of their students thinking to develop their students' mathematical skills, professional development providers can build on instructors thinking as they help instructors develop teaching skills. To do this effectively, they need more knowledge about instructor thinking.

That is the aim of this study, for improved theoretical understanding of how MGSIs who are receiving support in learning to teach, think about teaching through a greater understanding of reasons behind MGSIs' instructional decisions and identification

of the challenges they face. The intention is not to measure the quality of MGSIs teaching but to characterize their goals or reasons for their chosen instructional activities. This study sought to allow MGSIs to share their ideas about teaching by reflecting on their own design practices and aimed to contribute to the limited knowledge base about MGSIs and teaching practices in post-secondary education by exploring MGSIs perspectives on teaching and giving MGSIs a greater voice in the research literature. Current literature provides some perspectives *about* MGSIs yet a deeper understanding of the MGSIs perspective should be informative for those working to support MGSIs development and improve instruction for undergraduate students.

# Chapter 3: Methods

"Only the person who listens patiently and critically is able to speak with the other." – Paulo Freire

This chapter discusses the methodology, data collection, and data analysis used to answer the previously posed research question and sub-questions. The data collection and analyses were designed to understand MGSIs planning, specifically identifying MGSIs goals for student learning, ways in which they worked to achieve these goals, and difficulties they perceive as arising while planning or teaching. External factors impacting MGSI planning emerged as an additional question to examine during data analysis.

## Methodological Approach

In order to understand MGSIs planning and teaching in terms of their goals for student learning and how they sought to achieve these goals, this study used a qualitative multiple-case study methodology. Case study was an appropriate method as it provides a more in-depth understanding of MGSIs thinking in this area. The field needs examples which illuminate what aims MGSIs are seeking to achieve and how this relates to decisions they make during planning (preactive and postactive phases of teaching) and while interacting with students (interactive phase) as there is limited research related to MGSIs thinking (Belnap & Allred, 2009). Yin (2018) defines qualitative case study as "an empirical method that investigates a contemporary phenomenon (the "case") in depth and within its real-world context, especially when the boundaries between phenomenon

and context may not be clearly evident" (p.15). Case study was appropriate for these research questions because the study looked at understanding MGSIs thinking and decision making about teaching in the context of actual classroom experiences. Thus, this study examined contemporary events of classroom teaching over which the researcher had no control. Citing Schramm (1971), Yin elaborates that "the essence of a case study, the central tendency among all types of case study, is that it tries to illuminate a decision or set of decisions: why they were taken, how they were implemented, and with what result" (as cited in Yin, 2018, p.14) which is consistent with the aim of this study which sought to understand possible reasons for MGSIs design practices.

Case study was also chosen because it provides a more complete picture of MGSIs planning and interactive teaching. Understanding another's perspective takes time. In this study, "inferences about others' actions and motives are from the perspective of researcher as audience member of the social drama. These inferences can sometimes be incorrect, and a follow-up interview with the participant-actor may be necessary for confirmation (Saldaña, 2016, p.149). He warns that "psychology cautions us, however, that humans do not always understand their own motives for action, and they cannot always rationalize and articulate why they acted and reacted in certain ways" (p.149). However, pilot study data indicated that MGSIs can talk about student learning in meaningful ways and often used references to student learning to explain why they made certain decisions during interactive teaching. Further, Schoenfeld (2011) claims that "people's decision making in well-practiced, knowledge-intensive domains can be fully characterized as a function of their orientations, resources, and goals" (p.182). Teaching is such a domain. To some extent, MGSIs were able to initially describe their own

motives. However, the research design provided ample reflection time and space to more completely describe their goals and decisions.

## Bounding the Case

Case studies must be "bounded" so that it is clear what belongs to the case and what does not (Yin, 2018). The site, course, timeframe, and participants themselves defined the bounds of this case. This case is comprised of MGSIs teaching Precalculus, an undergraduate service course in the mathematics department at the University of South Carolina (UofSC) as part of their teaching assistantship during fall 2019. These bounds are explained and justified in following sections.

### *Site Selection*

As MGSIs were the intended participants in this study, the study needed to be conducted at an institution of higher education that offered graduate degrees in mathematics and that allowed their graduate students to be the instructor of record for an undergraduate mathematics course. Further, the nature of this inquiry lent itself to classroom observations and interviews with participants who were willing and able to discuss and reflect on their teaching. UofSC was chosen as the research site for this study. At the time of the study, it not only typified the problems related to student struggles in the Calculus sequence (Bressoud et al., 2015) and utilized MGSIs as full instructors of record, but also had been incorporating a professional development program to support graduate students as they learn to teach.

At the time of data collection, UofSC offered formal support for MGSIs development in the forms of pedagogy courses and peer mentorship. All MGSIs enrolled in two consecutive one-credit courses (MATH 791 and 792) on mathematics pedagogy,

where they received advice on various elements of setting up their courses, were exposed to ideas from mathematics education research, and discussed teaching challenges with peers. At this university, first-year graduate students were typically assigned to lead recitation sections for the calculus sequence where they met twice a week with students to review problems or lead Maple labs. During the spring semester, they begin the pedagogy course sequence by taking MATH 791. During their second year in graduate school, most MGSIs are assigned to teach their own courses. They continue in the pedagogy course sequence during the fall, taking MATH 792. In addition, each MGSI was also assigned to an experienced graduate student who served as a mentor. The mentors observed MGSIs teaching, met to provide feedback and suggestions, and facilitated small-group discussions about teaching (Yee & Rogers, 2017). Thus, MGSIs at UofSC were supported in learning to teach and had some familiarity with reflecting on their own teaching.

The coordinator for these support programs, Dr. Yee, was also the faculty advisor on this project. He helped design the professional development program, had facilitated it for five years, and helped me identify participants for this study. This helped with the potential challenge of finding participants who were comfortable being observed and willing to discuss their teaching. In addition to his contextual knowledge about the program at UofSC and the MGSIs locally, Dr. Yee understands more broadly how professional development for graduate students is used around the nation and the significance of such work to the field of mathematics education (Yee & Rogers, 2017). Although it may have limited my willingness to be critical of the context and contributed

to delaying our discussions about study participants until the conclusion of data collection, the benefits of his familiarity with the program far outweighed the limitations.

***Course Selection***

At this university, MGSIs can be the instructor of record for a variety of courses yet typically are first assigned to a 100-level course such as Precalculus or College Algebra. These courses are known as service courses because they are provided to students whose majors are not solely mathematics. MGSIs teaching the same service course, Precalculus, were invited to participate in this study. The Precalculus course is a prerequisite to the Calculus sequence required for many STEM majors. Not only is this an important course for undergraduates, but it is also commonly assigned to MGSIs who are in their second year of graduate school and teaching as instructor of record for the first time. Typically, these MGSIs spent their first year of graduate school leading Calculus recitations and Maple labs while working in the undergraduate mathematics-tutoring lab, which offers drop-in tutoring for all university students taking mathematics courses. This set-up gives MGSIs teaching Precalculus a strong sense of the student's trajectory through calculus. A teaching guide, which provided lesson plans that included problem sets and teaching suggestions, had been developed to assist MGSIs with planning for this course. The guide was revised by MGSIs at UofSC with experience teaching Precalculus from materials used by MGSIs at another university and was available as a resource to all MGSIs teaching Precalculus. The Precalculus course helped bound this study and was chosen since it is a service course that is important to student success in STEM fields, was a common teaching assignment for second-year MGSIs, and provided additional materials to support new instructors.

***Participant Selection***

Intended study participants were mathematics graduate students at the University of South Carolina who were enrolled in graduate classes to receive a master or doctoral degree in mathematics while simultaneously teaching for stipend and tuition abatement. Their average age ranges from 21 to 35 with both female and male applicants being provided equal opportunity to apply. Most do not have formal training in education but nearly half are interested in pursuing academic careers in the future. Many of these instructors were “novice” full-time instructors meaning they were in their second year of graduate school and had not previously served as instructor of record for their own course during a fall or spring semester.

All MGSIs (n=7) who fit the bounds of the study, meaning they were teaching Precalculus for the first time in fall 2019 at UofSC, were invited to participate in this study. All were male. Five were second-year graduate students while the other two were in their third year of graduate school but had not previously taught Precalculus. Following IRB approval, I sent an email to all seven eligible MGSIs and put a copy of the email in their mailboxes. Four MGSIs either responded to the email indicating they would like to participate or verbally indicated they would participate after seeing me in the mathematics building. Although only three MGSIs were needed for the study, after discussion with my advisor, we decided it was manageable to collect data from all four MGSIs who volunteered to participate.

Participant recruitment was assisted by an opportunity that emerged at the beginning of the semester before IRB approval was attained. The first meeting for MATH 792 was supposed to include a meeting with the peer mentors. However, both Precalculus

mentors were unable to attend so I was able to fill in for them and explain the peer-mentoring program. At the end of the meeting, I briefly explained my upcoming study to them and asked them to think about if they would be interested in participating. I clearly stated the study was waiting for approval and that they were not being asked to participate but were being made aware of an upcoming email invitation. This conversation likely helped with recruitment as four of the five agreed to participate.

All four participants were second-year graduate students and were participating in the year-long pedagogy courses (MATH 791 and 792). Through these courses, they gained experience with observing lessons, being observed themselves, and reflecting on observations. All MGSIs were asked to suggest a pseudonym for themselves at the conclusion of the study and their suggestions were used in the write up of this study. Further, while four MGSIs completed the study, the analysis focused on describing the three MGSIs, Willie, Patrick and Chen, who were pursing doctoral degrees and were considering potential future careers in academia. The fourth MGSI, Deacon, made it clear from the beginning of data collection that he was not interested in pursuing a career in higher education. Following the conclusion of data collection, Deacon chose to leave graduate school with a master’s degree and move into industry. His data will be analyzed following the completion of this study as a separate case because his graduate school trajectory and career goals are different than the other participants. More details about the MGSIs are given in the individual case studies in chapter five.

MGSIs were financially incentivized to complete the study. All MGSIs were given an $80 VISA gift card at the conclusion of data collection and provided a pizza

lunch during the focus group. This level of financial incentive was intended to thank participants for investing in the study but not to influence data collection.

## Data Collection Methods

In a case study, multiple sources of data are collected for evidence (Yin, 2018). This study utilized the following sources of evidence: interviews with MGSIs, direct observation of MGSI teaching, various documents written by MGSIs, audio of mentoring meetings and participant observation during MGSIs teaching methods course (MATH 792). As there is limited literature related to MGSIs goals for student learning, this study was fairly exploratory. Further, MGSIs are mathematicians, not education majors, and while they have some training in pedagogy, this study sought to avoid using heavy educational jargon in interview questions to avoid confusion. The wording of the interview questions was intentionally left fairly open to allow MGSIs to speak freely in a manner that expressed their perspective. All MGSIs were given an ID number that was used on all documents collected. Upon agreeing to participate in this study, MGSIs were asked to sign a consent form indicating they agreed to be observed teaching, would participate in interviews and a focus group, keep a journal, and give access to their assignments from MATH 792. The consent form is included as an Appendix A. The methods of data collection will be described next.

### *Initial Interviews*

Once MGSIs agreed to participate in the study, an initial semi-structured interview was scheduled. “Interviews are an essential source of case study evidence because most case studies are about human affairs or actions” (Yin, 2018, p.121). This interview had several purposes including building rapport between the MGSI and the

researcher, allowing myself to become familiar with the language and orientations of the MGSIs, and providing MGSIs with an opportunity to begin to reflect on their teaching in an interview setting while becoming familiar with the types of questions that will be asked in future interviews. The semi-structured nature of the interview allowed for clarification of statements made by MGSIs or educational terminology they used. All initial interviews were conducted during the second week of classes in the fall 2019 semester (the week of September 2$^{nd}$).

The initial interview protocol was very similar to the background interview used in the pilot study and provided broad data on MGSIs thinking early in the semester. During the pilot study, it was modified slightly after the first interview, mainly in reordering of questions to provide rich data for analysis. The pilot study interviews were conducted mid-semester (September and October) and took roughly 40 to 60 minutes. As anticipated, these interviews were slightly shorter in the dissertation study due to MGSIs having less teaching experience to speak from. The interviews ranged in length from 23 to 50 minutes.

The topics for the interview include demographic information, teaching experiences, and beliefs about teaching and learning. The semi-structured interview protocol is included as Appendix B. The interview questions encouraged MGSIs to reflect on both positives and negatives of their teaching experiences while generating data about MGSIs orientations. Recall in Schoenfeld's decision making theory, orientations shape goals; thus, they can be useful in understanding MGSIs goals. Two questions, 10 and 11, directly ask about MGSIs goals for student learning. Although these were

hypothetical goals not tied to any specific classroom lessons or actual teaching practices, they did align with goals MGSIs described during lesson interviews.

**Piloting data collection.** Prior to this study, a pilot study was conducted (see chapter two). In the pilot study, evidence of goals for student learning and some insight into obstacles or challenges MGSIs were experiencing in regard to achieving what they wanted to happen with students in their classes appeared in these interviews. For instance, below are some quotes taken from the background interviews that illustrate goals that were repeated in later interviews. In the first quote, Brandon discusses some affective goals he has for his students.

> Um, and so that is a big goal of mine, um that students get away from mathematics is just memorizing all these esoteric things and if I don't understand it, then I'm not going to understand it … and I want them to be able to say, okay I'm faced with this problem I've never seen before, but I understand enough about mathematics that all these things make sense and I can find my way and sift through all the nonsense and get the answer. Um, so developing that mindset that mathematics is not just memorizing 1000 formulas and algebra rules and exponent rules and instead, all of the things make sense because we made them make sense, that's the reason we have mathematics.

This quote lines up well with the concept of developing productive dispositions defined as "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (NRC, 2001, p.116) which was a common theme with both pilot study participants whose interviews were transcribed and analyzed.

Another quote from Brandon's pilot study data discusses developing skills used to model everyday situations, again relating to the usefulness of mathematics.

> I like to really, um, push the idea of taking a real-world English problem that's written in common language that we can all understand, and then transfer that language over to math world, and write it with algebra and things like that. And throughout all of my lectures and in any class, I always like force that, that ideal.

Brandon later discusses wanting students to develop as mathematicians, which he explained could partly be done through developing their thinking or problem-solving abilities such as solving real-world problems. Similarly, Chris also wanted to illustrate the relevance of mathematics to everyday life and shared several "word problems" that he used with his students. Some were taken from the textbook while others he created himself. For instance, wanting to install a home security system and comparing company's prices for such a project was an example he thought of on his own. He referenced this goal in the following quote

> I guess the one thing I'm trying to really get across, one point I'm trying to get across this year is that math comes, it's like every day in their lives they will use math of some sort, like especially, which is nice about this book is there's those sections with like the word problems so like we did a word problem last week which I loved.

Chris also discussed affective goals throughout his interviews, repeatedly mentioning efforts his to build student confidence. In his background interview he stated,

> But that would be a good goal, for them to learn to work together and ask for help; don't be scared, ask for help. Because the math is all good and all, but these real world, but that's a life skill they should learn, to not be scared.

These quotes illustrate the manner in which goals for student learning were spoken of during the background interviews. In addition, the background interviews also brought up some struggles MGSIs perceived with learning to teach. One concern mentioned multiple times by all three participants was actually getting students to participate in group work. These MGSIs desired to use various forms of group work but seemed frustrated by quiet students. Chris expressed this struggle in the following quote taken from his background interview.

> So, I'm not really sure how to make it where they all feel really comfortable, that's why I try to do the group work so they'll at least speak to each other, 'cause usually they feel comfortable doing that but again this class, some people just taking it or very similar courses over and over again and they just work on their own and so it's not working as well as I would like it because I know there's students, like a few students struggling and for some reason they'll just sit and not say anything to anybody around them and I know their struggling and I just haven't figured out a good way to get them to include themselves in the conversation that's happening right behind them and to actually say, I don't actually understand how did we get this answer?

Another more subtle conflict emerged during the pilot study that was also in the background interview data. All three participants in some form or another saw themselves as an obstacle when discussing students reaching learning goals. As Chris

referenced above, he wanted to “figure out” how to get his struggling students to speak up but wasn’t having the success he wanted or expected. At other times, participants mentioned either feeling unsure that their teaching was effective, felt it was their responsibility to ensure that their students were learning and attributed student struggles to their poor facilitation skills, or expressed difficulties with their ability to motivate students “at this level.” Brandon was particularly hard on himself in interviews. For instance, when asked to discuss a lesson that went well, initially responded with, “I really don’t like this, to say that I did stuff well (exhale). It’s hard for me to talk, to compliment myself.” These quotes are provided as examples of the types of comments given by MGSIs during the background interviews of the pilot study, which were reinforced in later lesson interviews and related to codes of goals and conflicts used in data analysis.

The depth of the quotes above is indicative of data collected during the dissertation study. Additionally, some of the topics, such as challenges with getting students to participate in group work, were repeated in the dissertation study. However, the initial interviews were not tied to any classroom observations of MGSIs teaching. A key source of data for this study was observations of actual classroom teaching followed by interviews. The process of collecting that data is discussed in the next section.

***Lesson Observations and Lesson Interviews***

Following the initial interview, MGSIs were asked to select three lessons throughout the semester to discuss with the researcher. Any course topic would work but MGSIs were asked to choose lessons where they planned to use some form of active learning or student engagement. The term active learning was used because it was introduced in MATH 792 and was thus familiar to MGSIs in this study. Allowing the

MGSIs to choose the lesson provided insight into circumstances where MGSIs plan to use more student-centered methods and hopefully increased their comfort with sharing and discussing their ideas about teaching. They were asked not to choose lessons on test days or ones with only lecture. Roughly once a month (September, October, and November), I attended their chosen class and followed up with an interview within 48 hours after the observation. Although MGSIs could have emailed me about scheduling observations, we typically discussed the lessons they wanted me to observe in person either following MATH 792 or in our offices.

MGSIs were asked to provide a copy of their lesson plan, any handouts or materials distributed during class, and their answers to a brief questionnaire before the observation. The questionnaire asks for MGSIs to answer two questions. The first asks what they would like students to learn from the class and the second asks how they plan to help students learn. Unlike some K-12 settings, there are no formal lesson plan requirements for MGSIs. Thus, they were asked to provide whatever they use as their lesson plan. This included handwritten notes on how to introduce topics, problems to cover, problem solutions, and copies of student handouts to be used during class.

I observed and took field notes during the lessons but did not participate in class activities in any way. The lessons were audio and video recorded with a Swivl camera designed to follow the teacher and capture at least the teacher's voice. I offered to show the recordings to MGSIs during the follow up interviews, yet typically they did not wish to watch the recording and felt they remembered the class well enough to speak about it. A few videos were forwarded to some MGSIs who used it to write a reflection on their teaching for their methods class. Observing the lessons helped to create a shared

experience to discuss in the interviews. Further, it became the basis of some interview questions and helped me understand comments made by MGSIs during interviews.

Following each observation, a lesson interview was conducted to generate important data for answering the research question. To guide the design of the lesson interview protocol, pilot study questions were reviewed as well as questions from other interview studies. I continued to refine the interview protocol throughout the study by modifying or reordering questions yet consistently wanted to begin by letting them share their overall thoughts about the lesson. One question always asked something such as, "What happened during this class? What stood out to you?" Following Speer (2008), this approach allows the MGSI to "narrate" or explain what happened during class and provides their perspective on what was significant during the class. As Speer (2008) argued, this helps ensure the analysis is not solely conducted from the researcher's lens. Probing questions were added as needed.

After the first interview with Deacon, I found it helpful to continue a method from the pilot study, which was to write questions about specific moments in the lesson that I could ask more about during the interview. For example, these questions included "Tell me more about" a particular statement or "Why did you stay in the front of the room" during this part of the activity, or "How typical was this"? To help generate these types of questions, I would watch the video to review the lesson. At times this allowed me to better catch what the MGSIs specifically said during the lesson. As I rewatched the lesson, I added questions beside my field notes that I asked them during the interview if the answers had not arisen from prior questions. In this way, we thoroughly discussed

many aspects of the entire class. I continued to make minor revisions to the interview protocol and have included the final version as Appendix C.

The interview process was repeated with each MGSI for each of the three lessons they selected. Yin (2018) describes this type of interviewing as “prolonged case study interviews” and notes that case study interviews “resemble guided conversations rather than structured queries” (p.118). These interviews ranged from 50 minutes to 100 minutes, with an average of 73 minutes. The third interview included a few overall reflection questions and was often longer. As planning is both a practical activity involving creating a written plan and a psychological process of visualizing future actions (Clark & Peterson, 1986), the combination of collecting lesson plans, observing MGSIs teaching, and conducting semi-structured interviews provided a more complete picture of MGSIs planning.

***Focus Group***

On the last day of classes for the fall 2019 semester, I facilitated a focus group interview with all four MGSIs. The purpose of the group interview was to allow a space for MGSIs to collectively reflect on teaching Precalculus for the first time with a focus on student learning. The focus group protocol was developed at the end of the semester and shared with members of the dissertation committee for feedback. The questions addressed the sub-research questions from the proposal, focusing on MGSIs goals for student learning, design practices, and challenges. In addition, the focus group protocol asked questions about MGSIs experience learning to teach. Given the longer protocol, the actual focus group was broken into two parts. Following question five, we took a short break and came back together to reflect on their overall teaching experiences. In total, the

focus group lasted about two hours. The focus group was audio and video recorded using Swivl. Food and drinks were provided as we met around lunchtime. A topical version of the protocol for the focus group is included as Appendix D.

### *Journal*

MGSIs were asked to keep a weekly journal throughout the semester as an additional method for sharing their thoughts about teaching Precalculus for the first time. MGSIs were emailed a Google form link and asked to respond in writing to prompts. The prompts varied slightly from week to week, but MGSIs were typically provided with four prompts. A common prompt asked MGSIs to discuss what they learned about teaching their students this week and describe how they learned it. Another prompt asked MGSIs to rate on a scale from one to seven how well teaching went this week and to explain why. A total of 13 Google forms were sent for reflection. Emails were typically sent on Thursday or Friday and MGSIs were asked to respond by Monday.

However, consistently obtaining this data proved to be one of the most difficult aspect of data collection. By the end of September, MGSIs were busy and asking them to write a reflection was understandably not high on their priority list. One MGSI, who was an international student, expressed concerns about participating in the study as the weekly writing assignments were time consuming. Not wanting him to drop out of the study, I tried to be reassuring that he did not need to do anything extra for my observations and offered to have brief five-minute conversations each week instead of the writing reflection. He took a week off from the journals and began sending me an audio recording of his responses to the prompts. This allowed him to reflect on the questions

and alleviated his concerns related to the time needed to construct a written response in English. I transcribed each five-to-seven-minute audio recording during the semester.

By the middle of October, the journal aspect of data collection was growing more cumbersome. We met for MATH 792 on Mondays and MGSIs who had not yet submitted their reflections would sometimes look sad or guilty when they saw me. They would tell me they would do it, yet in a way that seemed more like a burden or that they were disappointed for having not completed the reflection. I did not want to harass them about writing, so I consulted with my advisor who suggested giving them candy as a thank you and boost for them. I wrote simple thank you notes and attached chocolate, nuts or gummies and tried to leave them on their office desks. If they were in the office, I just gave it to them. I tried to somewhat personalize the small gifts; for instance, giving chocolate baseballs in a navy-blue Yankees bag to the baseball fan. This helped shift the data collection dynamic from nagging to encouraging and seemed to help all our attitudes while developing rapport between myself and my participants. I repeated this process at the beginning of November. By the end of the semester, two MGSIs completed all journal prompts and one missed only one week. The last MGSI, Deacon, completed eleven of the thirteen prompts. He also sent his own reflection that he had written related to a peer mentoring meeting assignment. For each MGSI, I complied their weekly responses into one file, creating their semester-long journal.

### *Other Sources of Data*

Other sources of evidence used in this study were MGSIs class assignments from MATH 792, participant-observation during Math 792, and audio from mentor meetings. Towards the end of the semester in Math 792, MGSIs completed a self-observation paper

and wrote a teaching philosophy. The self-observation paper was a critical reflection of a lesson they taught. MGSIs were asked to explain a few specific decisions they made related to meeting their measurable learning goals and reflect on how those decisions related to their beliefs about teaching. The assignment was intended to help them prepare for their final course assignment, writing their teaching philosophy. The directions for the teaching philosophy assignment asked MGSIs to address beliefs about teaching and learning, what they wanted students to achieve and how to accomplish this, how they know they are a good teacher and how they can continue to improve their teaching. During the pilot study, I attended many of the Math 792 classes, including the final meeting where MGSIs shared a brief summary of their teaching philosophy. I noticed the comments made by both pilot study participants aligned well with comments they made during interviews. Thus, both documents were collected at the end of the semester as part of this case study.

Two final sources of data came from being a participant-observer throughout the MATH 792 course and audio from peer-mentor meetings. Attending MATH 792 provided an opportunity to listen to MGSIs thinking in a different setting; yet the even greater benefit was the opportunity to connect with study participants. In addition, audio transcripts from the MATH 115 (Precalculus) peer-mentor meetings were obtained from Dr. Yee. These meetings are designed as a space for MGSIs to share concerns related to teaching their classes with their peers and a mentor. The mentor is a more experienced MGSI who has been trained in mentoring. In order to keep the environment conducive to high-quality mentoring, I did not attend these meetings. Instead, an audio recording was obtained at the end of the semester. The written documents, observational data and

mentor audio provided a way to search for discrepant evidence or negative cases as well as for triangulating interview themes as part of data analysis.

### ***Mentor Interviews***

During my final observation of the semester, Chen's mentor also came to observe the same lesson. We both sat in the back of the room and as I had recorded the lesson, we talked briefly at the end of class. As I explained my study, he shared some of his thoughts about observing and mentoring Chen over the semester. I realized this was a valuable person for me to talk with as he had observed Chen's teaching three times during the semester and met with him weekly to discuss teaching. Thus, he could corroborate or clarify my perceptions of MGSI teaching and provided another perspective on both the classroom and the MGSI themselves. Further, he was mentoring Patrick, another one of the MGSIs in my study and agreed to be interviewed. I requested IRB approval and reached out the other mentor who was working with the other two MGSIs in my study. As this idea for data collection was added at the end of the semester, one interview was conducted in December and the other in January. The interview protocol is included as Appendix E.

### ***Organization of Data***

This study included 16 interviews with MGSIs and a focus group. The average length of an interview was just over one hour. Given the volume of data, software was used to help organize this data. Temi, an online speech to text transcription service, was used to help with transcription of the interviews and focus group. Dedoose, an online mixed methods data analysis tool, was used to organize the data and codes. The next section discusses the data analysis.

## Data Analysis

A researcher log was kept throughout data collection and analysis. It included various types of analytic memos and helped document the process of data collection and analysis. Saldaña (2016) explains analytic memos as a place to think critically about and reflect on anything related to the research process including participants, phenomenon, coding or analysis. "Future directions, unanswered questions, frustrations with the analysis, insightful connections, and anything about the researched and the researcher are acceptable content for memos" (Saldaña, 2016, p.45). Coding was done one MGSI at a time and began with their journals, then lesson interviews, self-reflection and teaching philosophy from MATH 792, and ended with the initial interview.

### *Dramaturgical Coding*

Based on the pilot study and proposal, data was coded using dramaturgical coding (Saldaña, 2016). "Dramaturgical coding approaches naturalistic observation and interview narratives as 'social drama' in its broadest sense. Life is perceived as 'performance,' with humans interacting as a cast of characters in conflict" (p.145) and it "attunes the researcher to the qualities, perspectives, and drives of the participant" (p.146). Saldaña argues it is useful for exploring underlying psychological constructs. Thus, it was fitting for a study seeking to understand MGSIs planning, conceptualized as "set of basic psychological processes in which a person visualizes the future, inventories means and ends, and constructs a framework to guide his or her future actions" (Clark & Peterson, 1986, p.260) and teaching which can be conceived of as a public performance. Further, its code categories align well with the research questions for this study.

Saldaña (2016) describes six types of codes that can be used for dramaturgical coding: objectives, conflicts, tactics, attitudes, emotions, and subtexts. Pilot study data was coded using these six codes. The emotion and subtexts codes were not useful for answering the research questions and were omitted from later analysis. The following codes were anticipated to be used as they lined up well with the research questions:

- Objectives defined as motives in the form of action verbs, which can include what the participant-actor wants other people to do. In this study, it often referred to what the MGSI wanted students to know, be or do.
- Conflicts or obstacles confronted by the participant-actor that prevent them from achieving the objective. In this study these codes allowed for analysis of the obstacles or challenges MGSIs perceived in their planning or teaching.
- Tactics or strategies used by the participant-actor to deal with conflicts and obstacles and to achieve objectives. This provides insight into elements of lesson design and classroom practices MGSIs selected and utilized in their classrooms.
- Attitudes of the participant-actor towards setting, others, and the conflict. In this case, this includes much of the MGSIs orientations about teaching and learning.

***Transcribing and Coding***

After data collection was completed, coding began in the middle of January 2020. All coding was done in Dedoose to help organize and manage the volume of codes and data. I decided to focus on only one MGSI at a time, seeking to better understand each instructor individually. I chose to begin with Chen's data since his interviews were the shortest and I wanted to get the coding process underway. As I cleaned his interviews, I made small grammatical edits, mainly changing verb tenses, so that his quotes could be

presented in standard English for ease of reading during coding and in the final paper. Once Chen's data was coded, I moved to Patrick next since his interviews were the longest. Willie's data was coded third and Deacon's was coded last. This order allowed for saving the project in Dedoose with only data from Chen, Patrick and Willie as Deacon's data can be analyzed as a separate study.

Seven types of data were coded for each MGSI: their semester-long journal, three lesson interviews, the initial interview, and two written assignments from MATH 792. The journal was chosen as a starting point for trying the dramaturgical coding scheme because it spanned the entire semester and could cover a broad range of the MGSIs thinking and experiences with teaching. Next analysis continued with the interview data. The semi-structured interviews provided more depth to each case and were used to expand the coding scheme from the journals. Lesson interviews were coded sequentially, and codes were added as needed. If a previous code described the passage, the code was reused. If it addressed a new objective, conflict, tactic or attitude, then a new code was added. More details related to coding are provided below. After coding the lesson interviews, I turned to the self-observation, teaching philosophy and ended with the initial interview. This order allowed me to observe that few new codes emerged from only the initial interviews, suggesting what was said in the initial interviews was either repeated or expanded upon during the semester rather than changed. Chen's self-observation and teaching philosophy were coded after the second lesson interview as I was still determining the order and was focused on establishing the feasibility of using dramaturgical coding with all types of data (journals, interviews, and written assignments). Each subsequent case was coded in the following order: journal, three

lesson interviews in sequential order, self-observation and teaching philosophy, and finally the initial interview.

Following the coding method established in the pilot study, I began coding using the four categories of objectives, tactics, conflicts and attitudes, which organized the data to address the sub-research questions. Thinking about the broad research question for this study, how do MGSIs plan (design and reflect), I added a fifth category called influences to capture references to external influences on MGSIs planning that did not fit the four anticipated categories. For instance, Chen's journal included references to the influence of peers on his planning as he stated, "I tried to come up with some more complicated active learning activities because a lot of my peers are trying jigsaw and some other activity". The journal entries also suggested that students seemed to influence Chen's planning as he reflected on students' feedback from a midcourse evaluation. Chen wrote, "a lot of people would rather take a small quiz rather than working in a group…I might have to adjust the way I do active learning in class, like give them an exit slip". As these types of external influences appeared and did not seem to fit in the other four categories, I added a fifth category called influences for direct references to other people or experiences that were referenced as reasons for an action or idea.

Coding was an iterative process which involved the use of a hierarchy to organize codes and search for themes. I began coding by placing codes under the main dramaturgical categories of objectives, tactics, conflicts, attitudes, as well as influences. For example, if there was a conflict, meaning a problem or obstacle or challenge with time, a category for time was added under conflict. This created what I will call "levels" of codes, where conflict was a level one code and time was level two. These could also

be called parent-child codes or super and subcategories. Some categories that were relevant to the research question or were referenced in more nuanced ways were further coded at a more detailed level, call it level 3. This level of coding was more specific, included some in vivo codes (Saldaña, 2016) which are taken directly from the MGSIs own words. This helps maintain the participants perspective in the analysis and allowed for deeper exploration of participants meaning. For instance, the code category of objective (level 1) was broken into student learning, students, and teacher (level 2). As goals for student learning is referenced in the research question, excerpts related to what the MGSI wanted students to learn were coded at a more detailed level such as connect mathematical ideas or “recognize and use appropriate tools,” which are examples of level 3 codes.

At multiple times throughout the coding process, I engaged in code mapping (Saldaña, 2016), which is a technique to organize data and improve trustworthiness of findings during analysis. It is a process of organizing the full set of codes into categories and then further condensing them into themes. It’s not a linear process, rather it involves lots of sorting and comparing, seeking to find codes that seem to belong together and considering how categories relate to one another. This was first done at the conclusion of Chen’s journal, and then again at the end of coding each MGSIs data set. Examples of this process are provided below. To give a sense of the quantity of codes and the need for this process, Chen’s code counts included the most references to tactics (n=162). The code counts for objectives (n = 135), attitudes (n = 132) and conflicts (n = 132) were quite balanced overall, while influences (n=40) occurred the least often and mostly during interviews or journal entries.

**Coding Clean Up.** One example to illustrate how decisions were made with respect to the levels of codes comes from reviewing my tactics codes for the first time. It was becoming difficult to process all the categories I had created in Dedoose, so I listed the codes out on paper and tried to rearrange or combine similar codes. Any code with only one excerpt I reviewed to see if it really fit better under another category. For instance, I had one "omit content" code (level 3) under assessing students (level 2) that I moved to "create/sequence content" (level 2) as it was an action taken related to content coverage. This created more categories under "create/sequence content" which were actions related to planning a lecture or resources used for finding good examples or questions and were factors traditionally associated with lesson planning. That category was different from what I called "activities" which were actions taken in the classroom to structure the learning format such as exit slips, group work, lecture/teacher explain or think-pair-share. I moved categories called "mix it up" and "offering help" out of the activities category and renamed "offering help" as "helping outside class" since it better described the excerpts. A few categories were combined such as "come back" and "slow down" which combined into "adjust timing." In these ways, the tactics codes became easier to manage.

This process of code mapping had to be repeated throughout coding. At the conclusion of coding Patrick's data, I again rearranged or cleaned up the tactic codes. Before moving any categories, I reviewed all the quotes to determine what the category was describing to confirm the quotes were describing the same concept. I listed out the 13 level 3 categories under "activities" which included "lecture teacher explain." However, I wanted lecture to be its own level 2 category and let the activities code refer to more

student-centered non-lecture methods. This separated data related to MGSIs thinking about teacher-centered actions from their thinking about more active learning or student-centered approaches. I also moved “provide worked example” which was an activity to be under lecture teacher explain because it references something done by the instructor. I also merged level 3 activity categories of “provide practice time” and “you try it” into one level 3 category as they both described allowing students time to work in class on similar problems to what had been presented. I decided three level 2 categories of “be clear,” “stress common mistake” and “show enthusiasm” were really elements of emphasis in a teacher focused lecture. Thus, these were moved to level 3 under lecture-teacher explain.

Another example of code mapping the tactics codes comes from listing out the 11 level 3 categories under create/sequence content. These codes varied greatly and showed me that I had some trouble distinguishing between things the instructor did, which I called tactics, and a few goals or even conflicts. For instance, “connect to prior material” was already an objective of teachers so I merged similar tactic codes with the goals. They were better described as goals, something the teacher is aiming to do. Similarly, I had “prepare for calculus content” as a tactic but then had “prepare students” as an objective under teachers. Again, these codes were merged as they described the same concept and was an aim rather than observable action of the teacher. Finally, “adjust timing” dealt with examples of times when the instructor had to finish something the next day, so this was merged with the conflict of time. Another category, “discussing why”, was moved to level 3 under lecture as it was a point of emphasis made by the instructor. I also added a new level 2 category of “preparation materials” because three of the categories under

“create/sequence content” had to do with what materials were used to prepare the lessons. This included references to the provided MATH 115 materials (premade course materials), looking online to find problems or questions (online resources) and Patrick’s settling into his own ordering of problems (my own way). Now “create/sequence content” which started with 11 sub-codes was down to 4 that better exemplified the code.

