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Developing Mathematics Teachers into Leaders for High-Need Urban Schools

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Abstract

Teacher leadership is essential for increasing teacher quality, addressing teacher turnover, and ultimately improving student learning. In this paper, we describe a teacher leadership program that developed 14 secondary mathematics teacher leaders. The quantitative data from the assessments and surveys indicate improvement of knowledge for teaching mathematics, leadership engagement, and skills for addressing diversity and equity in education for these teacher leaders. The qualitative data from self-reflections provide further insight into these teachers' perceptions of impact of the program regarding effective teaching, teacher leadership, and diversity and equity in education. Our findings contribute to the growing body of literature on teacher leadership by demonstrating a model program for teacher leadership and presenting its success in developing teachers into leaders.

Keywords: *Mathematics Teacher Leaders, Teacher Leaders Development, Teacher Leadership, High-Need Schools*

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Introduction

Teacher attrition has been a continuous concern in the United States, particularly in high-poverty and high-need schools (Carver-Thomas & Darling-Hammond, 2019; Edsall, 2022; Ingersoll et al., 2018). As teachers' careers progress, offering new and different challenges may encourage them to remain in the profession (Donaldson, 2007). Providing opportunities to develop teachers into teacher leaders, for example, is a potential solution to support sustaining highly qualified teachers in the profession (Wenner & Campbell, 2017; York-Barr & Duke, 2004). Teacher leadership refers to "a myriad of work" (Neumerski, 2012, p. 320) but can broadly reflect the work of "teachers who maintain K-12 classroom-based teaching responsibilities, while also taking on leadership responsibilities outside of the classroom" (Wenner & Campbell, 2017, p. 140). To foster teacher leaders, the National Science Foundation Robert Noyce Teacher Scholarship Program has devoted significant funding for teacher leadership development over the decades. Their efforts are grounded in supporting experienced exemplary K-12 science, technology, engineering, and mathematics (STEM) teachers to become teacher leaders in high-need school districts.

Funded by the Noyce program between 2016 and 2021, Rice University Master Teaching Fellowship (RU-MTF) program's goal was to develop secondary mathematics teacher leaders from a high-need school district with strong mathematical content and pedagogical knowledge, leadership engagement, and advocacy skills for equity and diversity issues in education. In this paper, using quantitative data, we explore the impacts of RU-MTF program on 14 master teaching fellows' (MTF): (a) mathematical knowledge for teaching; (b) leadership engagement; and (c) understanding of diversity and equity issues in education. In addition, using qualitative data, we gain insight into the MTFs' perceptions of impact of the program regarding effective mathematics teaching, leadership engagement, and equity and diversity in teaching and learning. In particular, we examine the following research questions:

(1) To what extent did the MTFs change their mathematical knowledge for teaching, leadership engagement, and understanding of diversity and equity over the three time points of the RU-MTF program: pre-program to mid-program and post-program?
(2) What were the MTFs' perceptions of the impact of the RU-MTF program regarding effective mathematics teaching, leadership engagement, and understanding of diversity and equity as described in their final self-reflections?

It is worth noting that, by using quantitative data, the first research question addresses teachers' changes over time whereas by using qualitative data, our focus in the second the research question was on the MTFs' overall perceptions of the program's impact and not necessarily the change overtime. Self-reflections are meant to complement the quantitative data by providing qualitative lenses onto the impact of the program.

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

Literature Review

Teacher Leadership and Teacher Leaders

Over the past few decades, teacher leadership has gained considerable attention as a means to facilitate school reform efforts and reduce teacher attrition (Brooks et al., 2004; Mimbs, 2002; Murray-Ward et al., 1998; Schott et al., 2020; Wenner & Campbell, 2017). As a result, many scholars have attempted to describe teacher leadership and teacher leaders and to explore conditions that may inhibit or support teacher leadership (see Nguyen et al., 2020; Wenner & Campbell, 2017; York-Barr & Duke, 2004). However, conceptualizations of what constitutes teacher leadership varies widely across the literature (Neumerski, 2012). The different titles/roles for teacher leaders (e.g., coach, department chair, coordinator, specialist) and different structures of leadership (e.g., formal/informal roles, responsibilities with varying levels in-class teaching) create even more complexity in pinpointing what it means to be or become a teacher leader (Mangin & Stoelinga, 2008; Neumerski, 2012; Wenner & Campbell, 2017).

Beyond classroom teaching responsibilities, teacher leaders need to undertake leadership responsibilities (Schott et al., 2020; Wenner & Campbell, 2017). York-Barr and Duke (2004) classified teacher leadership responsibilities into coordination and management; school or district curriculum work; professional development of colleagues; participation in school improvement; community involvement; contribution to the profession; and preservice teacher education. Some examples of these teacher leaderships are participating in administrative meetings and tasks (management and coordination practice), mentoring other teachers and promoting professional learning (professional development of colleagues practice), shared policy and decision-making (participation in school improvement and school or district curriculum work practice), or engaging with parents and community (community involvement practice; Darling-Hammond et al., 1995; Shen et al., 2020; Smylie & Denny, 1990).

As teachers progress in their career trajectories and gain more teaching experience, they are more inclined to take on new responsibilities through leadership roles (Katzenmeyer & Moller, 2001; Nguyen et al., 2020). To become an effective teacher leader, it is essential to develop necessary skills and knowledge that allow for building trust and relationships with colleagues, collaboration, and effective communication, assessing teachers' and students' needs, understanding the broader impact and organizational decisions (Wenner & Campbell, 2017; York-Barr & Duke, 2004). The Teacher Leader Model Standards present seven domains to describe the in-depth skills and competencies that experienced teachers need to become effective teacher leaders:

- Domain I: "fostering a collaborative culture to support educator development and student learning;"
- Domain II: "assessing and using research to improve practice and student learning;"
- Domain III: "promoting professional learning for continuous improvement;"
- Domain IV: "facilitating improvements in instruction and student learning;"
- Domain V: "promoting the use of assessments and data for school and district improvement;"
- Domain VI: "improving outreach and collaboration with families and community;" and

Journal of Educational Leadership and Policy Studies
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- Domain VII: "advocating for student learning and the profession" (Teacher Leadership Exploratory Consortium [TLEC], 2011, p. 9).

