DETERMINING THE IMPACT OF A CORRELATED SCIENCE AND

MATHEMATICS PROFESSIONAL DEVELOPMENT MODEL

ON TEACHER LEADERSHIP

by

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FAIR USE AND AUTHOR'S PERMISSION STATEMENT

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LIST OF ABBREVIATIONS

Abbreviation	Description
NCTM	National Council of Teachers of Mathematics
NRC	National Research Council
NGSS	NGSS Lead States
PD	Professional Development
NSES	National Science Education Standards
MIX	Mix It Up Project
TQ	Teacher Quality
B.S. Int. Disc.	Bachelor of Science in Interdisciplinary Studies
B.S.	Bachelor of Science
M. Ed Elem. Education	Master of Elementary Education
M.A.	Master of Arts
M.S.	Master of Science
B.A.	Bachelor of Arts
M.Ed. Ed Lead	Master of Arts in Educational Leadership
B.A. Int. Business	Bachelor of Arts in International Business.

ABSTRACT

The mathematics and science national standards advocate for educational reform by implementing research-based strategies and acknowledges the teacher's critical role in implementing effective instruction. Teachers who understand how to relate mathematics and science grade-level content in a meaningful way may often feel empowered and advocate for mathematics and science integration on their campus. The Mix It Up professional development program utilized the Correlated Science and Math professional development model to better enable science and mathematics integration by classroom teachers. My study aimed to determine the impact of the Mix It Up professional development program on teacher leadership growth (n=23). I investigated their teacher leadership using a mixed-methods approach to understand if and how teacher leadership growth occurred. I utilized the National Council of Supervisors of Mathematics' *PRIME Leadership Framework* to identify Stage 3 leaders, the highest level of leadership, for my case study. I selected four cases (n=4) for my multiple case study to gather enriched details on how teachers progressed into Stage 3 teacher leadership. Overall, I found my participants (n=23) reported possessing teacher leadership characteristics. Ninety-one percent reported taking on leadership roles outside their classrooms. Four cases in my multiple case study attributed their leadership growth to their participation in the Mix It Up program. Participants reported that they not only implemented and impacted their own students, but advocated for science and mathematics integration and the use of general best practices at the district and state level.

I. INTRODUCTION

The science and mathematics national standards were developed to advocate for educational reform (National Council of Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 1996, 2012; NGSS Lead States [NGSS], 2013). Stakeholders at the local and national level addressed concerns of science education reform by developing A Framework for K-12 Science Education (NRC, 2012*)* and subsequently the NGSS (2013) which includes a guideline for integrating science content with other disciplines such as mathematics. All of the standards recognize the teacher's critical role in effective instruction and implementing research-based strategies. Improving teacher practices through a high-quality professional development (PD) program should also focus to create teacher leaders who will promote these best practices teaching techniques (Yow & Lotter, 2016). EL-Deghaidy, Mansour, Aldahmash, and Alshamrani (2015) indicated for educational reform to occur, it is essential for teachers to act as agents of change. Hong Kong's educational reform encouraged teachers to be proactive in the decision-making process by engaging in shared leadership roles (Lai & Cheung, 2015). The NRC (1996) acknowledged a teacher's role in education reform efforts and implemented the effective leadership structure standard requiring schools to move away from hierarchical leadership to shared roles and responsibilities.

Teacher Leadership

Hanuscin, Rebello, and Sinha (2012) suggested that all teachers have the potential to become teacher leaders. York-Barr and Duke (2004) found that teacher leadership involves many aspects including improving teaching skills individually and beyond the classroom. The National Council of Supervisors of Mathematics (2008) recognized there are various forms of teacher leadership and developed the PRIME Leadership Framework for mathematics that included three stages of teacher leadership, with Stage 3 being the highest form of leadership. For teacher leadership growth to occur, teachers must implement best practices within their own classroom before they can make an impact on a larger scale (Yow & Lotter, 2016). Teachers play a central role in school improvement when they are provided with opportunities to lead PD and are given a supportive environment. (Poekert, Alexandrou, & Shannon, 2016). Luft, Dubois, Kaufmann, and Plank (2016) discovered that science teachers who improved their content knowledge and who were included in their school's instructional vision were encouraged to take on leadership roles within their school or district.

A school's success can be attributed to recognizing and fostering teacher leadership development (Cheng & Szeto, 2016). The development of teacher leaders using targeted curriculum materials that incorporated best practices, such as guided inquiry, was shown to be linked to overall improved student achievement (Klentschy, 2008). Leithwood and Mascall (2008) found a significant association between collective (shared) leadership and enhanced student performance in school. Nicholson, Capitelli, Richert, Bauer, and Bonetti (2016) provided PD intended to improve the leadership skills of their participants by modeling professional interactions, including communication, strengthening skills and facilitating inquiry processes with colleagues. The authors suggested that such empowered environments and shared leadership, including teacher leadership, will enable school improvement.

Professional Development

PD is an ongoing need for teachers throughout their career (Luft et al., 2016; NRC, 2012). PD for in-service teachers is necessary for their professional growth (Holloway, 2006; Schleigh, Bossé, & Lee, 2011). PD beyond the university preparation program is intended for teachers while in-service to improve their knowledge or teaching skills (Holloway, 2006). A well organized and purposefully directed PD program enhances teacher's content, general and content pedagogical knowledge (Guskey, 2003). Guskey and Yoon (2009) reported that PD which consisted of 30 or more contact hours in a school year had positive effects on student learning. Holloway (2006) suggested research-based, high-quality PD contributed to improved student performance and overall school effectiveness. Characteristics of effective PD have been identified in numerous literature (Abu-Tineh & Sadiq, 2018; Guskey, 2003; Guskey & Yoon, 2009; Tohill, 2009; Zimmerman & May, 2003). Bates and Morgan (2018) identified seven elements of effective PD which recognized that teachers' practices were linked to positive student learning outcomes. Teacher learning through PD contributes to student learning outcomes which is ultimately the goal of PD (Kennedy, 2016).

PD within Integrated Science and Mathematics

Numerous researchers report reasons for integrating science and mathematics (Berlin, 1990; Berlin & Lee, 2005; Berlin & White 1992, 2010; Huntley, 1998; Hurley (2001); Lehman, 1994; Lonning & DeFranco, 1997; Nadelson et al., 2013; Watanabe & Huntley, 1998; West & Tooke, 2001; West & Singh, 2007; West & Vasquez-Mireles, 2006; Westbrook, 1998). In the *National Science Education Standards* (NSES), the NRC (1996) recommendations included that science should be connected to mathematics to enhance student learning. Integrating mathematics and science can be represented in a continuum model illustrating the various modes of integration with mathematics or science as the focus or balanced with equal amounts of mathematics and science content in the lesson (Lonning & DeFranco, 1997). Hurley (2001) found science and mathematics integration had a positive effect on student learning outcomes and revealed there was a higher effect for science on student achievement than mathematics.

Several authors recognized ways to integrate science and mathematics (Berlin, 1990; Berlin & Lee, 2005; Berlin & White 1992, 2010; Huntley, 1998; Lehman, 1994; Lonning & DeFranco, 1997; Nadelson et al., 2013; Watanabe & Huntley, 1998; West & Tooke, 2001; West & Vasquez-Mireles, 2006; Westbrook, 1998). Common ways suggested to integrate science and mathematics encompass: (a) themes, (b) pedagogy, (c) inquiry and other processes, (d) real life problems, (e) phenomena, projects, (f) technology-based projects, (g) competitions, (h) concepts, and (i) discipline/content (Davidson, Miller, & Metheny, 1995; Meyer, Stinson, Harkness, & Stallworth, 2010). Content integration has been defined in science and mathematics such that the learning objectives for each discipline are combined for conceptual understanding (Davidson et al., 1995; West & Tooke, 2001). For example, West and Browning (2008) described identifying links between science and mathematics content in their PD project. A focus of one session was on the major role that the density of Earth materials played in the Earth's movement within subduction zones. The National Research Council (2012) and the NGSS Lead States (2013) recommended integrating mathematics and science by using examples of real-life problems and phenomena.

The Mix It Up (MIX) program in this study was created for teachers to better enable science and mathematics integration by using the Correlated Science and Math (CSM) PD model. The CSM model is a PD model and not an instructional model for teachers to use in their classrooms. The CSM content PD model is unique in that it integrates science and mathematics content more thoroughly and differently than other types of integration models (West & Tooke, 2001). In contrast, other models include science and mathematics integration through projects, technology, inquiry and real-world phenomena. CSM instruction is ideally co-taught by science and mathematics experts, both of whom are well versed in science and mathematics content, Science, Technology, Engineering, Mathematics (STEM) specific pedagogy and general best teaching practices. PD providers who effectively utilize the CSM model are typically experts with a master's degree in their content fields, extensive K-12 classroom teaching and teacher training experience.

The CSM content specialists design lessons in order to meet seven specific PD goals for teachers that are being trained in the CSM model. Those goals include: (a) teaching for conceptual understanding in both science and mathematics, (b) using each discipline's proper language, (c) using standards-based learning objectives, (d) identifying the natural links between the disciplines, (e) identifying language that is confusing to students, (f) identifying parallel ideas between the disciplines when possible, and (g) using inquiry format in science and mathematics when appropriate (see Figure 1). The CSM approach to PD as described above is "centered in the critical activities of the profession-that is, in and about the practices of teaching and learning" (Ball & Cohen, 1999, p. 13).

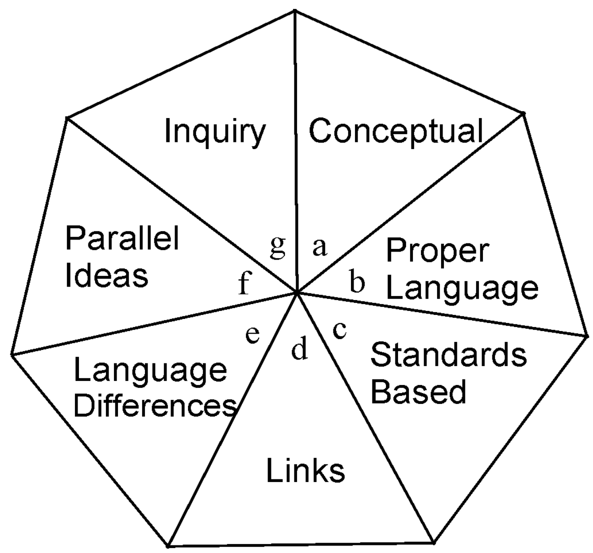

Figure 1. Components of CSM PD model.

The CSM content PD model was implemented for fifth through eighth grade science and mathematics teacher teams and their principals from summer 2006 through February 2016 at Texas State University. The MIX projects consisted of a minimum of 70-hour summer institutes and 30 hours of Academic Year (AY) training sessions for the teachers. Principals were participants and were also a part of the school's MIX team along with their teachers. The principals received 12 hours of summer training and an optional 30 hours of AY training. The principals also attended a minimum of one day during the summer with their teachers to enable the principals to understand the type and high quality of PD their teachers were receiving. The MIX program also included field trips outside regular scheduled hours that included families of the participants who were welcomed to attend. Principals were also invited to attend MIX field trips with their teacher teams.

The need to improve a variety of student outcomes can only be met with a combination of solutions. However, part of the solution involves allowing important decisions to be made by the professionals responsible for guiding student learning for those who are most involved in student learning on a day to day basis (NRC, 1996). Researchers reported the benefits of participating in an integrated mathematics and science program and recognized the importance of implementation (Berlin, 1990; Berlin & Lee, 2005; Berlin & White 1992, 2010; Czerniak, Weber, Sandmann, & Ahern, 1999; Huntley, 1998; Hurley (2001); Lehman, 1994; Lonning & DeFranco, 1997; Nadelson et al., 2013; Watanabe & Huntley, 1998; West & Tooke, 2001; West & Browning, 2008; West & Vasquez-Mireles, 2006; Westbrook, 1998). Teachers who improve their practice through content, pedagogy, and leadership can ultimately lead to teacher efficacy to influence outside their classroom (Yow & Lotter, 2016). Teacher leaders understand the importance of receiving high-quality, ongoing PD to enhance their own professional growth prior to advocating beyond their classroom.

Teacher Leadership in MIX

My study examined the teacher leadership outcomes of participating in a two-year MIX PD program. Teacher leadership encompasses various stages of development. Recognizing leadership characteristics of participants in a high-quality PD, such as MIX, will provide perspective into how growth occurred. My literature review will describe the need for science and mathematics integration, PD, and teacher leadership in creating educational reform to improve the outcomes of student achievement.

Purpose of my Study

The purpose of my study was to determine the impact of the MIX PD program on teacher leadership growth. My study sought to identify the teacher leadership characteristics of participants who completed the two-year MIX PD program and how

Stage 3 leaders progressed into the highest level of leadership as defined in the *PRIME Leadership Framework* (National Council of Supervisors of Mathematics [NCSM], 2008). Teacher leaders who demonstrated growth in specific leadership characteristics identified in the *PRIME Leadership Framework* can endorse and advocate for the use of research-based best practices in the classroom, within their own learning community and beyond.

Three research questions were used to guide my study:

1. What are the teacher leadership characteristics of the teachers (n=23) who participated in the MIX program?

2. What are the teacher leadership characteristics of a Stage 3 teacher leader (n=10) who participated in the MIX program?

3. How are teachers (n=4) who participated in the MIX program progressing into Stage 3 teacher leadership roles?

II. LITERATURE REVIEW

Defining Teacher Leadership

Teacher leadership is difficult to define due to teacher leaders serving diverse roles (Consenza, 2015; Poekert et al., 2016; York-Barr & Duke, 2004;). York-Barr and Duke (2004) defined teacher leadership as "the process by which teachers, individually or collectively, influence their colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement" (p. 287-288). Teacher leadership has also been defined or described as teachers who are mentoring new teachers, working on school improvement efforts, developing curriculum, and providing PD for their colleagues (Dozier, 2007). Teacher leaders use effective instructional strategies (Green & Kent, 2016) and collaborate within their professional community (Luft et al., 2016). The Teacher Leadership Exploratory Consortium (2011) helped to define teacher leadership by developing standards which included seven domains of teacher leadership attributes. Domains include: (a) fostering a collaborative culture to support educator development and student learning, (b) accessing and using research to improve practice and student learning, (c) promoting professional learning for continuous improvement, (d) facilitating improvements in instruction and student learning, (e) promoting the use of assessments and data for school and district improvement, (f) improving outreach and collaboration with families and community, and (g) advocating for student learning and the profession.