Another example of code mapping comes from reviewing objectives codes after finishing Patrick’s data. This process ultimately led to the creation of some themes for MGSIs goals for student learning. Upon review, I had 23 objectives for student learning and the list was difficult to look through when coding new passages. I needed to reduce and organize the list better so that I could use it more effectively with future passages. The codes were mostly distinct, although a few were unique to an individual such as “mathematical maturity” for Patrick or study skill/monitor learning for Chen. I again used the tabletop method and grouped similar ideas together. This led to adding a level 4, which was beneficial in that I could visually see the entire code category in Dedoose. This process led to a “procedural” category that had to do with being able to do math problems and included “know/memorize facts”, “recognize and use appropriate tools/techniques”, “develop algebra/content skills” and “solve problems.” It included an affective category which I called productive dispositions because it fits the definition from *Adding It Up* (NRC, 2001). I also grouped some codes together as “reasoning” because these had more to do with thinking skills such as constructing new knowledge, thinking or developing intuition, connecting ideas, proving and so on. In trying to organize these codes, I did review the mathematical standards to see if any of those

frameworks captured the codes well which is why I used the productive dispositions term.

A final example of this type of analysis occurred upon the completion of coding Willie's data. I again reviewed my codes and only made one change in Dedoose. It was an important change since I moved two code categories ("mix it up" and "learn about students") from under tactics (level 1) to objectives of the teacher (level 2). I had debated if when Willie wanted to vary his class structure, should that be a goal, something he aimed to have happen, and not a tactic, something he did that I could observe? I decided it was an example of an objective, what the teacher wanted to accomplish, and made the switch.

The examples of code mapping described above, and coding in general, were facilitated by meeting with my advisor every week or two throughout the coding process. I kept a list of questions so that we could examine passages that were challenging to code, reflect on the use of the codes and discuss decisions to rearrange categories. By sharing my coding with another person, it helped me clarify the categories, code more consistently, and provided a space to reflect on trends and insights sparked by coding. Additionally, a log was kept documenting the coding process and excerpts from the researcher log were used above. Analysis transitioned to defining the research design and writing findings in the fall of 2020.

***Preparing for Writing Findings***

Each case, or instructor's data set, was coded as described above and analyzed individually through coding and memo writing. A researcher log of analytic memos was written throughout data analysis to create an audit trail of this process (Yin, 2018).

Saldaña (2016) suggested two other concepts that were relevant to dramaturgical analysis which proved helpful to understanding MGSIs planning and interactive teaching and preparing to write about findings. These were identifying the superobjective and writing vignettes. Saldaña used respect as an example of a teacher's superobjective meaning "the overall or ultimate goal of the participant in the social drama" (p.148). MGSIs had many goals for student learning, yet one emerged strongly as a superobjective as it was mentioned by all MGSIs beginning with the initial interview and they continued to reference it throughout the semester. Another concept Saldaña suggested for dramaturgical analysis of conflicts was to write vignettes to consider, "what kind of trouble is this person in?" (p.148). Although MGSIs did not seem to be "in trouble", they did experience tension between their goals for student learning and student learning measured by students tests or quizzes. The idea of vignettes was used to introduce each MGSI in the individual case studies as a way to bring the reader into their classrooms.

Next, I reviewed the research design for the study in consultation with my committee. At this time, I decided to focus the remaining analysis on the three MGSIs, Chen, Patrick, and Willie, who were all pursing PhD's and considering academia as a possible career path. Thus, they could be considered potential future faculty and their early teaching experiences are important for helping professional development providers and mathematics departments think about how to support instructor growth and improve undergraduate student learning and course experiences. Additionally, I chose to make minor adjustments to the sub-research questions at this time. The main change was the addition of a question to address the influence codes that were added in recognition of

external factors influencing MGSIs planning and teaching. Minor revisions were also made to the wording of other sub-questions for clarity.

Finally, I hypothesized a structure for presenting findings to answer the research question by addressing each sub-question. For reference, the overarching research question for this study was: During their first semester teaching a new undergraduate course, how do MGSIs plan (design and reflect) and implement their plans, with a focus on their goals for student learning? Thinking about the multiple cases that had been studied throughout data collection, dramaturgical coding and memo writing, there were many common themes in terms of both participants objectives for students and conflicts experienced. Thus, I decided to answer the sub-questions a) What goals do MGSIs aim to achieve for student learning? and d) What challenges do MGSIs describe as they reflect on their planning and classroom instruction? through cross-case analysis, presenting MGSIs findings together. However, individual case studies would better answer the remaining sub-questions, b) In what ways do MGSIs seek to achieve their goals for student learning? and c) In what ways, if any, did MGSIs describe external factors relative to their goals for student learning or planning practices? It seemed logical to discuss the goals before explaining how MGSIs sought to achieve them. Thus, chapter four address sub-question (a) by discussing the four overarching goals MGSIs had for their Precalculus students. Next, chapter five addresses sub-questions (b) and (c) through individual case studies of Willie, Patrick and Chen. Finally, chapter six address sub-question (d) by sharing themes that emerged from the conflict codes. This structure is summarized in the table below.

Table 3.1 Research Design

| Sub-questions | Method | Data | Dramaturgical Codes | Additional Analysis | Tentative findings/ Importance |
|---|---|---|---|---|---|
| a) What goals do MGSIs aim to achieve for student learning? | Themes from cross-case analysis | From each MGSI:<br>• Journal<br>• 4 Interviews<br>• MATH 792 assignments<br><br>Focus group | OBJECTIVES for Student Learning (levels 1 – 4) | Check for consistency or differences or trends<br><br>Compare focus group themes with coding themes | Evidence for and examples of goals in new MGSIs<br><br>Insight into stability or variance of goals over semester |
| b) In what ways do MGSIs seek to achieve their goals for student learning? | Multiple case study showing within case analysis | From each MGSI:<br>• Journal<br>• 4 Interviews<br>• MATH 792 assignments<br><br>Mentor interviews | TACTICS, OBJECTIVE for student and OBJECTIVE for teacher, ATTITUDES lesson strengths and lesson weaknesses | Write vignettes describing MGSIs thinking when teaching connected to their intended goals for student learning<br><br>Compare categories for deeper perspective of individual instructor | Improved understanding of role goals may play in MGSI teaching and planning<br><br>Glimpses into MGSIs lived teaching experiences |

| Sub-questions | Method | Data | Dramaturgical Codes | Additional Analysis | Tentative findings/ Importance |
|---|---|---|---|---|---|
| c) In what ways, if any, did MGSIs describe external factors relative to their goals for student learning or planning practices? | Multiple case study showing within case analysis | From each MGSI:<br>• Journal<br>• 4 Interviews<br>• MATH 792 assignments | INFLUENCES | Consider how these influences impacted MGSIs | Theoretical understanding of how external factors influence MGSI planning |
| d) What challenges do MGSIs describe as they reflect on their planning and classroom instruction? | Themes from cross-case analysis | From each MGSI:<br>• Journal<br>• 4 Interviews<br>• MATH 792 assignments<br><br>Focus Group<br><br>Peer-mentor meetings | CONFLICTS | Check for consistency or differences or trends<br><br>Compare with focus group and mentor meetings to confirm, refute or expand | Suggest areas where support can be offered to MGSIs |

### *Summary of Data Analysis*

Qualitative data analysis is an iterative process that began with writing memos during data collection throughout fall 2019. The memos produced some ideas for questions that appeared in subsequent interviews, the closing focus group and helped track the data collection process. In spring 2020, interviews and the focus group were transcribed. All MGSIs interviews, journals, and assignments from MATH 792 were coded using tactics, objectives, conflicts, and attitudes from dramaturgical coding (Saldaña, 2016). An influence code was added to better capture MGSI planning. Code mapping (Saldaña, 2016) was used to create categories and arrive at themes. Throughout data collection and analysis, I consulted with members of my dissertation committee and other researchers about this process engaging in peer debriefing (Glesne, 2016) or what Saldaña (2016) calls "shop-talking".

## Role of the Researcher

As part of conducting qualitative research and seeking to practice reflexivity, I am acknowledging my subjectivity, my personal history and passions, and positionality, my relationship to participants and setting, related to conducing this study (Glesne, 2016). This is intended to help the reader understand what influences my behaviors and interpretations of this study.

### *Subjectivity*

My career and passion have centered on teaching young adults about mathematics. I view teaching as life-long learning and believe that I am still developing as an educator. Part of my own growth has been facilitated by studying mathematics education, participating in professional development, having discussions with peers about

student learning, beginning to conduct research in mathematics education, and reflecting on my own classroom experiences both as a teacher and student. These experiences have helped me think more about what I want my students to learn from my courses and how different learning experiences position students to learn different skills or ways of thinking. I believe incorporating active learning methods into my own teaching has benefited my students, predominately first-generation college students, in deepening their own mathematical understanding and developing productive dispositions towards mathematics. I have 18 years of teaching experience, with the last 14 being at USC where I have taught many of the introductory undergraduate courses. The choice of Precalculus as the course for this study was an intentional step to help me "make the familiar strange" as it is a course I was not teaching nor had taught for many years, yet I have much knowledge and experience with the Calculus courses that follow in the sequence. Wanting to help improve student experiences in introductory service undergraduate mathematics courses was a key motivation for me choosing to conduct this research study.

### ***Positionality***

I have taken on multiple roles in my work at USC including both working as part-time faculty in the mathematics department and working as a graduate student in the College of Education. For this study, I intended to primarily interact with and relate to my participants as a peer where my aim was to understand the participants, in this case MGSIs, point of view. I anticipated positioning myself as a fellow graduate student, although in the field of mathematics education rather than mathematics, who teaches many of the same courses they are assigned to teach. In addition, as a graduate student I

had many things in common with MGSIs such as learning how to conduct research in my field, balancing multiple roles of being both a student and instructor, and completing steps through graduate school such as taking qualifying or comprehensive exams and choosing a committee for your dissertation. In these ways, I was able to relate to my participants as an insider (Johnson-Bailey, 2004). I was an outsider in terms of age, teaching experience and overall experiences with working at a university, yet I tried to focus on our commonalities.

However, an interesting dilemma presented itself early on in the data collection process of this study. After the first lesson observation, I immediately started getting questions like, so what did you think? I assured them I was interested in their perspective, mine was not important and I did not want to taint their opinion. Deacon seemed okay with that. Then Willie blew me away with his jigsaw lesson. I wanted to be excited but tried to remain "neutral" and press for his perspective only in the interview. He seemed willing to talk but something bothered me. Interviews involve a lot of communication. Who would want to talk to someone who pretended to be neutral about the whole observation? The next day I went to Patrick's class. Same question and he pointed out that part of the appeal of the joining the study was to get feedback! From his perspective, I just observed his class and have more teaching experience, so it seemed natural to want feedback. That made me think; I am an amateur researcher but an experienced instructor. What should I do? I needed to revise my approach to positionality in this study.

After talking to my advisor about how, if at all, I could give them feedback but capture their thinking, I looked back to some training I had on cognitive coaching about types of feedback (Costa & Garmston, 2018). The idea of interviews as part coaching

conversations proved extremely useful and became part of my positionality for the rest of data collection. The passage below was taken from my researcher log and provides examples of how I tried to resolve the dilemma of giving feedback while trying to understand their perspective as objectively as possible. It was written after I interviewed Patrick about his first lesson that I observed, which was a jigsaw activity for students to learn about solving quadratic equations. "Beemers" was a term used in cognitive coaching to describe something people do when they are thinking.

Judgments, personal observations, and inferences are evaluative feedback while data and mediative questions are coaching feedback. This is a way I can provide some feedback to them, and it seemed to work well with Patrick. He and I talked a little before the interview about distinguishing between the research, which is about his thinking, and my feedback which could be given, as he realized, after the interview. During the interview, I tried to include data if relevant. For instance, he talked about the timing taking longer than expected. I was able to tell him how long it took before the expert groups started, how long they worked in expert groups and talked a little about how transitions take a few minutes. He seemed to find the information helpful. I also think I was getting into some mediative questions during the interview because I saw a few beemers from time to time, like when he would cock his head or even say, "that's a good question". After the interview, we turned off the recorders and clarified this conversation was separate from the interview. I read through the comment's students in the groups near me had made and gave my overall approval, said "it was good" (that judgment that shuts off thinking). I tried to share both "positive" and "negative" data such as, I saw a girl sitting by the door on her phone. He said, yeah, I saw that too. I mentioned the

student who said “I hate this, I really want him to show me how to do it” but did say she didn’t say it in an angry tone. I think he was surprised at how much I could say they talked to one another. This is something I will try to clarify (difference between research conversations and personal conversations) and do (give coaching feedback) with the other MGSIs too.

For me, conducting this study at UofSC was engaging in backyard research, which can have both benefits and challenges (Glesne, 2016). Benefits included knowledge of the setting, finding the research meaningful, simplicity in communicating with and building rapport with participants, and saving time and money for data collection. Challenges included scheduling difficulties, exhaustion, and holding back on discussing participants with my advisor during data collection, as he was their instructor in a pass/fail course. I did monitor and discuss challenges with other members of the research community during data collection and frequently consulted with my committee as the analysis unfolded.

**Trustworthiness**

Some researchers use the term validity to discuss the soundness of a study, while others argue this term is not appropriate for qualitative studies and prefer to discuss trustworthiness (Glesne, 2016). While the terminology tends to differ in qualitative and quantitative studies, some methodologists acknowledge both terms as they attempt to convey the same concerns: Why should a reader believe the results or findings of any study? This section discusses strategies used to improve the trustworthiness of these findings and potential concerns relevant to this study. As this study design utilizes Yin’s (2018) case study methodology, it concludes with his discussion of how case study

methodology addresses common validity threats using terminology more common in quantitative research.

***Strategies for Improving Trustworthiness***

Several strategies were utilized to improve the trustworthiness of this study. Glesne (2016) suggests “prolonged engagement; persistent observation; triangulation or use of multiple methods, sites, and/or respondents; negative case analysis; debriefing with peers and supervisors; member checking on collected data and on interpretations; thick description; monitoring of subjectivity; and data and theory audit trails (p.152) as strategies for establishing trustworthiness. Similarly, Maxwell (2013) identifies intensive, long-term involvement in data collection, rich data, respondent validation, intervention, searching for discrepant evidence and negative cases, triangulation, numbers, and comparison as strategies that can be used to improve trustworthiness in qualitative studies.

Several of these methods were included in the design of this study. For instance, data was collected over a semester and involved observing multiple lessons, conducting multiple interviews with multiple MGSIs and spending time with them in Math 792. The design of the case study and use of multiple interviews allowed the opportunity to “corroborate an interviewee’s stated views by asking about them in more than one way or on more than a single occasion – and hope to receive a consistent set of responses” (Yin, 2018, p.121). These repeated observations and interviews gathered over time created a rich data set that was useful for triangulation of data. Also, the design allowed for comparison of data collected in different settings. What was said in a private interview was compared to what was said in a group setting in class or during the focus group to

search for differing interpretations of MGSIs thinking and allow for negative case analysis. Further, interviews with MGSIs peer-mentors provided an opportunity to clarify and confirm my perceptions of MGSIs teaching. Observations made during MGSIs teaching helped inform and contextualize the lesson interviews. Finally, data from written documents such as the teaching philosophy was compared to interview responses.

Another challenge with interview studies, thus this study, discussed by some methodologists is the threat of reflexivity. Due to the "conversational nature of the interview," there can be "a mutual and subtle influence between you and the interviewee – previously referred to as *reflexivity:* Your perspective unknowingly influences the interviewee's responses, but those responses also unknowingly influence your line of inquiry" (Yin, 2018, p.120). Maxwell (2013) notes this is always present in interview studies, thus it is not something that can be avoided but is to be understood in qualitative research. As I am the research instrument, I am part of the interviews and do influence them. Besides obvious measures such as avoiding asking leading questions, I have openly stated my positionality and subjectivity and monitored them throughout data collection and analysis. Part of this meant reflecting on what I noticed MGSIs saying and asking myself, am I only hearing what I want to hear (Glesne, 2016)? I clearly stated upfront to the MGSIs that the study was supposed to be about their perspective and tried to limit my feedback to coaching. I also found keeping a log and discussing challenges with other researchers to be helpful. As mentioned above, multiple data sources were collected to help triangulate findings. Further, some effort was made to member check during interviews by using the coaching technique of paraphrasing when appropriate (Costa &

Garmston, 2018). As explained in chapter seven, MGSIs were also invited to review the research findings and provide their input.

Finally, peer debriefing and a data trail in the form of the creation of a case study database as described by Yin (2018) were strategies that were used throughout data collection and analysis. I frequently discussed progress and questions with my advisor and other members of the research community. Memos and careful documentation of data collection helped to create an auditory trail that can further speak to the trustworthiness of this study. An example of this log was provided in the data analysis section and the positionality section of this chapter.

### *Case Study Validity Tests*

Yin (2018) takes another approach to discussing the soundness of a research design by reviewing four validity tests, three of which are relevant to an exploratory study. Again, these terms may not be as accepted by all qualitative researchers but are included here as part of reflecting on the use of case study methodology as discussed by Yin.

Construct validity meaning “identifying correct operational measures for the concepts being studied” (p.42) is challenging in a field such as education where many terms are not well defined. For this study, a list of working definitions was provided in chapter one. The terms used in coding, particularly the level 1 codes of objectives, tactics, conflicts, and attitudes, became consistently defined through discussing coding with my advisor. To improve construct validity, Yin (2018) argues case studies address this through the use of multiple sources of evidence, establishing a chain of evidence that documents how findings relate to research questions, and allowing key informants to

review a draft of the study's findings. This research design utilized multiple sources of evidence including classroom observations, multiple interviews, participant observations, documents, a focus group, and mentor interviews. Efforts were made during data collection and analysis to create a chain of evidence through creating a case study database. All handwritten notes taken during classroom observations, interviews, and during participant observation in MATH 792 are kept in a binder sorted by MGSI. Researcher memos and un-coded copies of transcriptions are electronically stored on a password-protected computer. As previously mentioned, Dedoose was used to organize coded data. In these ways, notes were organized and are available for later access as needed. Finally, efforts to member check findings were formally implemented. Willie, Chen and Patrick all reviewed a draft of their individual case study and verbally discussed findings related to goals for student learning and challenges encountered.

External validity deals with "showing whether and how a case study's findings can be generalized" (Yin, 2018, p.42). Yin (2018) discusses the difference between statistical generalization, which uses a sampling logic to make inferences about a larger population, and analytic generalization, which is more likely relevant to case study research. Analytic generalizations are made as claims supported by argument and are discussed rather than stated. In this study, the case is bounded by MGSIs at UofSC who are teaching Precalculus, a service course commonly assigned to second-year graduate students teaching as instructor of record for the first time, in fall 2019 as part of their teaching assistantship. The participants were selected using replication logic rather than a sampling logic (Yin, 2018). Instead of trying to correctly sample from the pool of all MGSIs, in this study participants are chosen for the case because of their similar teaching

situations, meaning they have the same course assignment and departmental context, were provided the same training, had similar limited prior teaching experience, and are on similar career tracks as all are pursing PhD's in mathematics and are at least considering academia as a future career. It is hoped that this case will provide insight into the planning and teaching of MGSIs teaching other similar service courses at other universities that offer support for MGSIs learning to teach. To address external validity, Yin (2018) recommends using theory and replication logic. Chapter two attempted to address theory relevant to this study and replication logic was used to select the study participants.

The third validity test discussed by Yin (2018) is reliability or "demonstrating that the operations of a study – such as its data collection procedures – can be repeated, with the same results" (p.42). According to Yin (2018), this is done more in principle with the intent of minimizing errors or biases and is addressed by careful documentation. All protocols were set up to note the date, location and participants. As mentioned previously, a case study database exists and organizes all data collected. The data collection process was described in detail earlier in this chapter and was included in the researcher log which also documented the process of data analysis.

**Summary of Study Methods**

This was a multiple-case study bounded by the site, course, and semester. Further, participant characteristics bound this study as all were second-year male MGSIs considering academia as a future career path and teaching as full instructor of record for the first time in a full 15-week semester. Data collection included interviews with MGSIs and their mentors, observations of MGSI teaching, weekly journal entries, MATH 792

assignments and field notes, and audio from mentor meetings. Data was coded using dramaturgical coding and analyzed to report themes both with-in case and across cases to answer the sub-research questions. The findings are shared in the next three chapters and are organized by sub-question.

# Chapter 4: Goals for Student Learning

"If you aim at nothing, you will hit it every time." – Zig Ziglar

MGSIs work towards many types of goals over a semester. This chapter reviews the most salient goals that MGSIs discussed while preparing for and reflecting on teaching precalculus. These goals related to what MGSIs aim to help students learn and were shared among all MGSIs in this study. The majority of these goals for student learning are consistent with various mathematics standards documents, as they centered on student reasoning, understanding and sense making, developing productive dispositions as learners of mathematics, and procedural skills (NRC, 2001; NCTM, 2009; Blair, 2006). However, MGSIs primary aim focused on preparing students for their future. This aim could be termed the superobjective as it emerged as the "overall or ultimate goal" in this study (Saldaña, 2016, p.148). All MGSIs in the study clearly stated from the beginning of the semester, reiterated throughout, and confirmed in the focus group, the importance of precalculus as preparation for students' future coursework and careers, particularly for those who expressed interest in STEM careers. While preparing students may be considered more of an instructor goal than a goal for student learning, it is included in this chapter since it was so significant in MGSIs thinking and relates to student learning.

This chapter is organized by goals. It begins with the super objective and then continues with goals in order of the frequency and depth with which they were discussed by MGSIs. Goals were themed through code mapping of the dramaturgical student

learning objective codes and confirmed by looking at themes from the focus group (Saldaña, 2016). Each section seeks to describe what the goal encompasses and includes evidence of the goal in MGSIs thinking. Again, as each goal was expressed to varying degrees by all MGSIs, their data is presented together to illustrate the pervasiveness of the goal throughout the data set and among MGSIs. This presentation includes references to Deacon as a participant in the focus group.

### Goal 1: Prepare Students for their Future

MGSIs in this study spoke a lot about preparing their students for next steps, which primarily included future coursework or career-related skills, but also involved personal study skills or exam preparation. Some of the focus on preparing students may be due to the course they were assigned to teach, since precalculus is a prerequisite course for the calculus sequence. However, it was interesting to note how prevalent this factor was in the minds of MGSIs as they talked about planning. Knowing their students desired to major in a STEM field and would need to complete the calculus sequence also put added pressure on MGSIs as they recognized the foundational importance of the course for their students' future success.

#### *Future Coursework*

All MGSIs stated upfront in their background interviews that their goal was to prepare their students for calculus. Chen explained that his learning goal for students was for them to "know enough math to prepare them for Calculus 1 and Calculus 2 because I think that's the big part of this class." Patrick reflected on his previous experiences as a calculus TA and remarked, "my goal would be to prepare them and have them not make those mistakes [that prior calculus students made and]… be able to do whatever else they

need for calculus." Willie also explained he wanted to help students acclimate to college-level expectations and be "prepared for calculus because that's the whole point of this course." It was clear from the background interviews that in the minds of MGSIs, teaching this course was about equipping students with the necessary knowledge and skills to be successful in their subsequent coursework.

Student preparation emerged as the obvious overarching goal MGSIs held relative to their students and comments related to this goal were not limited to the background interviews but were continuously shared throughout the semester. All journals contain multiple references and similar phrases to "my main goal is to prepare these students for calculus," which was in Patrick's journal. Chen similarly stated in his journal, "My primary goal is to prepare my students for the calculus courses or other mathematics classes they need to take." Willie's final journal entry stated, "My thoughts on what I hope to accomplish from teaching have not changed. I still would like to have my students be able to apply the concepts from my class to either calculus or to their real-world careers."

At times this goal also appeared to explain decisions that MGSIs made throughout the semester. For instance, Willie wrote in his journal,

> My only challenges came from my students struggling to remember the unit circle. I hate to make students memorize things, but I know that in calculus they will be expected to know this. Thus, I will be quizzing them a second time this week to stress the importance of it.

Not only did MGSIs speak about how their assessments were influenced by the focus on calculus preparation, but at times they used this criterion to justify what material was

important to emphasize. Deacon clearly stated this is in the focus group, saying, “Because you have that hindsight of what's going to be in Calculus 1…The whole time I was like, it will be important for calculus… what I think is really crucial to calculus is what you're going to get.” Evidence of this goal at play in the planning of MGSIs also occurred during their teaching. Consider Chen telling students that recognizing the graphs of sine and cosine and distinguishing between them is important to know. In the following lesson two interview, he explained this was because in calculus, “They have to be able to at least draw a sine and cosine [function] and compare the derivatives.” Similarly, Willie recognized that completing the square was a skill he had seen prior students struggle with when he was working as a TA. Thus, he explained in his lesson one interview, “so that’s another reason why I want to focus on it, just because I know it’s going to come up later in calculus.” MGSIs clarified in the focus group that course preparation was not limited to calculus. For example, they cited instances that engineers might need to use the content in statics courses or their careers, but calculus preparation was predominately spoken of by MGSIs. For these MGSIs, their course, “pre-calculus” is very much as it sounds, the prerequisite foundation for calculus. Teaching it is then about student preparation; MGSIs desire for their students to be prepared and successful in their future coursework.

### ***STEM Career Focus***

In addition to focusing on future coursework, MGSIs also kept in mind their students’ future careers. MGSIs were cognizant of the fact that most undergraduate students enrolling in precalculus had chosen STEM majors other than mathematics. Thus, MGSIs desired to prepare their students for their future STEM careers, wanting to help students achieve their career goals and be competent workers in their STEM fields. As

Willie remarked during the focus group, “we are trying to prepare them for their life,” and knowing precalculus material will be imperative for students to obtain and keep their jobs. MGSIs agreed that students working in STEM fields used mathematics regularly. As MGSIs discussed the importance of future coursework such as calculus, Willie stated this was because “these kinds of kids, they need to know it …[because] in the future, they are going to be using this” in their careers.

Not only did MGSIs want students to be able to successfully complete their coursework and achieve their career goals, but they also stressed the importance of their students correctly using mathematics in their future careers for projects that can have real-life consequences. This may be particularly relevant for engineering majors as Deacon shared a story during the focus group about how a calculation error led to two people losing their lives. He concluded,

> That's a really extreme example, but it kind of like underscores the fact that, yeah, this isn't just about knowing some random theorem [or] being able to do a very mundane task. [It's] about kind of using these kind of examples to build tools to be able to quantitatively perform various tasks…[when] they didn’t do the mathematics correctly…they really screw people up.

Other MGSIs agreed this is not always a matter of life and death but recognize the real-life impact that mathematical errors can have, even in fields such as insurance or medicine. Thus, MGSIs want their students to have a solid mathematical background so they correctly use mathematics in their future careers.

This career focus appeared sometimes to be on MGSIs' minds when planning their content but to a lesser extent than the focus on calculus preparation. For instance, Willie shared in his lesson three interview,

> They need to have an application because they need to see the purpose… For example, I defined frequency of trigonometric functions… I didn't go anything more than just defining it because it's only applicable to like physics majors and people like, and I don't have any physics majors in that class… [If] they don't need to know it then I'm not going to go into depth about it.

Willie agreed he wanted to prepare students in ways that would be relevant to their future career aspirations. Here he used the criteria of students' majors to help determine what definitions would be most useful to his students.

***Personal Life or Study Skills***

Another way in which MGSIs spoke of preparing students was in developing personal work habits and study skills. Less frequently mentioned than the career-focused types of preparation, this category included learning how to learn, taking ownership of the learning process, and feeling personal satisfaction or pride in hard work.

Although MGSIs were deeply concerned about their students' mathematical learning, they also valued and wanted to promote students' general learning skills. Chen shared in the focus group how students' experience of studying precalculus was important for undergraduates in ways beyond the mathematical content. He explained,

> I also feel like it's useful for practicing like learning skills too because like it's not just like they have to know the material for calculus, but they still have to know

> *how to learn* the material… It's not just like math is math. Like you also need to learn the skill for learning like new knowledge.

He also referenced wanting students to learn how to learn in interviews and in his journal where he wrote, "I hope they kind of learn the process of studying for the exam or the process of studying in general." Similarly, Patrick shared advice he gave to students struggling with studying in his journal. He wrote,

> My suggestion to them is to spend 20-30 minutes every night looking back through class notes from that day: Do you understand the definitions that were introduced in class? Do you understand the examples that we did as a class? Can you do those examples on your own? These are the types of questions that I would encourage my students to try to answer.

MGSIs were working to help students develop broad study skills and habits.

In addition to developing general study skills, MGSIs wanted their students to take ownership of their learning by monitoring their own progress. Willie thought this was important as he shared what he disliked about a team baseball-style test review game he planned and utilized with his class. In his lesson two interview, he explained that the game provided a space for him to point out to students what they needed to study but saw this as the only drawback to the activity. He stated,

> I think that should be less of what I'm focused on. I should be worried about like what they reviewed already, like what they think they need help with... They should figure out what they don't know and then ask me questions instead of me telling them what they don't know…I guess personal like responsibility, like

> holding them accountable. They should be accountable for [figuring out] what they don't know and ask me questions about it.

In this way, Willie expressed his goal for students to take ownership for their learning. Similarly, Chen expressed in his journal how he was trying to encourage students to take responsibility for their learning through decisions about how to use his assessments. He shared,

> I am trying to make my student to be accountable for their own performance. So, I gave the exam two back last week and instead of doing the flat curve without them doing anything, I try to make them do the exam corrections. I try to make them go back and look at how the exam questions related to the lesson they learned before.

Rather than simply giving points to students, Chen designed his exam corrections in a way that required students to actively review and correct their work.

Another way MGSIs tried to encourage student ownership in their lessons was by incorporating aspects of discovery learning. For instance, Willie designed his jigsaw activity in a way that led students to arrive at various formulas and theorems such as the quadratic formula or method of synthetic division. He explained in the follow-up interview that what he valued about his jigsaw activity was the opportunity for students to make the activity their own or take ownership of their learning. In his third lesson, Chen structured the lesson to allow for students to try out a problem without an example to follow. In the interview he explained this was a way for students to "become more like self-aware I guess that they don't know how to do this right. They have to like, like be

with me, like stay with me, with the lesson kind of thing." He hoped this awareness would motivate students to remain engaged with and attentive to the material.

Finally, MGSIs discussed and agreed that they valued students' feeling personal satisfaction with their own effort. During the focus group, MGSIs reflected on the value of students struggling in the course yet preserving and successfully completing Precalculus. Some MGSIs felt this could contribute to their students' self-efficacy. Deacon explained during the focus group that students who struggled but still earned a C should know that "they [the students] work hard, but like they, they kind of have this fact that like, okay, I know what I'm talking about and maybe I can keep trying and persevering." Here he talked about perseverance as a general character trait anchored in recognizing the rewards of hard work. As Deacon continued to reflect on what he wanted students to take away from the course, he shared,

> I asked my students at the last class and first off, they said it was hard; the class is very hard. But, it kind of like taught them this type of thing that like if you work hard, you're going to be able to really get things done. Like was more of a general work ethic type of lesson I think that some got out of it.

Willie agreed and continued,

> Building on that, you want them to gain that life lesson of like working hard, you know, like that's something that you always strive for …I don't know about you guys, but I didn't study a lot [in high school], didn't put a lot of work into my schooling at all…I mean I definitely made that change somewhere along the way...It's good for them …to understand that they have to work hard to get what they want here [at the collegiate level].

Thus, when planning and teaching, MGSIs in this study were often cognizant of their students' future paths. Thomas and Yoon (2014) also identified the goal of wanting to prepare students for success in future tasks and assessments as a goal of a beginning secondary teacher. In this study, the significance of a prerequisite course on students' abilities to complete necessary coursework to pursue their intended majors, the importance of mathematical skills for working in STEM fields, as well as the students' personal development all frequently factored into MGSI thinking throughout the semester.

**Goal 2: Help Students Develop Mathematical Reasoning, Sense-making and Understanding**

The most frequently coded objective for student learning in the entire data set related to students' mathematical reasoning abilities. However, MGSIs often spoke of multiple elements or terms related to reasoning, sense-making, and understanding together. This section discusses how these terms were not used distinctly in the data and includes examples of how they overlap. It continues with examples or terms that fit within this goal.

MGSIs in this study frequently referenced multiple skills and processes they sought to develop in their students which included wanting students to apply or connect mathematical concepts, facts, or procedures, develop intuition and think creatively about mathematical ideas, and conceptually understand mathematical concepts and make sense of them. Initially, I tried to separate these codes into reasoning, understanding, and sensemaking, where reasoning included verbs such as apply, connect, generalize, derive, prove, or create, understanding was conceptual or vague or meant knowing why

something was true, and sense making meant making meaning of the problem, definition, or concept. NCTM (2009) defined reasoning as, “the process of drawing conclusions on the basis of evidence or stated assumptions” and sense making as “developing understanding of a situation, context, or concept by connecting it with existing knowledge” (p.4). However, these concepts were not clearly distinguishable in this study, as will be demonstrated below.

After completing the coding, I began to review passages where MGSIs discussed codes related to reasoning in an effort to begin writing about a goal of reasoning alone. Here I noticed that MGSIs did not always neatly distinguished between ideas of reasoning, understanding, or sense making but instead blurred them together or connected them when speaking. For instance, in the lesson three interview, Patrick discussed why he showed students the derivation for some trigonometric identities and explained the problem with just giving students a list of identities.

> They [the students] would have no sense of why they're true or no sense of where they came from. And so, I think that… it's important for them to not just use these things… If you have no idea of why it's true or what it's even saying, like, do you understand it? I mean I'm not saying I need them to memorize these proofs or anything, but at least they can see, you know, that they come from somewhere.

Here Patrick talks about students understanding where the identities come from and why they are valid identities. Thus, this passage was coded as both understanding and sense making. Further, the context of the passage was related to having students verify trigonometric identities, which I included under my reasoning codes. This passage shows

some of the difficulty in separating the constructs of understanding, sense making, and reasoning.

Willie also provides examples of these concepts intermingling. For instance, while teaching a lesson on the law of sines, Willie asked his class to figure out how to write the area of a triangle without using the height. It took the students a while, but Willie explained in his lesson three interview,

> I knew they could get there and so I really want, you know, figuring out where it comes from I think is pretty important because it gives you that more conceptual knowledge right here. You found it! Right, now you know how to do it again right? Instead of me telling you how to find it. I do the same thing for the Pythagorean identities … [I gave them an identity] then I said, look, okay guys, I want you to derive this from that… Now they knew how to get there and they did it… They thought through it and now they can repeat that same thinking that they did before if they did, for some reason, forget that identity.

This passage was coded as both understanding and reasoning since it includes wanting students to build conceptual understanding through deriving identities in order to understand the basis for the identity. In this way, Willie defines reasoning as a way to build conceptual knowledge by understanding why a formula exists.

The goal of developing students' mathematical thinking and the way MGSIs discussed understanding, reasoning and, sense making together was not limited to any particular course content. While both of the prior examples deal with trigonometry, the mixture of these goals also appeared in the algebra content. Willie provides another example from the lesson two interview when discussing what he liked about one of the

problems he designed for a baseball review game. The problem asked students to find "A" if a line passing through two points was perpendicular to y = Ax + 6. Willie said,

> It [the problem] does make me happy because it takes their understanding to another level … They have to know what a perpendicular line is… they're just thinking of process, right? But now, there's this random "A" here. Well, what the heck is that? I don't know. And it forces them to think about like in more of a different way about how to apply it. It ended up being the same process to that point. Right? But it definitely made them think differently…because it gets, once again, it generalizes their understanding. So takes what they've learned and makes it so they can apply it to other things.

Willie discusses what he valued in this problem, which includes having students make sense of the A as the slope of the perpendicular line, applying the concept of perpendicular slopes in a new setting, and developing a deeper understanding of slopes of perpendicular lines. In these ways, Willie aimed to develop his students' understanding of and sense making about slope as well as their ability to reason by applying or using concepts in new ways.

Chen also discussed the ideas of developing sense making, understanding, and reasoning together. For example, Chen discusses both students connecting ideas, what I considered reasoning, and sense making in the first lesson interview. The content in the first lesson I observed covered finding asymptotes of rational functions. He explained,

> So, when I introduced the [rational] function, right, I explained [to] them that the functions gonna have like a problem when they evaluate [at a point that causes you to] divide by zero. Right? So, I kind of hope that they see that that's the

> problem. Like, we cannot include that [value] in our function, that kind of thing. So, I hope they can relate that to the vertical asymptote and the graph and where the problem happened.

Here Chen wants his students to make sense of the meaning of a vertical asymptote by making connections between the equation of a rational function, evaluating the function at its vertical asymptote, and the graph of the function. By seeking to connect different representations of a function, he wants the students to make sense of mathematical equations and draw meaning from definitions, in this case asymptotes. In this way, he is seeking to develop students' reasoning and facilitate sense making.

This challenge with segmenting the data into components of reasoning also appears at a more granular level. I had coded for applying concepts, facts, or procedures and connecting mathematical ideas as two distinct codes under the broader category of reasoning. The "applying" code captured notions of taking something previously learned and using it in a new context or manner versus connecting more than one mathematical idea. However, consider Chen's thoughts on having students apply ideas of function transformations while seeking to develop the formulas for shifting graphs of sine and cosine functions:

> So, I feel like I can kind of go back to the stuff that they like everyone already know, like with the function transformation, right? So, they have to apply that knowledge to the graph of sine and cosine function. So, I think so this is a good place for them to like try to apply those two idea together and like they can talk to their friends and see like if they get the same answer. They can try to like explain their reasoning for their idea to their, like friends.