Despite the prior work on teacher leadership models and conceptual frameworks, there is a paucity of empirical research on teacher leadership preparation programs (Shott et al., 2020; Wenner & Campbell, 2017; York-Barr & Duke, 2004). At the core of these programs is providing long-term professional development to support teachers in becoming teacher leaders. However, only a handful of studies explored its impact (e.g., Alemdar, Cappelli, Criswell, & Rushton, 2018; Edge & Mylopoulos, 2008; Hofstein et al., 2004). Beyond supporting teachers to engage in leadership responsibilities, the main components of these programs include developing their content and pedagogical skills and knowledge. Although the increase in diversity of student population calls for develop teacher leaders' understanding of diversity and equity, there is only a few reports about teacher leadership preparation attended to issues of diversity and equity (Wenner & Campbell, 2017).

Content and Pedagogical Knowledge

To inform school-wide decision-making and improve school culture and instruction, teachers need to possess significant expertise and extensive knowledge for content specific area(s), teaching and learning, and curriculum to be an effective teacher leader. By these means, they can be prepared to assume responsibilities such as facilitating communities for learning, coordinating school or district curriculum, or peer coaching or mentoring (e.g., Darling-Hammond et al., 1995; Elmore, 2002; Yopp et al., 2019) and at the same time are uniquely positioned for stepping in when needed and modeling and/or refining specific instructional practices (Wenner & Campbell, 2017).

Teachers' knowledge comprises subject-matter content knowledge, pedagogical knowledge, and curricular knowledge all of which, as a whole, are referred to as pedagogical content knowledge—the term coined by Shulman (1986). Despite its necessity, pure subject-matter knowledge is not sufficient because knowing a particular subject matter does not imply effective teaching of it. Thus, what teachers need is the pedagogical content knowledge— "an important subdomain of pure content knowledge unique to the work of teaching" (Ball et al., 2008, p. 389). Teacher leaders need to possess pedagogical content knowledge for mathematics more than teachers so that they can guide and coach teachers effectively (Yopp et al., 2019). Mathematics teacher knowledge is referred to as mathematical knowledge for teaching (MKT), which can be broadly defined as "the mathematical knowledge that teachers use in classrooms to produce instruction and student growth" (Hill et al., 2008, p. 374). MKT marries subject matter knowledge and pedagogical knowledge. More specifically, MKT comprises not only knowledge about pure mathematics content but also knowledge about students' mathematical thinking as well as their ideas, knowledge, and conceptual understanding.

Through sustained professional development programs, teachers can establish a solid foundation of professional teaching skills (York-Barr & Duke, 2004). For mathematics teachers, such professional development programs should provide opportunities to learn mathematics intertwined with teaching (Hoover et al., 2016) and extend their students' mathematical thinking, reasoning, and problem-solving (Jacob et al., 2017; National Council of Teachers of Mathematics [NCTM], 2000, 2014).

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

Understanding of Equity and Diversity

To support teachers' and students' diverse backgrounds, beyond pedagogical content knowledge, teacher leaders need to become critically conscious about the problems related to educational and societal inequity and injustice (Bradley-Levine, 2012; Edsall, 2022; Wenner & Campbell, 2017). Brown and colleagues (2011) highlight the importance of attending to issues of equity and social justice: "A school culture that perpetuates the status quo and turns a blind eye to the social injustices that permeate our schools is not really 'excellent'" (p. 86). This is a particularly and even more critical aspect for teachers and teacher leaders who work in highly diverse and high-need schools and in an era in which racism, profiling, and ethnic divides are in the rise (Carver-Thomas & Darling-Hammond, 2019). Scholars urge that equity and diversity (e.g., critical race theory) must be given the same attention as curriculum, instruction, and assessment (e.g., Edsall, 2022; Gutiérrez, 2008). Thus, teachers must recognize the pervasiveness of culture in the teaching and learning environment and optimistically engage diverse cultures, perspectives, and skills that all students bring to the classroom (Lee, 2011). Providing culturally relevant instruction encompasses culturally mediated, engaging learning tasks that value and nurture the individual as a person and allows teachers to promote equitable educational opportunities (Brown et al., 2019; Howard, 2010; Ladson-Billings, 1994).

To provide and promote a learning environment that is effective for all learners, teachers need strong professional learning opportunities that incorporate equity and diversity research in education. Thus, it is critical for teacher leaders to take actions in facilitating such opportunities with their fellow teacher colleagues, which require reflecting on the historical and social context of the issues on equity and diversity as well as ways of providing equitable learning environment (Bradley-Levine, 2012, 2018). By participating in school change efforts, providing professional development for their colleagues, and involving in community and community organizations (see York-Barr & Duke, 2004), teacher leaders of mathematics can highlight the visions within culturally relevant mathematics instruction: (a) teaching mathematics for understanding, (b) centering instruction on students' experiences, and (c) developing students' critical consciousness about and with mathematics (Rubel & Chu, 2012). Only then teachers will be able to develop lessons that engage all students in rigorous and accessible mathematics (National Council of Supervisors of Mathematics, 2008). Equity and diversity in mathematics teaching implies high expectations, strong support, and access for all students to a challenging mathematics curriculum taught by capable teachers who receive adequate support and professional development (NCTM, 2014).

Present Study

In this paper, we present a long-term teacher leadership program, RU-MTF, to develop secondary mathematics teachers into leaders and explore the development of effective mathematics teacher leaders. The RU-MTF program focused on supporting the development of content and pedagogical knowledge, leadership engagement, and understanding of and addressing issues of equity and diversity in education. Our operational definition of an effective mathematics teacher leader is the intellectual leader of and an advocate for mathematics who engages in educational activities beyond the classroom such as mentoring teachers, helping with school

policy, and leading school committees. This aligns with the most prominent and widely accepted definition of teacher leadership by York-Barr and Duke (2004) as well as other explicit, research-based and more recent definitions (see Schott et al., 2020; Wenner & Campbell, 2017).