Defining Integration

Science and mathematics content is often viewed as logically connected (American Association for the Advancement of Science [AAAS], 1990; McBride & Silverman, 1991; Pang & Good, 2000), and therefore efforts to link science and mathematics have been attempted for many years (Berlin & Lee, 2005; Vars, 1991). While integration of the two disciplines is difficult to define, most researchers agree that integration involves teaching two or more disciplines together (Berlin & White, 1992; Davidson et al., 1995; Jacobs, 1989; Lederman & Niess, 1997; Lonning & DeFranco, 1997). Huntley (1998) described integration as “one in which a teacher, or teachers, explicitly assimilates concepts from more than one discipline during instruction” (p. 321). According to Berlin and White (1995), “Throughout the literature, there is a general sense that integration is a 'good thing.' However, very little has been reported that explicitly describes what it means to integrate mathematics and science” (p. 22). Nonetheless, the integration of science and mathematics has been of interest to educators and researchers for over 100 years (Berlin & Lee, 2005; Czerniak, 2007; Czerniak, Weber, Sandmann, & Ahern, 1999; Hurley, 2001).

Mathematics and Science Integration

A growing interest in mathematics and science integration has increased in the past years (Berlin & Lee, 2005). The *Benchmarks for Science Literacy* (AAAS, 1993) described integration as “The ideas and practice of science, mathematics, and technology are so closely intertwined that we do not see how education in any one of them can be undertaken well in isolation from the others” (p. 321-322). Students connecting mathematics to other subjects can develop a deeper and long-lasting understanding (NCTM, 2000). McBride and Silverman (1991) recommended school administrators demonstrate leadership by providing instructional strategies to elementary and middle school teachers for integrated mathematics and science instruction. Integrating mathematics and science content may be uncomfortable for educators initially, but providing support through an integrated mathematics and science PD program ultimately leads to professional growth and empowerment in their content knowledge (Gomez-Zwiep & Benken, 2012). Schleigh et al. (2011) suggested that integrating mathematics and science content should start in incremental steps.

Mathematics and science have overlapping concepts that can enrich the content of one another by implementing integration (Furner & Kumar, 2007). Therefore, integrating science and mathematics can occur in various ways such as problem-based learning invoking process skills (Davidson et al., 1995; Furner & Kumar, 2007; Meyer et al., 2010). Mathematics process standards and science's five E's are conceptually correlated when examining the learning process of both content areas (Bossé, Lee, Swinson, & Faulconer, 2010). The NCTM (2000) stated, "The processes and content of science can inspire an approach to solving problems that applies to the study of mathematics" (p. 66). The NGSS (2013) mutually supports both science and mathematics content by including mathematics in the development of the science standards.

Teachers must have the pedagogical content knowledge to be successful in integrating mathematics and science (Frykholm & Glasson, 2005; Schleigh et al., 2011). However, most educators lack experience and have no reference for integrating mathematics and science content unless they participated in an integrated PD program (Schleigh et al., 2011). Meyer et al. (2010) reported that teachers had difficulty identifying whether or not a lesson was integrated in mathematics and science when given multiple scenarios. Teachers would be able to better identify and implement integration in their lesson if they participated in a PD program focused on mathematics and science integration (Stinson, Harkness, Meyer, & Stallworth, 2009). Gomez-Zwiep and Benken (2012) suggested PD designers should be aware of teachers' lack of understanding of integration so designers can meet this challenge.

Professional Development

PD has been identified as an effective approach for improving professional growth (Basista & Matthews, 2002; Geldenhuys & Oosthuizen, 2015, Holloway, 2006; Kennedy, 2016; Schleigh et al., 2011; Yow & Lotter, 2016). Professional learning is too complex to compile a list of characteristics that make a PD program effective since school campus' needs vary (Guskey, 2003; Tohill 2009). Kennedy (2016) found most research agrees that PD should focus on content knowledge. Wilson (2016) stated teachers need supportive conditions and a shared vision for their campus to achieve their full potential. However, many teachers are involved in limited PD (Luft et al., 2016). Limited (35 hours or less in three years) PD and time constraints do not allow teachers to continue their personal growth or development (Wilson, 2016). Zimmerman and May (2003) found principals recognized the importance of providing effective PD, but time constraints and financial restrictions were often identified as a barrier.

Bates and Morgan (2018) recognized seven key elements that contributed to effective PD which included: (1) focusing on content, (2) promoting active learning, (3) supporting teacher collaboration, (4) modeling effective practice, (5) providing coaching and expert support, (6) creating opportunities for feedback and reflection and (7) sustaining the duration of PD. Tohill (2009) also found reflection, discussion, follow-up, support and active participation were characteristics of effective PD. Abu-Tineh and Sadiq (2018) described characteristics of effective PD, as perceived by teachers in Qatar, should enhance teacher's content and pedagogical knowledge, promote collegiality and collaboration, and focus on individual and school improvement. PD should foster a supportive environment where teachers can collaborate with their colleagues (Svendsen, 2017).

Teachers who use effective, research-based content and pedagogy can make an effective impact within their classroom (Poekert et al., 2016). Gomez-Zwiep and Benken (2012) reported over 85% of teachers who received effective PD were inclined to make changes in their future teaching practices after recognizing their own professional growth. Obtaining content knowledge and quality pedagogical skills through PD allows teachers to develop a sense of self-efficacy (Stohlmann, Moore, & Roehrig, 2012). Powell-Moman and Brown-Schild (2011) found an increase in teacher's self-efficacy for inquiry-based instruction and an increase in their depth of STEM content knowledge by participating in an intensive two-year STEM PD program, which primarily focused on inquiry-based instruction and content knowledge.

Schleigh et al. (2011) argued that mathematics and science integration is needed and recommended in-service PD as the most effective way to promote integration. Gomez-Zwiep and Benken (2012) found that teachers who participated in an integrated mathematics and science PD demonstrated professional growth in their content knowledge and pedagogical skills. Basista and Mathews (2002) recognized that programs with intensive summer institutes, academic year support activities, and administrator workshops have been successful in increasing science and mathematics teacher content and integration. Baxter, Ruzicka, Beghetto, and Livelybrooks (2014) found that teachers who participated in an integrated mathematics and science PD consisting of a two-day summer workshop and a six-day-long workshop throughout the school year increased their confidence and were more inclined to connect mathematics and science. Teachers often feel empowered when they understand how to relate mathematics and science grade-level content in a meaningful way and become advocates for integration on their campus (Yow & Lotter, 2016).

Teacher Leadership

Teacher leadership encompasses a variety of work at multiple levels in educational systems (York-Barr & Duke, 2004). Poekert et al. (2016) described a teacher leader as an influential member in their community that guides collaborative professional learning and advocates for those they work amongst. Cosenza (2015) found 5 common themes in teacher leadership. Themes included teacher collaboration, sharing best practices, taking action by advocating change, being a role model for teachers or students, and holding formal roles. Green and Kent (2016) proposed teacher leaders must possess strong pedagogy and content knowledge, be able to collaborate with adult learners, have good communication skills, remain humble, recognize their own growth needs, and be willing to learn from others. For teacher leadership growth to occur, teachers must implement best practices before making an impact on a larger scale (Yow & Lotter, 2016).

Teacher leaders exhibit a vast knowledge of skills and hold characteristics that ultimately result in leading others (Salimullina, Zatsarinnaya, & Nikolenko, 2020). Teacher leaders must possess strong pedagogy and content knowledge (Green & Kent, 2016). Teachers who have strong content knowledge and skills are impacting others within their community (York-Barr & Duke, 2004). Participating in an inquiry-based integrated mathematics and science PD project may lead to changes in a teacher's practice and confidence in their instruction (Baxter et al., 2014). Yow and Lotter (2016) suggest teachers who gain confidence by improving their content and pedagogy can influence teaching and learning mathematics and science outside their classrooms. When teachers become enriched with learning best practices, they often feel empowered to share their knowledge to other educators (Cosenza, 2015). As they learn and build onto their knowledge, they also transform their practice and essentially extend it onto their campus (Darling-Hammond, Bullmaster, & Cobb, 1995).

Teacher leaders are enhancing their own growth as well as contributing to their colleagues' growth (Hanuscin et al., 2012). Effective teacher leaders are able to work with others, but must also be willing to learn from others (Green & Kent, 2016). Teacher leaders seek to improve their own practices by refining their skill, and eventually promote their understandings of teaching and learning to their colleagues (Lieberman & Miller, 2005). Developing collaborative relationships is foundational to influencing their colleagues (York-Barr & Duke, 2004). Poekert et al. (2016) found the common impact of teacher leadership development is developing relationships. Klentschy (2008) recommends districts enable teachers the ability to work with others in order to enhance their classroom instruction.

Impacting the classroom, school, or community is an outcome of teacher leadership (Poekert et al., 2016). Yow and Lotter (2016) found that teachers who deepen their content knowledge and pedagogy began sharing teaching practices with their colleagues at school and within their district. Fostering teacher leadership requires preparation and support for developing effective instructional leaders (Nicholson et al., 2016). Teachers who felt supported reported feeling more encouraged to take on leadership roles (Luft et al., 2016). Ongoing PD that educates teachers on how to lead within their field must be provided (Luft et al., 2016). When there is a lack of shared leadership with administration, teachers do not feel a sense of empowerment and are discouraged to buy-in to PD (Wilson, 2016).

The science and mathematics national standards recognize the importance of mathematics and science content integration (NCTM, 2000; NRC, 1996). NCSM and NSES also agree that effective leadership requires teachers to be part of this process (NCSM, 2008; NRC, 1996). Teachers who seek to improve their knowledge and skills will possess the tools into leading others (Darling-Hammond et al., 1995; Lieberman & Miller, 2005; Salimullina et al., 2020). Considering these recommendations, I sought to understand how an intensive mathematics and science integrated PD program would impact teacher leadership.

III. METHODOLOGY

I investigated teacher leadership growth on participants who volunteered in a two-year MIX PD program by applying a mixed methods research approach. I explored if and how teacher leadership occurred to gather information about my three research questions. In my study, I used five data sources to understand teacher leadership characteristics of my participants after they completed the MIX PD program. These five data sources included: (a) Teacher Quality (TQ) reflections, (b) classroom observations, (c) Teacher Leadership Survey, (d) MIX/PRIME Leadership Framework Survey, (e) and a multiple-case study.

The process of collecting data occurred in three phases. During Phase 1 of my study (see Figure 2), I examined my participants' TQ reflections and MIX's classroom observation forms to understand if teacher leadership growth occurred and what types of leadership characteristics participants displayed. I created the Teacher Leadership Survey to identify the types of leadership characteristics my participants felt they attained after participating in the MIX PD program. I utilized the MIX/PRIME Leadership Framework Survey for my participants to self-report the stage of leadership they achieved.

The MIX/PRIME Leadership Framework Survey helped me identify participants who self-reported attaining the highest stage of teacher leadership, Stage 3, upon completing the MIX PD program. According to the *PRIME Leadership Framework*, Stage 3 is the highest level of leadership, which includes leadership at the district and beyond (NCSM, 2008). During Phase 2 of my study, I used my Teacher Leadership Survey to identify my participants' teacher leadership characteristics. I investigated the leadership characteristics of the ten participants who self-reported being Stage 3 leaders on their MIX/PRIME Leadership Framework Survey.

During Phase 3, I interviewed four participants that I purposefully selected in a multiple-case study to better understand how they progressed into Stage 3 teacher leadership roles. I selected a Type 3 multiple-case study by using purposeful sampling of self-reported Stage 3 teacher leaders who reported leading at the state level. I used a Type 3 multiple-case study to gather information from multiple cases of teacher leaders to gain a holistic approach on Stage 3 teacher leadership (Yin, 2018). Using a multiple-case study, I gathered enriched details to understand how four participants achieved Stage 3 teacher leadership after participating in the MIX PD program (Yin, 2018).

Three research questions were used to guide my methodology:

1. What are the teacher leadership characteristics of the teachers (n=23) who participated in the MIX program?

2. What are the teacher leadership characteristics of a Stage 3 teacher leader (n=10) who participated in the MIX program?

3. How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?

Research Design

I selected a mixed methods triangulation design by utilizing descriptive statistics and a multiple case-study. Using descriptive statistics, I was able to determine my participants' teacher leadership characteristics and the stage of leadership each one reported. I utilized a multiple-case study to understand how four participants, who I purposefully selected, achieved Stage 3 leadership. My three research questions were organized within three phases (see Figure 2).

Sampling Phases	Research Question	Sampling	N	Data Sources	Data Analyses
Phase 1	What are teacher leadership characteristics of a teacher who participated in MIX?	Criterion	23	Teacher	A Priori Coding for Teacher Leadership Characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				Classroom Observations	A Priori Coding for best practices in CSM pedagogical practices (West & Tooke, 2001)
				Teacher Leadership Survey	Transformed 4-point self-identified Likert scale responses by Teacher Leadership characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				MIX/PRIME Leadership Framework Survey	Transformed 3 self-identified Stages of Teacher Leadership (NCSM, 2008)
Phase 2	What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?	Criterion	10	Teacher Leadership Survey	Transformed 4-point self-identified Likert scale responses by Teacher Leadership characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				MIX/PRIME Leadership Framework Survey	Transformed 3 self-identified Stages of Teacher Leadership (NCSM, 2008)
Phase 3	How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?	Purposeful	4	Interviews	Emergent Coding (Saldana, 2016)

Figure 2. Research questions by three phases.

I used a mixed methods triangulation design to simultaneously gather qualitative and quantitative data to interpret how teacher leadership growth occurred. I collected qualitative data via teacher reflections, classroom observations, and teacher interviews to understand their teacher leadership growth. I further investigated the lived experiences of four participants who self-reported moving into Stage 3 leadership using a multiple-case study (Yin, 2018). I gathered quantitative data on my survey by assigning numerical codes to each teacher leadership characteristic to quantify the data of self-reported Stage 3 leaders and their teacher leadership characteristics.

Methodological Terminology

My study used methodological terminology throughout the methods section of my paper. Below is a list of definitions I used throughout chapter three to provide context for its meaning.

A Priori coding- A list of codes that I constructed of teacher leadership characteristics at the start of my study (Saldana, 2016).

Case study- A social science research method I used to investigate the phenomena of teacher leadership to gather detail on how it occurred (Yin, 2018).

Code- A word or short phrase that represents an attribute of teacher leadership characteristics I constructed from previous literature (Yin, 2018).

Descriptive statistics- to organize and summarize data from studies of samples (Holcomb, 1998).

Emergent Coding- Codes drawn from my cases (Blair, 2015)

Holistic Analysis- A case is the single-unit of analysis (Yin, 2018).

Multiple-case study- A case study organized around two or more case studies (Yin, 2018, p. 287).

Reliability- The consistency and repeatability of producing a case study's findings (Yin, 2018, p. 288).

Unit of Analysis- The "case" is a case study (Yin, 2018).

Validity- The accuracy with which a case study's measures reflect the concepts being studied (Yin, 2018).