He talks about applying and connecting former knowledge of function transformations to trigonometric functions, a new type of function being introduced in the course. While I coded this as passage as both applying and connecting, it illustrates the difficulty of distinguishing these skills for students relative to how MGSIs spoke about them.

The passages above show some of the ways MGSIs might discuss understanding, sense making, and reasoning together. Dedoose allows for review of code co-occurrences which showed many excerpts were coded in several ways, and about half the excerpts coded for understanding were also coded as reasoning. Initially, I conceptualized reasoning as mental actions such as applying or connecting concepts, facts, or procedures, developing intuition or creative thinking, or actions related to proof such as generalizing, conjecturing, deriving, proving, or verifying. While I tried to distinguish these from other ideas such as sense making or understanding as though they were distinct elements of learning, the MGSIs didn't consistently discuss reasoning, understanding, and sense making as separate categories. Therefore, I have combined them into one goal.

This goal was the most frequently coded objective for student learning in the dramaturgical coding of data and was discussed in the focus group as MGSIs shared their views on the importance of the course and their efforts to help students apply course concepts. During the focus group, MGSIs stated they wanted students to be able to apply course material in different contexts, comprehend and follow the material, and understand the "why" behind mathematical ideas.

Unlike the MGSIs' goal to prepare students, this goal is indicative of elements in the strands of mathematical proficiency (NRC, 2001) and overlaps with NCTM's call for

high school mathematics programs to focus on reasoning and sense making (2009). Conceptual understanding (the comprehension of concepts, operations, or relations) and adaptive reasoning (logical thoughts, reflections, explanations, and justifications) are described as two of five interlocking strands which are necessary for students to learn mathematics (NRC, 2001). NCTM (2009) further argues that reasoning and sense making are intertwined, are foundational to the NCTM process standards, and are both "important outcomes of mathematics instruction, as well as important means by which students come to know mathematics" (p.5). They contend that analyzing a problem, implementing a strategy, seeking and using connections, and reflecting on a solution are examples of productive reasoning habits that are used in mathematical inquiry and sense making. Rather than being a mathematical topic to cover, they conceptualize reasoning as a "stance towards learning mathematics" (p.17) and advocate for reasoning and sense making as "the foundation for true mathematical competence" (p.14). Additionally, they claim this focus will "ensure that students can accurately carry out mathematical procedures, understand why those procedures work, and know how they might be used, and their results interpreted" (p.3).

The passages above attempt to demonstrate the interconnectedness of reasoning, sense making, and understanding in MGSIs' comments and in how they can be described in K-12 mathematics (NCTM, 2009). This next section illustrates different aspects of these goals as expressed by MGSIs in this study. This section provides exemplary quotes of how the goals were expressed throughout the data set among all MGSIs. This theme saturated the data set. All MGSIs mentioned each subcategory of reasoning, sense making, and understanding goals at least once, with the only exception being Chen, who

was not coded for proving or verifying, which was only one aspect of reasoning. This does not mean that Chen did not value proving or verifying identities, but it may be related to the lessons discussed or the fact that Chen's data was coded first in more of a splitter style. As the coding process continued over several months, more codes were added, and my coding shifted towards clumping and including multiple codes for one passage. For the sake of space, there are not examples of each MGSI in each category, yet all MGSIs expressed the goals of developing their students' mathematical understanding, sense making, and reasoning. These examples are given as further evidence of ways in which MGSIs discussed their aims to help students develop their thinking. Again, more than one aspect of this goal may be expressed in a passage.

***Sense Making and Developing Intuition***

As shared in some passages above, MGSIs desired for their students to make sense of mathematics. Both Patrick and Willie reflected on this aim when discussing the jigsaw activities that they implemented during my first lesson observation in each of their classes. Patrick's activity included conceptual questions about quadratic functions that he wanted students to consider. He explained in the interview,

> So for example, we'll look at the graphs of quadratic equations and say, what do the roots mean? And you know, depending on how far up or down the parabola is, will determine how many roots you have, that kind of thing. Um, so I will relate back to these more open questions later, but I thought it was important for them to start considering them now and try to maybe develop some intuition as to like, what, what are these things talking about?

Willie had also included quadratic functions as a component of the content in his jigsaw activity. Similarly, he shared how he wanted his students to reflect on the derivation and usefulness of the quadratic formula. While explaining the purpose of the activity, he stated,

> For example, this one we're finding the quadratic formula. Like what, where did that come from? You know, a lot of people just know the quadratic formula. Where does it come from? So I want to emphasize their understanding of the quadratic formula, kind of emphasize where it comes from. Why, why do we notice? What is it for?

In both cases, MGSIs stressed the importance of students making meaning about quadratic functions. They wanted students to think beyond only identifying key points on the graph or solving quadratic equations or memorizing a formula.

Part of encouraging students to make sense of ideas seemed to relate to helping develop what MGSIs sometimes called students' intuition, or their ability to think mathematically or creatively. In the focus group, Deacon discussed ways in which mathematics "is like so fundamentally bedrock creative" and Chen reflected in his self-observation that "many students have a misconception that mathematics [problems] only have one correct answer. By developing their own reasoning, students become comfortable thinking mathematically." MGSIs expressed that mathematical thinking needed for higher-level mathematics, such as problem-solving or proving, includes many reasoning skills that allow for less algorithmic uses of concepts. MGSIs desire for their students to have some instincts for how to approach problems and to think in more diverse or creative ways. Further, they identified these types of reasoning abilities as

crucial in later mathematics courses and recognized this area as a space where their students could grow.

For instance, in the last interview, Patrick reflected on what he wanted students to learn from his lesson about verifying trigonometric identities. While he acknowledged this process is often difficult for students, he also sought to help build their intuition. He elaborated,

> That's the real question that they need to ask. What do I do when I can't start? What do I do when I get stuck? … But again, this is the difficult section because they don't have that intuition of where to go or what to do next. And I tried to emphasize …you can start these problems in five different ways, and you may not get anywhere. And then you take a step back and just try it again in a different way…you need to walk down a path until it doesn't go anywhere. And then you need to walk back and say, where did I make a decision? What can I change? So that's what's difficult for students. They don't like the idea that they don't know what to do next. Um, but sometimes you don't, and you just try stuff… For these problems, intuition is knowing what to do next… after you do enough of these problems, you'll start to realize maybe like more quickly, which is the right direction. That's the intuition I think.

Thus, part of MGSIs' goal for students to develop understanding, reasoning, and sense making includes developing their instincts and abilities to make sense of and use mathematical concepts. At times, MGSIs described this as developing students' intuition.

### *Applying Concepts, Facts or Procedures and Connecting Mathematical Ideas*

MGSIs often expressed a desire for their students to be able to apply previous material to the current lesson and wanted students to be able to apply current concepts in the future. As Willie commented during his lesson three interview, "Why are you just going to learn the material if you can't apply it?" He summarized some discussion during the focus group related to the value of teaching trigonometry and applications of triangles,

> That's just one, one way that we can show this, this thing that we learned is being applied ... I think that's been common throughout our entire course. I remember saying like, this is stuff from chapter P like five million times. So yeah, I think we're kind of just expressing how we're using all this stuff, right? We're building it up and then we're going to keep going back, you know, using this stuff to keep going further. It's like one step back to go two steps forward… so that they could see how to apply these things.

MGSIs kept connecting or applying prior material to the current lesson and felt this was important for students. Chen explained this in the second lesson interview when discussing how he planned for his lesson. He considered,

> How can I relate the material that they need to learn to the thing that they already know? That's why, that's how I create like exercise for students to like try to relate a thing that they already know to the new material [so] that they can use those ideas again…because for math, I feel like they have to use some certain idea like over and over. So, I think it's kind of important for them to like recall. They

> already know that part of the material and how can they like apply those idea to a new thing, that kind of thing [is what I thought about when preparing this lesson].

Chen aimed for his lesson to highlight relationships between previous and current mathematical content.

MGSIs frequently talked about applying material as making connections, yet they also referenced connecting mathematical concepts. Later in the same interview, Chen confirmed he tried to help students make connections between mathematical ideas while introducing the graphs of sine and cosine functions. He continued,

> So, I think if they do it on their own, they can think that they can get this graph from a unit circle, right? So from the unit circle they have a value for sine theta and different theta, so they can try to use those coordinates to graph on their own. So [in] case in the future, like if they have to produce this graph, hopefully they can try to recall [and] to use this unit circle to graph. Again, it's a connection between uh sketching point that they know that on the graph and try to use that or from with the information from unit circle. Because like in that way, if even they don't remember the graph of sine and cosine but they remembered the unit circle, they can try to like at least sketch something.

Chen is seeking to help his students connect points on the unit circle with the graphs of sine and cosine functions to improve students' retention and understanding of these trigonometric graphs.

***Understanding Why: Deriving or Proving***

Another aspect of developing students' reasoning, sense making, and understanding comes from MGSIs' references to wanting students to understand where

formulas “come from.” MGSIs liked to discuss which proofs they covered in class, how long they took, and why or when they may need to omit a proof. Although they did not always make the same decisions, they all agreed on the importance of providing students with justification or reasons for formulas. Often these were presented by the instructor as part of the lecture, yet sometimes MGSIs asked students to derive formulas or identities. For instance, Willie’s discovery jigsaw activity engaged different groups in deriving different formulas or theorems such as the rational roots theorem or the quadratic formula. He reflected in his lesson one interview,

> They all knew the quadratic formula. Yeah, so my goal was to not explicitly say you're finding the quadratic formula. It was to, for them to derive and say, oh look, it's the quadratic formula! [And have] the epiphany, the whoa! You know, like what you do when you get a proof and you spent forever doing and then you finally get there. I think that was, most of that was group two's activity [from the jigsaw] was a lot of epiphany moments.

As a result of the activity, Willie wanted his students to know that mathematical properties are not random but based on reasoning. Thus through the jigsaw, he aimed to improve students’ sense making or understanding of the material. In addition, MGSIs want students to be able to derive formulas or identities as a skill. For instance, Patrick stated in his final interview,

> And I think if they understand a topic well enough, then they should be able to do that [derive when you forget something]. So it's just like, and I want them to understand the topics. I don't want them to just be able to do these problems.

MGSIs know that on exams, their students can derive formulas when needed if they cannot remember one. Willie called this “a blessing in disguise” since it can be done often and “not everyone is a memorizing person.” Here he recognizes that derivations are not always needed but are useful and provide another tool for students to utilize.

### ***Generalizing or Conjecturing***

Another way MGSIs discussed wanting students to develop reasoning skills was by creating opportunities for students to generalize and conjecture. During the second interview, Chen explained how he thought about his lesson design. He wanted to vary from the usual presentation of material, which presents a formula and then shows students how to use it. He explained, “Sometimes I don't like just give them like the formula and [say] this is the result.” Instead, he tried to “go the other way” and ask students to begin with examples and build up to a general formula. Similarly, Patrick stated in his teaching philosophy that,

> Broadly, a main goal of my exploratory lessons is to have my students formulate a conjecture and then work through either a formal or informal justification. This process is incredibly important because it is more akin to how mathematics is done at a higher level.

In his first lesson interview, he reflected on his satisfaction with students who worked on a problem from the jigsaw activity that asked students to derive a theory of what took place.  He reflected, “They really got there. So I was pretty impressed by that... they didn't just give up. They kept talking to each other, like how can we generalize this kind of thing.”

MGSIs in this study aimed to help their students grow in key areas related to students' reasoning, understanding, and sense making. They describe this goal in many ways, including wanting students to develop intuition, apply and connect concepts or ideas, derive, prove, generalize, or conjecture about formulas or theorems in addition to wanting students to understand or make sense of mathematics. MGSIs discussed these goals in the focus group and the related codes appeared most heavily in the lesson three interviews yet appeared throughout all data sources related to MGSI planning. It appeared to be the most significant learning goal in terms of frequently being in the minds of MGSIs during their pre- and post-active thinking (Clark & Peterson, 1986) and directly relates to K-12 mathematics process standards (NCTM, 2000) and aspects of mathematical proficiency (NRC, 2001). Problem-solving, reasoning, and making connections between representations are also standards for intellectual development for post-secondary mathematics (Blair, 2006).

### Goal 3: Help Students Develop Productive Dispositions

Another important goal regularly shared by MGSIs comes from the affective learning domain. All MGSIs expressed affective goals for their students and desired for their students to develop positive mindsets about themselves as learners and towards the field of mathematics. This category included MGSIs' goals to build students' self-efficacy as well as goals for students to enjoy or take interest in mathematics and/or their MATH 115 course, appreciate the usefulness of mathematics, and develop a willingness to work on problems and persevere in solving them. All of these themes were directly identified by MGSIs during the focus group and all MGSIs referenced multiple goals related to students' attitudes at times throughout the semester. The manner in which

MGSIs discussed these goals is very similar to the definition of productive dispositions, another strand necessary for students to learn mathematics (NRC, 2001).

In *Adding It Up*, the NRC defines productive dispositions as the "habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy" (p.116) or, put another way, "the tendency to see sense in mathematics, to perceive it as both useful and worthwhile, to believe that steady effort in learning mathematics pays off, and to see oneself as an effective learner and doer of mathematics" (p.131). Thus, it includes both how students see themselves as learners of mathematics and how they understand the field of mathematics. In this way, the MGSIs' focuses on building students' confidence and influencing students' views of mathematics aligns well with this strand of mathematical proficiency as presented by the NRC.

To explore this theme, I will discuss focus group findings first and then give supporting evidence from dramaturgical analysis with other data sources. Again, the other data, interviews, journals, and writing assignments are mixed together for the purpose of showing the pervasiveness of these goals in different settings and among participants.

### ***Enjoy mathematics and class***

During the focus group, MGSIs discussed what they would like their students to say about their course. Willie recalled Patrick's recent comments during a mentor meeting where Patrick had stated that one of his goals was to help students enjoy mathematics and overcome the stigma of mathematics being scary. Willie then reflected

on a recent conversation with one of his students who said he now almost liked math. He continued,

> I thought that was good that one of my students was like, I'm this close [to liking mathematics]. And I think he actually did enjoy math. I think that was just him being funny, but … that's something I want to hear. Someone was like, yeah, I think I enjoy math now.

These comments were not unique to the focus group and had been referenced throughout the semester. For instance, Willie had previously stated during the lesson two interview,

> Every time I ask them, most of them say they like math. So, it's a good step, so it's, I've done something right. Because usually people say the opposite … I know that they didn't look happy to be in my class at the beginning cause it's math, so, but I think I think I've done a good job making them happier and [helping them] enjoy math. So maybe they like math now… at least [I'm] getting them to look at it a little in a better light.

During this part of the interview, Willie laughed as he remembered students not looking happy earlier in the semester and got a little quiet, almost hopeful, when sharing how he had done a good job improving students' attitudes towards mathematics.

Additionally, MGSIs mentioned wanting students to find mathematics interesting and enjoy their time in class. For instance, during the first lesson Patrick invited me to observe, he had done a jigsaw activity to help students learn methods for solving quadratic equations. During the interview, he explained,

> And again, I don't want them to just come to class and sit there and, you know, absorb or not [the] material. All right. I don't want them to just continue to do

> that. I mean, you know, math is not just supposed to be something that you have to do. Math is not supposed to be a chore. So maybe this type of activity or maybe these types of activities will make them more interested in or motivated [to learn mathematics].

In this instance, the choice to include a jigsaw activity was tied to Patrick's desire for students to have positive experiences in their mathematics course. The next chapter will further discuss ways in which MGSIs sought to achieve their goals for student learning.

***Build self-efficacy and confidence***

During the focus group, MGSIs also restated their hopes to improve students' self-efficacy for doing mathematics. Once Willie shared his desire for students to enjoy mathematics, Chen agreed and reflected on written feedback he received from a student where the student stated they were inspired by the way Chen worked out problems. Chen acknowledged, "I think I want to like make students more comfortable with math or like basic skills, you know, not like fear math and like push away from it". MGSIs wanted their students to be confident in their mathematical skills and recognized this quality would be important for students in the future. For instance, Deacon discussed the value of students becoming comfortable with messy answers, saying, "if they get 188 over root seven, like they need to go like, yeah, it looks ugly, but it's right. Cause I did it right." These quotes demonstrate that MGSIs desired to improve their students' efficacy for doing mathematics.

Again, this theme was not discovered during the focus group but had appeared in the data throughout the semester. Patrick, for instance, had expressed this goal multiple times since the beginning of this study. During his background interview he explained,

> A lot of these students I think are students that have struggled with math in the past … [they may hold] the opinion that they're bad at math or they don't like math. Um, so one goal I might have is to sort of change that opinion of some students, you know, you're not bad at math. Math is just a skill, you know, it is, as you practice it, like any other skill, you're going to get better at it.

Patrick believes that students are capable of improving their mathematical abilities and demonstrating mathematical competence. His goal is for his students to share and embrace this same thinking.

***View mathematics as useful***

MGSIs wanted their students to recognize how mathematics is applicable to everyday life. Chen addressed this directly in the focus group when discussing what he would like students to know or think about after taking the precalculus course. He shared,

> We do a lot of material but they [students] like, they don't see how those thing will be used like in their life or whatever. So, I kind of want to put more like word problem or like application problem in there, like basic modeling stuff like with different type of functions. So at least they get to see like how they can apply certain area to like specific certain type of problem…like I want them to see like why they have to study that.

MGSIs agreed that exposing students to the applications of mathematics could help motivate students and increase their interest in the material. Again, this was not just a comment made at a focus group but appeared throughout the full data set. For instance, Chen had overheard some students complaining about mathematics and stated in a journal entry,

> I hope to tell my students why they need to learn math. A lot of my students hate math because they don't see how they can relate what we learned to their lives. But I want to tell them that math is useful, they don't have to actually know how to do math but in their daily lives they use math, like modeling in business or biology or cell phones are signal processing. Like math can be related to their daily life and I hope they kind of appreciate the material or knowledge that makes all that happen. So, I hope my students appreciate the use of mathematics more.

Chen also explained in the final interview how he recognizes many of the ways mathematics makes daily life possible yet felt many people are not aware of the role mathematics plays in modern technology. He stated, "I hope like people don't think of math as like far from them. They use it without knowing that they are using it." Given that Chen is an applied mathematician, this goal may be naturally relevant to him. However, this goal was also articulated by other MGSIs who study pure mathematics.

For instance, Willie stated in his journal, "I believe I'm also responsible for motivating the material and making students understand the importance of the material to help them see the real-world applications to their life." Indeed, this was not just a hope of Willie's but a goal. He enthusiastically shared about a class discussion of the applications of factoring polynomials during the lesson two interview. A student had asked about the value of a theorem and Willie reflected, "If they're gonna ask me a question like that, they're like, there's a cool answer for it" and passionately recounted the discussion he had with his students. This seemed to be significant to Willie as he again referenced this event in his teaching philosophy when he stated,

> At the very end I got the question I was hoping for; “Isn’t the Rational Roots Theorem not going to be useful with most polynomials since there could be a million choices for possible roots?” This question to me was essentially asking, why are we learning this? To them I answered, “Good question! There currently is a whole field of mathematics devoted to finding sufficient algorithms for factoring polynomials. These are only a few ways that can be done. This is important for cybersecurity since most cryptographic codes are based on the difficulty in factoring large polynomials.” Answering this question gave the student and the class that final ‘bow’ on the topic emphasizing their learning.

During the background interview, Patrick also highlighted the importance of sharing the usefulness of mathematics when discussing why he thought a lesson had gone well.

> I feel like I spent a good portion of that class trying to convey to them like how powerful this thing that we developed was, and … I think a lot of people thought that what I was doing was actually very cool and … They kind of say, Oh, that's, you know, that's why we've been spent a month doing this. And, uh, so I think that's sort of a, that's sort of nice… when you feel like you've conveyed to them that an idea is important or interesting or useful.

In some ways, it is not surprising that graduate students, who are personally spending lots of time and energy studying mathematics, would desire for their own students to value and understand the usefulness of the field they are invested in. Further, mathematics graduate students may have knowledge of the ways in which and situations where mathematics can be applied. MGSIs felt the Math 115 course could be improved by including more applications and Chen stated in his journal that he would like to add more

modeling problems if he were to teach the course again so that students could “apply mathematical ideas to interdisciplinary problems”. Thus, MGSIs discussed helping students view mathematics in a useful light as another aspect of developing students’ dispositions towards mathematics.

### ***Perseverance in Solving Problems***

Another aspect related to their students’ attitudes towards learning that MGSIs aimed to develop was students’ willingness to persist when struggling. All MGSIs discussed this goal during at least one of their lesson interviews, often in the context of students persisting through long, tedious, or challenging problems. For instance, in the interview following Willie’s second lesson, he discussed one of the problems he really liked in his review game. The problem asked students to find the zeros of a polynomial and Willie described this problem as valuable for students because it was “a grind” and showed them,

> They have to try, you know, it's not just going to be plug in one, wallah, it worked. Cool, I got my roots right? Like this is, this is a process… I want them to know like you have to try them all, like it's, they're there. Right. Just don't give up on it.

In the final interview, Patrick explained the value of his students of working on verifying trigonometric identities.

> They need to be not afraid to be wrong… I feel like people have this aversion to, or they only want to do something if they can do it 100% right or something and [do it] well, and you know, sometimes, sometimes you're not sure and it's, it's okay if you try something and it doesn't work.

Similarly, Chen also expressed the importance of students' willingness to try out some ideas when solving problems. Chen's final lesson was on the law of sines. After demonstrating how to solve one triangle when given two angles and one side, he moved on to a different triangle with only one angle and two sides. He asked students how this problem was different, how to begin, and followed along with the students' ideas even though they initially would not head in a productive direction. In his final interview he explained why this was valuable for students to see,

> So, I want to show them that even we start with something, and we cannot get to the problem [solution], but we, if it's set up it differently, like we can eventually [solve the problem] … I want to show them that it's okay to like be wrong. Like it's fine, like just use another ratio or use another number, I guess. Because like the idea of trying is really helpful, especially in Calculus 2 when they like have a lot of tools to like, so integration problem. Right? They have to try like a different rule until it works. Especially when they don't see, haven't seen the pattern yet. Right. They have to like keep trying a few rules.

MGSIs understand that in order for students to solve mathematical problems, they must be willing to try different ideas and not become discouraged or give up when the first idea is not successful. Further, MGSIs did not limit this notation to solving problems but connected the idea of perseverance to more general affective states discussed with MGSIs' goals to prepare students for their future.

Thus, through aiming to build students' confidence and desiring for students to enjoy mathematics, hold positive views of mathematics, and be willing to persevere when solving problems, MGSIs describe affective goals they aim to help their students develop.

These categories echo the NRC (2001) description of productive dispositions as tendencies for students to think productively about themselves as capable learners and the field of mathematics as useful and worthwhile.

**Goal 4: Help Students Develop Procedural Skills**

Finally, MGSIs also aim to develop their students' ability to execute various mathematical procedures. Particularly common for mathematics courses at this level, MGSIs stated much of the course includes objectives for students to solve, compute, manipulate, or simplify, which often amount to replicating or following procedures. The course seems to play a role in the focus on procedural skills as MGSIs acknowledged that algebra and trigonometry typically involve lots of procedures or calculations and they wanted to equip students with tools that were useful for solving problems. As Patrick explained in the background interview,

> What we're asking them to do really is just procedural mostly... Can you factor? Can you perform polynomial long division? Can you multiply these two rational expressions together and simplify? All that is very procedural…Especially when you think about, what does a MATH 115 student need out of this class? They need to be able to factor because when they're going to calculus, they need these skills essentially. So I kind of view a lot of what we're doing as very skill based.

It may not be that MGSIs so much want undergraduate students to be able to accurately execute procedures as much as they see procedures as necessary skills for these students to continue to use mathematics in calculus or in their careers. Thus, this goal of procedural skill is related to other goals MGSIs have for their students. In terms of thinking about preparing students for their future, the goal of procedural competence was

addressed in a limited manner during the focus group. However, references to helping students develop procedural skills appear in the rest of the data as MGSIs addressed many specific algebra skills they wanted students to master, discussed helping students build a toolbox of skills, and the pointed to facts or formulas students needed to know. This goal is only discussed in ways which all MGSIs referenced developing their students' procedural skills.

***Develop specific content skills to solve standard problems***

Throughout the interviews and journals, MGSIs referenced a litany of algebra skills they wanted students to be able to do which included completing the square, solving systems of equations, factoring, solving quadratic equations, computing the difference, quotient, or the average rate of change in a function, solving triangles using the law of sines or cosines, identifying rational functions and their asymptotes, graphing polynomials, and evaluating trigonometric expressions. All of these can be tasks that follow a procedure to answer the question and were often identified as a goal of the lesson.

***"Recognize and use appropriate tools"***

All MGSIs at some point described procedural skills as tools they wanted students to have at their disposal to solve problems. Willie explained in his lesson two interview that he wanted students to see completing the square as much as possible "because it's a good tool. You'll see it all the time and they definitely see it in calculus." Similarly, Patrick explained in his final interview,

> I want them to be able to look at a problem, especially precalculus-based problem.. I would like them to be able to look at a problem and say, I have a set of tools that I might be able to use on this problem.

Procedural skills or tools are a critical, non-negotiable objective. In his final interview where Chen discussed a lesson on using the law of sines to solve triangles, he explains,

> It's like by the end of the day, like the goal for the lecture is for them to be able to solve using the law of sine. They don't have to actually know where it comes from. It would help with their intuition, but like it doesn't like align with the goal that I want to reach [that students can solve triangles].

Thus, the procedural skill, which in the above example was the ability to solve the triangle, was considered the main objective. The reasoning was good and desirable, but the procedural skill was essential.

MGSIs also discussed how students need to both correctly use a procedure and use it at an appropriate time, which could be a matter of recognition or understanding. As Chen explained in his second lesson interview,

> Because a lot of math is basically, you have to be able to recall [that] you need to do a certain thing. They need to able to recall like what they have to do. So, at some point, I want them to be able to recall what thing they need to do [for] a particular task.

Not only did MGSIs want students to be able to perform algorithmic or procedural processes, but to recognize when these skills should be utilized. As Chen stated in his journal, "My goal for my students is that they know how to use formulas; know *when* and know *how* to use formulas." The emphasis on knowing when to use a procedure does

relate with the prior goal of reasoning or understanding. Willie provided an example of this during his lesson one interview when he discussed why he wanted students to understand concepts such as the quadratic formula.

> I guess a problem that could come up is like, what are the zeros of this quadratic right? So it could be factored in which they don't actually need the quadratic formula. Now, most people when they memorize the quadratic formula, like the minute they see it, they will use it for everything. And so, um, that's honestly a big waste of time, right? … The point is so that if they can just factor it, just factor right. You don't need to do the whole quadratic formula, but there may be points when you do, so it's a tool that you have, but you don't have to use it all the time.

Thus, MGSIs did not only want students to be able to execute procedures but also apply them appropriately.

***Know or memorize facts***

While MGSIs frequently spoke of wanting students to understand procedures, they are ultimately working to ensure that students can perform them, which can be achieved through memorization. While MGSIs generally did not want students to memorize procedures, they did acknowledge at some level, there are skills, facts, or processes that students need to simply know. Knowing could mean memorizing.

During his second lesson interview, Chen raised an interesting question when reflecting on whether students should memorize material. While talking about function transformations, he asked, "What's the difference between memorize and like they just know it because they have seen it, [they just] know it by heart?" At times, the bottom-line goal can be for students to just know how, or memorize how, to execute a procedure such

as shifting a function. Similarly, Willie acknowledged that he wanted students to understand where formulas, such as the coordinates for the vertex of a quadratic come from, yet he remarked in the first lesson interview, “they will need to know it and they could just be able to memorize it.” Other times MGSIs identified formulas or values students needed to directly memorize. For instance, Chen wanted students to “memorize the values of sine and cosine now” from the unit circle so they could later evaluate trigonometric expressions at different angles. As Deacon stated and others agreed, “Unfortunately you can’t get past that [memorization] completely, but I try to sidestep it as much as I can.”

This goal of helping students develop procedural skills was commonly stated throughout the data and is a natural focus for a precalculus course. Interestingly, it was less prevalently discussed during the focus group, where it may have been understood to be part of preparing students for their future. Procedural fluency, which includes performing procedures accurately, efficiently, flexibly, and appropriately, is also identified as a strand of mathematical proficiency (NRC, 2001).

**Summary**

This chapter reviewed findings on the four key goals MGSIs aimed to help undergraduate students achieve throughout their precalculus course: (1) prepare students for their future, (2) develop reasoning, sense making, and understanding, (3) develop productive dispositions, and (4) develop procedural skills. These goals were described by MGSIs as the intended outcomes of their various teaching methods and precalculus instruction. These goals for student learning were shared by all MGSIs in this study and emerged as themes from the dramaturgical coding as well as the focus group, although

procedural skills were only discussed in terms of student preparation for the future during the focus group. The first goal, to prepare students for their future, has implications for supporting MGSIs and will be discussed further in chapter seven. This goal does not appear directly in any of the mathematics standards, although NCTM (2009) claims that high school mathematics should prepare students for life, the workplace, and the scientific or technical community.

Although these goals are presented from the perspective of MGSIs, three of these aims, (1) developing students' reasoning, sense making, and understanding, (2) fostering productive dispositions towards learning and mathematics, and (3) developing procedural skills, are very similar to some policy documents from K-12. They most resemble the five strands of mathematical proficiency needed for students to learn mathematics, which are provided for the purpose of defining what is necessary for students to become mathematically proficient in K-8 (NRC, 2001). To a lesser extent, they resemble the NCTM process standards of problem solving, reasoning and proof, communication, connections, and representations, which are ways secondary students acquire and apply content knowledge. In this study, these MGSIs did not describe communication as a goal for their students to learn, although the next chapter will reveal ways in which they promoted students communicating about mathematical ideas in the classroom. Additionally, MGSIs' goals align with some of the big ideas and essential skills advocated in mathematics standards for the first two years of college such as reasoning and developing mathematical power (Blair, 2006). Overall, MGSIs desired aims for their students agree with recommendations provided by mathematical standards. However, the

four goals found in this study describe the takeaways MGSIs actively work to develop in their undergraduate students and do not directly appear in any previously found studies.

Much like Kang's (2017) secondary science teachers who utilized high-level cognitive demand tasks, MGSIs in this study were able to frame their goals broadly in a manner which included important disciplinary practices. The ability to identify such goals is a critical element of instructional design (Wiggins & McTighe, 2005). The depth and volume of responses throughout the data set illustrates the importance of student learning from the MGSI perspective. This echoes findings from Burn, et. al (2000) who noted secondary student teachers and early-career teachers took student learning seriously. The next chapter will explore in more depth how and why individual MGSIs tried to achieve these goals.

# Chapter 5: Individual Case Studies

"The word 'why' not only taught me to ask, but also to think." – Anne Frank

"Whether you think you can, or you think you can't, you're right." – Henry Ford

In order to look at how MGSIs sought to achieve their goals for student learning, this chapter provides individual case studies of three MGSIs, Willie, Patrick, and Chen. Each case study includes a vignette to illustrate common features of each MGSIs' classroom and descriptions of objectives, tactics, and lesson strengths expressed and utilized by MGSIs. The objectives include goals MGSIs held for themselves as instructors as well as aims for their students. Further, each case study includes an analysis of most frequently referenced external factors that influenced MGSIs' planning. These findings will be summarized in a table towards the end of this chapter. The table below provides context related to MGSIs' backgrounds and lessons I observed. All MGSIs in this study were in their twenties and enrolled in their second year of graduate school. All were taking a full course load of graduate courses and teaching Precalculus (Math 115) for the first time as full instructor of record.

Table 5.1 Participant Descriptions

| MGSI | Race/ Ethnicity | Field of Study | Prior Teaching Experiences | Lessons Observed |
|---|---|---|---|---|
| Willie | White | Number Theory | Taught Math 122 in summer with 8 students<br><br>GTA for Calculus II<br><br>TA as undergraduate for courses in number theory and abstract algebra | 1. Jigsaw covering quadratic functions, remainder theorem, synthetic division and rational zero theorem<br>2. Baseball test review game<br>3. Using law of sines to solve triangles and find area |
| Patrick | White | Discrete Mathematics | Taught Math 142 in summer<br><br>GTA for Calculus I and III for four semesters at two universities<br><br>Worked at Tutoring Center for almost a year | 1. Jigsaw covering solving quadratic functions<br>2. Point betting test review game<br>3. Verifying trigonometric identities |
| Chen | Asian | Applied Mathematics | GTA for Calculus I & II<br><br>Tutoring | 1. Rational functions and asymptotes<br>2. Graphing sine and cosine functions<br>3. Using law of sines to solve triangles and find area |

**Willie**

> *The class has moved their desks to form four somewhat round ovals with students facing each other, notes on their desks and worksheets in hand. Willie squeezes and twists between the desks, carefully stepping over backpacks and calling out, "This is the lesson! If you don't know each other introduce yourself." Students shuffle their papers and begin to read; a few speak quietly. A student near me whispers to the student beside them, "Should we work alone?" Willie continues to pace, occasionally popping his knuckles as he circles another group. Two students near me compare their answers to the first question and discover differences as Willie calls out encouragement to the class, "Talk to each other." One of the students straightens up, "I see my mistake," while the other nods. A hand is raised, and Willie stops to listen to the question and make a correction to an exponent on the handout. He straightens up and calls out with a mild strain in his voice, "It's so quiet in here. Talk to each other! Ask each other questions if you are confused or ask me." The low rumble of students' voices begins to pick up. Several students near me appear satisfied after confirming answers with their peers. Another raises his eyes and asks a question to nearby peers. Willie pauses in the front of the room to speak to his Supplemental Instruction leader, who serves as a peer assistant with the class. "I think it's actually going okay. You want to just keep telling them to talk?" A smile creases Willie's lips as he wipes his sweaty palms on his jeans and moves towards another raised hand while the low chatter of voices gradually increases.*

The passage above describes my first observation of Willie's teaching. On this day, Willie designed a discovery-type jigsaw activity for his class. In this activity, students are split into groups to master a set of material. Willie had four groups, with each group exploring a topic such as the vertex form of a quadratic function, deriving the quadratic formula, synthetic division, or discovering the rational roots theorem. Later groups are rearranged so that each new group contains at least one member from each original group so that the students can explain their material to the students from other groups. Willie included lots of content in his jigsaw and it stretched over two full classes. Further, he created his own worksheets in a discovery format, meaning students were guided through a process to discover or reach an important mathematical concept such as the quadratic formula. This lesson was significant to Willie; he continued to speak about

it at the end of the semester, even referencing it in his teaching philosophy. It required lots of time and effort to design yet illuminates many characteristics typical of Willie's teaching. To further understand Willie, I will describe him by using the data from his interviews, journal, and writing assignments from MATH 792. An interview with Willie's mentor as well as my thoughts from observing his teaching also inform the analysis.

In his initial interview, Willie explained he loves teaching, perhaps because he enjoys helping people. While a teaching career is "not necessarily off the table," he plans to pursue career in industry. Willie describes himself as "bouncy," "very jumpy and very excited." His mentor agreed that Willie is an engaging instructor, full of energy and perceived Willie to be quite comfortable in the classroom.

***Objectives for Students***

Coding revealed that Willie frequently referenced wanting students to explain their thinking, work and talk with one another, and ask questions. During the observations I made of the classroom, I noticed lots of student collaboration and sharing of ideas within groups as well as times students asked questions to Willie. For instance, during the jigsaw described in the vignette above, nine students made up the group I was seated closest to. In my field notes, I recorded at least eight of them sharing and talking to at least one other student during the jigsaw.

During the lesson two interview, I noted it seemed crucial to him that students talk to each other, and Willie responded,

> Yes! That's like my big thing. I want that. I want them to talk to each other because it helps them explain their reasoning, and I find that so important because

> if they can explain their reasoning for how to do a problem, they just took their learning to a deeper level. And so now they can apply this more generally, because now they have this big concept in their head that they're able to explain and now it's stuck there because it's deeper, and so they can apply it to other things, which is the goal, right? …Now they have it, now they could use it. It's there and it's because they gained a deeper understanding through talking through it.
>
> It also helps the other [student]. That person also sustained a better understanding of it because they heard it from a different perspective. They're like, oh, now I heard Mr. Willie tell me this and then you explained it this way. Now I have two ways to look at this problem…It's a win-win.

As this quote shows, Willie strongly values having his students explain their thinking and work with or talk with peers. Creating opportunities for discourse is central to Willie's teaching philosophy. As he wrote in his self-observation,

> My main philosophy as a teacher is to have students explain their answers to themselves on paper, to a peer verbally or by depiction, and to the class verbally or depiction on the board by guiding me or doing so themselves. I believe this gives students a much deeper conceptual understanding of the material and the potential to apply the concepts more generally in life and in future classes.