Our goals were to first evaluate the impact of RU-MTF program using the quantitative data from surveys and assessments around teachers' mathematical knowledge for teaching, leadership engagement, and understanding of and addressing issues around diversity and equity. These quantifiable measures related to the impact of the program are triangulated by qualitative data. Using self-reflections as qualitative data, we examined teachers' perceptions of the impact of the RU-MTF program in relation to effective mathematics teaching, leadership engagement, and understanding of diversity and equity.

Methods

Participants and Context

The Rice University hosted the Noyce Master Teaching Fellowship program from 2016 to 2021. The Rice University is a private research university located in a metropolitan area in Houston, sharing the same location with one of the largest urban school districts in the nation. Currently, the Rice University has enrolled more than 7000 students (around 4000 undergraduate and around 3000 graduate) of whom 44% are White, 26% are Asian, 16% are Hispanic, 8% are Black/African American, and 6% are two or more races.

The recruitment of the MTFs for the RU-MTF program took place during the summer and early fall of 2016. In total, 14 MTFs completed the five-year RU-MTF program. These MTFs were middle and high school mathematics teachers who taught in a high-need school district (as defined in section 201 of the Higher Education Act of 1965), the Houston Independent School District (HISD), Texas, United States. At the beginning (2016–2017 academic year), HISD's student population (elementary, middle, and high school) included 62% Hispanic/Latino, 24% Black/African American, 9% White, and 5% other race/ethnicity as well as 78% economically disadvantaged and 63% with Limited English Proficiency, English as Second Language, and Bilingual students. At end of the RU-MTF program (2021–2022 academic year), HISD's student population's demographics stayed almost the same (62% Hispanic/Latino, 22% Black/African American, 10% White, 6% other race/ethnicity; 79% economically disadvantaged and 68% Emergent Bilingual, Bilingual, and English as Second Language).

Among the 14 MTFs, six identified as male and eight identified as female. Three Hispanic/Latino, three Black/African American, two Asian, and six White identified among these MTFs. All MTFs had graduate degrees in mathematics or mathematics education except for two teachers, one with an engineering degree and another with a law degree. The MTFs' years of teaching experiences ranged from 4 to 40 years with an average of 20.7 years.

The Noyce Program: RU-MTF

The RU-MTF program aimed to provide an active learning environment that emphasized learning mathematical content, understanding students' thinking and learning processes, and connecting professional development learning experiences to daily teaching tasks (Boston &

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

Smith, 2009; Desimone, 2009; Loucks-Horsley et al., 2010). The MTFs individually and collaboratively enhanced their leadership experiences by engaging in leadership activities within their schools and school district (e.g., parents and community interactions); planning and co-teaching professional development for other teachers; and mentoring pre-service and intern mathematics teachers. Throughout the RU-MTF program, the MTFs were engaged in discussion about providing and promoting equitable educational opportunities through the lenses of culturally relevant mathematics instruction.

The work of RU-MTF program began in the spring of 2016 with program planning and continued in the summer and fall of 2016 with document preparation and recruitment. The first meeting with the selected MTFs was held in the spring of 2017 where we prepared for the first summer of professional development activities. Throughout the five-year RU-MTF program (2016–2021), the MTFs attended two progress meetings each year to discuss the goals and expectations at the beginning of each academic year and to share their experiences and progress at the end of the academic year. Throughout the academic year, the MTFs were required and supported to participate in different leadership activities in their schools, in HISD, and at Rice University (see Table 1 for an overview of the RU-MTF program activities).

Table 1

Timeline of Major RU-MTF Program Activities

Activities/Courses	**Spring 2017**	**Summer 2017**	**Fall 2017 & Spring 2018**	**Summer 2018**	**Fall 2018 & Spring 2019**	**Summer 2019**	**Fall 2019 & Spring 2020**	**Summer 2020**	**Fall 2020 & Spring 2021**	**Summer 2021**	**Fall 2021**
NCSI 590; Math I; CRT-E		x									
NCSI 590; Math II; CRT-S				x							
Attend progress meetings	x		x		x		x		x		x
Demonstrate lessons for teachers	x		x		x		x		x		x
Plan & co-teach with teachers	x		x		x		x		x		x
Lead study groups or seminars for teachers	x		x		x		x		x		x
Mentor/observe teachers	x		x		x		x		x		x
Collaborate & interact with school community to promote math for all students	x	x	x	x	x	x	x	x	x	x	x

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

Participate/lead planning school & district math initiatives	x	x	x		x	x		x	x		x	x		x	x
Collaborate & interact with other MTFs	x	x	x		x	x		x	x		x	x		x	x
Plan co-teaching (summer PD)						x			x			x			x
Co-teach (summer PD)								x			x			x	
Mentor pre-service & intern math teachers						x		x	x		x	x		x	x
Assist in math methods courses						x		x							
Be observed by pre-service & intern teachers	x			x			x			x			x		
Demonstrate exemplary lessons at the Life in School Conference				x			x			x			x		

In addition to the above program activities, the MTFs also participated in and presented at regional and national conferences and assisted in planning and facilitation of programs for elementary and secondary school students and teachers.

First Part of the RU-MTF program (2017 – 2019)

In the first two summers of the RU-MTF program (2017 and 2018), the MTFs delved into the rigorous mathematics coursework and leadership building activities. These courses and activities included components on advanced mathematics content, secondary mathematics pedagogy, leadership engagement, and diversity and equity issues in STEM education. The MTFs completed two four-hour Rice University graduate courses in Contemporary Topics in Mathematics (NSCI 590, see Table 1). The advanced mathematics content was centered on the major strands of university-level mathematics identified by The Conference Board of the Mathematical Sciences (CBMS) as most critical for secondary mathematics teachers: (1) Algebra and Number Theory; (2) Geometry and Trigonometry; (3) Functions and Analysis; (4) Data Analysis, Statistics, and Probability; and (5) Discrete Mathematics and Computer Science (CBMS, 2001, 2012). The pedagogical component of these courses aimed to accomplish a deep understanding of effective precollege mathematics curriculum, instruction, and assessment. Thus, the MTFs engaged in active, student-centered, inquiry-based learning experiences using manipulatives and the latest technologies in a collaborative setting and then critically discuss how to elicit campus-wide adoption of such mathematics instruction at their schools. Additionally, the MTFs completed four Advancement Via Individual Determination (AVID) Path Trainings strands including mathematics I, mathematics II, culturally relevant teaching for educators (CRT-E), and culturally relevant teaching for students (CRT-S) (see Table 1). These strands were designed to provide strategies for rigorous mathematical instruction and methodologies that validate the diversity of MTFs' students. During AVID Path Trainings, the MTFs engaged in critical

conversations around race, gender, class, and sexual orientation, and discuss ways in which they can cultivate and celebrate diversity for individual and collective development among their students. These advanced math content topics, pedagogical components, and culturally-relevancy component are all aligned with the common core standards for mathematics (CBMS, 2001, 2012).