Ethical Considerations

For my study, I increased the likelihood of my participants' protection by ensuring their confidentiality for those who chose to volunteer to participate in my study within the guidelines that fall under Instructional Review Board (IRB) # 2018662. Participants who volunteered in the MIX program were asked to provide their consent to participate in my study. I gave each teacher a consent form which stated that each participant could withdraw from my study at any given time. I ensured each of my participant's identity would remain confidential by the usage of pseudonyms throughout my study.

During my study, I communicated with each of my participants during each MIX summer training session. As a researcher, I tried to remain unbiased while gaining insight into teacher leadership. I had conversations with each participant to determine if or how they implemented teacher leadership on their own campus. These discussions helped me to understand what stage of leadership the participants attained. I asked my participants to describe if or how they introduced general best practices and/or if they integrated science and mathematics into their instruction without acknowledging that my research was on teacher leadership. For my multiple-case study, I worked closely with four participants that I purposefully selected and interacted with each one individually during each of the MIX summer training sessions. I also ensured each case's audio-recorded interview would remain confidential and their information would solely be used for the purpose of understanding teacher leadership.

The MIX PD program coordinators also increased the likelihood of the participant's protection and rights by adhering to the requirements under IRB #2016W4728. The TQ Grant is a federally funded grant provided by the U.S. Department of Education's Fund for the Improvement of Postsecondary Education to the Texas Higher Education Coordinating Board protected by IRB #1702-015-1702. The Texas Higher Education Coordinating Board provided the TQ consent form that requested a participant give their permission to participate in the TQ program evaluation. The Texas Higher Education Coordinating Board assigned a TQ number to each participant who participated in the MIX PD program. At the start of the program, a MIX video consent form was provided to participants requesting their permission to be recorded during the MIX sessions. Participants were also asked to sign a project agreement that stated expectations, such as attendance, of the MIX PD program. Mix program coordinators also asked their participants to turn in their state mathematics and/or science test scores using their assigned TQ number.

MIX two-year Professional Development Program Completion

My research study took place at the end of MIX's 2016-2018 two-year PD program to collect data on each of my participant's teacher leadership growth. After reviewing teacher reflections and classroom observations forms, I wanted to understand their teacher leadership characteristics and the level of leadership each participant attained. I e-mailed each participant and asked to volunteer in my study by filling out the

Teacher Leadership Survey and the MIX/PRIME Leadership Framework Survey. Using their responses, I was able to identify participants who self-reported they attained Stage 3 leadership. Teachers who were purposefully selected for my case study were asked to participate in an interview on their school campus to understand how the MIX PD program helped them achieve Stage 3 leadership.

Participants

The process of collecting data for each participant occurred in three phases. In Phase 1, I selected participants from the 2016-2018 MIX cohort, which consisted of 23 in-service teachers (n=23) certified in fifth through eighth grade mathematics and/or science at Texas State University in San Marcos. Participants' experience ranged from 0-23 years of classroom experience (see Table 1). I collected their level of education by college hours in mathematics or science topic area and the highest degree they obtained. Table 1 illustrates the grade level the participants taught at the time of study. The grade level participants taught ranged from fourth through twelfth grade. Phase 2 participants included self-reported Stage 3 teacher leaders (n=10). Phase 3 participants were four participants (n=4) within my case study that I purposefully sampled who self-reported they attained Stage 3 leadership.

Table 1

Participant Level of Education and Teaching Experience in Years

Teacher Name	Years Teaching	College Hours In Project	Highest Degree Attained	Grade Level Teaching
Cindy	0	12	B.S. Int. Disc.	5
Bianca	1	76	B.S. Biology	6
Sonya	1	0	B.S. Int. Disc.	5
Mary	1	15	B.S. Int. Disc.	5
Helen	1	17	B.A. Int. Disc.	5
Samantha	1	77	B.S. Biology	12-Sep
Madeline	2	51	B.S. Int. Disc.	8-Jun
Jean	2	8	B.S. Int. Disc.	6
Linda	2	79	B.S. Int. Disc	7
Sean	2	45	M.A. Higher Education	7
Claudia	2	15	B.A. Int. Business	5
Jessica	3	21	M.A. Education	5
Lisa	4	30	B.S. Education	7
Dorothy	4	83	M.A. Math	7 & 8
Marsha	4	7	M.Ed. Elem. Education	4
Jane	6	28	M.A. Special Education	5
Michelle	6	59	M. Ed. Elem. Education	7 & 8
Elizabeth	6	24	M.S. Education	7 & 8
Samuel	8	0	M.S. Psychology	8
Diane	9	16	B.S. Int. Disc.	5
Ellen	11	11	M.Ed. Ed Lead.	5
Julia	20	9	B.S. Int. Disc.	5
Dora	23	6	M.A. Elem. Ed.	5

Note. B.S.= Bachelor of Science; Int. Disc. = Interdisciplinary Studies; B.A.= Bachelor of Arts; M.A. = Master of Arts; Int. Business= International Business; M. Ed Elem. Education = Master of Education in Elementary Education; M.A. Elem. Ed.= Master of Arts in Elementary Education; M.S.= Master of Science; M.Ed. Ed Lead= Master of Arts in Educational Leadership.

Sampling

For my three research questions, I selected a sample of participants using three phases to gain a better understanding of teacher leadership. I used criterion-based sampling in Phase 1 and 2, while using the purposeful sampling method in Phase 3. My sample in Phase 1 included 23 participants (n=23) to determine their teacher leadership characteristics. Using the MIX/PRIME Leadership Framework Survey, I asked participants to indicate the stage of leadership they attained at the end of the MIX PD program (NCSM, 2008). I identified the participants who self-reported they attained Stage 3 leadership for Phase 2 sampling using their responses from the MIX/PRIME Leadership Framework Survey (n=10). Participants who self-reported Stage 3 leadership were purposefully sampled for my case study (n=4) to provide enriched detail about how they attained Stage 3 leadership.

Phase 1: Criterion-based sampling. I utilized criterion-based sampling for collecting data on teacher leadership. The criterion for my sample included certified teachers in fifth through eighth grade mathematics and/or science who completed the two-year MIX PD program. In Phase 1, I initially sampled 23 participants (n=23) to investigate if participants reported growth in teacher leadership and what stage of leadership they attained.

Phase 2: Criterion-based sampling. I utilized criterion-based sampling by selecting participants from Phase 1 (n=23) who self-reported they attained Stage 3 leadership on their MIX/PRIME Leadership Framework Survey. The sample included participants from Phase 1 who completed the MIX PD program and reported they advocated for implementing best teaching practices at the district, region, or state level.

Ten participants (n=10) who self-reported reaching Stage 3 leadership were sampled in Phase 2 of my study to understand their Stage 3 leadership characteristics upon completing the MIX PD program.

Phase 3: Purposeful sampling. For my case study, I purposefully selected four individual cases (n=4) from my Phase 2 sample. The four cases from my case study self-reported attaining Stage 3 leadership and were leading at the state level. I used purposeful sampling to select four participants that best represented the broader scope of my study; teacher leadership (Yin, 2018).

Procedures

I utilized five data sources to understand how Stage 3 teacher leadership occurred in the MIX PD program (see Figure 3). Based on my literature review findings, I wanted to understand if teacher leadership growth occurred in the MIX PD program and to identify their teacher leadership characteristics. For my first research question, I investigated what teacher leadership characteristics were exhibited after participating in the MIX PD program. The TQ Reflection Prompt, classroom observations, Teacher Leadership Survey, and the MIX/PRIME Leadership Framework Survey gave me insight into which teachers self-reported they progressed into Stage 3 leadership. I was able to use the data I collected to answer my second research question, "What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?" I identified participants who self-reported they attained Stage 3 leadership and purposefully sampled four participants for my multiple-case study.

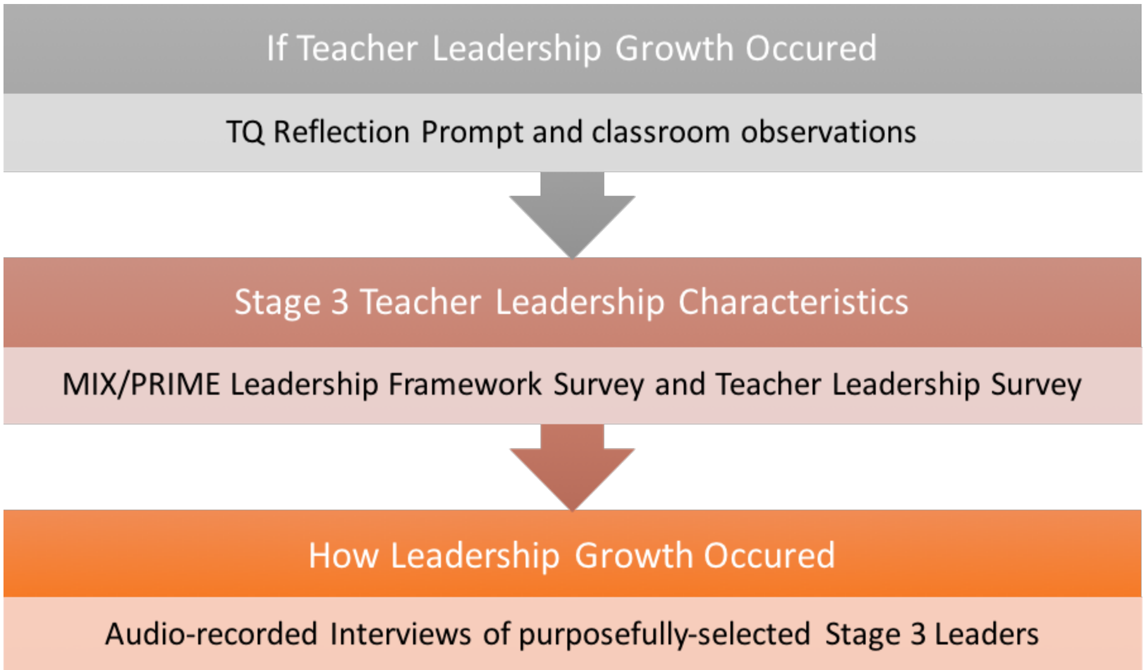

Figure 3. Timeline of procedures for collecting data.

Phase 1 procedures. In Phase 1, I used four instruments to collect data from participants from the 2016-2018 MIX PD program. My instruments included the TQ Reflection Prompt, TQ Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, and the MIX/PRIME Leadership Framework Survey (see Figure 4). These four instruments helped me in understanding my first research question, "What are teacher leadership characteristics of the teachers who participated in the MIX program?"

Sampling Phases	Research Question	Sampling	N	Data Sources	Data Analyses
Phase 1	What are teacher leadership characteristics of a teacher who participated in MIX?	Criterion	23	Teacher Reflection Prompt	A Priori Coding for Teacher Leadership Characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				Classroom Observations	A Priori Coding for best practices in CSM pedagogical practices (West & Tooke, 2001)
				Teacher Leadership Survey	Transformed 4-point self-identified Likert scale responses by Teacher Leadership characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				MIX/PRIME Leadership Framework Survey	Transformed 3 self-identified Stages of Teacher Leadership (NCSM, 2008)

Figure 4. Phase 1 procedures.

Initially, I collected data from the TQ reflection administered at the end of the two-year MIX PD program on teacher leadership. The TQ reflection prompt given by THECB asked participants to report their own professional growth throughout the MIX PD program. I used this reflection prompt to understand if teacher leadership was being reported after participating in the MIX PD program.

I collected the data from classroom observations using the TQ Mix It Up: Correlated Science and Math Observation Form (see Appendix A) to detect if the MIX program instructors observed participants using general best practices and/or integrating science and mathematics in their instruction during their classroom observation. This helped me understand if the best practices introduced in the MIX PD program were being implemented in their classroom.

Reviewing the literature of mathematics and science teacher leadership, I created a Teacher Leadership Survey (York-Barr & Duke, 2004; Green & Kent, 2016). My survey included teacher leader traits and MIX identified pedagogical characteristics. I administered the Teacher Leadership Survey to my participants to understand their perception of their teacher leadership characteristics. I used the MIX/PRIME Leadership Framework Survey for my participants to indicate the stage of leadership they felt they achieved after participating in the 2016-2018 MIX PD program (NCSM, 2008; Yow & Lotter, 2016).

Phase 2 procedures. I utilized two instruments in Phase 2 of my study to gather data from my participants who self-reported Stage 3 leadership (see Figure 5). My instruments included the Teacher Leadership Survey and the MIX/PRIME Leadership Framework Survey. I used the MIX/PRIME Leadership Framework Survey to identify self-reported Stage 3 teacher leaders (n=10) in my study (NCSM, 2008; Yow & Lotter, 2016). Administering the Teacher Leadership Survey to my participants helped me to recognize the leadership characteristics self-reported Stage 3 leaders felt they held.

Sampling Phases	Research Question	Sampling	N	Data Sources	Data Analyses
Phase 2	What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?	Criterion	10	Teacher Leadership Survey	Transformed 4-point self-identified Likert scale responses by Teacher Leadership characteristics (Green & Kent, 2016; York-Barr & Duke, 2004)
				MIX/PRIME Leadership Framework Survey	Transformed 3 self-identified Stages of Teacher Leadership (NCSM, 2008)

Figure 5. Phase 2 procedures.

Phase 3 procedures. I purposefully selected four participants for my multiple-case study (n=4) who self-reported they attained Stage 3 leadership on their MIX/PRIME Leadership Survey and reported leading at the state level. I interviewed and audio-recorded four purposefully selected Stage 3 teacher leaders in Phase 3 (see Figure 6). I conducted an interview on each selected case (n=4) to capture the details of Stage 3 teacher leaders and their professional growth.

Sampling Phases	Research Question	Sampling	N	Data Sources	Data Analyses
Phase 3	How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?	Purposeful	4	Interviews	Emergent Coding (Saldana, 2016)

Figure 6. Phase 3 procedures.

Instrumentation

I collected data from the 2016-2018 MIX PD program participants for my study through five instruments, which included the TQ teacher reflection prompt, TQ Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, MIX/PRIME Leadership Framework *S*urvey, and audio-recorded interviews (see Figure

7).

Sampling Phases	Research Question	Instruments
Phase 1	What are the teacher leadership characteristics of the teachers who participated in the MIX program?	Teacher Quality Reflection Mix It Up: Correlated Science and Math Observation Form Teacher Leadership Survey MIX/PRIME Leadership Framework Survey
Phase 2	What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?	Teacher Leadership Survey MIX/PRIME Leadership Framework Survey
Phase 3	How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?	Interviews

Figure 7. Instruments per research question.

Phase 1 Instrumentation. In Phase 1, I collected data from the TQ Teacher Reflection prompt, Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, and MIX/PRIME Leadership Framework Survey. I also described issues regarding reliability and validity within my selected instruments.