This passage further illustrates why Willie aims for students to explain their thinking: it helps achieve his goal for students to develop their reasoning, understanding, and sense-making abilities as well as prepare them for their future. In addition, Willie references tactics he used in his classroom to facilitate classroom discussions which frequently result

in students working together and asking questions. The tactics will be discussed further in a later section.

***Objectives for Instructor***

When speaking of objectives for himself, what he as an instructor aimed to do, Willie often spoke of his role in establishing a learning environment where students were comfortable speaking and his efforts at engaging and motivating his students. Classroom environment was important to Willie, and he expressed a desire in the initial interview to create a "relaxed" classroom environment where students were comfortable talking to their peers and "blurting out" their questions, no matter if they were "something small or something big." While reflecting on the semester in his final journal entry, Willie wrote,

> I think the most important thing I did in my class to help students learn was creating the classroom environment. At first my class was skittish and afraid to ask questions. But the way I formatted my class with forced groups at the beginning of the semester, it seemed students had someone to talk to in the class, which improved their comfortability with asking questions!

According to Willie, he began the semester by creating formal groups the first few weeks of class and establishing an expectation for his students to talk with one another. This way students had a chance to get to know one another and become comfortable working with peers. Willie aimed to encourage students to ask questions right away and to respond to their questions in a manner that encouraged them to ask more questions in the future.

Another objective Willie expressed for himself at times was his aim to "mix up" his lessons by adding more engaging activities such as the jigsaw or a baseball review

game. According to Willie's journal and first lesson interview, the idea to include these activities was motived by observing students pulling out phones, having side conversations or appearing disinterested in the material. This bothered Willie, and he intentionally created more engaging activities to change the rhythm and help his students focus.

Thus, one of Willie's primary teacher objectives is to nurture and foster an environment where communication occurs, particularly as students talk to one another and explain their thinking. The tactics discussed in the following section illustrate how he structured activities to create opportunities for communication and classroom discourse. These objectives, both for his students and himself, as well as the tactics he frequently incorporated all mesh together well to create an engaging Precalculus classroom.

***Tactics***

Willie seemed consistently interested in and willing to experiment with various forms of group work, regularly seeking to use different structures of group work for student engagement. At times this meant designing large-scale activities to incorporate active learning techniques, such as the previously described jigsaw. Another example of a large-scale activity I observed was his baseball review game. Willie enjoys sports and had played baseball, so he designed a test review in a baseball game format. He utilized an online set-up similar to a Jeopardy board to digitally display problems at different levels of difficulty (single, double, triple and home run) and sprinkled in a few random trivia questions for fun. Students worked in two large teams to answer questions or tried to steal a base if the opposing team missed the problem. Again, I observed most students engaging with their peers; at least 13 of the 14 students in the team next to me spoke to

another team member at least once. One student even stood up and walked across the group to show their work to peers farther away from their seat and other students were passing notebooks back and forth to share their work.

On a smaller scale, Willie often planned shorter interactions for peer-to-peer engagement by providing times for students to respond to questions. Willie declared in his self-observation think-pair-share to be one of his favorite and most frequently utilized methods. This is where the teacher poses a question, allows students to think about the question alone, then discuss their thoughts with a partner and finally has some groups share ideas or solutions with the whole class. During the lesson three interview, Willie shared how he always thought group work was important but now he realized it was "vital to the understanding of students." For Willie, the value of group work comes from students discussing their thinking, which requires students to be engaged. He concluded in the interview, "That's why think-pair-share is like golden to me. It's like the king because it does it in three ways. You're explaining it to yourself, and explaining it to each other, and then you're explaining it to me". Willie noted he considered student engagement "quite important" in his classroom because he believed having students explain why is "the best way for a student to learn in my opinion".

Another tactic I observed Willie use was related to teacher questioning. In his third lesson interview, he fondly shared about asking "undercover yes or no" questions, meaning questions that on one hand were answered yes or no, but would be followed up with having students explain why the answer was yes or no. These questions could begin like, "Is there a way we can…?" Willie stated, "those are my favorite [questions to ask] …because the obvious answer is no …. I like those questions a lot because it makes me

think. Let's me see how they think too." He occasionally asked the class these types of questions to encourage thinking and making connections, wanting students to "stop being narrow-minded" when applying concepts and to consider how to connect class concepts. Willie also felt these questioning techniques helped facilitate student engagement.

Willie not only views the tactics of group work and teacher questioning as helpful to student learning, but they also align well with his goals of providing opportunities for student discourse. These examples show how Willie designed his classes to include frequent opportunities for student engagement and conversation. Even Willie's mentor was surprised by how little of his class time was used for more traditional lecture. The mentor stated from his perspective, Willie seemed to spend over half of the class, maybe even two-thirds of the time, engaging students in some type of active learning. Further, the mentor identified classroom management and classroom expectations as areas of strength in Willie's teaching, noting how the transitions "flowed seamlessly" as he pulled the class back together after group activities.

***Lesson strengths***

At times Willie would identify moments or events that he felt were important or valuable. Each lesson interview also directly asked Willie what he felt were the strengths of the lesson. Passages coded for perceived values or strengths from all four interviews and his journal provide further indication of how Willie seeks to achieve student learning and reiterates some of the previous descriptions of tactics and objectives.

In the interviews, Willie often spoke about his classroom environment which he aimed to be engaging and motivating for students. He reported good attendance, on the days I observed there were few empty seats which supports his claim, and he identified

his ability to manage and monitor classroom activities as important for building the classroom atmosphere. When reflecting on the course overall, Willie stated in his final interview, “I'm actually really happy with how the course has gone. I feel like I got the classroom environment I wanted. I got the engagement that I was looking for most of the time.” He also wrote in his journal,

> I am very pleased with my classroom atmosphere. I have created an atmosphere where students are not afraid to ask their questions the minute they have them. I feel this is essential for students because the goal is for them to understand the material fully and if they feel they cannot ask a questions while I'm erasing the board or have my back turned for a reason, they may forget to ask the question and never fully get an understanding of that topic.

He attributed the student collaboration during the baseball game I observed to an established classroom atmosphere. As he explained in the second interview why the students were more intense as the game continued,

> Overall, I think they really bought into the talk to each other kind of thing. And I think that once again, it has to just do with my classroom atmosphere prior to the game. I like them talking to each other. I want them to just call out, ask questions, you know, shout to each other if they have a question. Be willing to like during class to ask the person next to you, and I think that's what works in a game, you know? …They're like, aw man, I don't know what I'm doing. Let me do what I normally do, and ask blank over here, the person next to me, you know? So I was happy with that.

This environment was needed to create the classroom discourse Willie consistently sought. He desired students to be talking, asking questions, and explaining their thinking; he often utilized forms of group work to create the dialogue. In addition, Willie recognized times when his questioning techniques contributed to the conversation. For Willie, all this discourse leads to his goal of developing "deeper understanding" in his students evidenced by their ability to think, generalize, and connect. Willie also identified "epiphany moments" during group work, students' persistence during challenging tasks, and good work on quizzes or homework as successful events. Analysis of these 34 excerpts suggests Willie aimed to design a classroom environment to create or foster student conversations, which he believes leads to student understanding and promotes the ability to reason about mathematics. Willie used his classroom design to promote reasoning through peer-to-peer discussion, open classroom communication, and student collaboration. The analysis of Willie's tactics, objectives, and lesson strengths most closely aligns with his goals for students to understand, reason, and make sense of mathematics.

### *Influences*

Willie's teaching experiences allowed him to watch and learn from his students' responses. He explained in the interviews that at times, he determined how well the lesson was going by reading students' faces and asking students for feedback. During my classroom observation and as explained in his journal and last interview, Willie sometimes asked students to show him a thumbs up, down or in the middle to provide immediate feedback on how well they were understanding the content. Willie also seemed to believe students were more interested in the material when they could see it

being applied or used. In his last lesson interview, which was the only lesson I observed that included some lecture time, Willie noted,

> When I started writing we could apply this to area, everyone had their pen [moving]. You could hear them scratching on their papers. So I was like, they liked that more cause they can see more things go with it [law of sines], it's not just plug and chug.

Willie thinks students value seeing applications of mathematics and had also mentioned his students asking to see more applications in their mid-course evaluations.

Student feedback and Willie's observations of his students seemed to confirm some of his beliefs about learning and choices of instructional activities, particularly the importance and merits of group work. For instance, in the mid-course evaluations, Willie's students suggested a change in the typical class structure. Students wanted more lecture and less group worksheet time, so Willie tried this for a few classes near the middle of the semester. He then wrote in his journal, "This week I learned that what my students may suggest to do is not necessarily what is best for them" and noted "the class atmosphere and overall morale was poor!" He addressed this in the second interview as well, noting when he lectured more, students "looked like they were falling asleep" and that one student actually fell asleep. Therefore, he went back to the group worksheets because "it does work…I for sure believe it [that group work is helpful] based on those three days that I did my lecturing. Oh, they were struggling! … You could see it on the homework." He explained students struggled on the work from the material covered by lecture yet, in contrast, students' homework was better on the material covered with

group work. Similarly, in the second interview, Willie concluded what he learned from the baseball lesson was,

> I should do group work. It does work because they get more engaged. They talk to each other, then they're getting that deeper understanding that I think is happening. I believe it's happening… whenever there's group work and it's happening less when I do my lecture… It just strengthened my thought of what I already figured out, just pushed it even further. [It] made me realize I shouldn't go back to the lecture example only, but really put in those worksheets so that they can talk to each other.

Thus, Willie’s belief that group work was valuable to student learning was confirmed by his observations of his students during the semester.

Another example of how Willie’s perceptions of his students confirmed his beliefs comes from his reflections on a challenge he had with one group in from his jigsaw activity. While being very pleased with three of the groups, one group seemed to dislike the activity and had angry “red faces” during the jigsaw. Tapping on the table during the final interview, Willie recalled his interactions with the group whose problems focused on completing the square,

> Whenever they would ask me questions, it was how do I do this? It wasn't a like why, it was how. It was like, I want to do this. Tell me how to do this! Instead of, I've gotten here, why am I stuck?

Even though the group resisted the discovery format and seemed to want Willie to give them answers, Willie continued to explain what seemed like “a catastrophe” was really “a shining star in the end” because “that group actually did really, really well on completing

[the] square, interestingly enough on the exam and stuff like that. So I thought that was really interesting." Willie had tried to provide the group with hints and even asked his Supplemental Instruction leader to join the group to push them on, yet the group continued to fall behind and appeared angry to Willie. However, Willie concluded, "I don't regret any of it. I think that was exactly what I should have done." Even though the students seemed to not enjoy the activity, Willie perceived they ultimately understood the material since they performed well on the test.

Finally, Willie attributed some of the development of his teaching philosophy to learning from his experiences teaching students. Willie's teaching philosophy opens with a quote from Anne Frank, "The word 'why' not only taught me to ask, but also to think." Willie often mentioned in interviews that he believes having students work on asking and answering why is important for student learning. In his final journal entry, Willie explained "the main reason" he wanted to pursue this type of questioning and reasoning came from his jigsaw lesson where he "saw a lot of good work from students when they did discovery-based learning. With this came a lot of awesome questions!" He referenced a student asking him why they would use the rational roots theorem and perceived the student and class gained knowledge and interest from his answer. Willie concluded, "Thus, I began to find ways to ask why and get them to ask why?"

Willie pointed to teaching experiences, both positive and more challenging, where his students' responses solidified his ideas about effective teaching. These quotes illustrate how Willie's students, through the quality of their work and classroom behavior, confirmed his belief in the value of students sharing and discussing their ideas.

### ***Reflections on Change***

When asked in the final interview if he thought he had changed his instruction much this semester, Willie replied, “honestly, no.” His mentor stated overall he perceived less change in Willie and more observed Willie having fun trying different methods. He noted a small shift in that Willie relied less on premade worksheets as the semester continued and started writing up his own problems for group discussion. However, Willie wrote in his journal that he had

> changed as an instructor a lot. The way that comes to mind first is that I now see many activities and techniques as vehicles for my main goal of teaching [which is] students being able to apply the concepts from class to broader ideas. For example, I always thought group work was useful for students, but I never really thought of a good reason why. Now I know that group work is a tool I use to get students to explain their answers to each other and gain a deeper understanding of concepts.

Willie did not perceive his instruction to have changed significantly yet did perceive ways in which he as an instructor did change as he developed a better understanding of his own teaching. Interestingly, he describes group work as a “tool” much like this study described it as a tactic, which is used to achieve his “main goal of teaching.”

During the focus group, Willie noted, “there’s no perfect way” to teach and felt he would continue to modify his teaching “like a logarithmic curve” where you “learn a lot really quickly and [then] slow down.” He reflected on his growth as an instructor and noted that through teaching, he now had “an understanding of what I think I value as a teacher and so now I can build on that and try to branch out to new techniques.” Further,

he reiterated previous comments about wanting to "have control" over his lessons and felt better writing and designing his own lesson plan while referencing other provided materials. Willie remained open to suggestions and new ideas about teaching yet communicated confidence in his goals about how he would like his classroom to function and settled in his beliefs about how to help students learn.

**Patrick**

> *Both boards at the front of the room contain neat rows of trigonometric identities and equations. The list on the right is written in black marker and three identities contain a red or green star beside them, indicating they were used when verifying an identity from the left side of the board. Patrick clicks the cap on his marker and gestures to the text on the board, "You can see the equality at every step. Now this is a process that is going to take some practice for you to get comfortable with. So hopefully today, you will get a chance to practice. You will also get a chance to practice in your homework. Please break into groups of three to five; actually move your chairs. I'll have each group present one of these problems." After a few seconds, the squeak of desks scraping the floor breaks the silence. Patrick stands by the table in the front of the room tapping a stack of worksheets on the desk. Nodding his head and mumbling to himself, "I see four, four, three, three, four, okay, cool," and moves towards the students, handing out worksheets to the group nearest the front of the room. I sit along the side wall in front of a group of three girls near the classroom door. I lean back and glance over my shoulder to catch their hushed voices. One student in a red sweatshirt asks, "Where do you start?" While the girl in the green jacket responds, "Can we…" Their voices trail off. The first girl nods and both start writing while the third girl keeps her eyes down.*
>
> *Patrick stands beside two male students focused on their papers. One student looks directly up at Patrick and raises his hand high. Patrick chuckles as the student lowers his arm and states, "We have two different ways of solving the first one and want to see if they both work." Patrick nods and listens as the student talks through what his neighbor wrote. "Sweet," Patrick remarks. The student continues, "okay, so I divided this to this side and that is cosine x over sine x and so is that." Patrick begins, "mmm okay, so," and the student sighs, "Of course my way is wrong." Patrick chuckles again, "No, you're not wrong, but I caution you against using both sides simultaneously." The student looks between Patrick and his paper, listening as Patrick continues to discuss the implications of moving terms across the equal sign. As he points to a line on the paper, Patrick asks the student, "Did you prove what you're trying to prove?" As their conversation wraps up, the student gives a satisfied nod, "All right." Patrick moves towards a*

*raised hand along the back wall. "My hint would be to try to factor something out of the top to see what happens," he suggests as he walks towards another group. Two students make eye contact, and one asks, "factor sine?" They nod to one another and begin writing.*

The passage above describes my last observation of Patrick's teaching. On this day, Patrick continued a lesson from the previous class about proving trigonometric identities and demonstrated three examples of verifying identities. He then wanted to provide class time for students to practice this skill in groups. He planned for each group to present one problem at the board during the next class. While other lessons I observed involved group activities that spanned the entire class period, this lesson was more typical of Patrick's teaching and similar to lessons his mentor observed. In addition, it illuminates many characteristics typical of Patrick's teaching. To further understand Patrick, I will describe him by using the data from his interviews, journal, and writing assignments. An interview with Patrick's mentor, my thoughts from observing his teaching, and audio from mentor meetings also inform the analysis.

Patrick has not decided on what type of career he wants to pursue. He considers academia "a possible route" and enjoys pure mathematical research, yet also has interests in industry related to programming and computer science. He is open to, but not committed to, teaching in the future. In the background interview, Patrick identified knowing the content and having "a very organized class and very organized lessons" as important for effective teaching "because the more organized you are, the more understandable your lecture is going to be and the more that your students are going to be able to get out of it." His mentor described Patrick's personality as calm and inviting and identified his strengths as "being very clear" and helping students feel comfortable asking

questions. Further, his mentor described Patrick as very caring and attentive to students. According to his mentor,

> At the core of it, he just wants all of his students to be clear on what they're doing and on task, and not just at the back like, what the hell is going on, like that. I think he has that at the forefront of this thinking and planning. Even though its lecture driven, it's student-focused probably, like he's got them in mind, not the material.

Patrick did claim to frequently utilize "lecture," yet clarified in his background interview that he did not want to be boring, negative, or shut down any students who wanted to speak up.

### *Objectives for Students*

When discussing what Patrick wanted his students to be doing in the classroom, he spoke about students receiving feedback or help, asking questions, talking together, and practicing. Compared to objectives for student learning or for himself, Patrick spoke less often about what he wanted students to be doing in classroom. The main objective seemed to be students asking questions and receiving help which Patrick mentioned during each lesson interview. For instance, in the first lesson interview Patrick suggested he might want to foster "this idea of like checking your work against each other and talking through some problems. I think at first their tendency is to just work on it by themselves." During the second lesson interview, he identified having questions answered as an advantage of group work when he stated, "Hopefully they can ask their group questions. They can talk through problems. And I was hoping that that would be an opportunity for them to get those questions answered essentially." In the final interview

he confirmed this use of group work, saying, “I want them to be in that group or that group environment to have like a freedom, I guess, to ask the questions” when they get stuck trying to prove an identity. Thus, when mentioned, Patrick’s objectives for his students often centered on students asking for and receiving help.

### *Objectives for Instructor*

Patrick spoke of a variety of objectives for himself as an instructor, such as structuring the lesson to create a good setting for learning, seeking to engage students, varying the class format, motivating students, or connecting to prior material. During the first lesson interview where Patrick did a quadratic jigsaw activity, he stated part of the reason to include the activity was, “I wanted to try something a little different, kind of mix it up…having different types of lessons is good. Variety is good.” He noted in his teaching philosophy that he aimed to “choose the best option for the specific situation” and “the techniques that I use to incorporate those [student-focused] aspects are anything but fixed.” However, “a commonality among all of my lesson plans is that they incorporate some form of active learning.” Thus, Patrick’s objectives seemed to revolve around structuring various activities and content to facilitate student engagement.

### *Mathematical Maturity Objective*

In the background interview, Patrick mentioned wanting to help students develop their mathematical maturity. In this study, this term was unique to him, and he continued to reference it several times during the semester in his journal and included it in his teaching philosophy. Thus, it is included as an additional objective section here, although it aligns with Patrick’s goals for student learning.

In the third lesson interview, Patrick explained the source and meaning of the term for him. He first heard the term in a graduate class where the only prerequisite was a "level of mathematical maturity." Initially, he was not sure what mathematical maturity meant. He first noticed something that was not always evident in his students, more thinking of "what isn't there." Yet he took time during the interview to describe what he thought mathematical maturity might look like in his students and explained,

> There are few things I guess I could describe. Skill level is definitely one and by skill, there are certain skills I guess you can be comfortable with, and those skills could be at a certain level. So, like maybe you're comfortable with all the algebraic operations that would be sort of one level of maturity that you might develop. And then, okay, let's go to the next level. You are now comfortable with the various elementary functions that we consider… I guess the next level after that would be the processes in calculus… One aspect of mathematical maturity is, can you do these operations that we need you to do?
>
> But deeper than that, I think is more about how you think about and approach problems. Problem solving, I think is a big, big deal, a big aspect of mathematical maturity. It's do you have techniques that you use? How do you deal with a problem when you get stuck? What do you do then? How do you view problems? …When you see a problem, the question is, are you intimidated by the problem? Are you able to read it and say, I have different things I can apply to it? Let me try them. And if they don't work, can you think about it in a different way? And maybe you can apply different ideas to it. And I guess I think that process, just being able to do that more readily for more problems, that development, that is

another core aspect of mathematical maturity. So, if you grow in mathematical maturity, I think you enhance your ability to do that. So, there's those two aspects. There are skills and then there's how do you do and perceive problems.

As Patrick seemed to come back to the term mathematical maturity throughout the semester, I included it as an objective unique to him. It does overlap with goals for student learning in terms of developing procedural skills, productive dispositions, and reasoning.

***Tactics***

Patrick described his typical style of teaching during the first lesson interview as "sort of a traditional lecture style" where he introduces topics, provides some examples, and then allows students to try some examples "either in pairs or maybe by themselves." He continued, "I do try to give them time to work in class though. I think that's important… I tried to achieve some balance between what I do and what they work on." His mentor agreed that the majority of his instruction is delivered through lecture, yet noted Patrick did not shy away from group activities. The mentor observed "back and forth" type lessons where Patrick transitioned between lecture and group work, such as students putting work on the board.

A common tactic employed by Patrick throughout the semester was to utilize group activities. From my observations and discussions with Patrick, he incorporated a variety of activities, such as students working on worksheets in groups, presenting problems at the board, exploring function transformations using Desmos technology, a jigsaw, and a competitive team review game. While reflecting on the semester as a

whole, Patrick wrote in his final journal entry, “I tried to incorporate, as often as possible, time for my students to work on problems in class. This might have been in the form of organized activities or casually working through problems either individually or in small groups.” There was not one most common method, but many variations of group work were incorporated throughout the semester.

From Patrick’s perspective, the opportunity for students to get questions answered seemed to be the benefit of using group activities. In the second lesson interview, Patrick indicated students receiving a clear explanation was more important than who provided the explanation. He stated, “If they're going to work on these questions in groups, hopefully, they can ask and can get some of their questions answered by their peers rather than having me answer it. Either one is effective, I think.” When asked if both were equally effective, Patrick paused to think and tentatively concluded, “I want to say yes. As long as the peer that they're talking to feels confident about, you know, uh, that they're, that they're correct and they have their good way of explaining it and they're comfortable explaining it.” Thus, various group activities provided a way for Patrick to meet his objective of students asking for and receiving help.

Another tactic Patrick often spoke of as part of his planning focused on how he aimed to structure and sequence the mathematical content. While all instructors spend time preparing lecture notes, it is included here because of the frequency of which Patrick spoke about organizing his content and the significance he attributed to it. This included providing worked examples and a process for students to follow, varying the types and difficulty of problems, and at times, including more exploratory lessons. Each of these relates to how Patrick organized the mathematical content. For example, Patrick

explained how he prepared for class in the third lesson interview on verifying trigonometric identities,

> I think the most important thing was to pick out good problems. You know, you can't anticipate that they'll be good; that they'll [the problems] all be what they [the students] need. But that was the goal. [It] was to pick out good problems. That was sort of my focus. I picked two for me to do first, just to get the process down…I wanted them to be able to hopefully easily see each step… The problems I presented to them were not too straightforward, but I didn't want to present like crazy difficult problems either because I wanted them all to be able to follow. If you present a problem that's too complicated and half your students get lost, it's not really going to help them when they go to do their own… I mean, they will just feel like they can't do it.

The problem selection and problem difficulty were both part of Patrick’s thinking while planning this lesson. He also wrote his self-reflection on the same lesson. In his self-reflection paper, he stated,

> The questions on the handout were chosen strategically so that there was a range of difficulty. In particular, I have found that the success (or not) of group work is largely due to the task that is being asked of my students.

Patrick seemed to consider the task, the problems themselves, and the lesson structure, such as a group activity, as key factors in his planning. Selecting a good task was also linked to the success of engaging students in group work.

Patrick's teaching philosophy also mentioned the importance of problem selection and related it to building students efficacy. After mentioning students with a "negative association to mathematics," he wrote,

> It is my goal to reduce this anxiety by changing their experiences. This can only be accomplished through multiple positive experiences and small successes. I always keep this in mind when choosing examples and tasks; it is important to mix high and low cognitive demand tasks. In particular, low cognitive demand tasks can often contribute to these successes and over time this should help them build enough confidence so that they no longer feel intimidated by new topics.

Here Patrick mentions the value of low cognitive demand tasks, while in the first interview, Patrick mentioned valuing the conceptual questions on the jigsaw worksheet. He seems to use an assortment of problem types and often reflected on their importance to his planning. In this case, tasks with lower cognitive demand were useful for building students' comfort and self-efficacy.

In addition to the discussing the problems on the handout in his self-reflection, Patrick also described a systematic method for presenting material, and stated, "It is often greatly beneficial for students to see a concrete example of the process that's being explained before describing the process, idea, or technique in more generality." Patrick concluded this was an effective way to teach "a lot of mathematics" and believed it was "beneficial to show students a good model of what organized work looks like." Thus, Patrick often emphasized the manner in which content was organized and sequenced when discussing his planning.

***Lesson Strengths***

During each lesson interview, I directly asked Patrick to identify the strengths of the lesson. In addition, he would at times identify other moments or aspects of a class that were important, good, or valuable. Analysis of the 47 passages coded for perceived values or strengths from all four interviews, his journal, and teaching philosophy provide further indication of how Patrick seeks to achieve student learning.

**Student Affect.** When discussing lesson strengths, Patrick often spoken of students "liking" some aspect of the class. He identified positive affective student responses by highlighting students' attitudes, feelings, or emotions when discussing aspects of teaching he perceived to have gone well. This included times when he spoke about students enjoying or being excited about an aspect of the lesson, peaking students' motivation or interest, lessons being memorable for students, or observing higher levels of student engagement.

For instance, the first time I observed Patrick's class, he utilized a jigsaw activity where students learned a technique for solving quadratic equations in a group and then changed groups and explained their technique to their peers. While reflecting on how he felt the lesson had gone during the first lesson interview, Patrick stated with a chuckle,

> I think it went well… Most people seem to be *interested* in learning their specific topic. And then I think, especially when it came to teaching the group, I definitely think everyone was certainly doing that or doing their part in a way. I definitely saw some people get *excited* about that… I think the students *enjoyed* the different change of pace.

Patrick identified his students' interest, excitement, and enjoyment as evidence the lesson was successful. Further, when reflecting on what he hoped students took away from the jigsaw activity, he responded,

> I think today's [class is] probably going to be more *memorable*. They'll probably remember this lesson two months from now because it's like, 'Oh! I remember that day. I taught someone I taught my group how to do to complete the square…' That's sort of the hope is that this lesson is more memorable just because it's a little different. And again, I don't want them to just come to class and sit there and absorb, or not, the material. I don't want them to just continue to do that. I mean, math is not just supposed to be something that you have to do. Math is not supposed to be a chore. So maybe this type of activity or maybe these types of activities will make them more *interested* in [mathematics] or *motivated*.

In both passages where Patrick reflected on his use of the jigsaw activity, he often spoke about students' feelings or emotions. He did not want mathematics to feel like a chore for students and considered tactics, such as jigsaw, to enhance his students' attitudes towards the subject. Further, he may have seen such emotions as helpful to strengthening students' participation in the activity. At the conclusion of the interview, he pointed to higher levels of student engagement as a strength of the lesson, concluding, "Almost every one of my students was *engaged*." He continued to explain this varied from a typical day where "there's a handful of students that just aren't [engaged]. So that was one strength of this lesson." Patrick wanted to deviate from standard lecture and try something different; thus, he incorporated a jigsaw activity provided by his mentor. He

hoped this change of pace would create a positive memory for his students and help them remember the various methods or techniques for solving quadratic equations.

Another example where Patrick described students' positive feelings about the lesson as a strength comes from a test review game. During my second observation, each team had to bet some amount of their points before attempting the problem. Incorrect responses lost points while correct responses earned the points that were wagered. During the second lesson interview, he explained how he tried a similar game with his summer class and recalled his previous students "got a kick out of it." Reflecting on the reasons to try it again, he shared,

> They were very chatty today. I think that they were sort of *excited* that we were playing this game, which was good… I think the idea that it's a game makes people more *comfortable*. And I think that since it's competitive like this, they're competing against each other, I think it brings out *competitiveness,* which also I think increases results and hopefully like if they got a question right, it would increase their retention. That's sort of what I meant I guess, when I said hopefully it's a conducive environment for learning.

Again, Patrick wanted to create excitement and motivation, so he chose a game format to promote students' interest and involvement. Further, Patrick values facilitating these feelings or emotions since he perceives them to help build or improve student's confidence and understanding. As he wrote in his journal, "I would like for my students to have a positive opinion of mathematics and of learning mathematics. A positive mindset will make the learning process significantly easier for my class as well as all future math courses." Thus, Patrick describes efforts to create experiences that may

stimulate positive feelings or emotions in his students as strengths of his lessons because he perceives this as beneficial to students' learning.

**Opportunities to Practice in Class.** Another lesson strength Patrick identified was the opportunity for students to practice problems in class. As stated in his teaching philosophy,

> Including this time to work on tasks is incredibly valuable for students. Reading a solution to a worked-out problem and creating your own are two very different things. It is through this hands-on experience that students can begin to build confidence.

Although hands-on experience was not limited to group work, one way in which Patrick sought to provide opportunities for students to practice in class was to incorporate various forms of group work. Strengths of group work included peer collaboration and students interacting with the material. In the lesson one interview about the jigsaw activity, Patrick recalled times he "heard a light bulb go off" while answering a student's question and that he encouraged these students to explain to the rest of their group what they had just figured out. In addition, he saw value in giving students responsibility for explaining the material to their peers and explained later in the interview how having this role in the jigsaw activity may have motivated students to participate since they knew they were responsible for teaching their peers. He continued,

> My class is not normally a social class. Today I think they were [social] in a good way… They were being more interactive with each other or being more interactive with the material and they were not very distracted … I thought that was a good aspect of today.

Although Patrick described his class as typically fairly quiet, he identified group interactions as a strength when it occurred.

Similarly, he saw benefits to using a group structure as a place for practicing problems when discussing his review game. During the second lesson interview, he identified “the social aspect” as the “biggest strength” of the group review game since students were in a setting where they could safely share ideas and experience “no repercussions” for wrong ideas. He continued by sharing the intended benefits of the review game. When a student attempts a problem and does not know how to solve it, “First of all, hopefully it makes them realize that there's something they're missing. And hopefully in that setting that they're in, it gives them the best opportunity possible to ask and receive help.” The notion of students receiving feedback or help seems to be a significant reason why Patrick seeks to incorporate group work and opportunities for students to practice problems in class. He wrote in his journal, “I like to give my students the opportunity to try/practice a concept during class so that they can ask questions and get immediate feedback,” yet noted students often choose “to work individually rather than with those around them.” When reflecting on the importance of practice and group work, it seemed Patrick valued these opportunities since they provided feedback to students on how well they understood the content and help for students when they are stuck. For instance, when discussing why he used groups for practicing verifying trigonometric identities in the final interview, Patrick explained, “I didn't necessarily need them to be like talking as a group, but even if you had just one person to ask for help, that's what I wanted.”

Finally, Patrick talked about the importance of his problem selection when reflecting on ways to provide students opportunities to practice during class. He wrote in his journal,

> I have tried different kinds of activities throughout the semester, and some have been more successful than others. After having done these (with last week's included), I think that the success of a group activity is largely dependent upon the task that I assign. The task needs to be challenging enough so that students see it as a benefit to work together, but also needs to be doable so that students don't get overwhelmed and give up.

Not only is the difficulty level of the problem important for students' engagement, but Patrick also noted the sequence or ordering of the problems was a factor in building students' confidence. As he reflected in his final interview on a lesson where students worked to verify trigonometric identities,

> I think the strength of the lesson was in the assignment itself. So I tried to pick good problems for them to work on. The first three, they should have been able to go through and I think most groups went through the first three in like five minutes. So hopefully that gives confidence, and they were able to do it. And then maybe you don't, okay maybe problem four you get a little stuck. And that's okay. So, I think that in both the choice of problems and then the order of the problems was a good thing. And I think having them work in groups was a good choice. So that's something else I'd call that the strengths of that lesson.

Thus, when reflecting on lesson strengths, Patrick often referenced seeking to create activities that foster students' positive feelings, attitudes, or emotions and hoped these

experiences would improve students' confidence in their own ability, attitude towards, and understanding of mathematics. He also valued giving students time to practice skills in class so that they could receive feedback on their progress and be prepared for future assessments. As he summarized in his final journal entry,

> I believe that this utilization of class time was important to the learning process of my students for multiple reasons. Working through problems helps develop problem solving skills and builds intuition. The problems would often directly relate to material that was covered that day or the day prior and helps to create connections between new and old material. They also serve as concrete examples for the possibly higher-level and more abstract ideas discussed during lecture. These problems help set expectations for students so that they know in what way they should be able to apply the theory learned from class and serve as a kind of preview for later assessments. Finally, when students are given the time to work through problems (possibly with help from their peers or from me) it should over time build confidence in their mathematical abilities.

Patrick valued offering students' opportunities to practice in class with carefully selected problems and creating positive student experiences in class to help achieve his goal of improving students' mathematical dispositions.

***Influences***

Patrick often reflected on how his own personal experiences as a student, tutor, or early teacher influenced his planning. Beginning with the background interview and continuing throughout the semester, Patrick referenced his desire to help his students improve their attitudes towards learning mathematics. During the third lesson interview,

Patrick shared why this goal was so important to him. He began with a reflection on tutoring a family member. Patrick shared,

> She would get very frustrated very quickly with math and I would work with her, and she would just get more frustrated. But you know, I feel like I'm a very patient person and we got through, we got through…We've talked about it and she kind of apologized for … the way that she kind of was about math. She said, it's just like she gets this feeling right when she sees these math problems; it's just not good. I don't know how to describe it. [I suggested maybe anxiety] Yeah, definitely. That's probably the right word is anxiety. You're working on problems, and you can't do it and you get this anxiety… That feeling, it certainly didn't help her. I think that I felt good after everything was done. I think she was able to look back and say, you know, I really did do well, but she had to be successful somewhere… She had a very bad experience in middle school and high school with math, the whole time. That's not her fault, honestly… It was totally the school system's fault.

According to Patrick, he himself “never really struggled with math,” yet he has encountered others besides his family member who had struggled to learn mathematics. He shared his takeaway from many tutoring experiences with kindergarteners through adults, and noted that many students “don't think they can do it [mathematics]. I got a lot of that, and I feel like they just need someone to be patient and sit down and work with them.”

Patrick expresses a belief that all students can learn mathematics. His concern for students’ affect seems to be grounded in experiences with other people who struggled

with mathematics and expressed low self-efficacy in their ability to do mathematics. In the interview, he continued,

> It's a very sad thing to have happen to where you have these terrible experiences with math and then you just think that overall, you're either bad at it or you're never going to be good at it. I mean, some factor or combination of those two things, when it's just simply not true! You just have to have good experiences to overwrite all those bad ones. In my opinion, and I have always been of this opinion, but if you want something and you put in the work, you can put in enough work to get that something. That's my opinion. So if you want that degree, and you have to go through these math classes first and that's your obstacle, put in the work and you will be good at math. I mean not everyone's going to like doing math, right? But I think not liking it and thinking that you can't do it are two different things.

Patrick identified his belief that hard work pays off, which easily translates into students can succeed at mathematics if they are willing to work at it. He’s encountered many students and worked closely with a family member whose negative experiences with mathematics have led to anxiety, lack of motivation, or lack of confidence in their ability to do mathematics. In these cases, Patrick believes students need to have some positive experiences to “overwrite all those bad ones” and thus aims to create these positive experiences for his students. Further, he has enjoyed getting to help peers or other students in the past. His teaching philosophy reiterates these beliefs.

> I know from experience that students’ abilities and conception of mathematics improve and change over time…I have found that students with a negative

association to mathematics often feel as though they do not know how to start a problem or get stuck along the way. In some cases, they become fearful that the content is "too hard" or just won't make sense. This is a learned response.

Patrick hoped through his teaching to help his students develop a different response towards mathematics.

A placement test often determines which undergraduate students begin in Precalculus. Patrick perceived that these students may have a weaker background in mathematics and may be more likely to bring some level of anxiety towards mathematics, given their lower placement scores. During a mentor meeting where MGSIs discussed their ideas for what they might write for their teaching philosophy assignment, Patrick shared with the group,

> Especially American students have this really weird or bad stigma of math [math phobia asks the mentor]. Yeah, they just feel like they themselves will never be able to learn math. I feel like at some point in my teaching, I would like to try to break that stigma for some people. I feel like it's really an important thing for them… especially in these service courses.

In the future, Patrick considered asking his students to think about what mathematics is throughout the semester and hoped to find ways he could break up the "repetitive" routine of presenting information, giving homework, quizzes, and exams to include more "cool math stuff." For now, Patrick's goals as a precalculus instructor included helping students build self-efficacy and enjoy mathematics and are grounded in experiences helping others overcome difficult mathematical experiences.