During the academic years between 2017 to 2019, the MTFs engaged in different leadership activities at Rice University, Rice University School Project (RUSMP), HISD, and their schools (at least once per month for each year). These activities centered on promoting the MTFs' knowledge about mathematics and innovative pedagogies, collaborative teaching, educational policies, and issues around equitable mathematics education. Thus, the MTFs attended different talks (e.g., state of education, education policies); presented at different meetings and conferences (e.g., Noyce, HISD, RUSMP, Networking Conference); participated in curriculum development and programs with HISD and Rice University; collaborated on lesson planning, interacting, and co-teaching with teachers at their schools or other schools. For example, in Spring 2018, a Noyce Track 3 group from the University of Louisiana at Lafayette visited our group to observe our MTFs in action and for conversations about leadership.

Second Part of the RU-MTF program (2019 – 2021)

During the summers, the MTFs directed and oversaw the RUSMP's Summer Campus programs for grades 1-12 teachers. The MTFs also continued to engage in leadership activities and participate in conferences and lectures on mathematics teaching and learning (e.g., Association for Women in Mathematics, Conference for the Advancement of Mathematics Teaching). They also organized RUSMP's networking conference with STEM professionals. Several MTFs mentored student teachers.

In the fourth year of the RU-MTF program, COVID-19 struck the greater Houston area in the spring of 2020. As the instruction in HISD moved to a virtual format, the MTFs were called upon to take the lead in their schools and in HISD in a variety of ways to support students and teachers. At their schools, the MTFs prepared videos, supported colleagues at their schools and across the district, and reassured parents and students. The challenges of COVID-19 prompted the MTFs to step up their leadership efforts across HISD including assisting teachers with virtual instruction and helping parents support their children's learning. Their expertise in online environment helped with the RUSMP's 2020 and 2021 virtual summer programs as well as RUSMP's 2020 and 2021 virtual networking conferences.

Data Sources

To answer the first research question, we collected quantitative data to assess the MTFs' mathematical knowledge for teaching, leadership engagement, and understanding of issues related to equity and diversity in education through self-reported surveys and assessments at three time points throughout the five-year RU-MTF program. These instruments included Learning Mathematics for Teaching (LMT; Hill et al., 2008), Survey of AVID Teachers (Watt et al., 2010), and Diversity Disposition Index (DDI; Schulte et al., 2008), all of which were previously developed and validated. To answer the second research question, we collected qualitative data in the form of written self-reflections from the MTFs about their perceptions of effective teaching of

mathematics, teacher leadership and leadership engagement, and issues around equity and diversity in education.

Mathematical Knowledge for Teaching

To measure teachers' mathematical knowledge for teaching (MKT; content and pedagogical knowledge), we used the LMT assessment (Hill et al., 2008) that related to the MTFs' content area the most: patterns, functions, and algebra. The LMT assessment also includes items assessing knowledge of content and students (Hill et al., 2008). The content scales have demonstrated adequate internal consistency with Cronbach alphas greater than 0.70 (Hill et al., 2008). Course grades for Contemporary Topics in Mathematics (NCSI 590) were also considered when evaluating teachers' progress in the program. In the RU-MTF program, the LMT assessment was administered at the onset of the first summer of RU-MTF (Summer 2017) to capture a baseline measure of teachers' MKT. It was administered again at the end of the second summer (Summer 2018) to measure the impact of the two rigorous mathematics content professional development sessions that took place in Summer 2017 and Summer 2018. The LMT assessment was administered a third and last time at the end of the RU-MTF program (Fall 2021) to assess the MTFs' sustainability in MKT.

Leadership Engagement

To assess MTFs' development of leadership, we administered a modified version of the Survey of AVID Teachers (Watt et al., 2009) as a pre-survey (Summer 2017), mid-survey (Summer 2018), and post-survey (Fall 2021). This survey has 16 items asking the MTFs how often they engaged in leadership activities such as "involvement in campus level decision-making" and "sharing ideas with colleagues." Survey responses resided on a four-point Likert-scale (1 = not yet; 2 = rarely; 3 = sometimes; 4 = often). Past studies have reported adequate inter-item reliability for this survey ($\alpha = 0.87$; Watt et al., 2009).

Understanding of Diversity and Equity

To measure the MTFs' understanding of diversity and equity issues in education, we administered the DDI survey (Schulte et al., 2008) at the beginning (2017), at the end of the first part of the RU-MTF program (Summer 2018), and at the end of the RU-MTF program (Fall 2021). This survey assesses the dispositions of effective educators across the beliefs, relations, and knowledge of culturally relevant teaching (Ladson-Billings, 1994). The survey assesses three dimensions of teachers' (1) *skills* in helping students gain knowledge (18 items), (2) *beliefs* about students and teaching/learning (16 items), and (3) *community connectedness* (9 items). All three dimensions have high reliability coefficients ($\alpha = 0.91$ for dimension-one, $\alpha = 0.90$ for dimension-two, and $\alpha = 0.84$ for dimension-three; Schulte et al., 2008). Sample items include "I am successful at creating meaningful relationships between knowledge and new information" (dimension-one); "I believe that all students can succeed" (dimension-two); and "I collaborate on providing community service opportunities for my students" (dimension-three). Item responses resided on a five-point Likert-scale (1 = Strongly disagree to 5 = Strongly agree).

Self-Reflections

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826

In each year of the RU-MTF program, the MTFs wrote their reflections for the summer, fall, and spring semesters. These reflections were about two to five pages long and centered around the MTFs' experiences and perceptions of effective mathematics teaching, particularly in a high-need school district, their engagement in leadership activities, and their views on and understanding of diversity and equity in education. They were prompted to reflect on their role as a teacher and teacher leader within their school and school district.