TQ reflection prompt (n=23). The TQ grant requires MIX participants to complete a final reflection at the end of each MIX training session. I used the TQ Reflection Prompt 48 (see Figure 8) on teacher growth for understanding their progression into teacher leadership. Participants completed the reflective prompt on their growth at the end of the school year. The TQ Reflection Prompt 48 gave me a better understanding to my first research question, "What are the teacher leadership characteristics of the teachers who participated in the MIX program?" Participants also elaborated on the level of leadership they attained while in the MIX PD program. Individuals were asked by THECB to openly respond on the various roles they served within and outside their classroom. I notated the roles participants upheld and understood how the MIX PD program helped participants achieve their growth in teacher leadership.

Validity. I did not validate the TQ reflective prompt instrument in my study. The TQ reflective prompt was required by the funder, THECB.

Reliability. Due to the MIX program only administering the teacher leadership TQ Reflection Prompt twice per year, I was unable to ensure the reliability of this instrument. The MIX program project coordinators administered the TQ reflective prompt twice throughout the 2016-2018 MIX program.

1. Describe how your Teacher Quality experiences have fostered your growth as a teacher resulting in an expanded role in your school or district setting. You might consider areas such as: departmental and school leadership responsibilities; collaboration with, mentoring, or coaching fellow teachers; participation in professional organizations (including presentations at the local, regional, or state level); school or district committee participation or leadership; leadership in extracurricular, academic programs; or other leadership examples.

Figure 8. Teacher Quality Reflection Prompt 48.

Mix It Up: Correlated Science and Math Observation Form (n=23). MIX observers (instructors and mentors) documented each classroom observation using the Mix It Up: Correlated Science and Math Observation Form (see Appendix A). Each participant was observed on their own campus during their classroom instruction. MIX observers documented if and how participants used best practices in general teaching strategies and if they integrated science and mathematics as modeled in the MIX PD program. I used this data to uncover if my participants were implementing general best practices and/or if they were integrating science and mathematics into their instruction to aid in their professional growth.

The MIX PD program defined integration for mathematics teachers as making connections between both disciplines by: (a) using science content/natural world phenomena examples, (b) using science equipment, (c) analyzing science data, (d) referencing relevant science classroom experiences, or (e) using the proper science language into mathematics curriculum.

Similarly, integration by science teachers is defined as making the connections between the disciplines clear and include: (a) using mathematics in science instruction, (b) using mathematics manipulatives, (c) using mathematics in the same manner as is taught in the mathematics classes and not undermine conceptual understanding by teaching mathematics' tricks, and (d) using the proper mathematics language (West & Singh, 2007).

The Mix It Up: Correlated Science and Math Observation Form included implementation of effective strategies, general best practices and integration of science and mathematics during their instruction. The observers rated the lesson based on what they observed within each section of the form. The observer ranked each section from 0-3, with 3 being the highest level implemented in the participant's instruction. N/A was also an option on the form because, for example, there are science or math topics in which integration would be artificial. MIX observers conducted field observations in each of the participant's classroom and observed if each participant used effective teaching strategies and/or if they integrated science and mathematics. MIX observers debriefed with each of the participants at the end of each lesson in their classroom.

Validity. The Mix It Up: Correlated Science and Math Observation Form, created by the project directors, was validated and based on the Texas A&M University meta-analysis on effective science teaching strategies (Schroeder, Scott, Tolson, Huang, & Lee, 2007).

Reliability. The Mix It Up: Correlated Science and Math Observation Form was not a reliable instrument. MIX project observers utilized the form for each participant they observed. The observation form was utilized to understand effective teaching strategies implemented in their classroom instruction.

Teacher Leadership Survey (n=23). I created the Teacher Leadership Survey that included literature identified teacher leader characteristics, and MIX identified general best practices, and integrated science and mathematics. I used a literature review to identify characteristics of teacher leaders and included them in my Teacher Leadership Survey (Green & Kent, 2016; York-Barr & Duke, 2004). I also incorporated MIX identified general best practices and science and mathematics integration that were explicitly taught and modeled through the MIX PD program.

I administered the MIX Teacher Leadership close-ended survey that I created to my participants containing 23 questions to gather their perception of their teacher leadership characteristics. Leadership characteristics in my survey included willingness to grow, possessing strong content, strong pedagogy, MIX identified general best practices, integrated science and mathematics, and working with their team along with other characteristics (see Appendix B). I asked participants in my study to select the characteristics of teacher leadership they possessed in a close-ended MIX Teacher Leadership Survey (see Figure 9 for example items).

Teacher Leadership Survey
Please fill in the response that best represents the characteristics you possess.
1. Willingness to grow. ○ A. Strongly Agree ○ B. Agree ○ C. Disagree ○ D. Strongly Disagree **2. Possess strong pedagogy.** ○ A. Strongly Agree ○ B. Agree ○ C. Disagree ○ D. Strongly Disagree **3. Intrinsically motivated.** ○ A. Strongly Agree ○ B. Agree ○ C. Disagree ○ D. Strongly Disagree

Figure 9. Example items of the close-ended Teacher Leadership Survey.

Each of my participants (n=23) responded on a four-point Likert scale survey. For questions 1-16, 22, and 24, I used a scale ranging from strongly agree, agree, disagree, and strongly disagree on my Teacher Leadership Survey to measure their use of general best practices as a reflection of their degree of leadership. In contrast, for questions 17-21 and 23, I applied a Likert scale ranging from always, often, not very often, and never. These questions were based on the CSM model and general best practices frequently practiced in the MIX PD training sessions. Using the teacher leadership characteristics responses, I was able to identify my participants' perception of their teacher leadership characteristics.

Validity. My Teacher Leadership instrument was not validated. I used multiple research studies to identify teacher leadership characteristics that I incorporated into my survey questions (Green & Kent, 2016; York-Barr & Duke, 2004).

Reliability. My Teacher Leadership Survey was not reliable. I administered the instrument once at the end of the two-year MIX PD program and did not use the survey consistently and repeatedly for measured reliability.

MIX/PRIME Leadership Framework Survey (n=23). The *PRIME Leadership Framework* is a guide that includes principles, indicators, knowledge, and skills that are used for educational leadership in mathematics (NCSM, 2008). The NCSM (2008) *PRIME Leadership Framework* is based upon four principles with three specific indicators. I selected Leadership Principle 2, Teaching and Learning, whereas the other principles were based on Equity, Curriculum, and Assessment Leadership. Specifically, within Principle 2, I selected Indicator 2 because of its focus on the implementation of research-based strategies, which aligns with the MIX PD program.

According to NCSM's *PRIME Leadership Framework* (2008) Indicator 2, Stage 1 leaders use research-based best practices for effective student learning. Stage 2 leaders engage in collaborative dialogue with their colleagues to support teachers in implementing and understanding the importance of research-based strategies. Stage 3 is the highest level a teacher attains by advocating and implementing research-based best practices at the district, regional, or province level.

I created the MIX/PRIME Leadership Framework Survey (see Figure 10) based on NCSM's *PRIME Leadership Framework* (2008) Indicator 2 and included science integration within the descriptors (Yow & Lotter, 2016). I administered my survey to the participants at the end of the MIX PD program. Using my survey, I asked each of my participants to self-report what stage of leadership they attained within the MIX PD program. The participants selected from Stage 1, Stage 2, or Stage 3. This helped me to understand what stage each participant reported they achieved at the end of the MIX PD program.

Using the MIX/PRIME Leadership Framework Survey below, please select the leadership level you have attained during Mix It Up training.

<table>
<tr><td colspan="4">MIX/PRIME Leadership Framework Survey
Teaching and Learning
Principle 2: Ensure high expectations and access to meaningful mathematics instruction every day.</td></tr>
<tr><td>Indicator</td><td>Stage 1 Leaders
Leadership of Self</td><td>Stage 2 Leader
Leadership of Others</td><td>Stage 3 Leader
Leadership in the extended community</td></tr>
<tr><td>2. Every teacher implements research-informed best practices and uses effective instructional planning and teaching strategies.</td><td>• Develop and model knowledge of research informed instructional strategies and best practices for effective student learning of science and mathematics.
• Formulate and implement effective lesson planning to achieve intended learning goals.
• Develop and model knowledge of tools necessary to assess the current status of teaching practices.
• Recognize the importance of technology integration into the science and mathematics curriculum.</td><td>• Determine the current status of teacher knowledge and implementation of research informed, effective instructional strategies.
• Facilitate growth of teachers' scientific and mathematical knowledge and implementation of research informed best practices.
• Engage teachers' in collaborative dialogue about research-informed instructional practices and planning for effective student learning of science and mathematics.
• Collaborate with and support teachers in integrating technology into the science and mathematics curriculum.</td><td>• Ensure implementation of best-practice instruction in every student's learning experience throughout the district, region, or province.
• Facilitate a systematic continuous process of science and mathematics instructional improvement that reflects current research informed practices.
• Ensure the ongoing use of technology as an embedded and systematic part of the science and mathematics curriculum and instruction at the district, regional, or provincial level.</td></tr>
</table>

Figure 10. MIX/PRIME Leadership Framework Survey. Adapted from "Teacher Learning in a Mathematics and Science Inquiry Professional Development Program: First Steps in Emergent Teacher Leadership*,"* by J. Yow and C. Lotter, 2016, *Professional Development in Education*, *42*, p. 325-351 Copyright 2016 by Taylor & Francis.

Validity. NCSM validated the *PRIME Leadership Framework* by experts in research from the math education writing team (NCSM, 2008). The goal of NCSM's *PRIME Leadership Framework* is to improve teacher and student learning in mathematics. In order to make this instrument applicable to teacher leadership in mathematics and science, I utilized Yow and Lotter's (2016) modified version of the *PRIME Leadership Framework* which included both mathematics and science contents in the description. A limitation to the instrument I used was its focus on mathematics. My MIX/PRIME Framework Leadership Survey was not tested for validity.

Reliability. My MIX/PRIME Leadership Framework instrument was not reliable because it was not consistently and repeatedly administered due to the time restraints of the school year.

Phase 2 Instrumentation. In Phase 2, I collected data from my participants using my instrument, the Teacher Leadership Survey. I used the MIX/PRIME Leadership Framework Survey for research question two to identify participants at Stage 3 leadership and what leadership characteristics they possessed. I described issues of reliability and validity with my instrument in Phase 2 Instrumentation.

Teacher Leadership survey (n=10). The data collected from the Teacher Leadership closed-ended survey in Phase 1 (see Figure 9) was used to identify self-reported Stage 3 teacher leaders (n=10) and the leadership characteristics they held (Green & Kent, 2016; York-Barr & Duke, 2004). The reliability and validity of this instrument was discussed in the Phase 1 Instrumentation section of this paper.

Phase 3 Instrumentation. My MIX/PRIME Leadership Survey helped me to understand which participants identified attaining Stage 3 leadership and this helped me purposefully select four participants (n=4) for my multiple-case study. In Phase 3, I purposefully selected four participants (n=4) from the sample of self-reported Stage 3 teacher leaders (n=10) from Phase 2. I conducted audio-recorded interviews on their experience of attaining Stage 3 leadership. I addressed concerns for reliability and validity within my instrument.

Stage 3 leadership audio-recorded interviews (n=4). I conducted an audio-recorded interview to get an in-depth story of teacher leadership experiences from Stage 3 self-reported participants (n=4) that I purposefully selected for my multiple-case study. For our interview, I asked the four participants the following four questions. My four questions included:

1. How has participating in MIX PD resulted in your professional growth as a teacher leader?
2. What type of roles have you served in your school, district, community, or state level as a result of MIX professional development?
3. Can you describe how you have advocated for mathematics and science content integration and the use of best practices starting from your classroom to others outside your classroom (team, campus, district, state level etc.)?
4. Are there any other details you would like to include to better understand teacher leadership in a mathematics and science integrated professional development program?

Audio-recorded interviews helped me to better understand the teacher leaders' characteristics and how their experience in the MIX PD program helped them attain Stage 3 teacher leadership.

Validity. This instrument was not validated in my study.

Reliability. My four purposefully-selected cases for my case study were all provided the same four interview questions and were audio-recorded to increase reliability in my study.

Data Analysis

I analyzed my five data sources, which included the TQ Reflection Prompt, Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, MIX/PRIME Leadership Framework Survey, and Stage 3 leadership audio-recorded interviews. I analyzed each data source within each of the three phases to answer my three research questions. In Phase 1, I analyzed the TQ Reflection Prompt, Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, and the MIX/PRIME Leadership Framework Survey. In Phase 2, I analyzed the data from the Teacher Leadership Survey and MIX/PRIME Leadership Framework Survey by transforming each of my participant's responses into variable data to be analyzed using descriptive statistics. I applied emergent coding within Phase 3 of my data analysis to recognize patterns that emerged from self-reported Stage 3 teacher leaders.

Phase 1 Data Analysis. In Phase 1, I collected and analyzed my data using my four selected instruments, which included the TQ Reflection Prompt, Mix It Up: Correlated Science and Math Observation Form, Teacher Leadership Survey, and MIX/PRIME Leadership Framework Survey. I analyzed my qualitative data using participants' reflections and the Mix It Up: Correlated Science and Math Observation Forms to determine if the participant held any specific teacher leadership characteristics. I analyzed the quantitative data using my Teacher Leadership Survey and MIX/PRIME

Leadership Framework Survey to identify their teacher leadership characteristics and the stage of teacher leadership each participant attained at the end of the MIX PD program.

TQ Reflection Prompt (n=23). Initially, I wanted to understand if the participant was a teacher leader or if growth in teacher leadership occurred as evidenced by teachers reporting implementation of general best practices and/or integrating science and mathematics at the end of the MIX PD program. I created a list and employed A Priori coding to analyze the TQ reflection prompts. I analyzed each TQ reflection prompt by coding each response with “clear evidence”, “some evidence”, and “no evidence” to determine if there was indication of teacher leadership characteristics or growth (Saldana, 2016). For example, evidence of teacher leadership could be holding the position of a department chair whereas growth in teacher leadership could be a teacher who is not a department chair introducing best practices to their team.

Mix It Up: Correlated Science and Math Observation Form (n=23). I wanted to investigate if and at what level participants were implementing general best practices and/or integrating science and mathematics in their instruction. I reviewed each observer’s observation form (see Appendix A) and created a data table to input each participant's date of the observation, best practices overall score for each observation, integration of science and mathematics observed, a summary score for each observation, a summary score for all of the observations and a Researcher's global score (see Table 2).