In his journal, Patrick noted another way his personal experiences influenced his planning. At times, he reflected on how his own experiences as a student also shaped his thinking as an instructor. While reflecting on factors that influenced how he taught, Patrick wrote,

> I find it valuable to reflect on courses that I thought were great (or not so great) and try to figure out which aspect of the course made it great (or not so great) so that I may incorporate (or avoid) those aspects into my own teaching.

At times, he referenced aspects of his own instructors that he found to be helpful, such as good organization or using wait time, and aimed to include similar elements into his class. On the flip side, aspects of teaching he perceived were not helpful when he was a student, such as instructors who could not communicate well, were aspects he hoped to avoid. He also identified his own learning experiences when writing about influences on his teaching statement in his journal. Noting he decided as a high school senior to major in mathematics, he now wants "to be cognizant of how my students view mathematics and encourage the same type of growth that I experienced and continue to experience."

Patrick's personal experiences, both working with others who held negative connotations towards mathematics and his reflections on his learning experiences, influenced his planning. His experiences with helping others overcome difficulties in mathematics seems to directly relate to his goals for student learning.

### *Reflections on Change*

Like Willie, Patrick wrote in his journal about how he felt he had changed as an instructor. He wrote,

> One way that I've changed is that I have a different definition of success when it comes to teaching. Before, I would look back at the class and reflect on my performance to determine whether the class went well or not. Now when I look back to decide if class went well, I am looking for evidence (usually via some form of assessment) that gives me some indication as to how much of the lecture came through for people.

Patrick changed how he evaluated the success of a lesson, now looking for student understanding rather than judging how well he presented the material. In this way, his thinking became more student focused during the semester.

When asked if he changed his instruction much this semester during the third lesson interview, Patrick quickly identified changes in how he prepared for class. Reflecting on the lesson-planning side of teaching during the last interview and focus group, Patrick appreciated the time-saving potential offered by using provided resources yet found it difficult to implement prepared plans and preferred writing his own lessons where he could decide the order to introduce things and examples he wanted to use. He reiterated this point during the focus group concluding by the end of the semester that he was "teaching my own sort of way as opposed to someone else's way." When asked again about changes to classroom instruction in the interview, Patrick chuckled and discussed how he's "still working on trying to get better teacher questioning" so that students could "get more out of the lesson."

Patrick seemed to become more comfortable teaching as the semester went on and remains open to improving his teaching, particularly so that he can find more ways to

improve students' attitudes towards mathematics. During one mentor meeting where MGSIs discussed motivating students, Patrick adamantly stated,

> One of my goals is to make my students, one, not feel like they suck at math, cause a lot of students that are in Precalculus feel like they can't do math for some reason, like it's against them or something. And two, I want them to actually enjoy math to some extent. I mean, they're going to have to take calculus, most of them, and probably calculus two, most of them right, so they'll take at least another year of math. So if you pile on a lot of negative reinforcement, are those two goals reachable?"

Patrick expressed these goals in response to a discussion about positive and negative types of motivation. His concern with students' dispositions towards the field of mathematics and feelings about themselves as learners will likely continue to affect Patrick's thoughts on teaching.

**Chen**

> *Students are sitting in rows of desks and nearly all are writing notes on papers in front of them. "If there are no questions, we will try to transform sine and cosine functions." Chen continues writing, adding trigonometric functions to the full dry-erase board. "I want you to think about how these graphs change the sine or cosine function. Then you can talk to your friend and see if you have the same answer." Chen finishes the fourth function and adds, "Actually, let's make groups. Talk to your friend about how this function changed and what will change about the midline, amplitude, or period if we do each transformation." Setting down the marker and papers, Chen sips on his drink and looks around the room. No students move their desks, but many students in the middle of the room turn their heads and begin to softly speak to their neighbors.*
>
> *Chen heads to the side wall and walks up one aisle, looking at students' papers as he slowly passes by. He pauses by one student, "How are we doing?" "Good," the student responds. Chen makes small chit-chat with another student then turns around and heads back up the aisle. Many students are speaking quietly with peers, some heads are nodding. Chen stops near the classroom door and speaks to a student in the front row, "So what do you think is happening to this function?*

*How will it compare to the sine function?" With hands on his knees, Chen leans in towards the student to listen. "Right, so the only thing that changes is midline…" Nodding, he crosses the front of the room to a row on the far side of the room and begins down the aisle to repeat the process. "How are we doing?" he asks again as he checks his watch. Within three minutes Chen returns to the front of the room to call out, "All right, let's take a look. What happened in general? Does it stretch vertically or horizontally?" Two or three voices respond to the question as students' eyes turn towards the board.*

This scene describes my second observation of Chen's classroom and typifies several of the strategies Chen utilized in his planning and teaching. Teaching this course was the first time he was full instructor of record for any undergraduate course. In the background interview, Chen mentioned he "was nervous" and "spent a lot of time preparing" when he was a TA for Calculus I the prior year. Upon graduation, Chen plans to teach in a higher education setting either in the U.S. or back home in his native Asian country.

To further understand Chen, I will use the data from his interviews, journal, and writing assignments, as well as an interview with Chen's mentor and my thoughts from observing his teaching. Before exploring the objectives, tactics, and perceived strengths of Chen's teaching, it is worth noting that in contrast to Willie and Patrick, who are both domestic MGSIs, Chen is an international MGSI. This aspect of his identity led to some differences in his experience learning to teach.

***International MGSI***

During the focus group, MGSIs discussed obstacles and challenges they faced during the semester. Chen shared how early on, he did not want to teach because "I was really worried about my English." Although seemingly fluent in English, it is not his native language. Hence, unlike Willie and Patrick, Chen had to overcome a language barrier when learning to teach. He shared his perspective on this experience in his final journal entry. Chen wrote,

> I, initially, did not want to be an instructor because of the language barrier. Among feedback from student evaluations last year [as a TA], I had a few students say that my lack of English proficiency hindered their learning. So, moving from TA to instructor means that I have to be more responsible to students learning than being a TA. I know that failing students are liking to find something to blame for their failure and all, but it still gives me anxiety about the idea of teaching. With encouragement from Willie and [mathematics professor], I asked the department to be an instructor anyway. I think I spend a lot of time preparing the notes. I have to learn how to do a few things differently than I would normally do. For example, I had never used the AC method for factoring and SOH-CAH-TOH for the similar triangles, but I have to learn how to do these tasks because Americans are more familiar with these methods. It also surprised me to learn that students do not know how to do decimals division until the end of the semester. I find the experience of being an instructor is full of ups and downs. I learn a lot about teaching and about students.

Chen's mentor, who was also an international graduate student, could relate to the additional challenges language barriers can present for an instructor. The mentor stressed, "Again, I keep going back to it but being foreign, it's got to be hard to teach not in your native language." Not only did Chen have to communicate in English, but he also needed a strong mathematical vocabulary that included both introductory level and graduate level terminology. As his mentor explained, this situation "really pushes the range of the amount of English he has to be doing." Further, Chen's mentor felt international MGSIs, such as Chen, often need time to gain confidence and feel they have control of the class

before they can try to "push their teaching" for fear of not being respected or laughed at for mispronouncing English words. This may have been true for Chen, as he tended to incorporate smaller-scale active learning activities during my classroom observations than Willie or Patrick.

Although Chen could be soft-spoken, his English was solid. I agreed with Chen's mentor who stated, "Even though he is not a native English speaker, I did think he was as clear as he possibly could be. He was speaking slowly probably to help with that." In addition, I noticed Chen seemed to have good ways of explaining the content or introducing a topic. Chen's mentor noted "every time I walked into his office, he was planning" and believed,

> Again, it goes back to just the amount of planning he does. He might see it as because it isn't his first language, he's sort of like rehearsing lines. He's thinking to himself, what is the *best way* of explaining this and he's going to really nail learning that chunk of speech.

In this way, it is possible that Chen's efforts to speak clear English at times may lead to better mathematical explanations for students. Although Chen seldom mentioned these language barriers and they were not a focus of this study, Chen's experiences learning to teach were uniquely impacted by this factor.

Further, Chen's schooling experiences prior to college varied from typical American classrooms. He reflected on some of these differences in his journal.

> I did my undergraduate in the U.S., so, I am quite familiar with classroom environment and classroom expectation for college here in the states. In high school [in Asia], the students-to-teacher ratio is much larger than here. [Students

> there] also see teachers as authoritative figures. It could be considered rude to question teachers, so learning is very much one-way communication. Compared to [Asian country], teaching in America is varies in style from instructor to instructor. Teachers usually expect students to participate and are more open to discussion.

Since Chen attended college in the U.S., he was familiar with the differences in educational settings and seemed to adapt well to an American classroom. During the focus group, he added, "I like having a say in how students learn, and I also like the interaction between myself and my students. I feel I can get to know them more as an instructor [compared to as a TA]." Though he described his first semester teaching as "stressful" in his journal, he enjoyed aspects of getting to be the instructor of record and planned to continue working as an instructor in future semesters.

### ***Objectives for Instructor***

Chen identified several objectives for himself, what he was trying to accomplish in his classroom, which included monitoring student learning, engaging and motivating students, varying lecture structure, and creating two-way communication. He stated in his teaching philosophy, "I believe that it is my duty as an instructor to keep students engaged during the lesson and to provide in class activities for students to practice and for teacher[s] to get formative feedback." The formative feedback mentioned here was frequently identified by Chen as a goal of his while teaching and will be the focus of this section.

The main objective Chen described for himself was to monitor his students' understanding during class. He mentioned this in his background interview when

describing what he thought would make a productive classroom environment for student learning. He explained, “I spend some certain time on the definition or formal statements and then they have to practice. I can walk around to see, get the real time feedback, if they understand the material. That's kind of my ideal for now.” Similarly, he stated in an early journal entry,

> I currently use active learning methods, such as wait time or finger signals, to get instant feedback from students. I find it helpful to be able to see which part of the lesson that students have difficulty with, and I can address them instantaneously.

Chen wanted this feedback from students so that he could monitor their understanding of the material and adjust his lessons as needed. In the third lesson interview, while reflecting on what he might say in his teaching philosophy, Chen noted,

> I do kind of get feedback from students during lecture. I do that because I can see where they stand, and I can adjust my lesson accordingly to how well students are doing. Or if they are lacking [understanding] then I know where to emphasize and try to help students to learn.

This typically meant adding an example or aiming to verbally clarify an idea by emphasizing or repeating a relevant point. During the second lesson interview, Chen estimated he added an example or more explanation to his notes somewhat often; “not every lecture but at least once a week.” Although the adjustments seemed to be minor teacher moves, these quotes illustrate how the objective of monitoring student learning was a consistent aim for Chen. Some of Chen’s other objectives, engaging students and creating two-way communication, also helped create opportunities for Chen to determine how well students were following the lesson.

Chen identified his goal of monitoring student learning throughout the semester, at times using the term formative assessment. In the third lesson interview, he explained,

> I feel like that's important for me because I know a lot of people just do lecture and then claim that we already do this, this, this. Then when it comes to the exam, students don't know how to do it. Which is completely bad for me. I feel like if you're with students, you should be able to tell which parts students are struggling with, so you can help students learn. Again, by giving them like formative assessment, I can at least see what the common mistakes are. And if I don't work one-to-one with a student, I can show an example on the board that these are common mistakes. And if you have problem, you should come talk to me or try to fix it.

Chen accepts some responsibility for student learning and wants to monitor student understanding so he can offer students help before they are held accountable for knowing content on a formal assessment. He aims to identify and address common student errors before the exam in hopes of improving students' performance.

***Objectives for students***

Mentioned less frequently than other types of goals, Chen wanted students to ask questions and practice problems both during and outside of class. His aim was for students to spend time working on mathematics so they could be successful in the course. During the first lesson interview, he noted a "connection" between students not scoring well on a quiz with students not "spending time practicing outside of class" as evidenced by the online homework system showing they waited until the due date to attempt homework. He wanted his students to better recall the information and "try to spend more

time with the material." He hoped, "If I make them struggle more, they might spend more time with the material. Maybe, I don't know." Chen also mentioned in his teaching philosophy that,

> I try to make sure that I give time in class for students to work on problems by themselves or by group work. Having students struggle through problem encourage them to have discussions and reflection on which part of the lesson they are having difficulty with, and at the same time, these activities help me identify what concept students are having difficulty with and how can I adjust my teaching to help them learn better.

Chen aimed to monitor student learning as an instructor, yet also wanted his students to assess themselves and monitor their own learning. One way he sought to assist students in this goal was to promote some level of student struggle through a tactic of incorporating lessons where students were asked to draw conclusions, which is addressed in the tactics section.

***Tactics***

Many of the tactics Chen employed, such as observing his students working, using exit slips, and, at times, allowing students to work in groups, helped him implement his objective of using formative assessment. These tactics will be discussed first and then the section includes ways in which Chen worked to modify his lessons to include discovery-like elements into his teaching.

**Observing students.** Chen wrote in his journal, "I try to check whether the students understand what was taught by walking around and observing students' work." Both his mentor and I observed this in Chen's classroom. When Chen paused the lecture

to ask students to work on a problem, he would often circle around the classroom, occasionally stopping at student's desks to look over their papers. Chen spoke of "observing" his students to see how well they could work through a problem. In the third lesson I observed, Chen had given his students about two minutes to work on a problem. He watched them but never spoke while moving around the room. During the interview he explained,

> I mostly try to observe how people use the formula and try to walk around to see where they get stuck…I try to walk around [and] make sure that people are trying to do the problem or see where they have difficulty using the formula. I saw people just write down the formula and plug in the value… and they couldn't figure out how to solve for the variable. So once I notice some pattern that people doing the same, I can emphasize on the board… Show them these are things that you can do to solve for the missing variable. And the reason that I kind of keep quiet [is] because I want them to keep working on it… I want them to think that like I am pushing them to do [the] problem and [I don't want them] just sitting there and doing nothing.

Chen also stated in the lesson two interview that he watched students' facial expressions to check if they were understanding. Further, he noted in the interview that sometimes his students would "just sit there" and not "try to do the problem." Chen explained, "that can be a problem because I don't know if they actually already know how to do the problem [or if] they are just disconnected with the lesson." Although his efforts to observe students provided him with valuable information about student understanding, they still

left some uncertainty as to why students appear unable to solve a problem. He wrote about this towards the end of the semester in his journal,

> I often make assumptions that my students have to know certain things. But lately I have a feeling that I make too many assumptions and sometimes students just don't know how to get from step to other step that I skipped. So I've been doing group work and sometimes students just kind of sit there and don't really work so I've been trying to force them to work on problems and then walk around. I can see that a student doesn't know how to replicate the steps, like they don't know how to simplify radicals. It kind of gets in the way of the process that they should get the answer but they struggle because they don't know how to do the steps. I hope that I can go through more steps when I can show them problems.

Watching students work was a common tactic discussed by Chen, yet he also used other tactics for formative assessment, such as group work and exit slips.

**Group work.** All MGSIs in this study used some form of group work during the semester. The frequency and formats varied, yet this tactic was common among all three MGSIs. Chen explained in the first lesson interview that for him, group work often took the form of asking students to "work in a group of four" or "compare your answer with your neighbor" or "explain what you did to your friend." However, he "never really assigned groups." During the background interview, Chen described a typical class as beginning with a lecture on new topics for a bit and then asking students to work together in groups. He noted, "When I tell them to work in group, they start grouping on their own. They would be like quiet for like five minutes and when they finished working, they start talking to each other."

During the interviews, Chen described group work as important since it provided an opportunity for students to better understand the material. In the background interview, he stated it was not necessary for students to work in groups, yet believed, "I think group work is important… If they don't understand, they can talk to each other and if one of them understands, they can try to explain to and teach their peers…They will understand better like as a group." Thus, from the beginning of the semester, Chen desired to incorporate group work time in his lessons.

While Chen valued giving students an opportunity to help one another through group work, at times he encountered some difficulty in getting students to engage with their peers. He began to see this as problematic since it did not advance his instructor objective of monitoring student learning. Chen explained during the second lesson interview how he could not tell if students were not working because they were bored or lost or for some other reason. He explained,

> What I used to do in the previous lectures, I tried to get them to work in group. If one person like has no idea, I tried to get their friend to explain to that person that doesn't do the work. So I tried to get people that at least were trying to work to explain thing to other people…but it doesn't really help me to know if that particular person understands or they just bored, I don't know.

As a result of this dilemma with group work, Chen decided to adopt another tactic.

**Exit slips.** Exit slips were another tactic Chen employed and that he directly linked to helping him achieve his goal of monitoring student learning. He began this tactic in the middle of the semester in part since he was not getting the participation he wanted from attempting to incorporate group work. He explained in his journal,

> I spend a lot of time lecturing and I don't have enough time for them in class to practice examples. I wish I do better with time management, and I can [give] them more time to work in class so I can observe and see how well they do and how well they understand the material. For this week, this was my first time giving out a student exit slip. I think it went well. A lot of students can do, can replicate the procedure that we learned during that day. I hope I can include it more in my lecture because I try to do group work and my class, two of my classes are in the morning at 8:30, and a lot of students are inclined not to work in groups. So I kind of try to have more methods to measure [student learning] and have them actively learn in my class. So that's why I tried the exit slip for the first time.

Chen restated how some students' reluctance to participate group work contributed to his decision to include exit slips as another form of formative assessment during the second lesson interview, explaining,

> I know that I have a lot of people who just prefer to do work on their own instead of doing group work. So the first time that I implemented [exit slips was] because of that. I cannot have them just sit there and take notes, like copy me, copy what I wrote on the board. So I asked them to work on a few problems...So that's why I got the idea [to use exit slips]. If they don't want to do group work, then I have to do some other like formative assessments, so I know if they are learning.

Chen's decision to include the tactic of exit slips came in response to other tactics, in this case group work, seeming to be less effective. While still seeking to achieve his goal of monitoring student learning, Chen continued to incorporate exit slips in future lessons. He confirmed this in his self-observation, where he wrote,

> This is the third time that I implement the exit slip. I have been doing group work in class, but many students do not like it. The goal of the exit slip for me is to use it as formative assessment… The most important reason that I started the exit slip is that I can quickly check if students are keeping up with me. Additionally, I can identify if students need extra help with the lesson.

Chen seemed satisfied with his use of exit slips and planned to continue using this tactic.

While all MGSIs experimented to some extent with different teaching methods during the semester, this is one of the few clear instances in this study of a MGSI altering his tactics by consistently implementing a new tactic to achieve one of his objectives. In this case, Chen held to his objective of using formative assessment to monitor student learning but adapted his tactics by trying and then continuing to include exit slips as part of his lesson structure. More than Willie and Patrick, Chen seemed to continue to search for teaching moves that worked well for him and seemed satisfied with the use of exit slips to help him monitor student understanding.

In addition to meeting his own objective for formative assessment, Chen also believed exit slips were helpful for his students. He explained during the third lesson interview,

> I want them [the students] to see that these are the kind of problem that I expect them to be able to do. With this information, they can evaluate themselves. If they can do it, then that's great. But if they cannot do it, they have to go back and review their notes [and] what we are doing that day. So at least they have some idea of what's important for them to know. Like what I expect them to know and try to study those.

At times, Chen spoke of wanting students to monitor and be responsible for their own learning. His use of exit slips also provided his students with relevant feedback in order for them to assess their own skills and understanding of the material. Thus, this tactic served Chen's goal of monitoring student learning well since it provided feedback to both his students and himself.

**Creating "slightly guided" or discovery-based lessons.** Another tactic Chen discussed in every lesson interview related to his efforts to organize his lesson in ways that allowed students to "discover a little bit" or "try to come up with a conclusion on their own" by "synthesizing" ideas from the lesson. For instance, in the first lesson, he asked students to look at the graphs of rational functions first in order to lead them to the definitions for vertical and horizontal asymptotes. Chen shared in the interview,

> They kind of have a chance to try to come up with their own idea about the problem. It's a slightly guided problem. I give them the functions and they try to come up with a conclusion on their own, like we don't normally do that for the typical lecture. I kind of liked that part of the activity.

Chen clarified in second interview that he utilized this discovery-style structure in other lessons as well, and explained, "Sometimes it's just I don't like how the book presents the material, like just give them like the formula and this is the result, that kind of thing. Sometimes I want to like mix it up." Chen's self-observation of another lesson later in the semester also referenced this lesson design, as he stated, "The active learning technique that I use is giving them time to investigate and trying to come up with some conclusion on their own." Chen tried various ways to order the presentation of new material, such as having students explore some examples that lead to a formula or definition. However, he

did not regularly use this structure in his lectures but seemed to include it when focusing on active learning techniques.

In the final lesson observation, Chen varied his presentation style again when covering the formula for law of sines. In this case, he presented the formula and asked students to try to use it. He stated in the interview, “For this lecture, I just give them formula and ask them to solve without me showing them first. So that's what I do differently in this lecture compared to the stuff that I usually do. I want them to struggle with the formula first.” He further noted,

> So instead of doing like discovery, I can give them the formula and they try to use it. I walk around and I can see where students can make mistakes… I can emphasize on the board when we get back together. I think that's one of the benefits about asking them to do it first.

The interviews highlighted the thought and consideration Chen gave to ordering the content in hopes of helping his students understand and make sense of mathematical concepts.

Finally, each lesson plan contained at least two planned conceptual questions to ask the class. For example, in the second lesson about graphing sine and cosine functions, Chen wrote in his notes to provide two graphs and ask students how they could differentiate between sine and cosine functions if the graphs were not labeled. In the third lesson covering the law of sines, he began by asking what rules for right triangles can work for non-right triangles. As Chen explained in the third lesson interview, he often planned those kinds of questions when introducing new material to show how it relates to previous material and then lead students in a new direction. These tactics, or ways Chen

structured the lesson content, were aspects of lesson planning he perceived as relevant when explaining how he aimed to help students learn and understand the course material.

### *Lesson Strengths*

The interviews and journals provided opportunities for Chen to mention aspects of teaching that he liked, and he was directly asked in the interviews to identify strengths of his lessons. The 27 passages coded for perceived values or strengths provide additional insight into Chen's planning and overlap with some previous discussion of Chen's objectives and tactics. When Chen reflected on strengths of his classes, he talked about achieving a balance between lecture and time for students to practice, desired student behaviors and learning, and getting feedback from students so he could monitor and adjust the lesson.

Chen strived to achieve a good balance between time spent in traditional lecture, with him presenting material at the board while sprinkling in questions for his students, with providing class time for students to practice problems independently. He identified this balance as a strength of the lesson during the second interview stating, "I will say the strength of this lecture is that there's a good amount of me lecturing them and them working on their own…A good balance." Again, in the third lesson interview, he shared, "I like the split between lecturing and asking students questions and students having time to work. I do like that, and I want to continue doing that." As part of this balance, he considered it valuable to include plenty of examples, covering all planned material, and guiding student thinking in part through questioning techniques as part of the lecture.

Another area Chen identified as positives of his lessons related directly to his students' behavior or learning. He highlighted times when his students appeared more

engaged or participatory during class, as he desired for students to discuss answers, ask and answer questions, and work together. For instance, during the second lesson interview, Chen reflected, “I'm pretty satisfied by how the lecture went. I got a lot of response from students. I assign them to work on a small thing and they work together, they discuss and talk. So I like that.” He continued by comparing the class to the first lesson I observed, and noted, “I like it much better. I think they are more, like if I ask a question, they are more responsive.” Both lessons had offered students the opportunity to connect, synthesize, visualize, or make meaning of mathematical ideas which Chen also identified as strengths of his lessons. His mentor and I agreed that students in the center of the room appeared more responsive and on-task than students around the edges.

Finally, Chen referenced his previously discussed goal for monitoring and adjusting his lesson based on formative assessment feedback he received from students. During the third lesson interview when reflecting on ideas he thought were important, he stated, “I do like working with students, kind of get like feedback from students during lecture. I do like that because I can see where they stand, and I can adjust my lesson accordingly to how well students are doing.” The areas of balancing class time, student participation and learning, and formative assessment were all mentioned by Chen as strengths of his lessons or aspects of teaching he valued.

### *Influences*

When reflecting on his teaching, Chen spoke about a mix of influences, including personal experiences as a student and TA, professional development, and his current peers. Willie and Patrick also referenced these types of influences, yet they tended to speak more consistently of one strong influence on their planning. For Willie, it was

references to his students which confirmed his beliefs, while Patrick's affective goals for students were grounded in his tutoring experiences. In contrast, Chen spoke more evenly about different external influences impacting his thinking about teaching. This aligns with his statement in his teaching philosophy, where he wrote, "I am open for ideas/suggestions from students' perspective as well as from discussion with my colleagues to continuously refine my teaching to grow as an instructor." Various influences were associated with both shaping his beliefs about learning or teaching and tactics he chose to use in his classroom.

Chen's beliefs about how students learn were impacted by his observations of students both when he was a TA and again while teaching MATH 115. He noticed from teaching experiences that when he presented a problem in class and was the one who did all the explaining and solving, some students did not seem to learn. For instance, during the third lesson interview, he recounted a time from when he was a TA, and he accidently did a quiz problem in class right before the quiz. However, he found that,

> A lot of students couldn't get exactly the same problem [right on the quiz]!... That tells me that a lot of them are not paying attention in class. So even with exactly the same question, at least they should have some idea of like where to begin or what's going on. So if I do lecture alone, there would be people who [are] just disinterested, not try to engage with the material.

This observation that lecture did not seem to be effective for student learning came up again later in the same interview as Chen reflected on the semester overall. Chen noted presenting the material, through lecture alone did not lead to students being able to replicate procedures on an assessment. Further, he identified a change in his instructional

focus where he worked to include more time for students to work in class because he believed lecture alone was not helping his students based on some students' performance on assessments. He noted,

> I feel like when I do the lecture, some people just try to copy down things, without them actually trying to think, like why I do things that way. So instead of having me doing all the work, if they try to start working on problem, they're going to see what doesn't work, which part that they know [or] why they couldn't do the problem, instantaneously. And if they need help, they have me as a resource, to at least guide them in class. So, I think having that opportunity to practice is kind of important for student to learn things…
>
> I observe from the quiz that they did, I can see currently, I do exactly the same problems [and] a lot of people don't know how to do it! That's kind of shocking to me that even if I show like completely do the homework, do the work and half an hour later they already forget everything. So I kind of want to change from that like lecture mostly to having them time to at least struggle, at least try to apply the material that we learned that day, like work on their own more.

This belief that lecture alone was insufficient for students to learn how to solve a similar or even duplicated problem led Chen to incorporate other tactics into his teaching.

This belief change was reiterated in Chen's teaching philosophy, where he stated,

> For the longest time, I considered lecturing to be the best medium to teach students. If an instructor constructs a well-prepared lecture, breaking down problems into bite sizes so that students can digest the knowledge easily, students should be able to understand the material. When I was a TA for Calculus I/II, I

> tried to help students learn by summarizing the lessons that they did the prior week, then showing examples of how to apply the knowledge, and quizzing them at the end of the class. The thing that surprised me the most is that students could not retain the knowledge and repeatedly make algebraic mistakes. I questioned the effectiveness of my teaching style. To these ends, I have been continually refining pedagogical strategies to help students learn especially by including active learning activities into the lesson.

In this way, Chen's teaching experiences influenced his beliefs about learning. His observations that students could not replicate problems recently shown to them in class on an assessment led Chen to vary the tactics he utilized when instructing his students.

In addition to teaching experiences, Chen also referenced how his own learning as a student played into his ideas when lesson planning. He expressed in his journal,

> When I think about my teaching statement, I think a lot about how I personally learned and what I like or dislike in teachers that I have had. These help me thinking about how learning occurs and why I teach the way I do.

The lesson interviews provided examples of times Chen referenced himself as a learner when discussing his beliefs related to lesson planning. For instance, Chen explained in the second lesson interview why he wanted students to explain their reasoning. He shared,

> I feel like if they say it out loud, that they kind of have to think, actually think about the problem and relate it to what they learn. I feel like a lot of times when I think, and I say it out loud, I have to like make [or] arrange my thought process to

> try to reason my answer. So I hope that process is going to happen to students when they try to explain to their friend.

Here Chen knows having to verbally explain something makes him reason through ideas, thus he believes this same process may be a way for his students to learn. Another example of Chen's beliefs about learning relating to his personal experiences comes from the first lesson interview. He explained that although some students didn't like the lesson structure where they needed to conclude an idea from examples, Chen still saw value in students struggling with mathematics as a way to improve their retention of the material. He explained,

> I think there's value in it though. They can reflect back. For me personally, I remember my mistake more than stuff that I can do…If they can come up with their own conclusion, I think they can remember more than [when] I tell them what the results are.

At times, Chen reflects on how he personally learns when explaining what he hopes his students will gain from an activity, such as being able to verbalize their thinking.

In addition, he also referenced times when professional development activities shaped his belief in how students learn. He explained in the first lesson interview how an activity with notecards in MATH 792 helped him explain his beliefs about how learning worked. He reflected on the importance of students working together and verbalizing their reasoning since,

> If I tell them it's just, they're going to forget the next day. Like the activity that we did [in MATH 792]… telling verses having them figure out by themselves…If

> they kind of summarize or putting in their own word, they tend to remember more than like [if] I give them formal definition.

Thus, there is evidence that Chen's beliefs about how learning occurs, which align with the types of teaching tactics he aims to include, relate to his observations of his students, his own experiences as a student, and even professional development activities.

Further, Chen's tactics were at least at times directly influenced by his own peers and mentors. For instance, in his journal he expressed, "This week I tried to come up with some more complicated active learning activities because a lot of my peers are trying jigsaw and some other activity." While explaining his planning in interviews, he occasionally referenced various conversations with fellow graduate students and a prior professor's "cool" use of questioning techniques as a model he could follow. He also adopted suggestions from mentors. For instance, while he was a first-year TA, a faculty member had advised him to expand the types of questions he asked students during class and Chen explained during the first lesson interview that was something he had "been trying to practice." Thus, when Chen spoke of external influences on his planning, they came from a variety of people and experiences that he used to explain his beliefs about learning and tactics for teaching.

### *Reflections on Change*

When asked in the third interview if he had changed his instruction much over the semester, Chen stated that he had. He explained he had started the semester in the same style he had established as a Calculus TA, which was a more teacher-centered style of demonstrating and explaining mathematical processes to students. However, he was now

more intentional about making students do the thinking and solving in class by providing time in class for students to work on problems. He explained,

> I started with basically just do a bunch of examples like when I [was] a TA. [Then] I would try to summarize what they learned over that week and try to do as many problems as I can. Right. So that was like mostly [I would] be doing all the work for students… So [now], I've been trying to include [or] give time for student to work and I try to get feedback from students of how well they are doing and which parts of the thing that they need help with.

Chen explained in his journal more about why he made this change in his teaching.

> When I was a TA during my first year and my instructor asked me to just answer student questions, my students had no questions usually. So what I did was I would try to summarize what they learned during the previous week and show them examples. The examples that I showed were usually similar to their homework or the quiz that they were supposed to take. I hoped that I prepared them to take the quiz. Now I feel like when I do that, the students don't really learn. They just sit there and try to copy what I wrote on the board. So now I've been changing in a way that I try to put myself in the students' shoes. I try to make students to do more work in class so I can get feedback and check if they are really learning rather than just copying down whatever I wrote on the board.

This reiterates the discussion above about how Chen's tactics changed to incorporate more opportunities for students to work problems in class and how this tactic aligns with his goal to monitor student learning. Chen confirmed this in the focus group, telling his peers, "Now I think that students in math learn more when they actually work on a

problem themselves or with their peers," as opposed to when they watch him do examples.

## Conclusion

This chapter described ways in which each MGSI sought to achieve their goals for student learning in terms of their other objectives, tactics included in class, and perceived strengths of their lessons. Johnson et al. (2018) argued for research about the range of instructional practices faculty consider and how they think about these practices in order to encourage greater implementation of reformed teaching practices. This study provides some examples of MGSIs' instructional practices and their reasoning for choosing various practices. Further, this chapter explored additional factors, such as students, prior personal experiences, professional development, and peers that MGSIs identified as shaping their goals, beliefs, or teaching practices. The table below contains a summary of these findings for each MGSI.

Title 5.2 Summary of Individual Case Study Findings

| MGSI | Objectives for students (to do) | Objectives for instructor | Tactics | Lesson Strengths | Key External Influences |
|---|---|---|---|---|---|
| Willie | Explain thinking<br><br>Work and talk together<br><br>Ask questions | Facilitate classroom environment<br><br>Engage or motivate students<br><br>Vary lessons | Group work activities<br><br>Questioning techniques | Building classroom environment to create classroom discourse which leads to deeper understanding | Students |
| Patrick | Receive feedback and help<br><br>Ask questions<br><br>Work and talk together<br><br>Practice | Structure lesson<br><br>Engage or motivate students<br><br>Vary lessons | Group work activities<br><br>Create and sequence content | Create positive affective student experiences to improve confidence or change beliefs about mathematics and improve understanding<br><br>Practice during class to provide feedback and help | Personal experiences – both tutoring and reflecting on own experiences as a student |
| Chen | Ask questions<br><br>Practice problems to assess own learning | Monitor student learning<br><br>Engage or motivate students<br><br>Create two-way communication | Observing students<br><br>Group work activities<br><br>Exit slips<br><br>Create and sequence content | Balance class time between lecture and students working<br><br>Improved student engagement<br><br>Receiving feedback to monitor learning | Personal experiences – both teaching and reflecting on own experiences as a student<br><br>Professional development<br><br>Peers |

# Chapter 6: Challenges

"I am still learning." - Michelangelo

An analysis of obstacles described by MGSIs provides one final perspective on MGSIs' planning and teaching for student learning. The previous chapters described goals MGSIs aimed for their students to learn and a look at how MGSIs sought to help students reach these goals. Goals identified by MGSIs centered on preparing students for their future and helping students develop mathematical reasoning, sense making, and understanding skills, develop productive dispositions, and develop procedural skills. However, not all goals were easily or completely attained, and while MGSIs desired and strived to create learning experiences for students, they also encountered obstacles or challenges along the way. This chapter seeks to describe areas MGSIs addressed as problematic from their perspective as an instructor.

Data from the journals, interviews, and MGSIs' writing assignments from MATH 792 were coded using dramaturgical coding which included a conflict code. When MGSIs identified aspects of teaching that were challenging or difficult, these passages were coded as conflicts. The journals contained the most passages coded as conflicts, followed by the lesson interviews with slightly declining frequency from first lesson to third lesson. These codes were used to arrive at themes for challenges experienced by graduate student instructors. MGSIs perceived many types of obstacles while working to achieve their goals for student learning.

This chapter begins by describing challenges MGSIs expressed related to their interactive thinking (Jackson, 1968), which is during the time MGSIs were interacting with students. Most frequently referenced challenges during classroom instruction included difficulties with time management, dealing with students' responses to teaching methods, and maintaining student engagement throughout the semester. Next, the chapter describes challenges mentioned by MGSIs during their preactive or postactive thinking (Jackson, 1968), times when MGSIs are thinking about teaching but are not working with students. This encompasses time spent planning and reflecting on teaching. Challenges in this area included preparing for teaching, particularly balancing their dual role as student and instructor, as well as understanding precalculus students' performance on quizzes or tests and coping with variation in students' prior preparation. During the focus group, all MGSIs acknowledged aspects of teaching for student learning that were challenging and found there would always be some level of student resistance despite their efforts to teach effectively. However, MGSIs overall reported being able to overcome or cope with the majority of challenges they faced during the semester.

**Challenges with Implementing Lesson Plans**

While MGSIs tended to stick to their plans, MGSIs' lessons did not always proceed exactly as desired. The greatest difficulties expressed by MGSIs related to implementing their plans came from time management concerns and students' resistance to some teaching methods. Logistical challenges as well as maintaining student engagement were other challenges MGSIs described related to lesson implementation.

***MGSIs Managing Class Time***

Running out of time to complete a planned activity, which often related with struggling to estimate the time needed for an activity or assessment or experiencing some logistical challenges with facilitating activities which consumed class time were difficulties identified by MGSIs related to implementing their lessons.

***MGSIs Estimating Time Needed***

Patrick and I chuckled during the third lesson interview as he reflected on the lesson, concluding,

> Time management always seems to be an issue. When I made the idea in my mind I thought, Oh, they'll be able to work on the problems. I'll give them a specific problem to work on and they'll be able to present [it] in my 50 minutes after I spent [time introducing everything], yeah. So really that was the biggest weakness is just time… I [was] way off on the timing. That was the weakness of that lesson, I think in my eyes.

MGSIs noted several ways in which a mathematical task or classroom activity took longer than they had anticipated. Not knowing how long students would need to complete a problem or task as well as challenges with facilitating an activity are ways MGSIs expressed difficulties related to managing class time. These types of challenges often resulted in MGSIs not being able to cover as many problems as they planned or desired, having to cut an activity short or alter in it in some way, or in some cases, push the activity or content into the next class.