Data Analysis

We answered the first research question by analyzing the collected quantitative data (the MTFs' responses to LMT, Survey of AVID Teachers, and DDI). The MTFs had standardized normal scores ($M = 0$, $SD = 1$) in LMT assessment for each time point. For the Survey of AVID Teacher, the MTFs had an average score (mean of 16 item responses) between 1 and 4 for each time point. Finally, for each of the three DDI dimensions, the MTFs had an average score between 1 and 5 for each time point. The change in these three main areas (LMT, AVID, DDI), were explored using paired-samples (repeated measures) *t*-tests comparing pre-to-mid, mid-to-post, and pre-to-post time points. Therefore, we ran a total of 15 *t*-tests (three for LMT, three for AVID, and nine for DDI—three for each of the three DDI dimensions) for 14 participants. Given the small sample size, particular attention was paid to confirming normality assumption for the dependent variables, power of analysis, and effect sizes for these *t*-test. Normality assumption was verified for all analyses. Power analysis using G*Power (version 3.1; Faul et al., 2009) with effect size of 0.8 (Cohen's *d*) with a sample size of 14 estimated a power of $1–\beta = 0.88$, a mid/high power value for paired-samples comparison (Cohen, 1998). The effect size for significant results is provided in their respective tables in the results section. The assumption of normality of difference scores for each comparison (mid – pre, post – mid, and post – pre) has been met.

We answered the second research question by analyzing the collected qualitative data (the MTFs' *final* self-reflections). In this analysis, we only focused on the MTFs' ***final*** self-reflections, because we specifically asked them to write about their perceptions of the impact of the program. To complement the report on the quantitative data analysis, we explored the MTFs' final self-reflections in three areas: perceptions of effective mathematics teaching, leadership engagement, and diversity and equity. We applied a deductive thematic data analysis (Saldaña, 2021). Specifically, for the effective mathematics teaching, we coded the MTFs' self-reflections into pedagogical content knowledge categories within Hill et al.'s (2008) MKT framework (i.e., knowledge of content and students, knowledge of content and curriculum, and knowledge of content and teaching; see Table 2). To identify the MTFs' perceptions of their leadership engagement, we categorized their self-reflections based on the seven practices of teacher leadership in York-Barr and Duke (2004; see Table 2). For the MTFs' perceptions of diversity and equity in education, we categorized their self-reflections using three dimensions of beliefs, skills, and community connectedness (diversity dispositions framework; Schulte et al., 2008; see Table 2). We further examined all these categories for any sub-categories (Patton, 2015). For example, one of the sub-categories for "contribution to profession" for the leadership engagement was "attending, holding, and presenting at conferences."

Table 2

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826

Categories for Effective Mathematics Teaching, Teacher Leadership, and Diversity and Equity

	Categories
Effective mathematics teaching (Hill et al., 2008)	Knowledge of content and students Knowledge of content and curriculum Knowledge of content and teaching
Teacher leadership (York-Barr & Duke, 2004)	Management and coordination Preservice teacher education School or district curriculum work Participation in school improvement Community involvement Contribution to the profession Professional development of colleagues
Diversity and equity (Schulte et al., 2008)	Beliefs Skills Community connectedness

It is important to note that some categories within the effective mathematics teaching, leadership engagement, and diversity and equity were not mutually exclusive. Particularly, the "community involvement" (leadership) and "community connectedness" (diversity) had an overlap. The "knowledge of content and students" and "skills" categories had an overlap. The "knowledge of content and curriculum" overlapped with "school or district curriculum work." All the coding was done by the first author.

Results

Mathematical Knowledge for Teaching and Effective Mathematics Teaching

All MTFs successfully completed the two Contemporary Topics in Mathematics courses (with grades of A). The MTFs' mathematical knowledge for teaching in functions and algebra content area steadily improved over the course of the five-year RU-MTF program (see Table 3). From pre-program (M = .832, SD = .577) to mid-program (M = 1.230, SD = .780), the MTFs' LMT scores significantly improved. Even though there was no statistically significant improvement from mid-program to post-program, the improvement from pre-program to post-program (M = 1.448, SD = .657) was significant, even greater than the improvement from pre- to mid-program.

Table 3

The MTFs' LMT Scores Standardized to National Norms

						95% C.I. (diff.)		
	***t* value**	**df**	***p* value (2-tailed)**	**Mean (diff.)**	**S.E. (diff.)**	**Lower**	**Upper**	**Cohen's *d***
Pre to mid	*2.903*	*13*	*.012*	*.397*	*.137*	*.102*	*.693*	*0.80*

Mid to post	1.644	13	.124	.218	.133	-.069	.505	--
Pre to post	*4.467*	*13*	*.001*	*.616*	*.138*	*.318*	*.914*	*1.24*

The MTFs' reflections revealed that they believed that their participation in the RU-MTF program enriched their mathematical knowledge for teaching through "problem-solving activities, exploring personal mathematics pedagogy…and rich discussions with colleagues and sharing ideas." In their self-reflections, the MTFs' *knowledge of content and students* aligned with the descriptions of their skills and beliefs in helping students gain knowledge. For example, Kyler (pseudonym[1]) described how learning about a new digital platform allowed him to "monitor students solving problems," provide them with feedback, and "adjust pacing to fit" their needs. The MTFs' *knowledge of content and curriculum* was evident in their school or district curriculum work. For instance, Robert learned about the "interactive and adaptive textbooks" throughout his research to find a curriculum for his school district. He thought that using such curriculum will create "a new set of behaviors for both teachers and students." Kyler's and Robert's discovery of these new tools and the way they utilized these tools reflect the focus on MKT in the graduate courses offered in the first part of the RU-MTF program.