The participants were randomly observed anywhere between two to eleven times between September 2016- February 2018. MIX observers reported a Best Practices Overall Score, which could range from 0 (not at all)-3 (greatest extent). An Integration of Science and Mathematics Score was reported by the MIX instructors for each observation ranging from yes, no, or not applicable (N/A). N/A was used by the observers when integration was not appropriate and should not be in the instruction. I assigned a range of scores of integrated lessons from 0-2 with 0 for not integrated, 1 for N/A, and 2 for integrated. I calculated the sum of the Best Practice Overall Score and their Integration of Science and Mathematics Score to obtain their Total Individual Observation Score. For their Average Score of All Observations, I averaged each participant’s Total Individual Scores.

I created a Global Score by first applying A Priori coding to understand the level of MIX identified general best practices participants incorporated during the MIX instructors’ classroom observations (Saldana, 2016). I coded each summary score as providing “clear evidence”, “some evidence”, and “no evidence" of general best practices implementation and/or integration of mathematics and science (see Appendix C). Participants whose average ranged from 0-1.9 received “no evidence” on their Average Score of All Observations. Participants whose average ranged from 2.0-3.6 received “some evidence,” while participants whose average ranged from 3.7-5 received “clear evidence.”

Table 2

Summary of Participants' Observation Scores and Researcher's Global Score.

TQ Number	Date of Observation	Best Practice Overall Score	Integration of Science and Mathematics Score	Total Individual Observation Score	Average Score of all Observations	Global Score:

Note. n=23.

Teacher Leadership Survey (n=23). For each of the 23 identified teacher leadership characteristics of my Teacher Leadership Survey, I analyzed the data by transforming each participant's response from a four-point Likert scale into ordinal data (Green & Kent, 2016; York-Barr & Duke, 2004). For questions number 1- 16, 22, and 24, I assigned numerical values to each response such as 1 to "strongly agree", 2 to "agree", 3 to "disagree", and 4 to "strongly disagree". For questions number 17-21, I assigned numerical values to each response such as 1 to "always", 2 to "often", and 3 to "never". I applied descriptive statistics using the numerical data from their responses to calculate the percentage of participants who reported holding each characteristic. I used Microsoft Excel to calculate the total percentage of each participant's teacher leadership characteristics and plotted the data onto a bar graph.

MIX/PRIME Leadership Framework Survey (n=23). I analyzed my data by utilizing the three stages of leadership from the MIX/PRIME Leadership Framework Survey to determine what stages of leadership participants reported. Using descriptive statistics, I calculated the percentages of participants in each of the self-reported stages of teacher leadership using Microsoft Excel. I plotted the percentages of each of the three leadership stages my participant's self-reported onto a bar graph.

Phase 2 Data Analysis. In Phase 2, I analyzed the data of Stage 3 self-reported teacher leaders from my MIX/PRIME Leadership Framework Survey and Teacher Leadership Survey. I transformed each of my participant's MIX/PRIME Leadership Framework Survey responses by using a three-point Likert scale to indicate which participants attained Stage 3 leadership. I transformed each of the participant's Teacher Leadership Survey responses, using a four-point Likert scale, to determine the leadership characteristics self-reported Stage 3 leaders attained. Using descriptive statistics, I calculated the percentage of self-reported Stage 3 teacher leaders. I also calculated and plotted Stage 3 self-reported teacher leaders and each of their indicated characteristics onto a bar graph.

MIX/PRIME Leadership Framework Survey (n=10). I analyzed the data of Stage 3 self-reported teacher leaders. Using descriptive statistics, I calculated the total number of Stage 3 self-reported teacher leaders. I identified ten participants (n=10) in my study who self-reported they were at Stage 3 teacher leadership according to the *PRIME Leadership Framework* (NCSM, 2008). I plotted the percentages of Stage 3 self-reported teacher leaders onto a bar graph using Microsoft Excel.

Teacher Leadership Survey (n=10). I analyzed the data from the Teacher Leadership Survey of self-reported Stage 3 leaders (n=10) and their identified leadership characteristics and transformed each of their responses using a four-point Likert scale. I applied descriptive statistics by calculating the percentage of each Stage 3 teacher leader's characteristics using Microsoft Excel. I plotted Stage 3 teacher leader responses onto a bar graph to understand if patterns emerged from their reported characteristics.

Phase 3 Data Analysis. I purposefully selected four Stage 3 participants (n=4) who obtained the highest level of teacher leadership and interviewed them for my case study. A case study report was written up for each of the case study participants that I selected. Using the case study report, I applied emergent coding to understand patterns across all four cases of their personal teacher leadership growth. I was able to conduct a holistic analysis approach on how participants progressed into higher stages of teacher leadership.

Stage 3 Leadership interviews (n=4). I identified participants who self-reported they attained Stage 3 teacher leadership according to the *PRIME Leadership Framework* (NCSM, 2008). I purposefully selected four Stage 3 teacher leaders (n=4), as my unit of analysis, who advocated for best practices at the state level. For example, participants who testified at the Texas State Board of Education (SBOE) or presented at a state science or mathematics conference. I used a multiple-case study to write an individual case report on each teacher leader to identify characteristics of Stage 3 science and/or mathematics teacher leaders (Yin, 2018).

I analyzed the data via pattern matching by looking for certain trends in the data to identify characteristics of teacher leadership growth (Saldana, 2016). I conducted a holistic analysis on teacher leadership to determine how teachers in the MIX PD program were moving into teacher leadership roles (Yin, 2012). For example, evidence of participants moving into teacher leadership roles would include being selected as a department chair or science and mathematics specialist or serving on district level committees. I was able to understand the similarities and differences in multiple cases by conducting a cross-case analysis to understand the patterns of their teacher leadership growth (Yin, 2018). I analyzed the survey data and coded the responses of the four teacher leaders using emergent coding to understand differences in their responses (Saldana, 2016).

A mixed methods approach helped me to identify my participants' teacher leadership characteristics and how growth occurred for teachers who participated in the MIX PD program. I used qualitative and quantitative in a mixed methods triangulation design to help me identify Stage 3 leaders and gather enriched details from their lived experiences. As the researcher of my study, I ensured that I remained ethical while conducting my research by providing confidentiality protection and following the guidelines under IRB. Based on the previous literature findings, participants who were in a program that modeled pedagogical and content specific best practices were taking on leadership roles. For example, participants who volunteered to learn research-based best practices in mathematics and science program. I aimed to find how the phenomena of teacher leadership occurred in the MIX program using my five identified data sources.

IV. RESULTS

I organized my research findings according to each of my three research questions. My research questions were:

1. What are the teacher leadership characteristics of the teachers who participated in the MIX program?
2. What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?
3. How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?

For my first research question, I reported the teacher leadership characteristics that my participants (n=23) felt they held. For my second research question, I presented my findings of teacher leadership characteristics that Stage 3 leaders (n=10) held. For my third research question, I discussed my within-case findings of the four participants (n=4) that I purposefully selected. I reported how they achieved teacher leadership growth during their participation in the MIX PD program. I discussed my cross-case findings of the similarities and differences that emerged from the data from my four purposefully selected Stage 3 participants.

Research Question 1: What are the Teacher Leadership Characteristics of the Teachers Who Participated in the MIX Program?

For my first research question, I used qualitative and quantitative data to reveal if teacher leadership growth occurred and what teacher leadership characteristics were attained by participating in the MIX PD program. I determined if teacher leadership occurred while participating in the MIX PD program by using teacher reflections and classroom observations. This data helped me to discover the leadership characteristics that were held by the participants. I reported their teacher leadership characteristics using the data from my Teacher Leadership Survey. I also reported the stage of teacher leadership that each of my participants self-reported on their MIX/PRIME Leadership Framework Survey.

TQ teacher reflection. Initially, I wanted to understand if teacher leadership growth occurred in the MIX PD program and what leadership characteristics the participants displayed. Their TQ teacher reflections revealed 10 out of 11 participants described leading outside their classrooms. Their leadership characteristics were evident by their description of collaboration efforts within or outside of their department. Six out of 11 participants indicated they were mentoring teachers by introducing best practices they learned in the MIX PD program. Nine out of 11 reflections specified they were leading outside their district such as presenting at state conferences, serving on the District Advisory Committee, and serving at the Texas Education Agency's Science Streamlining Committee. The participant who stated they were not leading outside their classroom showed some evidence of leading by describing their implementation of best practices within their classroom. They stated they used manipulatives, reduced their usage of imprecise language to avoid student misconceptions, and used wait-time to allow students to have thinking time before responding to questions.

Classroom observations. Using the GLOBAL scores from the Mix It Up: Correlated Science and Math Observation Form, I found all the participants displayed "some evidence" or "clear evidence" of implementation of best practices in their instruction, which is the first stage of leadership (see Table 3). Nine participants displayed “some evidence” of teacher leadership characteristics. Their average scores ranged from 2-2.9. I discovered fourteen participants’ observations presented “clear evidence” of implementing general best practices and integrated science and mathematics in their instruction. Participants who displayed “clear evidence” of implementing best practices during their classroom observations attained an average score ranging from 3 - 4 out of maximum of 5 possible points.

Table 3

Participant's Global Score for Classroom Observations

TQ Number	Average Score of all Observations	Global Score:
548107	4	Clear
548112	4	Clear
548214	4	Clear
548110	3.8	Clear
548109	3.7	Clear
548111	3.3	Clear
548209	3.3	Clear
548219	3.3	Clear
548217	3.2	Clear
548212	3.2	Clear
548105	3.1	Clear
548205	3	Clear
548214	3	Clear
548215	3	Clear
548210	2.9	Some
548222	2.8	Some
548221	2.8	Some
548211	2.75	Some
548203	2.7	Some
548220	2.5	Some
548218	2.4	Some
548213	2.3	Some
548108	2	Some

Note. n= 23. TQ Number signifies the participant's assigned Teacher Quality number. Average score of all observations displays the average of each participant's Total Individual Observation Scores. Global Score is the summary score ranging from no evidence, some evidence and clear evidence. Participants ranging from 0-1.9 were assigned as no evidence, 2.0-3.6 as some evidence, and 3.7-5 as clear evidence.

Teacher Leadership Survey. The results of the participants' (n=23) closed-ended survey report indicated that most participants "strongly agreed" or "agreed" with possessing teacher leadership characteristics and applied MIX pedagogical teaching strategies into their instruction. Using descriptive statistics, I displayed the results of the participants' teacher leadership characteristics (see Table 4). I also displayed the results of the participants' teacher leadership characteristics using a bar graph for visual purposes (See Figure 11). Overall, 91% of participants reported their willingness to grow as a teacher leader. Eighty-two percent of teachers reported being trustworthy. Over sixty-nine percent of participants reported that they "strongly agree" and 30.43% "agreed" that they collaborated with others and supported their team. Forty-three percent of participants reported they "strongly agreed" to having principal support, while 21.74% "disagreed" with having support from their principal. Twenty-six percent of teachers "disagreed" with being familiar with the science and mathematics national standards.

Characteristics varied from inherent behaviors such as intrinsically motivated to learned behaviors from MIX PD such as the importance of integration. More participants reported possessing inherent characteristics of teacher leadership than learned behaviors modeled in the MIX PD program. I displayed my data onto a graph with inherent behaviors located on the left side of the graph and learned behaviors on the right side indicated with an asterisk (see Figure 11). I displayed the data according to the percentage of leadership characteristics they attained. Although principal support did not fit into inherent or learned behaviors, I used this data to further understand teacher leadership development.

Table 4

Teacher Leadership Characteristics Inherent versus Learned as a Percentage

Teacher Leader Characteristic	Strongly Agree	Agre e	Disagre e	Strongly Disagree
Willingness to grow	91.30	8.70	0.00	0.00
Trustworthy	82.61	17.39	0.00	0.00
Work with community	13.04	73.91	13.04	0.00
Collaborate with others	69.57	30.43	0.00	0.00
Support Team	69.57	30.43	0.00	0.00
Positive Attitude	56.52	39.13	4.35	0.00
Intrinsically Motivated	52.17	47.83	0.00	0.00
Vision personal Growth	52.17	43.48	4.35	0.00
Highly Organized	34.78	43.48	21.74	0.00
Vision for department/campus	30.43	47.83	21.74	0.00
Confidence	43.48	39.13	13.04	4.35
*Achieve Student Growth	52.17	47.83	0.00	0.00
*Importance of Integration	47.83	47.83	4.35	0.00
*Strong Pedagogy	34.78	60.87	4.35	0.00
*Familiar National standards	13.04	60.87	26.09	0.00
*Attend Non-required PD	43.48	56.52	0.00	0.00
*Strong content knowledge	43.48	56.52	0.00	0.00
Has Principal Support	43.48	34.78	21.74	0.00

Note. n= 23. Asterisks indicate learned behaviors in the MIX program.

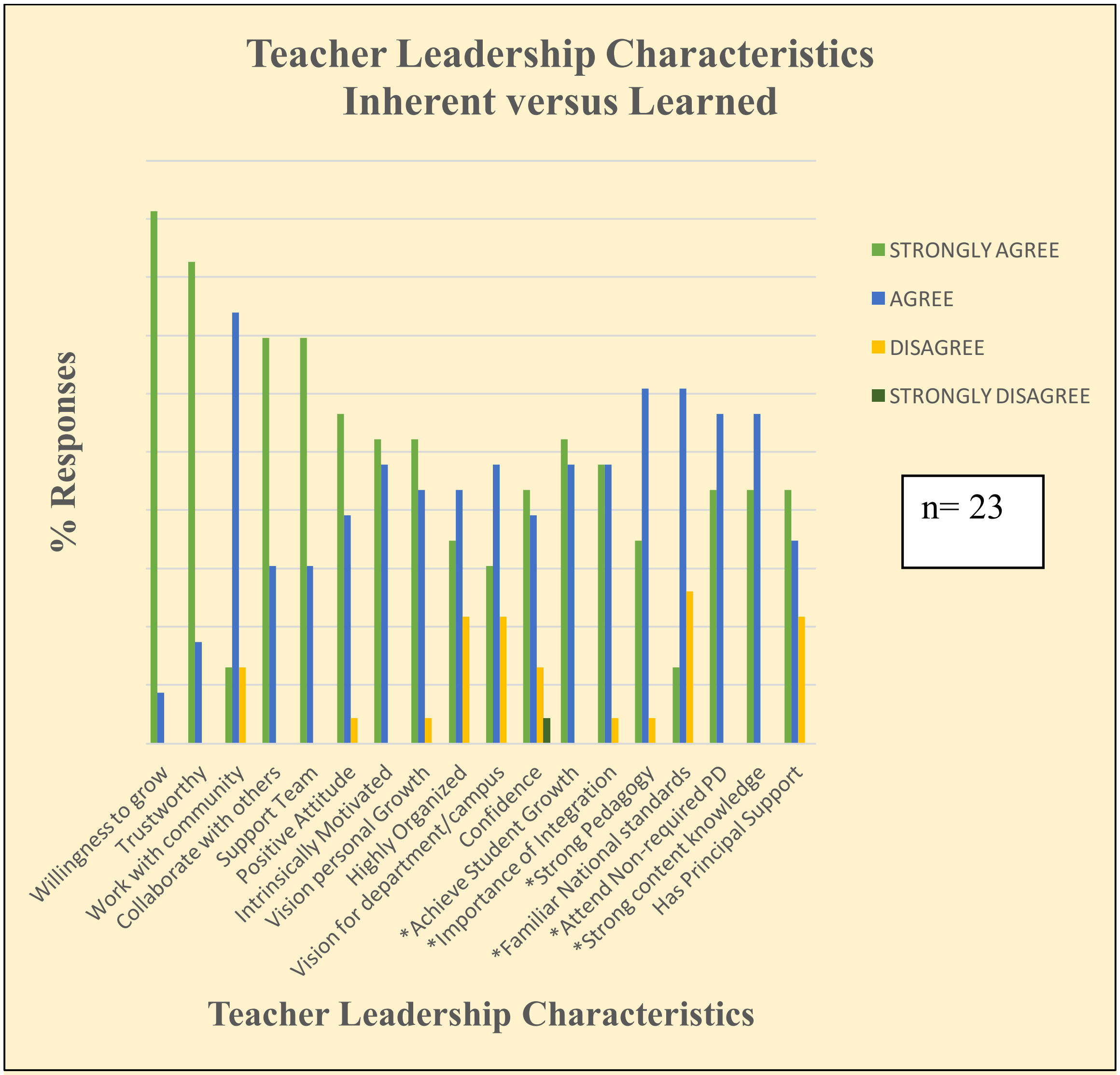

Figure 11. Closed-ended survey of teacher leadership characteristics self-report. Asterisks indicate learned behaviors in the MIX program.