For example, both Willie and Patrick had incorporated test review games into their classes, yet neither was able to cover the desired number of problems during class

time. Willie stated in the second lesson interview, “I wish I could have gotten through more material on their review game.” He continued later in the interview, “My goal was to at least get through question six. I wanted to get to question six because that means I hit a lot of the material and everything, but [we] didn't get [there].” Still, he felt the review game “went very well” and speculated on ways he could revise, such as making smaller teams, to cover more problems. Similarly in his second lesson interview, Patrick agreed that the weaknesses with his game were the time it took to complete each round, which led to not covering many problems. He identified the inability to cover much material as the weakness of the lesson and stated, “They didn't see as much as I wanted them to see, and I hope that tomorrow they don't feel like that was a waste of a day for a review.” In both cases, MGSIs provided problem solutions to students via Blackboard, a learning management system, but both wished to be able to cover more problems during class.

Challenges related to running low on class time were not limited to review games but also occurred in other contexts such as while covering new material in more typical lecture style. For instance, Chen noted in his journal,

> The major thing that I learned about my teaching is that I have to adjust my teaching plan accordingly, I have to go with the flow. This week I teach my students about exponential functions and logarithmic functions. This is one lesson that my students have a lot of questions. So I kind of have to slow down and try to explain the material more clearly. I have to give them more examples of a similar type to the problem that they had questions [about]... Sometimes I have to slow down, and I can come back for the rest of the material the next day.

Hence, even when presenting new material in a more traditional lecture type manner, MGSIs are still learning to anticipate the time needed for problems or tasks. Chen provided an example of slowing down to allow more time for responding to student questions, which resulted in his decision to move material into a future class. Patrick also gave an example of a time when covering material required more time than anticipated. Expressing a similar challenge to Chen, Patrick wrote in his self-observation,

> It took longer to finish the derivation of the three core trig identities at the beginning of class than I had predicted. I think it may have been more beneficial for my students to have had that much more time to work through the handout to gain more much-needed hands-on experience.

As a result, Patrick provided time in the following class for students to further work on the handout. Together, these examples highlight how learning to estimate the time needed in class to complete their plans is a challenge that can occur with both larger-scale games and activities or on a smaller scale with individual problems or topics.

As a result of still learning how to estimate the time needed for activities, MGSIs occasionally perceived that there was not enough time for other desired activities. For instance, Patrick expressed in his journal, “I find that the biggest problem that I have is that I sometimes run out of time and my students don't have as much time to practice concepts in class that I'd like.” Similarly, Chen expressed a similar concern in his journal,

> Another thing is time management. I feel like this week we are in a section that requires me to do a lot of lecture, and like I said, I didn’t have enough time for students to work in groups during class. So that was challenging for me to balance the lecture time and give students enough time to practice.

The MGSIs in this study are teaching a new course for the first time while still learning to teach. At this early teaching stage, they are still learning how to estimate the time needed for various problems, tasks, activities, and assessments, as well as how to adjust activities if needed due to time constraints. This can result in MGSIs feeling at times as though they cannot include as much in-class practice time for students as they would like since they are running low on class time. Chen illustrated this challenge during the third lesson interview when he reflected on cutting out parts of his lesson plan as he perceived that his students needed more time to work on and understand the new material. He explained,

> I have to like improvise a little bit on this class, cut down the material [and] move it to [tomorrow] instead kind of thing. And part of the lesson could have been better if I knew where students were going to struggle. But this is my first-time teaching. I didn't anticipate the parts that student have difficulty with. That kind of gets in the way of students learning, I guess.

As can be seen in Chen's reflection above, this challenge of learning to estimate time needed for examples and activities also impacts lesson planning in terms of pacing content and planning for the next class meeting. Learning to estimate the time needed for tasks is one area where MGSIs, as first-time instructors of record, were still developing.

### *MGSIs Facilitating Logistics*

The MGSIs in this study also expressed some logistical difficulties or challenges with facilitating various activities, particularly those spanning an entire class. These time-management or classroom-management challenges typically related to facilitating a large activity, such as a jigsaw activity or review game. Both Willie and Patrick incorporated these into classes I observed. While there were many successful aspects of both activities,

both MGSIs also experienced some challenges with making the activities work as planned in the allotted time.

For instance, Patrick explained how students forming and changing groups during the jigsaw was more complicated to direct and explain than anticipated. It required some time for students to physically move around the classroom. He stated during the first lesson interview, “Definitely the biggest challenge is just time. I didn't anticipate how long it would take to facilitate and you know, to change groups and all that. So that is certainly something to work on.” In a later lesson, the review game, the students still formed groups but then remained stationary. However, Patrick needed to frequently move around the classroom to post the problems, collect wagers and answers from each group, and update the score sheet, which once again, made some of the logistics of facilitating the activity time-consuming. He noted during the second lesson interview, “It was hard to keep it moving because of all the little things I had to do… I think that there could have been a better way to organize that. I didn't really have that planned out very well.” Further, he had several students arrive late that day and found it difficult to direct them into a group in the middle of the game. During the second lesson interview, he explained he noticed a large group formed in the back, and felt, “That was another reason as to why I don't think today went very well.” Patrick gave examples of how rearranging the classroom or having multiple responsibilities can take more time during a game and illustrated some logistical challenges MGSIs might encounter with implementing planned activities.

Willie also encountered a few minor logistical challenges with implementing his activities. In the case of Willie’s review game, he adapted the format in which he

collected answers from teams due to needing to keep the game moving. He explained during the second lesson interview,

> I tried to make it so it wasn't just one person answering, but I realized time was an issue. I wanted them to get to the answer and then share it with each other. So my goal from the beginning was to go to each group and be like, okay, blank [point to a student]. What do you think? … But I think time became an issue… That's something I would try to change, [so I] have time so I could be like okay, you, how did you get that?... I wanted it to engage the students who may be struggling or [make it] so everyone's learning… [since] you want to ask the people who are maybe struggling with it so that they can explain the answer and now maybe they know that. They know how to do it and then you ask them what the answer so now they feel better about it.

While his original intent had been to select a random student in each group to provide the answer, Willie found there was not adequate time and chose to allow any student in the group to give the team's answer. This was a minor adjustment but illustrates how MGSIs can and may need to adjust an activity during class.

Willie faced a greater logistical challenge with his jigsaw. Again, the activity took longer than anticipated to complete, pushing it into two full classes. This was not a great problem from Willie's perspective since the jigsaw covered so much material. However, the groups progressed through their problems at different rates which left them at different places at the end of the first class. I interviewed Willie after observing his first day of jigsaw and before the second class where he attempted to complete the activity.

One group was struggling to make progress and he explained during the first lesson interview,

> The other groups are almost done, so I have to get them moving on. So, time's a little funky here now because I think group three finished…group four and group one are almost done. The rest of the groups are done, but I'm trying to figure out what I'm gonna do with group three and group two.

As a result, Willie needed to adapt his plans to try and help group two finish without leaving group three without anything to work on. I did not observe the second day but did hear from both Willie and his mentor that group two continued to struggle with the activity, making it more difficult to complete the jigsaw.

Finally, while implementation challenges more often derived from large-scale activities, they were not limited to jigsaws or games. Sometimes this meant not including a certain question in a way that resulted in student collaboration or not providing time for students to think independently as planned. For example, during the second lesson I observed, Chen had planned to give time for students to think, pair, share. He asked the class to talk to their neighbor about a problem but one student in the front row quickly gave the answer to the class. Chen remarked in the interview,

> I meant to ask them like about sine and cosine too. But [a] student just answered. So, I didn't do that. Yeah, I meant to do think, pair, share here [pointing to lesson plan]. [And ask] what happens if we rotate the graph? What's going to happen to the sine or cosine?

Sometimes students' responses surprised MGSIs, leading to minor adjustments in their teaching. In this case, Chen omitted the planned think, pair, share segment of his lesson

due to the student's response. This was not the only time Chen perceived the facilitation aspect of teaching to not go as desired. When I asked Chen in his lesson three interview how he thought the class went, he remarked, "I didn't like the lesson because I plan to do a lot of things and I didn't like commit to it." He explained he had not gotten to a question he wanted to ask and wanted students to be more engaged during the lesson.

MGSIs encountered some difficulties with implementing their lesson plans as intended due to challenges with time management. Speer (2008) argues that MGSIs need to develop pedagogical content knowledge, such as understanding student thinking, typical student difficulties, or common ways in which students approach tasks. Additionally, this study highlights an instructor's need to develop knowledge about the time required to complete activities and tasks. Lack of time for active learning, including both lack of time to design lessons and needing to use class time to cover content, have previously been identified as a barrier to instructors adopting reform teaching practices (Henderson & Dancy, 2007; Johnson et al., 2019). Although these MGSIs embraced many student-centered practices, they also encountered challenges with implementing them in the time they allotted. The examples provided above may clarify what some of these challenges look like in practice.  Although some difficulties with implementing their plans were related to time management, MGSIs also experienced student resistance.

***Students Responding to Teaching Methods***

While MGSIs in this study often planned activities to create student engagement, at times they identified students' responses to these methods as a conflict arising from implementing their plans. All MGSIs discussed times when students reported disliking or

resisting methods while Patrick and Chen reported repeated difficulties with students working independently during group work.

***Students Disliking or Resisting Activity***

MGSIs described some experiences where students either provided feedback indicating they disliked an activity or appeared during class to be frustrated by or not engaged in an activity. These challenges seemed to relate to times when MGSIs planned activities intended to engage students and MGSIs tended to reference a few students or a group of students rather than an entire class when reflecting on this difficulty. For example, during the first lesson interview, Chen explained how he received feedback from a few of his students on both a mid-course evaluation and in person following a lesson, indicating, "they don't like when I do this kind of stuff, have them struggle and conclude an idea from the lesson. A few people don't like that. They like to be taught in [a] linear order kind of thing." He continued to reflect on the structure of his lesson, which aimed to have students look at examples of rational equations and their graphs in order for students to determine how to identify horizontal and vertical asymptotes. Chen continued,

> Like I said, a few people complain about that; they don't like to synthesize. They don't want to struggle. Like they rather have me tell them. I can see that it could be problem for some students [if] they cannot like come up with the idea. So [that method is] kind of not helpful for those students.

Chen had designed his lesson to incorporate some aspects of student discovery to help students make meaning of asymptotes, yet he noted some students provided feedback indicating they did not like learning in this manner. Deslauriers et al. (2019) found that

physics students interpreted the increased effort needed for higher cognitive demand as a sign of poor learning and prefer well-delivered lectures to active learning settings that require them to figure out how to solve problems. Chen did not give up on this strategy but expressed during the third lesson interview, “I want them to like cooperate and try to come up with the conclusion themselves. But it doesn't seem to happen.”

Patrick also received some student feedback that indicated students were overall not excited about the jigsaw activity he used to cover solving quadratic equations. He had been curious to know what students thought of the activity, whether they enjoyed it and how well it helped them understand the process of solving quadratic equations, so he administered a brief survey during the next class. He wrote about the student responses in his journal.

> The second question averaged 2.65 [on a 5 point scale] with 21 of 23 students marking 3 or lower indicating that, on average, my students felt neutral about the activity or would *not* want to do it again. The most common response to the third question is that my students didn't like the topics being explained by their peers because they felt that their peers didn't understand the topics well enough. Many comments suggested that they prefer a standard lecture because the way that I explain topics is clearer and more organized.

Patrick was willing to try this type of activity again if the students preferred it or found it helpful to their learning. However, the formal feedback he received from his students indicated they did not like it better than “standard lecture.” This is consistent with Deslauriers et al. (2019) findings that students rated the quality of instruction in passive learning lectures more highly than active learning settings.

More than preferring traditional activities, there were times MGSIs observed some students strongly disliking or refusing to participate in some of their activities designed to engage students. An extreme example of this comes from Willie's jigsaw activity, where he divided his class into four groups. Three groups seemed to make good progress on the problems and from my observations, engaged well in the process. However, one of the four groups took a different approach. As Willie explained at length during the first lesson interview,

> Everyone was quiet at first. I didn't notice anything about it. They started talking to each other a little bit and then they all just, that group just went quiet while the other groups just continued to talk. That was when I kind of noticed. I had to go over there and that's why I went up to the board to try to get them somewhere, feed them. But still didn't click for them. I think they essentially just wanted me to do it out, which was not the whole point of the activity. I didn't really know how to get them to want to do it further. They weren't really motivated in this environment, I guess.

This topic came up multiple times during the first lesson interview. Willie tapped hard on the table recalling the frustration he perceived from a few students in the one group that struggled with the jigsaw. He added during the interview,

> But I had that one group, you know, in that one corner. And so, whenever they would ask me questions it was how do I do this? It wasn't a why, it was how. It was like, I want to do this, tell me how to do this! Instead of, I've gotten here, why am I stuck? Or something like that, you know? I think the way I tried to handle that, the way I will continue to handle that [is] I'll try to lead them there. I'll give

> them little flicks. I still want them to get there. I don't want to be the one who explicitly tells them the answer. That activity, the whole purpose was for them to come up with it… They didn't get there and that happens.

Willie remained fairly optimistic about the group. He continued, "It wasn't a total failure. I think they all put the brakes on real hard. They tried and they just, I can't do it." However, he expressed concern about a few student responses.  He continued, "I saw a lot of red faces, like angry and I was like, well that was not the point." Later in the interview, he reflected on how he often watched his students' expressions during class. With the jigsaw, this led him to conclude the majority of the students seemed to enjoy the activity. He explained during the interview, "as long as I don't see anger. That's what you don't want to see" from students. Then, thinking back to the group that struggled with the activity, he continued,

> I just remember it was three red faces right in front of me. I was like, Oh no, that's not good! I tried to help. [It] just wasn't sticking. They weren't putting in effort. They just want to come into class, take notes and leave is what it felt like. They were unhappy.

Willie confirmed the students were unhappy with the *teaching method*, explaining, "I had one of them come up to me and said, can we not do this again? So yeah, she was not happy with the method." However, the experience did create a conflict for Willie. He also shared during the interview, "She just wanted the answer, and she was getting mad that she wasn't just getting the answer… That was quite bothersome to me. Nothing I can do if they're not going to try to work with the activity." Willie did not give up on the group and planned for his SI leader to join their group during the next class to try and push them

along. I noted he demonstrated a lot of patience when speaking with that group and I recalled how he asked them all to take a deep breath. He laughed, "And they did. That was the crazy part. They actually did. Like they all went [exhale]. I was like, Oh god, they are mad." Again, this resistance to the discovery-style jigsaw activity only occurred with one of the four groups yet it created a challenge for Willie. This lesson was significant to Willie to the point that he continued to reflect on it later in the semester.

These examples illustrate ways in which some undergraduate students at times expressed their outright dislike for some of the teaching methods MGSIs employed in their Precalculus course. Again, these challenges were typically only expressed by a small group of students. MGSIs perceived these types of responses as a conflict they experienced with teaching and expressed during the focus group a consensus understanding that it is not possible to please all students.

***Students Working Independently during Group Work***

MGSIs perceived success with group work varied greatly in this study. Willie was a strong advocate for group work and expressed satisfaction with how he believed it generally worked in his class. However, Patrick and Chen repeatedly expressed overall difficulty with getting their classes to engage in group work, indicating that students tended to work alone despite their urging for collaboration. As Patrick summarized in his journal,

> I am having trouble getting my students to interact with each other. I like to give my students the opportunity to try/practice a concept during class so that they can ask questions and get immediate feedback, but during that time my students seem

> to just want to work individually rather than with those around them (which I encourage).

Students seeming to work alone during class time intended for group work was a continuous challenge expressed by Patrick and Chen throughout the semester. Chen stated in the second lesson interview,

> When I tell them to work in a group of four and they just sit there, and I have to make a group for them. And even [when] they do that, they just don't really talk. [It] doesn't work, [it's not] really working.

Patrick and Chen agreed with each other during the focus group that getting students to work together was a challenge they encountered with their classes. Patrick commented during the focus group, "My class was just determined to do the stuff themselves."

Both Patrick and Chen first mentioned this concern in the background interviews and reiterated the concern throughout the semester. This difficulty was not limited to a few students or to a few class meetings but seemed to be a continuous theme. For instance, Patrick explained in the background interview, "I told them, you can move your desks around, talk to each other, [and] work with people around you. I tell them every class; they just haven't responded to that yet." During the first lesson interview he discussed concern about his quiet classroom. He shared,

> Maybe I can find some way to make my lessons so that they are helping each other a little more or at the very least so that it's not just silent in my classroom. Sometimes it is. A lot of times it is… I'll say you can work on these problems. You can work with people around you or people next to you. They just work by themselves mostly. I don't know if it's a matter of they just want to try it or what.

Patrick desired for students to interact with one another yet was disappointed by the apparent lack of student-to-student communication.

From Patrick's perspective, this situation did not seem to change over time. During the second lesson interview, he added, "Normally if I ask them to work in groups, it's like this hesitation and they don't really want to get in groups." According to Patrick's mentor and from times I observed his class, students certainly did speak up. However, when describing Patrick's classroom, his mentor explained Patrick, not unlike other mathematics instructors, mainly uses a monotone voice. Combined with his calm personality, the mentor felt this can present a challenge for making the classroom engaging. As the mentor explained, Patrick is not one "to be jumping around at the front" of the room telling students "We're going to have so much fun today!" He noted,

> So overcoming that to get people involved *is* really hard. You know, if you're lively, then monkey see, monkey do, right? But if you're sort of reserved and calm, then the students will sort of see that as oh, this is quiet time.

I agreed with the mentor about Patrick displaying a calm and caring attitude in his classroom which made the atmosphere rather peaceful and quiet. He was also concerned about making sure students received clear explanations which all students could follow and understand. Despite the quiet classroom, Patrick continued to offer students the opportunity to interact with varying degrees of success.

Similarly, Chen repeatedly mentioned students' tendency to work alone when invited to work with peers. While discussing group work during the first lesson interview he stated, "They tend to not participate... So a lot of them actually prefer to do the exit slip rather than working in groups…. That's what they put on their mid-course evaluation.

So that's kind of surprised me.” As the semester continued, he did incorporate exit slips into his class but continued attempts to include group work. From Chen’s perspective, the challenge with limited group discussion continued until the end of the semester. During the third lesson interview, he shared how he perceived “a lot of people” trying to answer his questions during a whole class discussion yet “when we moved to worksheet, they don't respond well to do work in group kind of thing. Like they try to work but not, they are not willing to work with other students I guess.” He continued, “When I asked them to work in groups they just sat there [and] worked on their own. I didn’t fight them enough to work as a group I guess.” When reflecting on a time during the lesson he asked students to work together he added,

> I can see that they like start working, but that they just didn't communicate. I could have pushed harder for them to work in a group, but I didn't do it… I mean like to be honest, I wish I kind of pushed them more but I was too tired. So as long as they work, I was like okay, you're working. I really want to [have them] work in a group because at least they try to help each other out or compare ideas… and it's kind of difficult to do it on your own. So yeah, I definitely should have pushed more on this problem.

Chen still viewed group work as valuable and important and aimed to facilitate student collaboration. He concluded during the interview, “I mean I'm not gonna like give up doing group work so, but I have to like find a better way to do it.” Chen discussed different types of problems and considered more challenging problems to possibly be better for using with group work. During the focus group, Patrick and Chen agreed with

each other that group work was an area of teaching they tried and didn’t think it went as well as they had wanted.

In addition to the challenges with facilitating student-to-student interactions in structured group work, Patrick and Chen also spoke generally about trying to increase student engagement. For instance, Chen expressed in his journal, “I try to ask them to pause and ask them to do work in groups or on their own but a lot of them doesn’t really participate in that.” During the third lesson interview he reflected,

> When I show them an example and give them time to work, sometimes they just sit there. Like they're not trying to do problem. That can be a problem [for me] because I don't know if they actually already know how to do the problem [or] are they just disconnected with the lesson kind of thing?

Similarly, Patrick noted, “My class is not normally a social class” during the first lesson interview, and continued,

> Unless I specifically form groups and tell them we're doing group work, work within your groups today, unless I specifically do that, they really don't talk to each other. I might have two pairs of students that will talk to each other while they're doing work. … Most of the time, it's very quiet. I encourage every time, talk to people around you and it just, it hasn't happened yet. I mean at this point, I don't know how to fix that per se.

He wanted his students to converse more among themselves and admitted it was difficult to read students to determine why they were so reluctant to speak. One week he wrote in his journal, “I'm still having a hard time getting class interaction (jigsaw activity aside), but maybe if I feel more comfortable, they will too.” During the final lesson interview,

Patrick confirmed that student participation has been consistently difficult to achieve in the manner he desired. He shared, “There's this energy in the room that says don't talk for some reason, but I don't think I've ever tried to like encourage that energy.” It is possible that the instructors’ personalities contributed to the tone of their classrooms as the mentor described Patrick and Chen as having very similar personalities. Personalities aside, MGSIs continued to offer students opportunities to interact throughout the semester.

Both Patrick and Chen associated time of day with this challenge of getting students to interact. Chen explained in the background interview,

> I tell them to move into groups but sometimes they don't want to do that. Sometimes they have 8:30 class and they don't want to really do anything. I have to assign them to go there and work together and talk to each other. So when they [are] doing that on their own, that I feel good about that.

Chen stated in again in his journal, “I try to do group work and my class, two of my classes are in the morning at 8:30 and a lot of students are inclined not to work in groups.” Similarly, Patrick mentioned in the background interview with a nervous chuckle,

> My students are a little too focused, which sounds weird, but like they don't talk. It's 8:30 in the morning mind you, but I'm having a hard time getting them to talk to each other at all. So I would like them to communicate with each other a little more, maybe work in groups. So I might have to facilitate that myself soon cause I kinda thought they would warm up to each other, but that's not been the case. I have them start to work on the worksheets and the room is just silent. It's just, it's really awkward.

Patrick's class met at 8:30 in the morning each day while Chen's class met at different times depending on the day of the week but included 8:30 class times. Willie's class met late in the afternoon. It is possible that time of class meeting played a role in some student's energy level although no data was collected from the student perspective to support or refute this theory. However, undergraduate student survey data has suggested many students appreciate group work as it provides opportunities to pursue various solution paths, to connect with peers, and focus on understanding the material (Uhing et al., 2021). Yet, Uhing et al. also found students reported dissatisfaction with group work when they prefer to work at a different pace than their group, are uncomfortable, shy or introverted, or need more clarity on a topic.

Student responses to teaching methods was another challenge encountered by MGSIs when trying to implement their lesson plans. Although student attitudes have also been identified by faculty as a reason to not utilize reform materials or teaching methods (Henderson & Dancy, 2007; Deslauriers et al., 2019), this study adds illuminating examples of how novice instructors might experience and interpret these student reactions.

### *MGSIs Maintaining Semester-long Student Engagement*

At times, MGSIs in this study expressed some difficulty with maintaining or recreating student engagement, often at points in the semester where students may have been experiencing fatigue. All three MGSIs discussed moments where their classes seemed less responsive than desired or less responsive than on a typical day. For instance, Patrick noted in his journal, "I'm getting the sense that as we head towards the end of the semester, more of my students seem more checked out than before. They seem more tired

during class and much less receptive no matter how enthusiastic I am.” Similarly, Willie discussed points in the semester when students seemed more tired and thus less engaged. This often corresponded to upcoming breaks. Willie noted during the second lesson interview,

> I think were at that mid-course lull... People are starting to not show up. It's the kind of stuff like people are putting in less effort, showing [or] doing less work … I think I had five people not there, which is unusual for my class… I mean obviously day before break, but it's been getting more and more.

He noted again during the third lesson interview,

> I've noticed some of my students are like on their phone more than they were before and things like that. We had a lull in the middle of the semester before as well… So here I am again, week before Thanksgiving falling into a lull. I've tried to get it out of them, like get them to engage. But I think some of them are checking out right now.

He explained students could be tired and ready for a break but still wanted to increase the level of engagement in class. Willie also noted in his journal, “I have noticed that my lessons for the beginning of chapters do tend to be drier than later in the chapter. Thus, some students are not as engaged. I am trying to figure out a way to fix this.” Similarly, Chen noted in his journals, “Students seem to be less responsive than usual. It could be just because they got back from the break, but I really hope my students are more responsive when they ask questions. They are more willing to participate.” Certain content or weeks of the semester seemed to be more difficult to create the desired level of

student engagement. Thus, MGSIs perceived their classes overall to exhibit higher or lower levels of energy and effort at different points in the semester.

All MGSIs in this study considered student engagement important and desired and attempted to create opportunities for student interaction. Achieving and sustaining the desired level of engagement was at times mentioned as a challenge by these MGSIs related to implementation of their plans to create student learning.

## Challenges with Preparing to Teach

MGSIs also discussed challenges around preparing to teach which mainly centered on time constraints due to their stage of life and requirements of planning. Finally, MGSIs occasionally reflected on course coverage concerns.

### *Limitations of Time*

Graduate student instructors have to take on a dual role, working as both a student and an instructor. They are still students themselves; all the MGSIs in this study were in their second year of graduate school taking a full load of classes while still needing to prepare for comprehensive exams. At the same time, these MGSIs were taking full responsibility for an undergraduate Precalculus four-credit hour course, teaching as an instructor of record. As Willie wrote in his last journal entry, this means from his perspective, he felt he was “essentially working two full time jobs.” Learning to balance these two responsibilities and mange workloads was a challenge experienced by all MGSIs in this study. The need for this balancing act does distinguish the experiences of graduate student learning to teach from beginning K-12 teachers who from a career or professional perspective, can fully focus on teaching.

Throughout the semester, MGSIs found weeks where the time needed for their own coursework conflicted with their responsibilities as an instructor. This appeared in each MGSIs journal entries at least once. For instance, Chen shared in his journal towards the end of the semester,

> I find it difficult to balance between teaching and grad student life. I have a lot of work and I have to spend a lot of time preparing for class for teaching while I have to do my own studying. So far, I put a lot of time on teaching but not enough on my studying so that's been really difficult for me.

Willie expressed this conflict early in the semester, writing in his journal about wanting to create an engaging classroom but needing time to complete his own work. He wrote,

> I had so much work to do for my own classes that teaching became a get the material done, assess them formatively via worksheets, and, if all went well, move on. I can understand this is not ideal, but [my] own education is the reason I am here…That being said, I'm hoping to make up for some of the boring days this week with some more interesting and interactive classes next week to get some of the less involved people engaged…Managing my time with my classes and preparing and executing things for teaching [was challenging]. I have discussed this enough above, but I feel this was my main challenge [this week].

Patrick also mentioned in his journal the difficulty he faced with balancing teaching and learning responsibilities. He wrote,

> This week I have had very limited time to prepare for my lectures due to a large increase in my own workload. I try not to let my own work affect class too much, but with less time to prepare for lessons, I found myself to be less organized. The

> lack of preparation time includes less time spent on lesson plans; a less organized lesson plan correlates to a less organized lesson.

Each of these MGSIs invested significant time and effort into their teaching and studying which led to a juggling act of their time and energy.

The significance of this challenge for MGSIs in this study can be seen in the final journal entry written after the conclusion of the semester. One prompt asked them to reflect on the semester overall and asked, what part of teaching or planning did you find most difficult? Chen's response illustrates the challenges of balancing time commitments,

> Time management is probably the most difficult in the past semester. This semester is the first time that I teach MATH 115. We meet four times a week, so, I have to do a lot of lecture preparation (which I have been trying to align with homework, quiz, and exam). Even though we have the lesson plans in online material and worksheet, I still usually go over the book, look for extra material online, and compare my notes to other people's notes. These planning worked fine when I am not busy, however, toward the end of the semester, I find it difficult to balance planning the lesson with focusing on my own study.

Responding to the same prompt, Patrick identified the same challenge as Chen, balancing time for teaching with the time needed for his own graduate studies.

> The difficulty of teaching mostly stemmed from trying to balance the teaching workload with my course workload. There were weeks this semester where it felt as though I had to choose between doing well in my role as a MATH 115 instructor and doing well in my courses. This is a no-win situation that I feel that, as a graduate student, I should never be in.

This theme was also touched on in the focus group where MGSIs collectively agreed they felt as though they spent most of the day teaching, holding office hours or preparing for teaching in some way and then would go home and complete their own graduate coursework in the evening or over the weekend. Willie explained during the focus group,

> I feel like if you want to have a good class, it takes a lot of preparation. It's pretty much writing all those assignments and grading. You know, if you really want to be a good teacher, you're going to spend more time.

These MGSIs chose to spend a large amount their time on preparing to teach and wanted to be effective instructors.

Lesson planning, particularly for non-lecture types of lessons, represented one especially time-consuming aspect of teaching during a semester where time was in limited supply. Patrick wrote in his journal, “Time management seems to be a constant problem. Because of my own classwork, I never seem to have as much time as I would like to put into lesson plans.” Lesson planning itself is a time-consuming task and MGSIs in this study noted that certain types of activities require more time to plan. For instance, Chen shared in his journal about wanting to include “more complicated active learning activities” like he heard some of his peers discussing. He added, “It’s kind of difficult for me to come up with those activities, it needs a lot of planning. But I really want to include those activities sometimes.” When Willie was asked if he would do another discovery-based jigsaw activity, he responded during the first lesson interview, “Yeah, I think I would if I had more time. This took a lot of time to plan. I mean, to write four different activities was a lot.” He continued later in the interview, “my biggest issue was planning. I took a lot of time [to prepare this lesson]. Time that I don't have, so that was

tough.” Similarly, Patrick liked the activity level and discussion his jigsaw generated. He had borrowed the problems from his mentor and explained during the first lesson interview,

> It's hard cause like these lessons, that jigsaw specifically, they take a lot longer I think to prepare. Now granted this one was nice because somebody else spent time making it, so I just sort of adopted it a little bit. But I wouldn't be able to do this on a super regular basis… If I find out that they did like it, I think it would be nice to maybe do more jigsaws throughout the semester so maybe like twice a month.

In each of these cases, MGSIs noted the active learning components of lessons tended to take them more time to prepare. Experienced faculty often cite lack of time to redesign courses as a reason for not incorporating active learning (Johnson et al., 2018; Plush & Kehrwald, 2014). Perhaps these types of activities may be more valuable to share examples of for new instructors than examples of traditional lecture-type notes.

The MGSIs in this study were provided some resources, such as sample lesson plans, and regularly met with mentors teaching the same course who could offer advice. They frequently consulted with one another as well. However, the MGSIs in this study wanted control over their lesson plans and would consult these various resources, but still create and implement their own plans. As Willie said in his third lesson interview, “I prefer to teach in my own words.” The time commitment needed to prepare lessons in the context of still taking their own courses was thus a difficulty expressed by the MGSIs in this study.

### *Course Content Coverage*

To a lesser extent, MGSIs at times mentioned course coverage requirements as a challenge with planning. This included times when MGSIs felt they were behind schedule or when they mentioned challenges with pacing the material or selecting the right problems at the right difficulty level. For example, Chen reflected in his journal about slowing down during a lesson to explain the material in more depth. He noted, "As a result, I am slightly behind my schedule. I have to consider how should I adjust my lesson accordingly?" Patrick seemed to have the most trouble with pacing. He mentioned in the background interview,

> It's been a little tough because I've gotten slightly behind already based on what schedule I've created or obtained. I'm trying to cover one section a day, but if you get behind one day then every other day is now messed up. I don't know if I'm going to just eventually say, okay, we're just officially a day behind… because I don't want to cheat them out of stuff either. Maybe just some section won't take that long. I don't know.

Patrick seemed to be satisfied with how he was able to catch up at the end of the semester by reorganizing the chapter focused on trigonometric identities. He shared in the third lesson interview,

> In general, my class is behind schedule wise, so I think by doing the chapter this way, I'm actually able to catch up. I think I was able to convey the information that was necessary and still do that speeding up because I just because I don't like the way the book is structured. So, it kind of lent itself well [to catching up].

Covering the required course material seemed to be a challenge MGSIs were able to more easily manage.

Another aspect of planning occasionally mentioned as challenging related to selecting "good" examples that would be interesting or at the desired level of difficulty. For instance, Willie mentioned during the lesson three interview about the law of sines and cosines lessons, "This one it was a little dry. As I was reading through the book, I was struggling to find good stuff to work with." He wanted to find more applications but found the content difficult to expand upon. Another example of debating over content comes from Patrick during the third lesson interview. He explained,

> There's a lot of material out there… There were a lot of resources for trig identity worksheets kind of things, but none of them were what I wanted. Basically, I think that most of the worksheets either didn't have enough problems or the problems were too easy. I didn't want to just give them easy problems because I don't know if they'll learn as much from that. I mean I feel like they'd be able to do it but then, on the exam I would be restricted to giving them these easy problems because that's what they've seen.

At other times, Patrick mentioned the importance of selecting problems at an appropriate level of difficulty to engage but not overwhelm students.

### Challenges with Interpreting Students' Performance and Course Preparation

MGSIs also discussed challenges related to their Precalculus students, particularly with their performance on quizzes or tests, which MGSIs identified as a challenge they experienced with teaching. Also, students' prior preparation, how students chose to

prepare for their current course, and the role of Precalculus as a foundation for future coursework were other challenges reflected on by MGSIs.

***Student's Performance on Quizzes or Tests***

All MGSIs in this study described some of their students' quiz or test results as a difficulty they experienced with teaching. MGSIs in this study were concerned that some students at times struggled to demonstrate mathematical knowledge, understand concepts, or recall facts or procedures on quizzes or tests. In this study, MGSIs referred to quizzes and tests (or exams) as written assessments of students' knowledge of some mathematical content which MGSIs collected and graded. Generally, quizzes sought to gauge students' understanding of and ability to perform algebraic methods on a limited number of topics, while tests or exams covered a larger quantity of concepts. Thus, quizzes were shorter, were given more frequently, and may have covered only one or a few sections of material compared to a longer test or exam, which may have covered one or more chapters. Although an analysis of MGSIs' perspectives on using assessments is beyond the scope of this study, MGSIs in this study discussed students' poor scores or poor performance on exam or quiz as a challenge they experienced with teaching.  MGSIs' feelings, and perhaps efficacy for teaching, seemed to be impacted by student performance on graded assessments and at times they pondered to what extent they were accountable for student learning. This reaches beyond this current study yet may be an area worthy of further examination related to understanding MGSIs' perspective on teaching.

The experience of seeing students struggle with problems on a quiz or test that had been, from the instructor's perspective, clearly covered during class was a source of conflict for these MGSIs who aimed to help students develop mathematical thinking and

procedural skills so that they could succeed in both current and future courses. This tension between achieving their personal goals for student learning and students' performance on quizzes or tests appeared throughout the semester. For instance, Willie responded to a prompt in his journal asking about what he found challenging this week and responded with, "Most of the challenges came from the exam and how to handle the class overall not being able to answer these questions they've seen before." Challenges with student performance on quizzes or tests often related to students struggling to demonstrate mastery of or remember previous content. During the second lesson interview, Chen also noticed some students having trouble combining the material and knowing when to use what tool on a problem during exams. He stated, "Yeah, that's my major concern for my students." MGSIs were troubled by times when their student's repeated errors that MGSIs attempted to prevent through their teaching. Quizzes and exams seemed to highlight facts or procedures that students did not remember or could not replicate.

All MGSIs spoke about students' poor quiz or exam performance in their journals as a challenge they faced with teaching. Patrick expressed his thoughts in his journal after grading an exam. "The results were less than I expected. I thought that I had made a fair exam, but the number of people that did poorly was surprising to me". Similarly, Chen noted in his journal, "I kind of expect my students to do better than the score that they get because my exam questions were quite straightforward. So that's kind of disappointing to me." Willie also reflected on his second exam, writing in his journal that, "Unfortunately, they did not do well on this." MGSIs experienced conflict when their students performed poorly on quizzes or tests. Perhaps this concern was especially salient for these MGSIs

who spent a lot of time reflecting on their goals for student learning while participating in this study. Thus, they may have easily identified students' struggles as a challenge since it conflicted with achieving their goals.

MGSIs described their challenge with students' performance on these assessments as problematic in various ways. For instance, Chen identified errors students made on a quiz as a sign that students were not remembering or correctly applying concepts discussed in class. He explained in his journal,

> I feel like students don't remember what they learned in general. On Thursday I had a quiz on the material that they learned, and they already had homework on it. They couldn't do a basic problem that we kind of already went through in class. For example, a lot of students think arcsinx is equal to 1/sinx. I already told them that this is not a correct statement, but they still repeat that on the quiz.

Chen was disappointed by the number of students who did not demonstrate an understanding of standard notation used with inverse trigonometry. The realization that learning did not always happen as desired was a repeated challenge mentioned by MGSIs in this study which was often associated with grading quizzes or tests.