The MTFs' *knowledge of content and teaching* focused on incorporating technology in teaching mathematics or applying and connecting mathematics to other disciplines. Andrew wrote about the extent to which mathematics education is influenced by technology. For example, technology provides "access to different sources of knowledge, different styles of teaching, affordability to the knowledge from any place and time, organization tools for educators and students." He, like some other MTFs, thought by incorporating technology, mathematics lessons would be more enjoyable and accessible for students and allow for "exploration, verification, and construction." Frankie's work in "illustrating how these two disciplines [mathematics and computer science] can enhance each other" was an example of applying and connecting mathematics to other disciplines. Andrew's and Frankie's views and practices regarding technology integration and connection of mathematics to other fields were undoubtedly a product of what they learned in the Math I and Math II portions of the RU-MTF's summer programs.

Leadership Engagement

The MTFs' responses to the Survey of AVID Teachers indicated a steady improvement of their leadership practices throughout the RU-MTF program. Although the changes in the MTFs' self-reported leadership practices from pre-program ($M = 2.675$, $SD = .545$) to mid-program ($M = 2.917$, $SD = .482$) and from mid-program to post-program ($M = 3.094$, $SD = .597$) were not statistically significant, the change from pre-program to the post-program of the RU-MTF program was statistically significant (see Table 4).

Table 4

The MTFs' Leadership Engagement Scores

[1] All the names mentioned in this paper are pseudonyms.

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

	t value	df	*p* value (2-tailed)	Mean (diff.)	S.E. (diff.)	95% C.I. (diff.) Lower	95% C.I. (diff.) Upper	Cohen's *d*
Pre to mid	1.878	13	.083	.205	.109	-.031	.441	--
Mid to post	1.535	13	.149	.170	.111	-.069	.408	--
Pre to post	*4.088*	*13*	*.001*	*.375*	*.091*	*.177*	*.573*	*1.13*

From the MTFs' final self-reflections, we found that through the RU-MTF program, they "gained more credibility, became a stronger, and more knowledgeable teacher leader." In the MTFs' final self-reflections, we found evidence of the six practices of teacher leadership (i.e., preservice teacher education; school or district curriculum work; participation in school improvement; community involvement; contribution to the profession; and professional development of colleagues). Although the *management and coordination* may be embedded in some of the MTFs' leadership activities, none of the MTFs directly wrote about this practice in their final self-reflection. The practice of *preservice teacher education* was mentioned by an MTF, who hosted a student teacher and said, "Mentoring student teachers [which is a requirement in the second part of RU-MTF] has been one of the biggest satisfactions in my teaching career… a big responsibility of being a *good model* …I think mentoring is one way to leave a legacy of the knowledge and experience to others."

The MTFs described the *school or district curriculum work* and *participation in school improvement* together. These two activities were among the core leadership activities that were highly encouraged by the RU-MTF program and supported by the RU-MTF faculty. They explained these practices in relation to their attempts to find and adapt resources (e.g., textbooks) that promote student success in mathematics. For example, the director of secondary mathematics in Robert's school district asked him "to examine a variety of open-source resources to see what [textbook] might be suitable" for students and teachers. He did so by "rat[ing] the books and resources as to how well they align in content, conceptual orientation, and context to the HISD."

The MTFs' *community involvement* included facilitating or leading summer schools or after school programs for students, which was also among the important leadership activity requirements of RU-MTF program. For example, Frankie was in charge of "the hour of code" in her school where she "…invited experts in computer science to talk to the students about the importance and the need of computer science skills and promoting coding activities to use in math classes."

The MTFs' *contribution to the profession* involved conducting projects with college students or attending, holding, and presenting at conferences. Even though, these activities were not required by the RU-MTF model, they were highly encouraged and counted towards MTF's leadership engagement duties in the second part of the RU-MTF program. For example, Andrew's interest in integrating technology in mathematics teaching led him to work with students to provide resources for teachers by describing "one technology source and how to use it in some lesson." Paula shared her experiences of attending and presenting at a conference:

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

I was a member of a panel that represented experienced teachers. Pre-service, beginning teachers as well as experienced teachers came and asked questions. This opportunity allowed me to understand just how much knowledge I do carry with me about being a mathematics teacher and leader. Other teachers are often eager to hear about how to be a great teacher and leader.

The MTFs discussed the *professional development of colleagues* by leading a professional learning community at their schools or planning and teaching RUSMP's summer campus programs for teachers around greater Houston area. For example, Frankie described the purpose of the summer campus program "was to bring the [high school] math teachers the opportunity to *do the mathematics*, and to provide pedagogical references that support their teaching practice." Through the support of RU-MTF program, the MTFs could provide a space for their colleagues to "share resources, pedagogical strategies, and technological skills."

Understanding of Diversity and Equity

The MTFs' understanding of diversity and equity varied depending on the dimensions of Diversity Disposition Index (DDI) survey. There was not much room for improvement for the two dimensions of the *skills* and *beliefs* about teaching and learning to start with. In other words, from a scale of 1 to 5, the MTFs' average disposition indices for these two DDI dimensions were 4.5 or above. Nevertheless, the MTFs' *skills* dimension within DDI (i.e., ability to address diversity issues in their teaching) steadily improved. Although the changes in the MTFs' *skills* between two consecutive time points were not statistically significant, their scores from pre-program to the post-program significantly improved (pre-program: $M = 4.494$, $SD = .124$, mid-program: 4.524, $SD = .081$, and post-program: 4.627, $SD = .101$; see Table 5). For the MTFs' *beliefs* about diverse learners and learning environments, there were no statistically significant changes across three time points. They had already started very high in this dimension (close to 5—the maximum score; pre-program: $M = 4.884$, $SD = .238$, mid-program: $M = 4.875$, $SD = .117$, and post-program: $M = 4.857$, $SD = .247$; see Table 5).

In the *community connectedness* dimension (i.e., teachers' connection to the community about promotion of diversity), the pre-program average score was 3.9 out of 5—leaving some room for possible improvement in this dimension about the *community connectedness*. Although not statistically significant, the MTFs slightly improved from pre-program to mid-program and slightly decreased from mid-program to end of the program (pre-program: $M = 3.897$, $SD = .936$, mid-program: $M = 4.056$, $SD = .721$, and post-program: $M = 3.968$, $SD = .846$; see Table 5). The slight decline from mid- to post-program may be due to the adverse effects of COVID-19 pandemic. Perhaps, without these adverse effects, it might have been possible to see some significant improvement at the end of the program.