I discovered my participants self-reported that they incorporated general best practices and MIX identified practices into their lessons. Table 5 revealed how frequently (always, often, not very often, and never) the participants reported using MIX identified pedagogical characteristics and general best practices in their lessons. I found general best practices (3 second wait time, call on non-volunteer) were more frequently applied than MIX identified best practices. Fifty-six percent of the participants reported they were "always" using the 3 second wait time in their classrooms. The survey also revealed

30% of participants “always” called on a non-volunteer and used one concept per lesson while more than half of the participants “often” used these teaching strategies. Participants indicated they were not “always” incorporating mathematics and science integration into their lessons. Sixty-five percent of participants reported they were “often” integrating mathematics and science into their lessons and nearly 35% reported they were “not very often” integrating mathematics and science content. I displayed the participants’ responses from the data table using a bar graph based on the percentage of teacher leadership characteristics (see Figure 12).

Table 5

MIX Identified Pedagogical and General Best Practices Characteristics as a Percentage

MIX Pedagogical Characteristics	Always	Often	Not Very Often	Never
3 second wait time	56.52	34.78	8.70	0.00
Call on Non-volunteer	30.43	60.87	8.70	0.00
*1 concept per lesson	30.43	56.52	13.04	0.00
*3 LPPs	17.39	60.87	21.74	0.00
*Known to Unknown	8.70	78.26	13.04	0.00
*M&S Integration	0.00	65.22	34.78	0.00

Note. n=23. 3 LPPs denotes MIX’s 3 Lesson Planning Principles. Asterisks indicate MIX identified pedagogical characteristics.

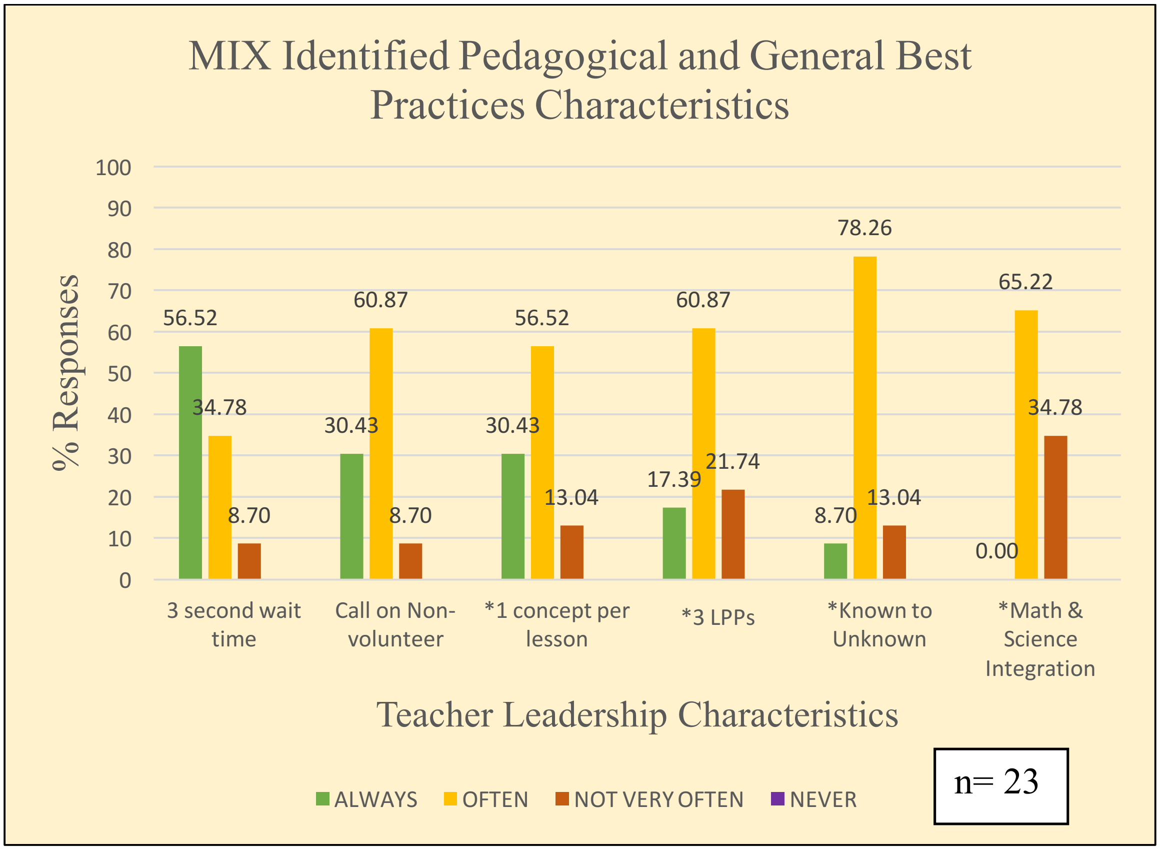

Figure 12. Closed-ended survey of teacher leadership characteristics with MIX specific pedagogy and general best practices frequency self-report. Asterisks indicate MIX identified pedagogical characteristics. 3 LPPS denotes MIX's 3 Lesson Planning Principles.

MIX/PRIME Leadership Framework Survey. I used the MIX/PRIME Leadership Framework Survey as an indicator of the participants' stage of leadership (NCSM, 2008). Overall, 52% of participants reported attaining Stage 2 leadership and were leading outside their classroom, while 4% of participants reported Stage 1 leadership by leading within their classroom (see Table 6). Forty-three percent of teachers reported they were at Stage 3 by displaying leadership at the district or state level. Most of the participants revealed they were taking on various leadership roles outside their classrooms. I plotted the data from Table 6 onto a bar graph based on stages of leadership and percentage of teacher responses (see Figure 13).

Table 6

Stages of Leadership as a Percentage

Characteristic	Stage 1	Stage 2	Stage 3
Stages of Leadership	4.35	52.17	43.48

Note. n=23.

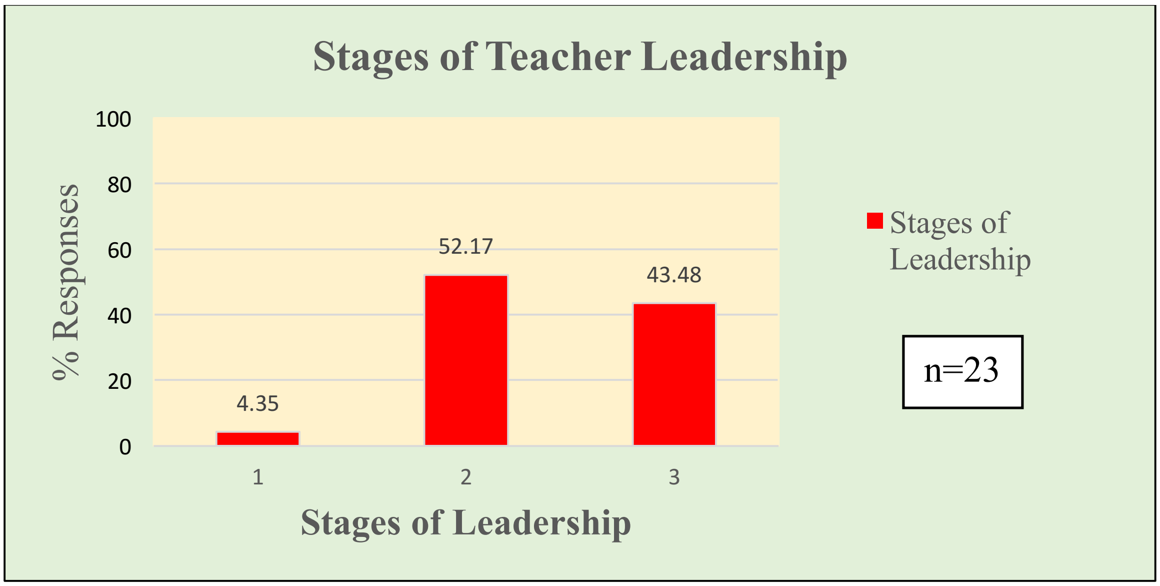

Figure 13. Questionnaire of NCSM's Indicator 2 teacher leadership stages self-report.

In this section, I reported the results of my first research question. I found participants held teacher leadership characteristics at various levels. MIX mentors observed participants leading within their classrooms by implementing MIX identified integrated science and mathematics and general best practices. Participants reported on their teacher reflections that their professional growth in MIX helped them to lead at the district and state levels. All participants agreed they were willing to grow, which wasn't unexpected since they volunteered to participate in a two-year PD program. Participants self-reported on their MIX/PRIME Leadership Framework Survey that they were leading at various stages of leadership, but most participants self-reported advocating beyond their classroom.

Research Question 2: What are the Teacher Leadership Characteristics of a Stage 3 Teacher Leader Who Participated in the MIX Program?

My second research question sought to understand what teacher leadership characteristics Stage 3 leaders held. For this research question, I used quantitative data to present my findings. I utilized the MIX/PRIME Leadership Framework Survey to report how many participants self-reported obtaining Stage 3 leadership. Stage 3 leaders advocate for best practices and integration of science and mathematics by endorsing them at the district, region, or state level. I used my Teacher Leadership Survey to display the percentages of Stage 3 leaders' teacher leadership characteristics.

Stage 3 leaders. I utilized the MIX/PRIME Leadership Framework Survey and discovered 35% of participants self-reported leading at the Stage 3 leadership level (see Figure 13). According to NCSM (2008), Stage 3 leaders ensure implementation of best practices at the district, state, or region level. I found Stage 3 self-reported leaders were implementing general best practices and/or integrating science and mathematics in their instruction during their classroom observations. Ten out of eleven participants reported advocating for teaching best practices at the district and state level on their TQ teacher reflections.

Stage 3 Teacher Leadership Survey characteristics. I extracted the data from my Teacher Leadership Survey (see Figure 11) to identify self-reported Stage 3 leaders' (n=10) leadership characteristics. I found 90% of Stage 3 leaders indicated they "strongly agreed" on their willingness to grow (see Table 7). Seventy percent "strongly agreed" they possessed trustworthy characteristics, while 30% said they "agreed" to being trustworthy. Fifty percent of the participants reported they "strongly agreed" on their ability to collaborate with others and support their team. I also found half of the participants "agreed" they had principal support, while 40% of Stage 3 leaders "disagreed" to having principal support. Eighty percent of Stage 3 leaders agreed with being familiar with the mathematics and science national standards, which was more than all participants' data. I plotted Stage 3 leaders' data onto a bar graph (see Figure 14).

Table 7

Teacher Leadership Characteristics as a Percentage of Stage 3 Teacher Leaders

Characteristic	Strongly Agree	Agree	Disagree	Strongly Disagree
Willingness to grow	90.00	10.00	0.00	0.00
Trustworthy	70.00	30.00	0.00	0.00
Collaborate with others	50.00	50.00	0.00	0.00
Support Team	50.00	50.00	0.00	0.00
Vision personal Growth	40.00	50.00	10.00	0.00
Intrinsically Motivated	30.00	70.00	0.00	0.00
Positive Attitude	30.00	60.00	10.00	0.00
Confidence	20.00	40.00	30.00	10.00
Work with community	10.00	80.00	10.00	0.00
Vision for department/campus	10.00	60.00	30.00	0.00
Highly Organized	10.00	50.00	40.00	0.00
*Attend Non-required PD	50.00	50.00	0.00	0.00
*Achieve Student Growth	30.00	70.00	0.00	0.00
*Strong content knowledge	30.00	70.00	0.00	0.00
*Importance of Integration	30.00	60.00	10.00	0.00
*Strong Pedagogy	20.00	70.00	10.00	0.00
*Familiar National standards	10.00	80.00	10.00	0.00
Has Principal Support	10.00	50.00	40.00	0.00

Note. n=10. Asterisks indicate learned behaviors in the MIX program.