Similarly, Willie expressed disappointment with his student's quiz performance on problems he felt they should have been prepared for. He wrote in his journal about what he learned about his students one week,

> I learned that my students require excessive examples and cannot retain information from the week before. I learned these two things all thanks to my quiz. I quizzed them on material from last week and they did not perform well. I

also put an example explicitly from the homework and notes that the students performed poorly on.

Willie was concerned that students did not seem to retain material even when it came directly from previous assignments. Willie's journal provides another example of his concern about students struggling to recall information being his main challenge in a given week. He wrote, "My only challenges came from my students struggling to remember the unit circle. I hate to make students memorize things, but I know that in calculus they will be expected to know this." This struggle with students not remembering mathematical content conflicts with MGSIs achieving their goal of preparing students for future coursework.

Students' struggles on tests and quizzes also occurred when they approached problems in unintended ways. For instance, Patrick had given a quiz students struggled to finish. However, he explained how some students distributed out a partially factored polynomial when trying to find the roots of a polynomial; thus creating much more work for themselves. He concluded in the second lesson interview, "People didn't finish because of the way they attempted the problem … and people didn't really know how to use it." This was surprising to him since he further explained,

> In class we did a group activity for maybe 20-30 minutes where I put two similar polynomials like that on the board. And I had them get into groups and sketch them like from start to finish. So, and I did examples during lecture. So definitely not the first time they had seen that.

Not only did Patrick perceive he had covered the quiz material, but he felt he had even used solid active learning methods to cover the content that some students struggled to

demonstrate an understanding of on the quiz. Generally, grading quizzes or tests seemed to highlight for MGSIs moments when students were seemingly unsuccessful in achieving mathematical learning goals despite MGSIs efforts to include student-centered teaching methods or provide clear explanations.

MGSIs responded to students low scores in a variety of ways, such as curving scores, offering extra credit or dropping quizzes, and discussed these ideas and decisions with one another and their mentors. At least once, all MGSIs in this study allowed students to correct exams to earn back points. However, these efforts did not always seem to solve the problem. For example, Chen allowed students to correct their exams to earn back half of the points they had missed. However, he wrote in his journal,

> I just graded my exam corrections and I feel like a lot of students who need to understand the material, they just didn't turn in the exam corrections. So I don't know. I really wish my students would go back and look at the exam, that's why I asked them to do exam corrections, but it doesn't benefit the people that I hoped it would benefit.

Having some students choose not to complete the corrections was disappointing for Chen and illustrates how MGSIs efforts to address students' performance on assessments did not always resolve this difficulty.

MGSIs also encouraged students to come to office hours or Supplemental Instruction (SI), peer review sessions offered for extra help. Patrick gives an example of responding to student's poor test grades in his journal where he wrote,

> When handing back Exam 2, I could feel that my students were, as a whole, very demoralized. I had some students that were clearly very upset or even angry about

> the results and I think that a bad morale is very dangerous for a classroom. One way that I'm *trying to deal with this challenge* is that I am meeting or asking to meet with all of the students who are not doing well in the class overall or who did poorly on exam 2. This lets my students know that I care about them and their concerns and gives them a platform to express concerns about the course.

These MGSIs seemed to be invested in their student's success and wished to avoid discouraging students. As they cared about their students learning, they actively responded to students low scores by providing extra opportunities and offering academic support. Still, understanding and responding to students' poor performance on a quiz or test was a challenge they spoke about somewhat frequently.

In some ways, this presented an emotional challenge for MGSIs as they expressed feeling responsible for student performance on quizzes and tests. Patrick wrote in his journal, "When quiz scores are lower than normal, it's hard not to feel like it's my fault somehow." Chen stated in the third lesson interview, "I feel like as an instructor I should be somewhat responsible for how they learn." Willie also expressed feelings of responsibility for student learning during the third lesson interview when he asked, "I mean 70 is like the minimum that I want it. So, when I get below it, I'm like, did I do something wrong?" At times, some MGSIs struggled with balancing their responsibility with their student's responsibility for student learning. Chen directly expressed this in his journal. He began by reflecting on things he could do to help students remember concepts and concluded "I don't know if it's the students or my fault that they don't learn, I don't know". Patrick provides an example of how student's poor scores are a point of conflict for MGSIs. Patrick explained during the third lesson interview,

> I don't like telling people or assigning numbers basically to people, like [their] knowledge. But I have to test them on certain skills and knowledge… I'm not telling them that they're bad as people… I'm judging their mathematical ability. I'm not judging you as a person; it's very specific mathematical knowledge.

Patrick wanted to clarify grading reflected on a student's mathematical skills and not on the value of the student as a person. Processing students' performance on tests or quizzes and communicating with students about low scores can be difficult for instructors, particularly first-time instructors of record who are still students themselves. The point here is that MGSIs identified their student's struggles on quizzes or tests as a challenge they were experiencing as instructors.

When their students are less successful on quizzes or tests, MGSIs may experience some level of distress, disappointment, or discouragement. In the final journal entry, MGSIs were asked what they found most challenging about the semester overall. Willie expressed in his journal,

> The most difficult thing for me was watching kids not do well and knowing I've tried everything I could and offered everything I could to help them. It made me feel bad as a teacher and bad for the student. However, I have to learn that I cannot help everyone!

This is a struggle for novice MGSIs who put a great amount of effort into their teaching and then do not always receive the benefit of large amounts of student success. In a study of physics faculty, Yerushalmi et al. (2010) found instructors often cited student stress with exam situations as a reason they chose to omit or use features of problems that did not align with their goals. For those supporting instructors in developing their teaching

practice, Yerushalmi et al. recommend addressing conflicts between learning and teaching goals and acknowledging instructor's values related to reducing student stress and providing clarity for students. Similarly, those supporting MGSIs may need to acknowledge the tensions MGSIs experience when they are investing heavily in their teaching yet are disappointed by some student's performance on exams. This may be especially significant for MGSIs whose goals include preparing students for the future, as was the found to be the overarching goal in this study. "Learning how to deal effectively with conflict (particularly with the students they teach) is a major concern for many GTAs" (Park, 2004, p.353). Implications for practice will be discussed further in chapter seven.

***Students' Course Preparation***

Another difficulty MGSIs experienced with teaching Precalculus related to working with students who entered the course with a wide range of previous preparation. While the department utilized a placement test to determine which students should enrolled in the course, all MGSIs noticed a great variation in student's backgrounds early in the semester. As Chen expressed in his first week's journal entry, "A lot of students already know the material, and there are many students who are not comfortable with the 'prerequisite' materials." MGSIs learned some of their students had already taken Calculus II in high school while others seemed to have no previous exposure to some of the Precalculus content. MGSIs also observed that although some students stated that they had already taken Calculus, they did not always do well on exams.

This difficulty was most noticeable towards the beginning of the semester. Patrick explained during the background interview,

> One problem that we're having right now is that the material is really easy for some people, for maybe half the class, and for the other half of the class, they appreciate the review. But for the half that it's easy for, they're just sitting there going, why am I here? This is boring…We've been covering prerequisites, and these are skills that I need you to know. So a lot of them do know. And that's the half of the class that is sitting there going, why are we doing this? So a lot of them do know, but I need as a whole, I need the class to know these are skills you need.

Similarly, Willie mentioned during the background interview that he had “a very polarized class right now” as some students appeared to be quite familiar with the prerequisite material while others were not. He also wrote in his journal,

> My students are coming into my class with completely different prior knowledge. I have students who have taken everything I will be covering in my class and students who have seen none of the prerequisites. This made my job very challenging, but I learned that if I have the students who are far ahead work with some of the lower-level students on worksheets, both will benefit from the interaction and remain engaged.

Willie observed some students seemed to struggle much more than their peers to keep up with the material. During the second lesson interview, he mentioned “most of them are caught up at this point” meaning his class seemed to have evened out in terms of knowledge of course material. However, Patrick mentioned during the second lesson interview, “It's not like I can say that my whole class is doing one thing because everyone seems to be at different places.” In Patrick’s class the variation in students’ backgrounds seemed to continue for a while.

This challenge was mentioned again during the focus group when MGSIs were asked about ongoing problems with teaching that they could not find a solution for. Willie again expressed the challenge with teaching students with various mathematical backgrounds and explained, “It really mixes things up in our classrooms. We have a lot to deal with there.” Other MGSIs chimed in as well as Willie continued,

> Is everyone going to be on the same plane? No. You're going to have people who aren't gonna pass. It's just the nature of the beast… Your hope is that your average is an A and everyone got a hundred right? But that's just not realistic. And so, you're going to have kids who are in college in your class that are not ready for this class.

Placing students in the right course and providing supports to help all undergraduates develop the skills needed to succeed in their mathematics courses is likely a common challenge at many higher education institutions. MGSIs understood this yet still had to deal with the variation in students’ previous instruction and incoming knowledge.

To a lesser extent, these MGSIs also tried to understand how their students prepared themselves for their current precalculus course. Often this occurred while MGSIs tried to process student’s precalculus quiz and test results. As discussed above, all MGSIs in this study had at least one quiz or test where some students were unable to complete a problem on an assessment when the problem directly lined up with an example recently covered in class. MGSIs tried to reason about the cause of this problem. Patrick reflected on this experience during the first lesson interview,

> What was illuminating was I still had some people not get that question right on the quiz. I went through it in like detail, right? That tells me, okay, you have

> either not been paying attention for the last three weeks, maybe you weren't paying attention during that review or some combination of the two. But this, the people that didn't get those questions that I just went over, probably didn't study, probably they studied less than others.

Considering the possibility that students did not study enough as an explanation of poor exam performance was also considered by Chen. He reflected on his experience spending an entire class reviewing for an exam and offering time for students to ask questions. He shared in his journal,

> What I learned is that not a lot of students ask questions when we did the review. A lot of people just ask general questions like to review a certain topic, but it doesn’t seem to me that they actually started studying for the exam. That’s why they don’t have any questions about the exam. When I grade the exam, the result wasn’t satisfying to me … so what I learned is that it doesn’t seem like they study for the exam.

Chen tried to process the lack of questions he received while preparing students for the exam with the disappointing exam performance. Together these events suggest to him that students may need to spend more time or effort studying.

In addition to trying to understand student performance on various assessments, MGSIs were also challenged to understand some student’s preparation for class and effort towards assignments. For instance, Chen reflected on his experience of allowing students to correct their exams and explained in his journal, “This week I learned that you cannot always get what you want from your students” since some students did not attempt the corrections while others submitted work that was “not very thorough.” However, he did

conclude, “Those who did put in the effort received much better scores. What this is telling me is either I am not doing a good job explaining the material to them or I'm not doing a good job motivating them.” Chen was contemplating the role of student motivation related to their effort to complete an assignment, in this case an optional assignment aimed at improving their grade and understanding.

Occasionally MGSIs encountered students who at times did not fully prepare for or engage in the course. For example, during the first lesson interview I asked Willie about the only student I saw never speak with the group during the jigsaw. Willie shared his perception of the student at that time of the semester,

> I've talked to him. Yeah, he's struggling. But, it's hard. He only does half his homework. He only does half of his quiz. Like he does like half of everything and it's not because of time. He just doesn't like go; he doesn't do it. Like he just doesn't want to do it? I don't know. It's weird. It's a strange situation. I feel like it's not my place to interject in that case…. He doesn't talk ever. Sometimes you can't win them all that way.

This is an example where an MGSI had trouble understanding how to motivate the student to complete work and was unable to get clear communication from the student about how to further assist. This instructor utilized a university reporting system so that the university could offer support to the student. MGSIs also encountered a few students who stopped attending class or attended infrequently. Patrick remarked during the second lesson interview how he had a few students who might “show up to take an occasional quiz” but otherwise failed to attend class regularly. “I don't get it,” he remarked.

MGSIs also occasionally reflected on their limited knowledge of student behavior outside of class. For instance, some students did not attend help sessions such as office hours or SI. Chen expressed in his journal, “A lot of students have not put a lot of work into this course yet. I learn this by observing from the quiz they took, and only few students come to office hours or SI sessions.” While the challenge with quizzes and tests has already been discussed, this quote adds the perspective of student’s limited participation with supports offered outside of class. Patrick shared during the end of semester focus group that some students told him,

> They did not know what office hours were for. It was like three or four weeks ago, and they did not know that office hours were a time that they could come and ask any questions they wanted. I told them *when* my office hours were, I told them *where* they were, but I did not tell them *what* they were apparently.

Other MGSIs commented that they had never considered this problem before and expressed disappointment that some students potentially may not have understood the opportunities they offered for assistance. These examples highlight the importance of MGSIs needing knowledge of university support systems for students and the skills to advise students on how to access relevant campus resources (Park, 2004).

Another example of MGSIs reflecting on how students prepare for class by considering their work outside of class comes from Chen’s journal. He used an online homework system that provided information about times students completed their assignments. He noted in his journal,

> I look at student homework and I found out that a lot of them just try to finish homework like two hours before the deadline, which is not ideal. I kind of hope

> they spend more time throughout the week to review the material, so they master the material before they come in and take a quiz that we usually have on Thursday. It's not great that they try to cram everything [and] they only spend a few hours outside of class practicing.

MGSIs experienced moments throughout the semester where it was challenging to understand some student's motivation in the course. Times when MGSIs observed students not completing assignments or attending class was considered problematic in the eyes of the MGSIs. Thus, student motivation could be an interesting and relevant topic to discuss with MGSIs in a professional development setting.

Student struggles in the calculus sequence is a common problem and is not unique to this study (Bressoud et al., 2012). The challenges with students discussed in this chapter cannot be simply attributed to poor teaching on the part of study participants. The point here is that MGSIs perceive a problem when at least a few of their students are struggling, or at times failing, to meet the goals MGSI have for their learning as suggested by test or quiz performance or when appear unmotivated to complete work.

One final challenge MGSIs perceived with student preparation, which was primarily discussed during the focus group, related to being the instructor of record for a "cornerstone" course needed to prepare STEM majors for future coursework. Going back to MGSIs goals for student learning, they wanted to prepare students for both their future careers and future coursework. During the focus group, MGSIs expressed this put a bit of pressure on them as instructors as they felt the course was "just so essential" or so significant to student's future success. They were well aware that most students who passed their course would next take Calculus I. Patrick explained in the focus group,

> I feel like if you give someone a passing grade, especially an A or B, then you're effectively communicating to them that they're ready for calculus and you're also communicating to the professor that they have next that you said that they were ready for calculus. So I think that it's important that if they pass your class, they are [ready] because I mean there are people in the future that are sort of relying on that fact.

The role of precalculus as a prerequisite course for the calculus sequence was frequently on the minds of these MGSIs.

In addition to needing to ensure students left the course with essential mathematical knowledge, MGSIs noticed they were teaching lots of freshmen. Since their students were just beginning college, these instructors felt they were setting the expectation and tone of what students should expect in their future undergraduate mathematics courses. Willie remarked and his peers agreed, “I always found it strange that they put graduate students at the [front]. Right when freshmen are coming in, they're dealing with graduate students as instructors.” He reflected on his experiences as a college freshman. Willie shared that he took specific classes and wrote his undergraduate thesis based on his experiences with the professor of his first math class. He continued, “So I find that class [your first college mathematics class] is what you're going to expect from then on in math courses. I mean any class…you're gonna expect underwater basket weaving two to be like underwater basket weaving one.” As these MGSIs cared about their students’ learning and course experience, they felt additional responsibility as the instructor of record for a foundational course for STEM majors.

**Summary**

This chapter reviewed different challenges MGSIs spoke of throughout the semester. These challenges appeared in the areas of implementation of lesson plans, class preparation, and understanding precalculus students. Difficulties related to classroom implementation and lesson planning often connected to challenges with aspects of time management. This included MGSIs learning to manage their own time as they struggled to balance their dual roles as student and instructor (Hauk et al., 2009) as well as learning to judge the time needed for students to complete tasks in class. Graduate students often express concerns related to time management, especially new GTAs with little prior teaching experience (Feezel & Meyers, 1997). MGSIs in this study invested their own time and energy into fulfilling their desire to create quality learning for their undergraduate students, yet also encountered challenges when working with their students. MGSIs perceived conflicts with their goals when students struggled in the course or responded negatively to teaching methods. Communicating with students is a significant practical issue for many GTAs (Park, 2004). MGSIs, like other faculty, may need advice on how to best work with students who express preferences for lecture style classes (Deslauriers et al., 2019). This chapter provides examples of difficult situations encountered by MGSIs and insight into how these experiences influence MGSIs thinking about teaching. The role of the course, a prerequisite for the calculus sequence in which student outcomes are traditionally lower compared to upper division courses for majors, may play a role in contributing to these challenges. Additionally, MGSIs views of the importance of a freshmen-level STEM major course for preparing students for the calculus sequence and establishing students’ expectations for college level work added to

MGSIs concerns about teaching. During the focus group, MGSIs reflected on their ability to persevere and manage the majority of these challenges and reported having support from one another and mentors as helpful in adjusting to teaching as full instructor of record. More implications for supporting graduate students are discussed in chapter seven.

# Chapter 7: Discussion

This multiple case study explored the planning and teaching of three MGSIs who were first-time full instructors of record for Precalculus. A draft of the study's findings was shared with all three MGSIs to incorporate their perspectives and feedback. Two MGSIs met with the researcher in-person and verbally reviewed and affirmed the findings related to goals for student learning and challenges. Then each read the draft of their individual case study and provided minor written and verbal feedback. The third MGSI reviewed his individual write up digitally and then met online via Zoom to discuss his feedback as well as cross-case findings of goals and challenges.

## Member Checking

All MGSIs verbally agreed with the goals and challenges, nodding or making comments such as, "I might not be able to articulate it, but I agree". One MGSIs did not remember as much about challenges with interpreting student's performance or course preparation and reviewed that section as well. He reported it was quite accurate and affirmed the work and time they spent identifying and working towards their goals for students made it hard to not view low assessments as personal failures. MGSIs seemed content with how they had been represented in the individual case studies and would laugh or light up while reading or discussing the findings as the review process brought back memories for them. Willie concluded he "liked it" and Patrick noted the interpretations and writing accurately reflected how he felt. Chen stated he had "no complaints" and the writing was "pretty accurate." He also reported that he liked what his

mentor said related to being an international graduate student. The review process helped confirm the validity of the case studies, including the international graduate student point of view. Both Willie and Patrick further reflected on how they have changed since the study, and highlighted factors such as COVID, more experience, and teaching courses besides Precalculus as contributors to such changes.

## Summary of Findings with Respect to Research Questions

For reference, the overarching research question for this study was: During their first semester teaching a new undergraduate course, how do MGSIs plan (design and reflect) and implement their plans, with a focus on their goals for student learning? Four sub-questions were created to address the overarching question. The sub-questions were: a) What goals do MGSIs aim to achieve for student learning? b) In what ways do MGSIs seek to achieve their goals for student learning? c) In what ways, if any, did MGSIs describe external factors as influential to their goals for student learning or planning practices? d) What challenges do MGSIs describe as they reflect on their planning and classroom instruction? To answer the sub-research questions, the analysis focused on MGSIs goals, tactics used in the classroom, lesson strengths, additional influences on planning, and perceived challenges or conflicts with planning and teaching.

### *Goals for Student Learning*

This study found MGSIs, when planning and reflecting on their teaching, expressed common goals for undergraduate Precalculus student learning. All MGSIs were focused on and concerned about preparing undergraduate students for future academic and personal success in both coursework and careers. MGSIs perceived that success in these areas would require students to gain procedural skills and abilities. They

also desired for their students to grow in understanding, reasoning and sense-making abilities while aiming for students to develop positive attitudes towards mathematics and themselves as learners. These goals echo the mathematical proficiency strands articulated in *Adding It Up* (NRC, 2001) and to a lesser extent, the process standards from *Principles and Standards for School Mathematics* (NCTM, 2000) and *Beyond Crossroads* (Blair, 2006). However, no one source contained all four goals as expressed by MGSIs. All MGSIs desired for their students to ask questions and either practice problems or work and talk together and all MGSIs wanted to engage and motivate their students and vary their lessons; thus, they shared many types of objectives. Further, MGSIs goals were shaped by the course MGSIs were teaching, particularly the prerequisite nature of the course.

Although all goals for student learning were described by all study participants, some goals were more consistently salient among certain MGSIs. Willie most frequently spoke about developing students' conceptual understanding of course content and about wanting students to make connections and apply concepts in various settings. Patrick consistently spoke about his students' attitudes towards mathematics and their self-efficacy for learning the material. Chen often spoke about the importance of students' mastering procedural skills. Still all MGSIs referenced each theme multiple times throughout data collection, although they were more cognizant of various goals at different times.

***Planning***

Although goals for student learning were shared among MGSIs in this study, more variation emerged in how MGSIs sought to achieve these goals. As illustrated in

chapter five, MGSIs classrooms, perceived lesson strengths, and external influences discussed when planning all varied. To a lesser extent, variation also existed between tactics employed to achieve student learning and more nuanced objectives for students and instructors. As illustrated in vignettes of the individual case studies, each classroom had a different vibe or feel to it. As noted by one of the mentors, Chen and Patrick had calm and quiet personalities which could have contributed to calm and quieter students. In contrast, Willie himself tended to be more energetic which easily transferred to the classroom atmosphere of student dialogue he worked to foster.

MGSIs also perceived different areas of strength in their lessons. Willie focused on classroom environment and discourse as he described efforts to create a classroom atmosphere where students frequently and willing expressed ideas and questions so that they improved their own understanding of the material. In contrast, Patrick focused on structure and clarity. He wanted students to speak up but identified creating positive student experiences and opportunities for students to practice skills and receive feedback as strengths of his classroom. Meanwhile, Chen focused on observing and monitoring his students. He identified being able to balance class time between lecture and practice, improve student engagement, and obtain feedback from his students as areas of strength in how he planned and enacted his lessons. This does not mean that MGSIs do not consider other aspects of teaching to be important, but rather illuminates different aspects of teaching these MGSIs valued and were consciously working to develop or incorporate into their instruction.

As MGSIs discussed their planning, at times they referenced different influences on their teaching. Willie consistently spoke about his students, mostly current ones, as a

source that confirmed his beliefs about teaching while Patrick referenced previous tutoring and personal experiences that shaped his goals. Chen, who may have been the least settled in his teaching style, made the most references to external influences including his own experiences as a student and TA, professional development training and his peers. All MGSIs would likely say all of the factors above influenced their planning to some extent. Further, all MGSIs in this study generally found support in their peers. They frequently interacted with one another; Willie and Patrick shared an office, as did Chen and Deacon, and I observed them visiting each other's offices. At times they discussed lesson plans together, utilized each other for feedback or review of assessments, and met as a small group with a mentor eight times during the semester. However, these factors: students, previous personal experiences, professional development and peers, appeared to different extents in this study as MGSIs reflected on their teaching. If the interviews had been structured to ask how each of these factors impacted their teaching, MGSIs might have answered in very different ways. The observation here is more in how these factors were consciously referenced in their general reflections on teaching. Schoenfeld (2011a), in his goal-oriented decision-making theory, notes what is relevant to understanding a person's actions or decision-making is not about what knowledge a person has, but what knowledge is being drawn upon in the moment of making choices. The aforementioned factors give examples of knowledge MGSIs drew upon.

One commonality among MGSIs tactics was that each MGSI incorporated various forms of group work throughout the semester and spoke about the value of including group work in their classrooms. This included both larger whole class activities, such as

jigsaws or review games, as well as smaller scale methods such as think, pair, share or checking answers with those sitting nearby. However, the perceived success with this general tactic of group work varied widely in this study. Willie was pleased with the overall student collaboration during group activities while Patrick and Chen expressed more difficulty with facilitating student-to-student collaboration. For instance, both frequently encountered moments where students seemed to work alone rather than with peers. However, all MGSIs persisted throughout the semester in their efforts to integrate group work opportunities into their classrooms.

***Challenges***

MGSIs limited teaching experience likely contributed to some of the challenges MGSIs discussed in this study, particularly those related to lesson implementation or course coverage. All MGSIs were teaching Precalculus for the first time and adjusting to becoming full instructors of record. All had some experience tutoring and working as a Calculus TA, and Willie and Patrick had taught a different summer course with smaller student enrollment. Yet, these MGSIs were still learning how to estimate time students would need to complete problems or tasks and how to smoothly facilitate activities. They were also trying out new teaching methods and encountered challenges with making some methods flow as planned. Further, they were teaching the course for the first time, still grappling with determining the time to spend on and depth to pursue various mathematical concepts. The difficulties MGSIs experienced with managing class time and course pacing could easily be attributed to their stage of beginning to learn to teach. Generally, MGSIs were able to manage these challenges with support from mentors and peers.

Other challenges, such as limitations on student success, difficulties with student's responses to teaching methods, and struggling to find sufficient planning time, were not completely or as easily resolved by MGSIs. MGSIs described conflict in terms of not always easily seeing students successfully accomplishing the goals MGSIs had for their students to learn despite incorporating active learning methods into their teaching. This was a struggle since these MGSIs put great effort into their teaching yet did not always see a large payoff on student assessments or in student's grades in spite of their efforts to include student centered teaching methods. Willie identified this as the most significant challenge of his semester. MGSIs had to contemplate who was responsible for their students' learning and on some level, to accept not seeing all students succeed. MGSIs responded to their students' difficulties with a variety of approaches including grading adjustments such as curving, extra credit, dropping low scores, or allowing test corrections and encouraging students to seek extra help through office hours or SI. However, these methods did not seem to completely resolve the issues with student achievement.

Further, while trying out active learning teaching methods, MGSIs experienced some push back from some students. Negative student responses varied from dislike to non-participation and MGSIs tended to reference only a few students or one group of students rather than the whole class when discussing challenges with students' responses to teaching methods.

Finally, MGSIs faced difficulty balancing their own time as they tried to fulfill the dual requirements of being a second-year graduate student with taking on the responsibility of serving as a full instructor of record. Much like the dual purposes of

higher education, to produce research and educate students, these MGSIs were tasked with juggling teaching and their own graduate coursework. This led to challenges with personal time management which MGSIs reported dealing with on and off throughout the semester. This was also cited as the greatest challenge both Patrick and Chen experienced overall.

**Discussion and Study Implications**

This study attempts to answer the research question by describing the planning and teaching of novice graduate student instructors from their perspective. It highlights the considerable amount of thinking about undergraduate student learning that MGSIs can process while teaching an undergraduate Precalculus course as full instructor of record. Their viewpoint is important to consider when seeking to improve undergraduate education as they too serve as instructors for undergraduate mathematics courses. Further, the findings from this study may be of interest to those working to support graduate student development. Implications of the study's findings are discussed below.

This study illustrates the planning and effort MGSIs invest in undergraduate education, their incorporation of active learning methods, and their needs for time, support and training as they transition from teaching assistants to full instructors of record. In addition to providing some insight into MGSIs needs, it points towards aspects for departments to consider with respect to making course assignments or designing course coordination. Further, the study contributes to research about teacher's planning and decision-making as well as methods for data collection and analysis. It is worth noting that the MGSIs in all three individual case studies were considering academia as a future career path, thus can be considered potential future faculty. Preparing for careers in

higher education is a common career aspiration for graduate students, as over half of new mathematics PhDs find positions in educational settings (Golbeck, Barr, & Rose, 2016). In addition, all MGSIs in this study cared about teaching. This context should be kept in mind when reading the discussion below.

### ***MGSIs Needs***

Based on the findings of this study, these graduate student instructors need opportunities to reflect on their teaching, support and training for working with undergraduate students, and planning time.

**Opportunities to Reflect on Teaching.** MGSIs desires to talk about their teaching were apparent throughout the process of data collection and highlighted in the depth of interview responses. Post-lesson interviews were modeled as cognitive coaching conversations (Costa & Garmston, 2018) with a focus on what was said and done in their classroom. At the beginning of the semester, I approached four strangers and a casual acquaintance about participating in this study, with the appeal of helping out a fellow graduate student. I asked for a real time commitment from them, writing weekly journals and participating in four interviews and a focus group, plus some vulnerability by allowing me into their classroom to observe their teaching. Four of them agreed and stuck with it! At this university, MGSIs were already receiving support for teaching through a peer mentoring program (Yee & Rogers, 2017; Ellis, 2015), had previously enrolled in a one-credit hour pedagogy course and were about to begin a second one-credit hour pedagogy course. Yet MGSIs often asked for my feedback and input after observations and interviews as well, demonstrating their interest in opportunities to discuss and process their teaching experiences.

MGSIs valued opportunities to reflect on teaching with others. When asked in the final focus group about their experience participating in the study, MGSIs felt they benefited from their participation. Willie explained, it “didn't feel like I was participating in a study to be honest. More so just like it felt like you were just like [mentor name] and [mentor name].” The others agreed our interviews went hand in hand with mentoring and helped prepare them for their pedagogy course. Chen noted, “when we teach, we didn't really think about like why we made some certain decision. And now talking to you, like made us think back. Like why did we do that?” Further, responding to what supports they found most helpful for learning to teach, they agreed with Willie who answered, “honestly, talking to each other. That was huge for me.” MGSIs mentioned discussing various topics with mentors and peers, including how to present and order content, sections where students can “get lost” or have questions, understanding “what takes longer” and having a safe space to complain if needed. Their participation and commitment in this study, mentor meetings, and the pedagogy course, show how valuable MGSIs viewed opportunities to share ideas, voice concerns, ask questions, receive suggestions, and reflect on their teaching. Thus, those facilitating professional development (PD) for graduate students should offer frequent opportunities for collaboration, discussion and feedback related to their classroom practices and experiences.

**Training to Work with Undergraduates.** Based on the challenges described by MGSIs in this study, one relevant area for PD to address would be understanding interactions and experiences with undergraduate students. Graduate student PD can address a wide range of topics, yet often focuses on generic teaching skills (Park, 2004)

or "administrative responsibilities and mechanical aspects of teaching" (Speer, 2008, p.313). While these topics are important and necessary, this study suggests they may not be sufficient for supporting graduate student instructors. As found in this study, prior research has suggested GSIs want to discuss and understand their undergraduate students and GTAs "are concerned about their teaching performance" (Feezel & Meyers, 1997, p.121). In a study of eighteen graduate students engaged in a mentoring program, Boyle and Boice (1998) found "discussions about their undergraduate students dominated the mentoring meetings" (p.171). Many GTAs are concerned about effectively dealing with student conflict (Park, 2004) and express concerns including communicating with students, credibility, GTA-student relationships, and knowing policies and procedures (Feezel & Meyers, 1997). At the precalculus level, undergraduate students' previous experiences and competency with mathematics likely vary greatly from their instructors (Deshler, Hauk, & Speer, 2015). MGSIs may need to develop pedagogical content knowledge such as common student difficulties, different ways students approach tasks, and illuminating examples to share with students (Speer, 2008).

As the findings about challenges with implementing lesson plans and understanding students' performance on assessments illustrated, MGSIs teaching does not always lead to the desired results across the board. In their efforts to facilitate student engagement, MGSIs may experience tension between their goals for student learning and the actual learning they see demonstrated on exams or quizzes and may encounter some negative responses or pushback from their students. Reflecting on these tensions and understanding and responding to various forms of student resistance may be important areas for PD to support novice instructors. For instance, when learning goals were not

achieved, MGSIs contemplated why not. If a student was not successful, were they to blame? Was the student responsible? How much are instructors responsible for motivating their students? Recall these MGSIs goal to prepare students for their future, which may amplify their disappointment or concern when students appear unprepared despite MGSIs best efforts. Allowing MGSIs to reflect on who should be accountable for student learning may lead to fruitful discussions.

Additionally, discussing ways to respond to and understand students' apparent dislike or complaints about a teaching method and sharing approaches for promoting student engagement with tasks would appear to be beneficial for graduate student instructors. Sharing examples of ways to work with students who do not engage productively in a classroom activity appears to be an area where MGSIs would benefit from support. Chapter six provides examples of student interactions MGSIs in this study found difficult. Recall that this study made no effort to collect data from the student perspective and did not evaluate the effectiveness of the teaching. However, as an experienced instructor, I can say the student responses in this study cannot be simply attributed to poor teaching or facilitation skills. Undergraduate student struggles in the calculus sequence are a national concern (Bressoud, et al., 2013). Research has shown that undergraduate STEM students perceive they learn more and prefer well-delivered lectures when compared to the increased cognitive effort required in active learning settings (Deslauriers et al., 2019). To combat this type of student bias that instructors who engage in efforts to include active learning in their STEM classrooms encounter, Deslauriers et al. (2019) recommends early intervention "by explicitly presenting the value of increased cognitive efforts associated with active learning (p.6)." Further they

suggest giving some type of assessments early in the course to help students accurately gauge their learning, using research-based facilitation strategies, encouraging students to work hard, and soliciting student feedback. Sharing this type of research and advice with MGSIs may help support their development as they experiment with various teaching methods.

As described in the individual case studies, group work was one common tactic chosen and valued by all instructors in this study. Although group work can be researched and conceptualized into terms such as collaborative learning or cooperative learning, here group work simply refers "to students working together on a common task with the goal of learning academic material" (Kung, 2013, p.2). It is worth noting that while active learning was discussed and encouraged in their pedagogy classes, all instructors had complete freedom to select their own teaching methods, yet at multiple times throughout the semester, all chose to incorporate activities centered around group work. This took many forms from large-scale full-class review games or jigsaws to group worksheets or think, pair, share questions, as well as less structured time to talk to peers about mathematical tasks. The main objective for these types of activities was typically for students to talk, meaning to be asking questions, receiving help or feedback, or explaining their thinking, all of which require students to verbally communicate. While the format of group work may vary greatly from instructor to instructor and it is not clear what features are necessary for maximizing benefits, research suggests the use of collaborative settings positively impacts students who may potentially learn more, show better persistence in college classes, and demonstrate improved attitudes towards content (Kung, 2013).

However, the perceived success of facilitating student-to-student communication varied among instructors in this study. From the instructor's perspectives, activities went well when students were actively discussing problems and solutions. Yet, students choosing to work independently during this time was a challenge frequently described by both Chen and Patrick and all instructors described moments where facilitation did not run as smoothly as they desired. This suggests MGSIs may desire to include group work and may benefit from training and support in learning to facilitate and enact these methods. Training and support may include discussions or suggestions related to setting class norms, features of tasks that make them more likely to generate group discussion, various models of group work, and question posing techniques. Some of these topics were addressed in these graduate students' professional development, which emphasizes the point that support cannot be limited to a one-time training. Rather novice instructors need *sustained* discussion and models of teaching methods as well as opportunities to share success and struggles with implementing various teaching methods in their classrooms.

Although this study did not directly examine the role of professional development, PD does seem beneficial for MGSIs. Connolly, Lee & Savoy (2018) found GSI participation in formal PD courses can improve STEM graduate student's college teaching self-efficacy among six dimensions: course planning, teaching methods, creating learning environments, assessing student learning, interacting with students, and mastering subject knowledge. Their findings were especially true for women and indicated most growth in teaching methods, course planning, and assessment of student learning. The authors speculated these may be common areas of focus for PD. However,

their findings were less robust for creating learning environments and interacting with students, which is consistent with findings in this study. It is worth noting MGSIs in this study received training on many topics including directly addressing adapting course pacing, active learning, and writing assessments. MGSIs reported minor challenges with content coverage or facilitating their lesson plans and generally felt these obstacles were manageable. They incorporated multiple teaching methods and created their own assessments without insurmountable difficulty yet found some student interactions to be more enduring challenges. Thus, the areas of interacting with students and creating learning environments may be areas where MGSIs could benefit from greater support. The current study describes examples of challenges MGSIs might perceive as they teach and may offer conversation starters for those working to support instructors in implementing more student-centered approaches.

**Planning Time.** Finally, this study describes the limitations of time felt by MGSIs at this phase of graduate school and illustrates their need for time to plan. Time managements concerns are common among newer GTAs (Feezel & Meyers, 1997). In this study, lack of planning time was a significant concern for second-year graduate students instructing a new course during their first full semester serving as an instructor of record. Balancing their time between teaching and their own coursework was identified by two participants as the greatest challenge they experienced learning to teach. Thus, PD providers and mathematics departments must be aware of the time strain some graduate students may be experiencing. More implications for departments related to supporting MGSIs time management are discussed in the next section. One aspect relevant to PD providers could be the types of reflection opportunities offered or

assigned. For some graduate students, particularly international students for whom English is a second language, writing may be more time consuming than intended. In this study, Chen wrote his first few journal entries, but became concerned about study participation due to the time it took to compose his thoughts in writing. We shifted to audio reflections to save time. This adjustment allowed him to continue in the study. Thus, PD providers should communicate with their MGSI and be flexible in providing different formats for MGSIs to reflect on teaching.