Table 5

The MTFs' Scores on Three Dimensions of Diversity Disposition Index

	t value	df	*p* value (2-tailed)	Mean (diff.)	S.E. (diff.)	95% C.I. (diff.) Lower	95% C.I. (diff.) Upper	Cohen's *d*

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

Skills	Pre to mid	.364	13	.722	.032	.087	-.157	.220	--
	Mid to post	1.537	13	.148	.103	.067	-.042	.248	--
	Pre to post	*2.595*	*13*	*.022*	*.135*	*.052*	*.023*	*.247*	*0.72*
Beliefs	Pre to mid	-.171	13	.867	-.009	.052	-.122	.104	--
	Mid to post	-.285	13	.780	-.018	.063	-.153	.118	--
	Pre to post	-.605	13	.556	-.027	.044	-.123	.069	--
Community connectedness	Pre to mid	1.546	13	.146	.159	.103	-.063	.381	--
	Mid to post	-.705	13	.494	-.087	.123	-.355	.180	--
	Pre to post	.541	13	.598	.071	.132	-.214	.357	--

In the MTFs' final self-reflections, providing an equitable environment for the students was one of the foci. We found evidence of their *beliefs* about students and teaching and learning and *skills* in helping students gain knowledge. These two categories were intertwined with sub-categories including student success, school culture and structure, and accessible opportunities. These topics were at the core of the AVID Path Training (CRT-E and CRT-S) that took place during the first two summers of the RU-MTF program. Chad nicely illustrated his beliefs about student success and the inflexibility of school culture and structure that inhibit students with diverse backgrounds from succeeding:

> Our students are not all identical. Some need to go to college. Some don't. Some are interested in academic pursuits. Others are not, and do not need to feel less about themselves because of it. Some are smart but not fast, and would like to continue school on a part-time basis, because it stresses them out if it's full time…

Because the students are "a heterogenous group," Chad expressed that "one-size-fits all model will no longer work…and schools would be wise to do the same." Kyler shared his beliefs about how the current school culture and structure dismisses the students' differences by relying on standardized testing:

> We all have different abilities and talents, nobody denies that. But the school system does not help with this. Wouldn't it be better to stop testing constantly, grading the students with the standard measurement tools, and the same test at the same period of time, just because they sit in the same grade level?

The MTFs believed in providing students with accessible opportunities to develop and build upon their interests. For example, Andrew raised his concerns about using online books that not all students have access to:

> Students need the internet access to open the book, often they have trouble with internet at home; often it takes excessively many clicks to find the necessary chapter or page; often

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

there is no one long pdf text – the book is represented with small pieces that makes it difficult to read, work with, and brows the book.

Mark said that students "need time within the day to explore their interests and not fill their schedule with the state mandated classes." Andrew wrote that "the problem is that this system ignored the interests of students." By allowing students to explore their interests and providing accessible opportunities to foster those interests, their education can be beyond "a couple of predetermined pathways." These views of MTF's on diversity, equity, and inclusion in education were fueled by moderated discussions that took place during the formal meetings of RU-MTF participants every semester and by the informal interactions among the MTFs on their own time.

Finally, the MTFs also described their *community connectedness* in their self-reflections. They described the connections to their communities by engaging in summer schools or after school programs. Fabian, for example, shared his experiences of coordinating and leading "summer school program as a summer school principal," which was a "re-calibration event for students, teachers, and all staff for the upcoming school year."

Discussion

The goals of the RU-MTF program were to develop mathematics teacher leaders by engaging them in rigorous research-based mathematical content and pedagogical knowledge activities, supporting their involvement in leadership roles and activities, and informing them about the role of teacher leaders, particularly in facilitating the issues around equity and diversity in the education system. We collected both quantitative and qualitative data to explore the extent to which we achieved these goals. We used the quantitative data to examine the impact of the RU-MTF's program. We used the qualitative data to complement our quantitative data by providing insight into the MTFs' perceptions of the impact of the RU-MTF program.

Mathematical Knowledge for Teaching and Effective Mathematics Teaching

The RU-MTF program had a positive impact on developing the MTFs' knowledge for teaching mathematics as measured by the LMT assessment (Hill et al., 2008). The *knowledge of content and students*, *knowledge of content and curriculum*, and *knowledge of content and teaching* (see Hill et al., 2008) were also evident in the MTFs' perceptions of the impact of the RU-MTF program in relation to effective mathematics teaching. We found that incorporating technology in teaching mathematics or applying and connecting mathematics to other disciplines were sub-categories of *knowledge of content and teaching*. Together, the RU-MTF program provided the MTFs with opportunities to continue growing their mathematical knowledge for teaching. Such opportunities engage teacher leaders in reflective dialogue and research-based effective practices (referring to domains II and III in TLEC, 2011). This way, a teacher leader can use the knowledge of teaching and learning to "advance the professional skills of colleagues by being a continuous learner and modeling reflective practice" (TLEC, 2011, p. 17).

Leadership Engagement

The MTFs' leadership engagement as measured by the Survey of AVID Teachers (Watt et al., 2009) progressed throughout the RU-MTF program. We also found evidence of teacher leadership practices (York-Barr & Duke, 2004) in the MTFs' final self-reflections. For example,

Journal of Educational Leadership and Policy Studies
ISSN#: 2473-2826
Southern Connecticut State University

for the *contribution to the profession* practice, we identified conducting projects with college students or attending, holding, and presenting at conferences as its sub-categories. Leading a professional learning community or planning and teaching RUSMP's summer campus programs for teachers were sub-categories for the practice of the *professional development of colleagues*. The RU-MTF program supported the MTFs to take on more leadership roles and engage in more leadership activities. Teacher leaders need to "enact and exercise their leadership role through influencing others" (Nguyen et al., 2020, p. 16). Therefore, when preparing teacher leaders, it is important to not only foster their leadership engagement, but also stress that teacher leadership is a process of influencing others (Schott et al., 2020; York-Barr & Duke, 2004).