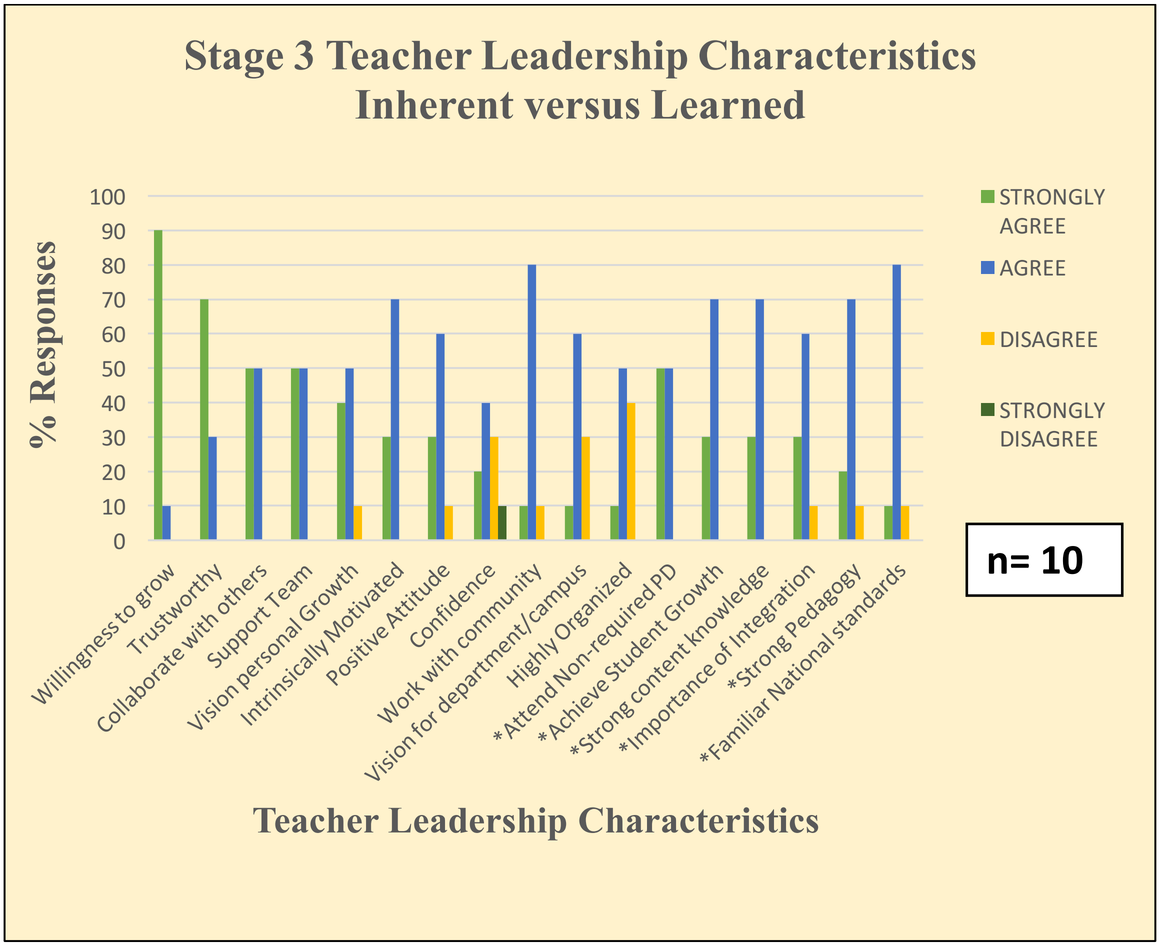

Figure 14. Close-ended survey of self-reported Stage 3 teacher leadership characteristics using NCSM Indicator 2. Asterisks indicate learned behaviors in the MIX program.

Using my Teacher Leadership survey, I identified self-reported Stage 3 MIX pedagogical characteristics and displayed the percentage of each on the data table (see Table 8). I discovered Stage 3 leaders were "often" or "always" implementing general best practices introduced in MIX. Participants reported using general best practices more frequently than MIX identified best practices. Sixty percent of teachers reported that they were "often" integrating mathematics and science within their lessons, but not "always" integrating mathematics and science content. Overall, all Stage 3 leaders were using MIX identified best teaching practices. I displayed Stage 3 teacher leaders' characteristics and percentages onto a graph (see Figure 15).

Table 8

MIX Identified Pedagogical Characteristics of Stage 3 Leaders as a Percentage

Characteristic	Always	Often	Not very often	Never
3 second wait time	40.00	50.00	10.00	0.00
Call on Non-volunteer	30.00	60.00	10.00	0.00
*3 LPPs	20.00	50.00	30.00	0.00
*Known to Unknown	10.00	70.00	20.00	0.00
*1 concept per lesson	10.00	70.00	20.00	0.00
*Math & Science Integration	0.00	60.00	40.00	0.00

Note. n=10. Asterisks indicate learned behaviors in the MIX program.

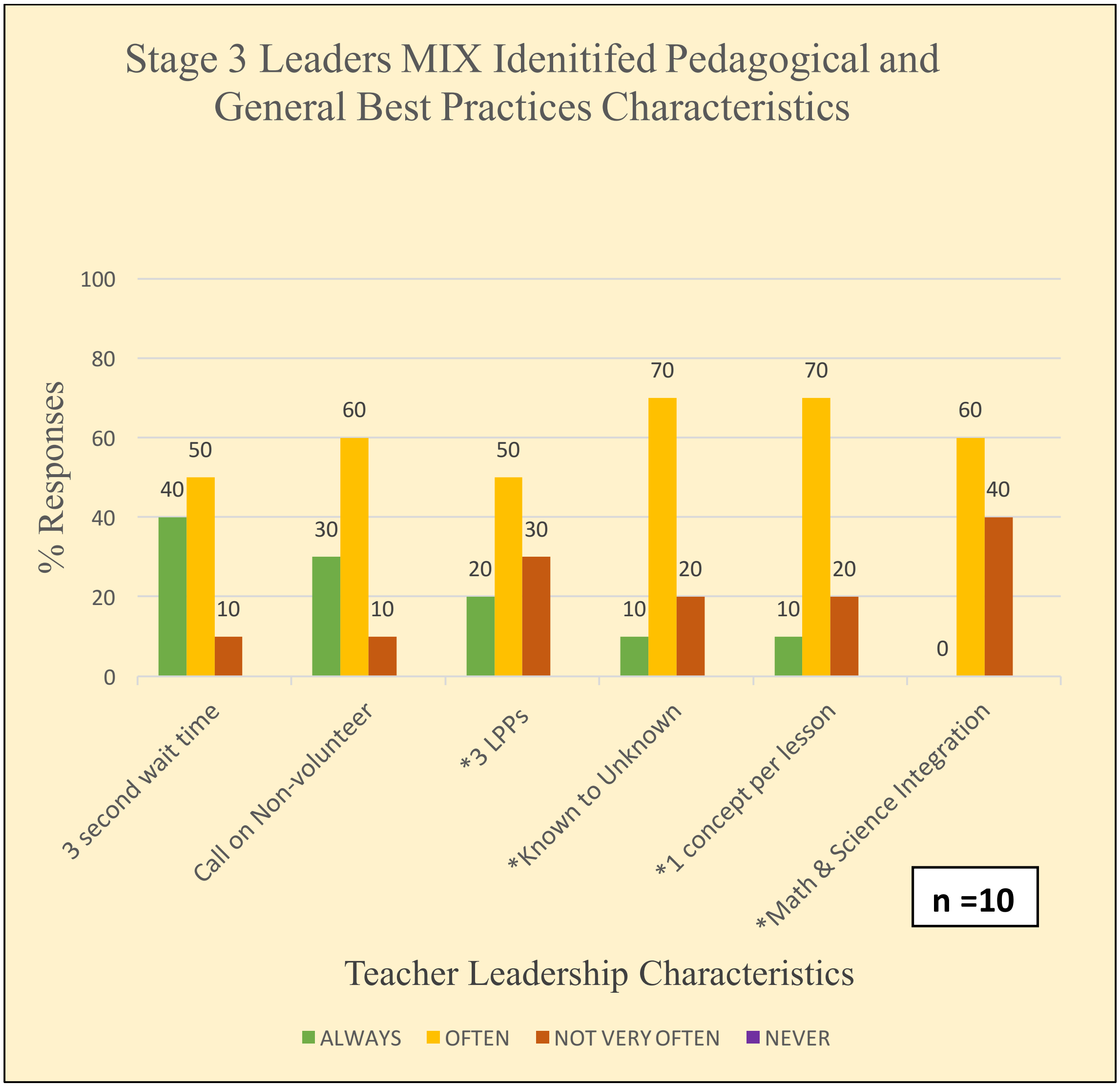

Figure 15. Close-ended self-report survey of teacher leadership characteristics with MIX identified general and mathematics and science best practices or integration. Asterisks indicate learned behaviors in the MIX PD program.

In this section, I reported the results of my second research question. I identified the participants who self-reported they attained Stage 3 leadership and I was able to determine what leadership characteristics they possessed. Stage 3 leaders reported their willingness to grow, which was evident from the data reported by all the participants. However, more Stage 3 leaders reported being familiar with the national standards for science and mathematics education. Stage 3 leaders also reported incorporating mathematics and science integration more often compared to the data from all participants.

Research Question 3: How are Teachers Who Participated in the MIX Program Progressing into Stage 3 Teacher Leadership Roles?

I used the results from my second research question to purposefully select four (n=4) out of ten participants for a multiple-case study. Within the multiple-case study, I reported my within-case and cross-case findings to reveal how four participants progressed into Stage 3 leadership. Using qualitative data, I presented my findings from the audio-recorded interviews to understand how four purposefully selected participants (n=4) were leading at the state level.

Within-case findings. I reported my within-case findings of my multiple-case study in this section. Their audio-recorded interviews helped me to answer my third research question, which sought to understand how each participant moved into Stage 3 teacher leadership roles. Each participant I selected was given four questions for their interview. The four questions were:

1. How has participating in MIX PD in your professional growth as a teacher leader?
2. What type of roles have you served in your school, district, community, or state level as a result of MIX PD?
3. Can you describe how you have advocated for mathematics and science content integration and the use of best practices starting from your classroom to others outside your classroom (team, campus, district, or state level)?

4. Are there any other details you would like to include to better understand teacher leadership in a mathematics and science integrated professional development program?

Teacher leader case one. Lisa is a seventh-grade science teacher with four years of teaching experience and holds a Bachelor of Science in Education. Lisa indicated she was hired as a mathematics teacher her first year and it was a "horrible experience." She stated her participation in the MIX PD program was an opportunity initially presented to her by her principal. She stated she wanted to grow and "get better" in her field, so she decided to join the MIX PD program. She expressed the benefits of the MIX PD program, which included team teaching with another MIX participant because he "helped her learn how to teach math." Lisa said her mathematics department used worksheets, but after participating in MIX, she "encouraged them to use math manipulatives." She didn't want to use "tricks" to teach mathematics but wanted to "support the math department."

She expressed that participating in MIX allowed her to build knowledge in teaching mathematics and science content. She found it easier to integrate mathematics and science into her instruction since she taught both subjects at her middle school. She also "talked to the mathematics department about using science examples in their lessons." Other MIX PD best practices she included were "not introducing vocabulary first" and working in mathematics and science teaching teams. She stated, "I liked the vertical alignment and working with the same grade level so I could talk to other MIX teachers and know what time of the year they taught this part of math." She enjoyed spending Saturdays in MIX and said she could "take back lessons that were very valuable."

She attributes her confidence in teaching by participating in the MIX PD program. She found herself taking on more leadership roles on her campus. She stated her short-term goal was "to become department chair for her science department." Her principal supported her advancement in leadership by giving her more opportunities on her campus. She stated that her principal saw her as a leader on campus. She shared that her first leadership position was "sponsoring Builders club, which is an organization that builds kids self-esteem."

She soon found her colleagues nominated her to sponsor other activities such as HOSA. She decided to volunteer to sponsor HOSA-Future Health Professionals. She stated, "we became the first ever junior high to ever attend the state leadership conference and then we were also the first junior high to ever represent the state of Texas at the International Conference." She described two of her students being placed top 10 in the HOSA competition. She also stated she took on other activities such as cheerleading and community organizations such as Boy Scouts and Girl Scouts of America.

She stated after her 2nd year in MIX, she achieved her goal in becoming the science department chair. From that point, she felt her former and current principal both had confidence in her ability to lead on her campus. She began to describe how she was appointed to the Literacy Leadership team, lead for the Strategic Instructional Model professional developer, District of Innovation team, and the District Advisory Committee. Becoming a department chair allowed her to teach MIX best practices by "talking to other 8th grade teachers that were interested in teaching concrete-pictorial-abstract and teaching from known to unknown." Lisa indicated her willingness to grow would hopefully allow her students to see her efforts and grow to become leaders in their own communities.

Teacher leader case two. Michelle is a seventh and eighth grade science teacher with six years of teaching experience and holds a Master of Education in Elementary Education. She started her first year off as a 6th grade science teacher in Kentucky under emergency certification. She stated, “after that year I realized how much work goes into this career, so I went on to do other things.” After taking a break from teaching, she came back and felt like a first-year teacher again. She entered her master’s program and worked with a MIX project professor who implemented MIX best practices such as concrete-pictorial-abstract and teaching one concept per lesson. Michelle stated, “I did not practice that, so it wasn't until I had the time to reflect with the MIX PD program that I was able to fully implement them.” She shared how happy she was that the MIX PD program allowed her time to lesson plan and reflect on how to implement best practices.

She stated the benefits of being in the MIX PD program was “being able to work with other people on lesson planning and having discussions with other teachers was powerful in shaping my understanding of the profession and what you should be doing for kids.” She described attending other PD programs, but they did not have the “longevity of the professional development program and the high expectations for teachers.” She also explained how she implemented “discovery-based lessons and not cookbook activities.” The MIX PD program gave Michelle a better understanding of how best practices were implemented because the instructors modeled the lessons for the teachers.

Michelle explained advocating for best practices was not easy because she could not see her own potential in leadership. She stated that her MIX instructor saw the potential in her, so she was able to testify to the SBOE regarding the new streamlined TEKS. She was also encouraged to present at the Conference for the Advancement of Science Teaching. Her principal also saw her potential by selecting her to serve on the District Leadership team, Vertical Instruction team, Superintendent's Panel, District Instruction and Curriculum planning team, selected as the science department chair, and as the National Junior Honor Society sponsor.

She described wanting to do what is best for her students, but not all PD on her campus aligned with what was done in MIX training sessions. At times, she stated her instruction "looked different from other educators." She incorporated more inquiry-based lessons and even shared research-based strategies with other teachers on her campus. She described how she wanted to be an agent of change and so she "volunteered to be the department chair." Her principal supported her decision by making her the department chair for science. She attributed her growth to the experience she gained from the MIX PD program and hopes to be more vocal in advocating for research-based best practices she received from MIX. She moved into leadership roles to bring about change in education. She also went on to describe how she wants her students to understand the value and purpose of education.

Teacher leader case three. Samuel is a seventh-grade mathematics teacher with eight years of teaching experience and holds a Master of Science in Psychology. He did not go through a traditional teaching program but went the alternative certification route. He stated his "pedagogy needed to be improved," so participating in the MIX PD program allowed him to develop his pedagogical knowledge. Through the MIX PD program, he understood the importance of using best practices. He also felt encouraged because his principal attended the MIX principal training and he saw the value of teachers using MIX best practices.

Samuel said MIX helped him with “lesson planning and developing good lessons.” He incorporated MIX identified best practices into his lessons such as moving a lesson from concrete to pictorial to abstract. He also understood the importance of implementing manipulatives in his classroom. His previous principal was a former mathematics teacher and “saw the value in using mathematics manipulatives,” so teachers in his prior district were able to incorporate manipulatives in their lessons. He expressed his concerns at his new school by stating he was “not able to buy manipulatives for his department because of the school budget.” He lent the mathematics department the manipulatives he received from the MIX PD program and showed them how to incorporate them into their own lessons. Samuel felt he could advocate for best practices now that he had a better understanding of research-based best practices.