***Course Assignments***

Findings from this study provide some insight into how teaching assignments may impact MGSIs. All MGSIs in this study were teaching a four-credit hour course while still establishing themselves as instructors. Teaching a four-credit hour course means course meetings were held every day Monday through Thursday. This rhythm is similar to secondary teaching, where teachers and students have consecutive days of interaction. However, secondary teachers' careers focus primarily on teaching and do not often require heavy coursework to be completed during their first year of teaching. This teaching format is also quite different from traditional three-credit college courses which meet Tuesday and Thursday or Monday, Wednesday, Friday, and provide instructors with a day off to plan or focus on other commitments. As MGSIs in this study valued discussing and reflecting on their teaching, having a day to reflect on teaching may be helpful for instructors who are still adjusting to becoming full instructor of record. However, teaching a four-credit course removes the breaks and requires MGSIs to continually prepare for the next day. Thus, teaching a four-credit hour course, in contrast to a three-credit hour course, created a different teaching experience for MGSIs.

The need for continual planning may have contributed to MGSIs describing heavy teaching workloads. These MGSIs were in their second year of graduate school; thus, they were still enrolled in a full graduate course load themselves and still needed to take comprehensive exams, which can be a busy and stressful phase of graduate school. Their discussion of time management challenges suggests such obstacles may prove less difficult for more experienced MGSIs. To help graduate students with the transition from TA to instructor, departments could consider assigning three-credit hour courses to first time instructors of record. This would continue the apprenticeship model (Ellis, 2015) which allows instructors to gradually assume more responsibility for practices in the teaching profession. This model is employed by some universities where graduate students first work as a TA, then move up to instructor of record. Beginning with a three-credit hour course would give more time for graduate students to become comfortable and familiar with teaching before moving onto the daily, consecutive in-class responsibilities which accompany four-credit hour teaching assignments.

Further, MGSIs in this study were teaching Precalculus and viewed it as a prerequisite course, foundational for the Calculus sequence. This impacted MGSIs goals for student learning and the prerequisite nature of the course was the basis for the super-objective identified in this study, (Saldaña, 2016) which was to prepare undergraduate students for their future. Findings from this study suggest being assigned to teach a prerequisite course with many first-year students may add pressure on MGSIs who are adjusting to serving as full instructors of record. As was the case in this study, many MGSIs desire for undergraduate students to successfully complete their required coursework and may perceive Precalculus to play a significant role in students' ability to

complete the Calculus sequence. MGSIs desire for student success can increase the pressure they experience or feel to teach well. Additionally, Precalculus courses often have heavy first-year student enrollment. As MGSIs discussed this during the focus group, Willie explained, “that [first] class is like what you're going to expect from then on in math courses. I mean any class, …you are gonna expect underwater basket weaving two to be like underwater basket weaving one.” MGSIs may feel responsibility for establishing undergraduate expectations for future college mathematics coursework. Thus, the findings related to MGSIs challenges and goals for student learning indicate the assignment to work as a Precalculus instructor could subtly bring a greater sense of responsibility and pressure on novice MGSIs who are learning to teach. Those providing support to MGSIs may want to provide opportunities for MGSIs to discuss their feelings about the courses they are assigned to teach and be sensitive to potential fears of messing up or hindering undergraduate students’ future success. This study only included instructors of prerequisite courses. However, MGSIs teaching terminal courses may also be anxious about how their teaching impacts their students in the future, although any concerns of students’ ability to succeed in sequential coursework could be negated by the terminal nature of the course.

Given the influence of the course on GTAs goals and teaching experiences, the findings of this study suggest that departments should consider the type of course graduate students are given when making course assignments. Consideration could be given to the differences between prerequisite, terminal, lower and upper division courses. Teaching assignments for prerequisite courses may bring more pressure to prepare students for the next course, while terminal courses may offer instructors more freedom

over content coverage. Similarly, lower division courses set expectations and build knowledge for upper division courses, while upper division courses require strong instructor content knowledge. The course format, number of course meetings and student enrollment, may influence how instructors' express empathy for and interact with students (Uhing, 2019). All courses have their own unique challenges and benefits.

The role of the course in this study suggests administrators responsible for organizing teaching assignments should consider several factors when determining how MGSI teaching placements are made. Course assignments are unquestionably difficult to make and must address a variety of factors such as faculty preferences and avoiding scheduling conflicts. This is not to suggest such factors are unimportant. Rather, the point is to emphasize considerations related to graduate students' overall experiences with navigating graduate school. When is the right time to increase the teaching load for MGSIs? Careful consideration of course assignments could improve MGSIs graduate experiences and knowledge of this work could help attract potential incoming graduate students. Given the context of this study and time management challenges experienced by MGSIs, some important factors for departments to consider when making teaching assignments include the course credit hours, their MGSIs current stage of graduate school, and the level of course assigned.

### *Course Coordination Implications*

In a study of college calculus courses across the United States, course coordination that included building communities of practice was identified as a common feature of institutions of higher education with successful calculus programs (Bressoud & Rasmussen, 2015). This coordination went beyond "surface level" features to developing

a community of instructors who worked together in such a way that valued both creating similarities across sections and “instructional independence” (Rasmussen & Ellis, 2015, p.107). Coordination efforts are emerging throughout the country and take many forms from tightly coordinated courses requiring regular instructor meetings as well as common syllabi, textbooks, exams, pacing and assignments to provide uniform experiences for undergraduates (Faudree, 2020) to incorporating fewer or more limited elements of such course features. When coordination includes deep collaboration, course coordination can be conceptualized as faculty development (Mingus & Koelling, 2020). Opportunities to examine standards and priorities as part of coordination conversations can help instructors understand and implement them (Mingus & Koelling, 2020).

My experience of conducting this study and the study’s findings provide evidence that even MGSIs with less than a year of experience teaching as an instructor of record can articulate meaningful ideas about teaching, can engage in reflective teaching practices, and are able to contribute productively to conversations about teaching and student learning. All MGSIs agreed with Willie who remarked in the focus group that while he learned from his own teaching experiences, “I feel like I actually learned more just from talking to everyone else because that helps! ... Something that like happened in my class may help Patrick with his class.” Further, they desired suggestions and feedback on their teaching and were willing to invest in conversations about undergraduate instruction. Thus, coordination efforts that provide opportunities for instructor collaboration and discussion seem appropriate for MGSIs interested in learning to teach. Agreeing with Faudree (2020) discussing benefits of coordination, “if discussion is helpful to seasoned instructors, it is surely crucial to novices” (p.5). Department

administrators should continue to invite MGSIs into coordination meetings or onto coordination teams, as they are capable of contributing to meaningful conversations about curriculum, assessment, and teaching practices and bring the important perspective of novice instructor that more seasoned instructors may unintentionally overlook.

MGSIs in this study shared common goals for student learning yet worked towards these shared goals in different ways. As described in the individual case studies, each instructor and classroom were unique and to some extent, reflected the personality, objectives, experiences and beliefs of the instructor. Although not the focus of the analysis, these MGSIs desired some level of control or freedom over their teaching, much as other faculty in higher education desire autonomy with respect to their instruction. These instructors felt more comfortable selecting and using methods compatible with their perceived teaching style rather than trying to follow prescribed lessons. This trend was mentioned during the semester and was repeated in the focus group where Patrick remarked,

> At the beginning of the semester, I read their lesson plans and I tried to follow that structure. And I definitely felt uncomfortable. I think because I was trying to do someone else's lesson essentially…I felt more comfortable when I planned my own lesson and I said, these are the topics I'm going to cover. This is the order I'm going to introduce things. These are the examples I'm going to use.

Willie strongly agreed, adding on concerns of responding to student questions about wording he did not choose. He continued,

> When I come up with a problem, I feel like I have more control over it. I can gauge like, what kind of questions are going to come in and what kind of

questions I can even ask… I like to have control, like more control, make my own things. It felt better.

These MGSIs needed and wanted to feel some level of ownership over their teaching.

Coordination may require some non-negotiable aspects, but this study suggests coordinators should also leave room for graduate student instructors, alongside other faculty, to experiment with new methods or examples and provide input into the course design. Thus, course coordinators should use caution if imposing tight coordination with MGSIs simply because they are inexperienced. Rather, coordinators could utilize the recommendations made by Rasmussen & Ellis (2015) to assist new instructors by offering "default options" such as homework assignments, syllabi or grading rubrics that provide structure yet can be changed by the instructor if desired. If coordinators are unfamiliar with the instructor's teaching philosophy or are working with first-time instructors, they could require a conversation or justification before allowing changes. Doing so focuses coordination on providing support, suggestions, models, and a space for discussing ideas rather than requirements or plans for instructors to implement verbatim.

### *Research Implications*

Next, we will turn to a discussion of lessons learned relating to methods and theory.

**Connections between goal-oriented, decision-making theory and dramaturgical coding.** This study's design and data collection aimed to understand how and why graduate students who were first-time instructors of record for Precalculus made choices in their classrooms with the intent of increasing the voice of graduate student instructors in the literature. The first half of this purpose, understanding how and why

people make choices in order to help them become more effective, directly aligns with the research agenda described in *How We Think* (Schoenfeld, 2011), where Schoenfeld lays out a goal-oriented decision-making theory. The theory's main claim is that "people's decision making in well-practiced, knowledge-intensive domains can be fully characterized as a function of their orientations, resources, and goals" (Schoenfeld, 2011, p.182). Thus, Schoenfeld argues that to understand a teacher's actions while in the act of teaching, one must examine these three components: goals, orientations, and resources. He argues teachers have multiple goals of various sizes, that orientations shape the prioritization of goals and how the individual views situations, and resources, such as knowledge, are utilized in service of achieving goals. This theory proved useful for designing interview protocols and the findings of this study align with many aspects related to Schoenfeld's conceptualization of decision making.

However, the framework of resources, orientations and goals proved to be a challenge for using data analysis to lead to a description of a novice instructors' perspective on learning to plan and teach. It did generate goals, identify multiple physical materials, and capture MGSIs attitudes towards teaching. However, in order to center the analysis from the MGSIs point of view, dramaturgical coding (Saldaña, 2016) was used instead. Saldaña describes this coding method as approaching life, in my case teaching, as performance and the participants as actors in a drama. He claims dramaturgical coding "attunes the researcher to the qualities, perspectives, and drives of the participant. It also provides a deep understanding of how humans in social action, reaction, and interaction interpret and manage conflict" (p.146). This coding scheme contains six components: objectives, conflicts, tactics, attitudes, emotions and subtexts. Physical actions and verbal

aspects are also suggested as additional coding options. This scheme seemed useful for conducting analysis of individual case studies of instructors and allowed me to center the analysis from the participants' point of view and privilege their perspective in the findings, thus increasing graduate students voices in research and achieving the second part of the study's purpose. As described in chapter three, although graduate students expressed many emotions, emotions did not dominate MGSIs decision-making when teaching or planning. Thus, the coding scheme used only four of the dramaturgical elements: objectives, conflicts, tactics, and attitudes.

Notice the overlaps between the two frameworks. Although Schoenfeld's framework is theoretical while Salada's is methodological, they share an intent as both seek to understand an individual's perspective, motivations or reasons for actions. Further, there are similarities in their components. Schoenfeld defines goals as "something that an individual wants to achieve" (Schoenfeld, 2011, p.20) while the objectives of the participant-actor are defined as "motives in the form of action verbs" (Saldaña, 2016, p.145). Both frameworks assume there is a motivation, intent or aim that is critical to understanding the individual's perspective and behavior. Also, both incorporate either orientations, a broad term meant to "encompass beliefs, dispositions, values, tastes, and preferences" (Schoenfeld, 2011, p.15) or "attitudes towards the setting, others, and the conflict" (Saldaña, 2016, p.146). For Schoenfeld, a teacher's orientations toward mathematics, learning, teaching, and students can all be significant in understanding decision making. This easily aligns with the attitude codes addressed in dramaturgical coding where mathematics, teaching and learning comprise the setting and students are others involved in the social drama.  That leaves only Schoenfeld's resources

without immediate direct correspondence to the dramaturgical coding scheme I used for data analysis. Dramaturgical coding further adds conflicts and tactics. Thus, the two frameworks bear many similarities to one another.

The decision to use dramaturgical coding for thematic analysis proved helpful in at least two ways. First, although MGSIs stories were not ripe with conflict, the addition of conflict codes proved to be useful in capturing MGSIs difficulties, obstacles, or challenges mentioned when reflecting on their teaching experiences. This was a valuable addition as it provided content to inform ways MGSIs could be supported in learning to teach and would likely have been missed if coding using only Schoenfeld's framework. Another benefit of this coding scheme was the concept of coding for tactics, which Saldaña (2016) described as tactics "or strategies" used by the participant-actor "to deal with conflicts or obstacles and to achieve his or her objective" (p.146). These allowed me to capture what might be considered decisions, the ways MGSIs acted or aspects they described when reflecting on their teaching. For example, this coding categorized aspects of planning such as classroom activities, creating and sequencing content, lecture, formative assessment and questioning techniques. Dramaturgical coding allowed me to capture conflicts and tactics, ways in which instructors worked to achieve their goals.

Limitations of using dramaturgical coding to understand MGSIs planning and teaching emerged as well. I had to add a coding category of influences to address times when MGSIs directly identified something, typically someone, as the reason for their actions. For instance, if MGSIs shared a personal experience from their past to justify why they tried a technique or considered an idea, I wanted to capture that in my coding, but it did not seem to fit as an objective, conflict, tactic or attitude. Influences were added

to identify sources outside of the instructor that played a role in MGSIs planning. Another minor difficulty I found with theming the codes was the need to focus exclusively on conflicts for an extended time. This was rather depressing and not indicative of the overall teaching of MGSIs. Overall, the benefits of this coding method far outweighed the limitations.

In seeking to understand MGSIs, the analysis highlighted some relationships between Schoenfeld's resources, the dramaturgical tactics codes, and the additional influences codes. For Schoenfeld (2011a), resources include intellectual resources such as all types of knowledge a person uses to "solve problems, achieve goals, or solve other such tasks" (p.25) which can include facts, procedural knowledge or routines, conceptual knowledge, problem-solving strategies, as well as social or material resources. Clearly the influence codes such as personal experiences, students, professional development and peers, indicate resources MGSIs utilized in their planning. Additionally, tactics codes indicated types of routines or knowledge MGSIs used to bring about student learning, thus they could be considered part of or at least related to resources. A closer look into Schoenfeld's description of decision making suggests conflicts could appear as "triggers" (p.70) for when teachers must stop and reevaluate their goals in the subjective valuation calculations. Without the dramaturgical coding scheme, this perspective may have been missed. Thus both goal-oriented decision making (Schoenfeld, 2011) and dramaturgical coding (Saldaña, 2016) were useful in understanding this study. Further, what may initially seem like two distinct frameworks are actually quite compatible.

**Role of goals.** Goals were central to the theory, data collection and analysis in this study. One key assertion of Schoenfeld's model (2011a) is that behavior in well-practiced

domains is goal oriented. Teaching was a fairly new practice for these MGSIs who potentially may not be working in a familiar arena. Thus, it was not clear how goals would emerge in this study. For instance, would MGSIs have well-known teaching routines to follow? Would goals be relevant to explaining their thinking? If so, what kind of goals would they be aware of and able to speak about? From the pilot study, MGSIs had a lot to say about student learning and their own hopes and aims to facilitate learning. With this focus, data collection explored the possibility that other MGSIs were interested and able to talk about student learning in a way that allowed them to explain their teaching. Data collection and analysis showed this was a productive endeavor. There was also some evidence that MGSIs planning could be described as goal-oriented decision making. A clear example was described in chapter five. Chen's individual case study described his objective to monitor student learning. When he was not able to achieve this goal using previous tactics, he intentionally began including exit slips to satisfy this aim. This example provided evidence that his decision making was indeed at times consciously goal oriented.

Schoenfeld (2011a) notes teachers have multiple, often competing goals which can exist at different "levels" or sizes and that goals can be conscious or unconscious. These ideas appeared to be true in this study as well. Instructors' goals ranged from small daily measurable content goals, such as students will identify rational functions, to broad goals for student learning described in chapter four. Some goals, such as the super objective of preparing students for their future, were clear and conscious in all MGSIs minds from the start to the end of the study. Other goals emerged or were discussed and identified more clearly as the semester progressed. All goals described in chapter four

became conscious goals at some point during the study and were confirmed by participants following the conclusion of data analysis. The analysis focused on overarching cognitive or affective goals as they best explained MGSIs planning on a larger scale and related to reasons MGSIs gave for planning or teaching decisions. Interesting, these goals were remarkably consistent across MGSIs, thus might provide fertile starting point for those just beginning conversations about teaching or trying active learning. Those seeking to build unity within a new community of practice, such as a course coordinator working to define the purpose of a course, may also find this point to be relevant.

Another interesting point about goals that emerged in this study relates to understanding more about how goals were formed. Although Schoenfeld's theory (2011a) asserts goals are shaped by orientations, it does not discuss the formation of goals. In this study, there were glimpses into how resources shaped MGSIs goals for student learning. The case study of Patrick in chapter five provides a good example of this. From the first interview, Patrick mentioned wanting to improve some of students' attitudes towards themselves as learners of mathematics. References to student dispositions continued throughout the semester. At the final interview, he shared how prior tutoring experiences and helping students who had traditionally struggled with mathematics lead him to develop his goal for improving his undergraduate students' self-efficacy. Thus, Patrick's knowledge about students and their mathematical experiences, considered to be part of an individual's resources in Schoenfeld's model, shaped one of Patrick's high-priority and conscious goals for student learning.

**MGSI planning.** Schoenfeld (2011a) describes his decision-making theory as useful for understanding an individual's in-the-moment actions. His applications always included a detailed analysis of a classroom lesson, often focusing on a small segment that seems problematic to understand. In this study, the theory was also relevant to understanding instructor's planning; the thinking done when they are not interacting with students, or the preactive choices made before teaching along with the postactive reflection and revision for future classes (Clark & Peterson, 1986). This may expand the scope of where the theory can be applied.

Much like the findings about secondary student teachers and beginning teachers (Burn et al., 2000), MGSIs tended to follow their lesson plans with only minor adjustments. The vast majority of the teachers' aims and classroom activity could be explained based on their preactive thinking. That is, their lesson plan and lesson image (Schoenfeld, 2011a; Morine-Dershimer, 1978), or their planning and thinking outside of the classroom, seemed to explain the majority of their interactive teaching at a macro level. Adjustments to the plans primarily included omitting a problem or element of an activity due to lack of time or adding a quick example based on a student question. Schoenfeld (2011a) also assumed what teachers do in their classrooms comes from either their planning or a trigger that occurred while enacting the lesson. The most common trigger in this study was lack of remaining class time. The tendency of MGSIs to stick to their lesson plans suggests novice instructors need to intentionally plan to incorporate active learning methods into their classrooms, as they are not likely to spontaneously attempt new methods in the classroom. As lesson plans and lesson images demonstrated a high level of influence on the actions taken in the classroom, consideration of MGSIs

thinking during the design and reflection stages of teaching is important for understanding MGSIs teaching.

Schoenfeld (2011a) conjectured that responsible teachers prepare a lesson to the level of detail where they believe “the rest is unproblematic” and noted, “this might require planning in great detail” if it is a new lesson (p.86). For the lessons I observed, MGSIs lesson plans typically included working out all the problems in advance and having the overall activity structure for class either written or clearly designed in their mind. Sometimes MGSIs would write in their notes questions they planned to ask the class to promote discussion. MGSIs reported consulting the textbook, provided lesson plans, the internet, peers and mentors as resources for useful problems and presentation style. In terms of their planning behavior, these MGSIs were similar to those studied by Winter et al. (2009) who found that all MGSIs in their study consulted the provided plans, but no one completely followed them. In some ways, each MGSI made their own mark on each lesson. Unlike the findings of Winter et al. study, these MGSI tended to specify learning objectives. Further, similar to novice secondary teachers (Burn et al., 2000), these MGSIs valued and gave a lot of thought to student learning. MGSIs justification for why they did things in the classroom was often related to their goals for student learning, which indicates perceived alignment between their goals and instruction or designed learning experiences. Intuitively or intentionally, they were addressing aspects of backwards design (Wiggins & McTighe, 2005).

**Positionality in data collection.** Data collection was assisted and enhanced by using techniques from cognitive coaching (Costa & Garmston, 2018). I certainly did not have much practice with coaching prior to data collection, nor do I make any claims that

the coaching was done well. However, taking on the role of peer coach was a helpful way to generate deep and thoughtful data while providing some benefit to the participants. The coaching practice of asking mediative questions aligns well with semi-structured qualitative interviewing. Applying some of the techniques of cognitive coaching, particularly asking mediative questions or providing data, allows the researcher to provide some benefit to the participants while enhancing data collection. Thus, cognitive coaching may be a helpful approach for others conducting research with teachers who are interested in receiving feedback to develop their teaching practice.

***Summary of Implications***

A summary of the key takeaways from this study is listed below for various audiences.

Takeaways for professional development providers and those interacting directly with graduate student instructors:

- Provide regular opportunities for graduate students to discuss and reflect on teaching. Cognitive coaching techniques (Costa & Garmston, 2018) may be helpful for promoting reflection. Reflecting on goals and building on them may be useful avenues for instructor development (see chapter four).
- Graduate students benefit from emotional support and empathy. Seemingly small displays of support, such as conversations, can be important to graduate students (Latulippe, 2009). Recognize and acknowledge they are likely expending high levels of time and energy experimenting with teaching methods while juggling dual roles (see chapter five). They desire undergraduate student success yet likely

experience tension and feel responsible when it does not appear to happen as desired (see chapter six).

- Relevant training topics may include handling student's resistance to various teaching methods, understanding instructor's responsibility for student learning, tips and tricks for improving facilitation of group work, managing and budgeting class time (see chapter six).

Takeaways for mathematics departments and their administrators:

- Consider graduate student's stage of graduate school and the type and level of course when making teaching assignments. Specifically, allowing first time instructors to begin with three-credit courses rather than four-credit courses may assist in easing their transition into serving as instructor of record.
- Focus coordination efforts towards providing collaboration, suggestions for adaption and encouragement rather than rigid requirements lacking instructor input (Rasmussen & Ellis, 2015).
- Acknowledge teaching as a time-intensive endeavor and be willing to invest resources into graduate students' professional development. You reap what you sow. If there is interest in improving undergraduate instruction, it is necessary to invest in your instructors.

Takeaways for researchers:

- Dramaturgical coding is viable for studying instructor's decision making.
- Reflection may be necessary in order for instructors to communicate their goals.
- Cognitive coaching techniques (Costa & Garmston, 2018) may be a helpful way to improve data collection while providing a benefit to participants.

**Study Limitations**

This study cannot address everything related to MGSIs planning and interactive teaching. For instance, this study does not observe MGSIs creating lesson plans but only collects finished plans. Other delimitations of this study (Glesne, 2016) include making no attempt to understand the effectiveness of MGSIs teaching and not including any student perspectives. Since the focus of the study was on understanding the planning and implementation of these plans from the instructor's perspective, student data was not collected, as it could not speak to the instructor's intentions. Further, the focus of the study was on understanding MGSIs thinking. Any attempt to evaluate or measure the effectiveness of beginning instructors may have created discomfort and limited MGSIs willingness to openly share their perspective, thus conflicting with the study's purpose. Findings are based on a limited number of lessons and participants. I could not observe and discuss all planning decisions or lessons made with MGSIs. Thus, the delimitations of this study, what is not being studied, include documenting physical planning of MGSIs, assessment of MGSIs teaching and student perspectives.

A limitation of this study is the inability to generalize these findings for larger populations or contexts. Again, the instructors in this study were all second-year male graduate students teaching precalculus for the first time as instructor or record. In addition, all included in the analysis were potential future faculty, meaning they considered working in academia as a possible career path, and were attending a single university which offered professional development courses and mentoring for graduate students. It is quite possible that MGSIs with different interests teaching in other contexts would articulate different goals or challenges and incorporate different tactics.

Additionally, it should be repeated that the MGSIs in this study volunteered to participate because they were all interested in teaching. Not all MGSIs, or even mathematics faculty, are willing to make this same investment into improving or understanding their teaching. It is quite a different challenge to encourage or convince faculty who are less open to incorporating active learning to change their instruction. However, the perspective of those willing to work at improving their teaching is important and provides a starting point for efforts to improve undergraduate mathematics instruction.

**Future Directions for Research**

This study shows there is much still unknown about how graduate students approach and learn about teaching. Future research could build on this study by exploring the planning of other demographics of graduate students in other contexts. For instance, future studies could include female instructors, graduate students with more teaching experience, graduate students who are pursuing master's degrees or are not interested in pursuing teaching careers, instructors of other courses besides precalculus, or those with different access to professional development opportunities.

Future studies could also examine instructors' goals in different ways. We do not know how instructor's goals for student learning might change over time or vary between courses taught. These instructor's discussed ideas about students conceptual understanding, sense making and reasoning abilities in very connected ways. The relationship and distinction between these types of goals and how graduate students understand these concepts could be better studied.

This study also made no attempt to include undergraduate student's perspectives. Future research could examine the extent to which students are aware of their instructors' goals and how, if at all, this impacts their responses to teaching methods or mathematical learning. Goal synchronization, situations where individuals work towards the same goal, may make conversations more productive (Schoenfeld, 2011a). If the students and instructors are pursuing different goals during class, this notion could be relevant for understanding and explaining more about students who seem to dislike or resist active learning methods in class.

Finally, this study highlighted other areas for future research related to graduate student instructors. Given the tensions between goals for student learning and some students' performance on quizzes and tests, future research could examine how graduate students approach and understanding grading and assessment. How does students' performance on assessments impact their instructors' teaching efficacy or teacher identity? Additionally, to what extent to graduate instructors feel responsibility for student learning or success? How do they understand student motivation? The way graduate students relate to and understand their students is an important area for future research. Uhing (2019) provides an example of this type of research. Just like other postsecondary faculty, MGSIs work as full instructors of record and care about student learning. Investing in their development as instructors is critical as their early teaching experiences shape their beliefs about teaching and learning (Woolfolk Hoy, 2004).

## Conclusions

This exploratory multiple case study examined the planning practices of three mathematics graduate student instructors focusing the analysis on their goals and ways

they worked to achieve their goals for student learning, influences on these goals, and difficulties encountered by first time instructors of record. It aims to provide insight into the lived experiences of novice graduate student instructors as they adjust to the role of instructor of record. The detailed examples may provide conversation starters for faculty working to support graduate students. This chapter also provides implications for mathematics departments on how to structure professional development, approaching graduate student instructors as learners growing through professional activity (Clarke & Hollingsworth, 2002), as well as factors to consider for course coordination and teaching assignments to support graduate student's development as instructors.

As we, researchers and mathematics instructors, work to improve student learning and undergraduate student experiences in "gatekeeper" courses, we must also consider the perspective of graduate student instructors. Graduate students wear many hats, and they can be asked to take on full responsibility for undergraduate courses. As we work with our graduate students, we need to be conscious of which hat they are wearing, being treated as wearing, and how quickly they switch or even stack these hats. There are times to talk with and treat them as equals. Although they are often inexperienced teachers, and benefit from and need support in learning to teach, this study found MGSIs also benefit from and are interested in opportunities to reflect on teaching and develop their practice. If goals are key to decision making, then reflection on goals may be valuable for instructor's growth and development. Current MGSIs are the next generation of mathematics faculty, so their thinking and growth is significant for future undergraduates. In some ways, not all of these findings may be unique to graduate student instructors. Similarities may exist between these instructors and others who teach lower division

mathematics service courses in terms of their goals and challenges. The findings of this study aim to inform efforts to improve the teaching in undergraduate service courses as well as support graduate student's development as educators.

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# Appendix A: Consent Form

**University of South Carolina**

**Consent for Participation in Interview and Video Research**

**Dissertation Study: Mathematics Graduate Student Instructors Thinking**

Purpose and Background: You are invited to participate in a study about mathematics graduate student instructors' thinking about teaching. Jen Crooks Monastra, with the help of Dr. Sean Yee from the University of South Carolina, is conducting this research because of interest in this area and as a dissertation study in Teaching and Learning. You were selected as a possible participant because of your status as a mathematics graduate student instructor and your willingness to talk about and reflect on your teaching methods. This study is being conducted at the University of South Carolina and will involve five or six volunteers.

Procedures: The following explains what my participation will include. Please read it carefully and feel free to ask questions before making a decision about participating.

1. Participation involves
   - participating in an initial interview
   - choosing 3 lessons to share with the researcher during the fall semester of 2019
   - participating in a focus group at the end of the semester
   - submitting any assignments you complete in Math 792

   The lessons should be ones where you intend to try some method(s) to engage your students during class. Sharing the lessons means sharing any existing lesson plans, allowing the researcher to observe and record the lesson, and being interviewed by Jen Crooks Monastra from the University of South Carolina following the lesson. The interviews will last approximately 45 – 60 minutes. At the end of the semester, a focus group will be conducted with other mathematics graduate students. Notes will be written during the interviews and focus group and both will be audio recorded. The lesson will be video recorded. If I do not want to be taped, I will not be able to participate in the study.

2. I understand that the project is designed to gather information about my thinking and choices made during teaching. Thus, I am willing to reflect on and share my thinking about my teaching and about my experiences with teaching. There are no measurable potential risks involved in this study other than possible anxiety caused by this reflection.

3. If I feel uncomfortable in any way during the interview sessions, I have the right to decline to answer any question or to end the interview.

4. I understand that I will not be identified by name in any reports using information obtained from this study, and that my confidentiality as a participant in this study will remain

secure. Information obtained from the study will be securely stored in locked file cabinets and flashdrives with no secure data available online. The results of this study may be published or presented at seminars, but the report will not include my name or other identifying information.

5. Faculty and administrators from my campus will neither be present at the interview nor have access to raw notes or transcripts. This precaution will prevent my individual comments from having any negative repercussions. Dr. Sean Yee, faculty from my campus, will not be present at the interviews or recordings but will have access to the notes and transcripts from this study.

6. My participation in this project is voluntary. I understand that I will be paid $80 for my time and effort. I may withdraw and discontinue participation. However, choosing to do so will result in the loss of any financial incentive.

7. I understand that this research study has been reviewed and approved by the Institutional Review Board (IRB) for Studies Involving Human Subjects: Behavioral Sciences Committee at the University of South Carolina. *If I have any questions, problems, or concerns, desire further information or wish to offer input, I may contact, Lisa Johnson, Assistant Director, Office of Research Compliance, University of South Carolina, 1600 Hampton Street, Suite 414D, Columbia, SC 29208, phone: (803) 777-7095 or email: LisaJ@mailbox.sc.edu. This includes any questions about my rights as a research subject in this study.*

8. I have read and understand the explanation provided to me. I have had all my questions answered to my satisfaction, and I voluntarily agree to participate in this study. I have been given a copy of this consent form.

____________________________________ ___________________________

My signature Date

____________________________________ ___________________________

My printed name

# Appendix B: Initial Interview (MGSI Background)

Initial Interview (Participant Background) Date/Time: ______________________
Location: __________________
Participant # ________

Thank you for agreeing to participant in a research study on mathematics graduate student instructors' thinking. The study is interested in understanding how you think about teaching undergraduate math. Please note that your answers will not be perceived as a reflection of your performance as an instructor but will provide valuable insight into your experiences. Please take some time to reflect and answer the following questions. There are no right or wrong answers.

This interview is part of a dissertation. The purpose of this interview is to help understand your teaching background and philosophy. Responses may be shared with the dissertation committee in a confidential manner.

1. Demographic information:
    a. Which degree are you pursing?
    b. When did you begin working on this degree? (semester and year)
    c. What are your plans for after graduation?
    d. Have you ever taught Math 115 before? If so, when and how many times?
    e. When and where does your class meet?

2. What teaching experience have you had prior to this semester (Fall 2019)?

3. Think about classes you have taught in the past (including recitation). Describe a typical day in a math class that you instruct.

    a. What would you like your students to typically be doing while you are teaching?

    b. What else do you often do that was not included above? What other types of teaching methods that you have ever tried to use?

4. Describe the best lesson you have taught (or one you think went well). In your opinion, what made it work well?

5. Describe the worst lesson you have taught (or one you weren't happy with). In your opinion, what made it not so good?

6. When you are learning a new mathematical concept in class, how do you learn it best?

7. When students learn mathematics in class, how do they learn best? How is this similar and/or different from how you learn?

8. What do you think makes an effective teacher?
   a. What should a mathematics teacher do to help students learn?

9. What do you think makes a productive classroom environment for students to learn mathematics?
   a. How do you want your students to behave in class?

10. In general, what learning goals do you have for your students in this course?
    a. What would you like your students to leave your class knowing about mathematics?
    b. How would you like your students to think about themselves as learners when they leave your class?

11. What mathematical skills do you want your students to develop?
    a. What would you like your students to be able to do upon finishing your course?

12. Is there anything else you would like to share about your perspective on teaching?

# Appendix C: Lesson Interview (Following Observation)

Lesson Interview (following lesson observation)

Date/Time: ____________________

Location: ____________________

Participant # ____________________

The purpose of this interview is to understand your lesson plan in terms of what you wanted students to learn, methods you are using in your class and your reasoning for choosing those methods. Again there are no right or wrong answers. Recall that this lesson was recorded so that we can watch portions of the class if helpful.

1. How do you think the class went?

2. How did you go about preparing for this lesson?
    a. What might be some of the resources you utilized to prepare for this lesson?
    b. Is this lesson related to anything else you are doing?

3. On the sheet you filled out before class, you said you wanted students to learn about (**see pre-lesson sheet**). Tell me more about what you meant.
    a. What does it look like or mean for a student to understand this material?
    b. What did you want students to gain from these problems?
    c. What did you want the students to gain from the activity?

4. As you reflect on what happened during this class, talk me through what stood out to you.

5. As you went through the lesson, I noticed a few things I was curious about. Follow up with questions written during observation.

6. What were some of the strengths of this lesson?

7. What were some of the weaknesses of this lesson?

8. As you reflect on this lesson, how did it compare to what you had planned?
    a. Were there any changes you made to this lesson while teaching?
    b. Did you gain any information during the teaching of this lesson that will be useful in planning future lessons?

9. Are there any other thoughts you would like to share about this lesson or how you think it went?

# Appendix D: Focus Group Protocol (End of Semester)

Thank you for coming and happy end of the semester. We are meeting to talk about your thoughts on student learning and your experience of teaching your own class for the first time. Some of your experiences and ideas might be the similar while others may be different from one another. This is okay. I'm seeking to understand your thinking about teaching, both what went well and what was difficult for you and why. The group format is a little different than prior interviews. I've still got questions to ask and like the interviews, there are no right or wrong answers. But more like class, you can respond to one another, piggyback off others' comments or offer a different opinion. It is important that everyone gets a chance to respond.

A - Goals for Student Learning
B – design practices
C – challenges
D – experience learning to teach

1. If your students were asked to describe your Math 115 class, what would you like your students to say? (A)
    a. About the class?
    b. About you?
    c. About themselves?

2. Given what we just discussed, what might be some things you want your students to know or think about mathematics or about themselves after Math 115? (A)
    a. Why do you think it is/should be important for their learning of mathematics?
    b. What does it mean for a student to "understand" precalculus?

3. I've noticed all of you mention at some point that it is important to you to prepare students for future courses such as calculus. Would you share with the group why preparing students for future coursework is important to you as an instructor? Some of you have said it's because of your time as TA and seeing the mistakes calculus students make, is that the reason or are there other reasons? (B)
    a. What are some skills or ideas that you have taught in this class that do not directly show up in calculus but may still be valuable for students? (A)

4. Given the goals you mentioned, what were some ways you designed your class or experiences you offered your students that may have worked well to help students achieve these goals/skills/abilities? (B)

    a. What might have made it difficult for you to help students learn such skills/ideas? (C)
    b. Was there anything you tried that did not work so well? (C)

5. In what ways might your planning or instruction change if you were assigned to teach a different course such as Math 170 or a terminal upper division course? (B)

6. Tell me about your experiences with teaching as a full instructor of record. (D)
    a. Tell me about what it's like to be both a student and instructor at the same time.
    b. Tell me about a difficult experience with teaching from this semester and what made it difficult. To what extent was it resolved? (C)
    c. Tell me about one of your best or favorite experiences from this semester and why it's one of your favorites.

7. In what ways, if any, have you changed as an instructor? (D)
    a. Why did you change? What might have led you to change?
    b. In what ways would you like to continue to grow?
    c. Where their obstacles were you able to overcome this semester? (C)
    d. What problems with teaching have you found "no solution" for? (C)

8. What supports have helped you with planning? Teaching? (D)

9. What was the process of participating in this study like for you? (D)
    a. Did this study or myself influence you or your teaching in any way?

10. Is there anything else you would like to share about your perspective on teaching Math 115?

## Appendix E: Mentor Interview

Mentor for MGSI #s _____
Date: _____
Location: _____

1. How would you describe the instructors teaching?

2. In what ways, if any, did you notice this instructor change throughout the semester?

3. What were some strengths you noticed about this instructor?

4. Were there any aspects of planning or teaching that seemed to be difficult for this instructor?

5. Is there anything else you would like to say about the instructor?