Understanding of Diversity and Equity

Although the MTFs' understanding of diversity and equity within the *beliefs* and *community connectedness* dimensions did not significantly change, their measured scores by the DDI survey (Schulte et al., 2008) at the onset of the program were high to begin with. Although not statistically significant, there was a slight decrease in the MTFs' *community connectedness* from mid-program to the post-program. This decrease could be attributed to the COVID-19 pandemic as most teachers' community connectedness and involvement in their community might have been weakened during this time. The MTFs' understanding of diversity and equity within the *skills* dimension, however, significantly improved from pre-program to post-program. Despite the challenging circumstance due to COVID-19 pandemic in the last two years of the program, the MTFs' positive changes, particularly in the dimension of *skills*, highlighted the benefits of the RU-MTF program in supporting them to become effective mathematics teacher leaders. The MTFs already had higher levels of availing *beliefs* related to diversity and equity at the onset of the program. They not only maintained these positive *beliefs,* but they significantly improved their *skills* related to addressing diversity and equity issues in education. This positive change can be attributable to the RU-MTF program.

The MTFs self-reflections provided us with deeper insights into their understanding and practices related to diversity and equity issues. In the MTFs' final self-reflections, we identified student success, school culture and structure, and accessible opportunities as sub-categories of their beliefs about students with diverse backgrounds and teaching and learning as well as the skills to help them gain knowledge. The improvement of student learning is at the heart of teacher leadership models and conceptual frameworks (Shen et al., 2020; TLEC, 2011; York-Barr & Duke, 2004). Thus, it is not surprising that student success was also one of the sub-categories mentioned by the MTFs in their self-reflections. The school culture and structure are conducive to teacher leadership development. Teacher leadership could only be fostered in a collaborative school culture and structure where teachers and teacher leaders can focus their efforts on the success of all students (referring to domains I and VI in TLEC, 2011; Nguyen et al., 2020; York-Barr & Duke, 2004). By understanding issues related to diversity and equity in their school culture and structure, teacher leaders can support their colleagues to develop culturally responsive teaching (e.g., empowering all students intellectually, emotionally, and socially; Ladson-Billings, 1994).

Implications and Contributions to the Field of Teacher Leadership

Over the years, many scholars have called for more high-quality research on teacher leadership preparation programs (Nguyen et al., 2020; Schott et al., 2020; Wenner & Campbell, 2017; York-Barr & Duke, 2004). The implications of this study are to provide insights into the design and analysis of a teacher leadership program. Our findings from the five-year RU-MTF program contribute to the growing body of literature on teacher leadership by: (a) demonstrating a model of a program for teacher leaders; and (b) the extent to which this model was successful in developing teachers into leaders as they engaged in program activities.

First, to further the field of teacher leadership, studies need to draw from a definitive concept such as the definition of York-Barr and Duke (2004) or more recent definitions by Schott et al. (2020) and Wenner and Campbell (2017). This way, researchers can more meaningfully compare the impact of the teacher leadership programs on effectively preparing teacher leaders. Therefore, we explicitly defined teacher leadership in the RU-MTF program and used it as a compass throughout the program: an effective mathematics teacher leader is the intellectual leader of and an advocate for mathematics who engages in educational activities beyond the classroom such as mentoring teachers, helping with school policy, and leading school committees.

Second, it is important to consider a wider range of methods and data to better understand the outcomes of teacher leadership programs. A recent study by Schott et al. (2020) found that only about 16% of empirical studies on teacher leadership used a mixed method approach and they often collected data in only one point of the study. In our study, collecting both qualitative and quantitative data at different points of the RU-MTF program allowed us to better describe its impact on preparing mathematics teacher leaders. A practical implication of our study was to demonstrate using previously developed and validated surveys and assessments in the context of teacher leadership program.

Third, prior studies on teacher leadership preparation programs have primarily focused on training and activities around leadership engagement, pedagogical, and content knowledge (Wenner & Campbell, 2017). Only 9% of reviewed teacher leadership literature by Wenner and Campbell (2017) focused on issues surrounding diversity and equity. In the RU-MTF program, we incorporated discussions around these issues particularly through the lens of culturally responsive teaching practices. Our findings illuminated the complexity of incorporating equitable practices in schools and school systems particularly in times like the COVID-19 pandemic. Therefore, when designing a teacher leadership program, it is essential to consider the underlying issues around diversity and equity in education. Addressing these issues will help to prepare teachers and teacher leaders who can face the uncertain circumstances such as COVID-19 pandemic.

Limitations and Future Work

Despite decades of work on developing teacher leaders, research on teacher leadership is still pressing. The future work needs to provide a more cohesive and holistic conceptualization of teacher leadership and highlight the impacts of teacher leadership programs in promoting teacher retention and student learning (Nguyen et al., 2020; Schott et al., 2020; Wenner & Campbell, 2017; York-Barr & Duke, 2004). Thus, researchers need to document not only the level of teachers' engagement in leadership activities but also its quality in relation to improving school culture and structure and student success. To do so, they need to incorporate other methods such as

observations or interviews of teacher leaders' colleagues and consider other data sources such as student assessment scores. In fact, one limitation of our study was to rely on self-reported surveys and assessments and self-reflections of teacher leaders. Additionally, it is important to monitor the extent to which teachers assume their leadership roles and engagement in leadership activities after completing the teacher leadership programs and over time. Although we did not report on the current status of our MTFs after the completion of the RU-MTF program in this paper, we are following their career trajectories and continuing our collaborations to enhance student success.

Conclusion

As the public education continues to suffer from the chronic issue of teacher attrition in the U.S. and the global challenge of diversity, equity, and inclusion, effective teacher leaders can make positive impacts on their school communities to address these issues (Wenner & Campbell, 2017). Developing effective teacher leaders who can lead outside their classrooms and goes beyond the typical boundaries of their bubbles is easier said than done. This requires long-term professional development informed by rigorous research-based frameworks for teacher leadership (e.g., York-Barr & Duke, 2004; Schott et al., 2020), pedagogical content knowledge (e.g., Hill et al., 2008), and diversity and equity (e.g., Ladson-Billings, 1994). This paper provides an example for a successful targeted model for developing teacher leaders with each program component carefully designed and enacted. We documented the success of this model in developing participating teachers' mathematical knowledge for teaching, leadership engagement, and understanding of diversity and equity in mathematics education through a mixed-methods study design. Teacher development and training programs and school districts can adapt RU-MTF program into their context to develop effective mathematics teacher leaders.

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