He felt motivated to help other teachers understand how to incorporate best practices. He wanted to ensure teachers understood what the students are doing and “how to help them become better.” Samuel felt encouraged that teachers were coming to him for advice in planning lessons. He described how MIX helped him develop his leadership skills. He recalled advocating for teacher leadership at the state level when he first joined the MIX PD program. He was asked by his principal to talk about the benefits of having Algebra 2 to remain as a requirement in front of the SBOE. He also described presenting an integrated mathematics and science lesson on conservation of mass at the Conference for the Advancement of Science Teaching (CAST).

He served in various teacher leadership roles during his participation in MIX. He stated, "part of my leadership came from being in the MIX PD program and also by my principal's support." While in the MIX PD program, he was selected as the department chair for mathematics. He also served on various committees which included the District Planning committee, Site Based Planning committee, District Calendar committee, and became the chairperson for the Positive Behavior and Intervention Support committee. Overall, he contributes his time in the MIX PD program to his growth in leadership and the modeling of best practices in helping him show other teachers how to incorporate best practices into their own classrooms.

Teacher leader case four. Diane's teacher leadership growth was largely attributed to her participation in the MIX PD program. She discussed how the program was "collaborative with all of us working together" that she could discuss various methods and practices to incorporate into her lessons. Diane shared how much she enjoyed the constructive feedback she received from the MIX instructors. She felt the program was "dedicated to collaboration, questioning strategies, and critiquing with constructive feedback." She felt those qualities allowed her to grow in the program.

Diane described her leadership as a result of her volunteering and wanting to grow by taking on leadership roles on her campus. She explained not having a teaching partner at her campus in MIX made "being able to work with teachers from other campuses within the district so important." She also stated she received "little support" from her previous administrator who did not attend MIX principal training sessions to better understand the MIX PD program and what resources it can provide to schools. She felt the need to advocate as a leader for science education because her campus was slowly reducing the amount of time spent in their classroom learning science.

She knew the importance of implementing best teaching practices. She stated her "bilingual students understood how to move the tiles around in the different colors in her classroom" and how they benefited from using mathematics manipulatives in her elementary classroom. She also incorporated the 3 LPPs by having students draw their colored tiles after touching them. She really wanted to include more concrete examples in her lessons. She also reported her bilingual students' scores went up by 18%. This helped her gain confidence and allowed her to tell other teachers on her campus about the research strategies she learned from the MIX PD program.

She felt the communication she received from educators in the MIX PD program gave her confidence in communicating with "educators and administrators at all levels." She collaborated with teachers from other grade levels for vertical alignment in lesson planning. She stated during the MIX PD program she served on the TEKS streamlining committee for kindergarten through second grade. She reported being selected by her committee to testify at the SBOE when it came to present their findings.

Cross-case findings. I reported patterns and themes that emerged from my cross-case findings. I described the similarities of Stage 3 leaders who advocated for best practices at the district and state levels. I displayed common themes between my four selected cases. I also described differences in their teacher leadership characteristics. I used similarities and differences between cases to obtain a holistic approach to teacher leadership in the MIX PD program.

Similarities of teacher leadership characteristics. Overall, I found their teacher leadership characteristics included a willingness to grow, strong pedagogy, strong content knowledge, confidence, collaboration, supporting their team, achieving student growth, and incorporating MIX's 3 LPPs (see Table 9). After attending MIX training sessions, participants felt encouraged to take on more leadership roles once they had a solid foundation on how to incorporate best practices into their lessons. Participants understood how important it was to collaborate with other teachers in the MIX training sessions. This helped them to collaborate and introduce MIX identified and general best practices with teachers at their own campus. Stage 3 teacher leaders in my case study all wanted to become better in their profession. They enjoyed having best practices modeled by MIX instructors in the training sessions, so they could see how to incorporate strategies into their own mathematics and science lessons.

Table 9

Common Teacher Leadership Characteristics between Four Cases

Leadership Characteristic	Michelle	Lisa	Samuel	Diane
Willingness to Grow	I've grown so much as a teacher	I want to grow	things that I didn't know that I learned through MIX	we're going to go over what we just learned through MIX
Strong Pedagogy	The best practices that I've learned in the program	How to teach the content	lesson planning, manipulatives to pictorial to abstract, presented an integrated math & science lesson	best practices and hitting those certain things were happening your first year in the MIX
Strong Content Knowledge	I have presented at miniCAST	I was building my knowledge and the content, present at CAST	show them how we can get 8th graders to start looking at molecules	Letting me instruct them
Confidence	The MIX instructor saw all that potential in me and then I could see that potential in myself.	they find value in it and so and that gave me a lot of my confidence.	MIX has help me and I'm helping others to see if they can do the same things	helped to give me a great deal of confidence in going back to my own campus
Collaborate with Others	working with other people on lesson planning, discussions with other teachers	Bring back to the team...7th grade math manipulatives	trying to get the teachers to do best practices and showing them how	collaborating with the lower grade levels and or if they had a question
Support Team	other 8th grade teacher about like suggesting hey here's this activity that I'm doing	talk to other 8th grade teachers that were interested in teaching concrete to pictorial to abstract and teaching from known to unknown	I had eighth grade math teachers asking how do they use manipulatives	lower grade levels were very receptive with me suggesting if you're going to teach this, I would prefer it if you approached it that way
Achieve Student Growth	best interest of kids all the time in any situation	kids get involved into things so that they can learn and grow	see any light bulbs going off once they start using manipulatives	bilingual students their scores increased 18%
3 LPPs	I use concrete models to help kids understand the content	teaching concrete to pictorial to abstract	using manipulatives in instruction	how to use manipulatives with one concept per lesson

Note. n=4

Differences of teacher leadership characteristics. I revealed differences between my cases' teacher leadership growth and reported the findings. Each case described their reasoning for needing professional growth. Michelle reported wanting to make the education system better for her students and wanted to be an agent of change. Lisa stated she wanted her students to remember her class and eventually become leaders out in their own community.

Samuel, Michelle, and Lisa received principal support and were more inclined to make changes in their own department by introducing research-based best practices so others could use it in their own classrooms. Diane reported not having principal support or a team-teaching partner. She struggled with how to take on leadership roles and implement teaching strategies she learned in the MIX training sessions. Michelle described receiving support from her principal and the MIX instructors who gave her the confidence to ultimately believe in herself as a teacher leader.

My research sought to understand my participants' teacher leadership characteristics and how Stage 3 leaders achieved the highest level of leadership through a multiple-case study. Using their TQ teacher reflections and classroom observations, I found all participants incorporated MIX identified and general best practices in their classrooms. I used their Teacher Leadership Survey and discovered all participants who participated in MIX wanted to grow in their profession. All participants "strongly agreed" or "agreed" to collaborating with others and supporting their team. Participants advocated for teaching best practices at different stages. Fifty-six percent reported they supported others on their campus, while 34% reported that they implemented best practices at the district or state level.

I used a multiple-case study and discovered how four purposefully selected participants attained Stage 3 leadership. I interviewed each of my four cases and found their need for improving their own teaching practices led to helping other educators around them. Three out of four were leading at the department chair level and made some changes which affected their campus. All four participants reported that improving their pedagogy and implementing best practices gave them the confidence to lead at the state level, such as testifying at the SBOE or presenting at state conferences. I found their differences included their level of principal support and their reasons for wanting to grow. Overall, the participants expressed their progression into Stage 3 teacher leadership while participating in the MIX PD program.

V. CONCLUSION

The purpose of my research was to develop an understanding of my participants' teacher leadership growth after completing MIX's two-year PD training program. My study consisted of 5th through 8th grade science and mathematics teacher teams who participated in a long-term and intense (140 hours) MIX PD program. The MIX project used a content-based model of PD called the Correlated Science and Math PD model whose purpose was to better enable science and mathematics educators to implement science and mathematics integration and research-based best practices into their instruction. Teacher leaders who emerge from participating in a high-quality PD program such as MIX can then endorse best practices on a larger scale (Yow & Lotter, 2016). I investigated my participants' teacher leadership growth after participating in the MIX PD program by using a mixed-methods approach. I used three research questions to understand if and how teacher leadership growth occurred.

The following is comprised of my three research questions and my conclusion:

1. What are the teacher leadership characteristics of the teachers who participated in the MIX program?

2. What are the teacher leadership characteristics of a Stage 3 teacher leader who participated in the MIX program?

3. How are teachers who participated in the MIX program progressing into Stage 3 teacher leadership roles?

Research Question 1: What are the Teacher Leadership Characteristics of the Teachers Who Participated in the MIX Program?

Initially, I investigated if the MIX PD program impacted teacher leadership growth by using their TQ teacher reflection on professional growth (n=23). I found all the participants who completed the reflection reported using research-based strategies in their instruction. Nine out of the 11 participants advocated for them at the district or state level, revealing each held various teacher leadership characteristics. Most participants reported coming into the program with some knowledge on content and pedagogy, but upon the completion of the program, they understood the importance of consistently using research-based strategies. Participants reported the benefits of having the MIX instructors introduce research-based strategies and also model how to incorporate them into their classroom instruction. Through classroom observations, I was able to see how motivated participants were to use the new tools they learned in MIX.

Based on their classroom observational data, I discovered fourteen out of the twenty-three participants were “clearly “implementing best practices into their instruction. The other nine participants displayed “some” evidence of implementation. All the participants displayed “some” to “clear” evidence of best practices in their classroom observations. This result revealed how the participants sought to grow as professionals, which according to NCSM, is the first stage of teacher leadership (NCSM, 2008). The classroom observations aligned with the teacher reflections that stated participants applied best practices into their classroom instruction, such as implementing general best practices and MIX specific best practices.

Using their Teacher Leadership Survey, I found all my participants reported possessing teacher leadership characteristics and 91% of them reported taking on leadership roles outside their classrooms. All of the participants agreed on their willingness to grow, which was not surprising since they volunteered to be in the MIX PD program. Eighty-two percent strongly agreed that a leader must be trustworthy. This characteristic may reflect on studies that suggest leaders must be able to communicate as well as collaborate with other educators (Nicholson et al., 2016). Interestingly, 17% of participants disagreed or strongly disagreed that a leader has confidence.

According to the NCSM's *PRIME Leadership Framework* Indicator 2, Stage 2 leaders advocate for integration of mathematics and science by leading outside their classroom at the team or department level (NCSM, 2008). Of the 23 participants, 56% reported on the MIX/PRIME Leadership Framework Survey that they achieved Stage 2 leadership by advocating for mathematics and science integration to their colleagues or department. Most of the participants were surprised to learn that they fell into the Stage 2 leadership category. Many of my participants felt teacher leaders were those who held a formal title or role, but did not recognize that wanting to improve their teaching inside the classroom through use of research-based practices, was an indicator of teacher leadership (Hanuscin et al., 2012). Forty-three percent reported falling into the Stage 3 leadership category and were implementing best practices at the district or state level.

Research Question 2: What are the Teacher Leadership Characteristics of a Stage 3 Teacher Leader Who Participated in the MIX Program?

I utilized the NCSM's *Prime Leadership Framework* to identify Stage 3 teacher leaders and to determine their teacher leadership characteristics. I found that participants who achieved Stage 3 leadership (n=10) implemented research-based strategies and also advocated for science and mathematics integration at the district and state level (see Figure 13). Stage 3 leaders stated in their teacher reflections that they presented inquiry-based lessons at state conferences, such as CAST and Conference for the Advancement of Mathematics Teaching (CAMT). Participants identified as Stage 3 leaders were selected by their principals to represent their campus at the district level in decision making for Year at a Glance and District of Innovation meetings.

Stage 3 teacher leader's efforts to implement the mathematics and science national standards supports educational reform by recognizing how educators can improve student learning (NCTM, 2000; NRC, 1996, 2012; NGSS, 2013). Table 7 revealed that ninety percent of Stage 3 teacher leader participants (n=10) agreed or strongly agreed to being familiar with the national standards. Participants who were proficient in the state and national standards were able to assist in the development of the new streamlined Texas science curriculum standards, the Texas Essential Knowledge and Skills. Some of the participants even testified at a Texas SBOE meeting in Austin, TX. In their teacher reflections, Stage 3 leaders reported understanding the importance of vertical and horizontal alignment and not introducing new concepts outside their standards.

Stage 3 leaders did not all grow professionally with the support of their principal. Only 10% percent of the participants (n=4) reported that they "strongly agreed" to having principal support compared to 43% from all participants (n=23). The results were surprising since Stage 3 leaders were leading within their district or at the state level. This data led to my third research question of how Stage 3 leaders were moving into Stage 3 teacher leadership since one out of ten participants reported they strongly agreed to having principal support while 40% "disagreed" that they received principal support.

Research Question 3: How are Teachers Who Participated in the MIX Program Progressing into Stage 3 Teacher Leadership Roles?

I investigated how four participants (n=4) progressed into Stage 3 leadership during their time in the MIX PD program by using a multiple case study. The NCSM's *PRIME Leadership Framework* helped me to identify participants who were advocating at the district level and beyond. I was able to purposefully select four participants that best represented Stage 3, the highest level of teacher leadership. The participants I purposefully selected reported that they were leading at the state level. I wanted to gather more information on how they progressed into this level in efforts to create educational reform. Their interviews provided me with enriched details of how they participated in a long-term PD program and moved into advocating for research-based best practices at the district and state level.

During their interview, each participant was given the same four questions. Their four questions were:

1. How has participating in MIX PD led to your professional growth as a teacher leader?
2. What type of roles have you served in your school, district, community, or state level as a result of MIX PD?
3. Can you describe how you have advocated for mathematics and science content integration and the use of best practices starting from your classroom to others outside your classroom (team, campus, district, or state level)?

4. Are there any other details you would like to include to better understand teacher leadership in a mathematics and science integrated professional development program?

I found all four cases attributed much of their leadership growth to their participation in the MIX PD program. The participants understood the overall goal of the MIX PD program was to integrate mathematics and science along with general best practices for the purpose of enhancing student learning. They reported that the MIX PD program helped them to implement best practices into their own lessons. They learned how to teach the content and used this knowledge to collaborate with others to advocate for the implementation of best practices on their campus. The effectiveness of the MIX PD program supports the notion that teachers are inclined to make changes in their instruction after recognizing their own professional growth by participating in effective PD (Gomez-Zwiep & Benken, 2012). Gaining these tools helped them to build confidence in presenting to others on a larger scale (Powell-Moman & Brown-Schild, 2011).

I found that principal support varied among the cases. Three out of the four participants stated they received support from their principal. Diane did not receive the same type of support from her principal because he was not as involved with the MIX PD program as the other principals. However, she felt supported by the MIX instructors and the other participants in the program. She credited her leadership growth to the MIX PD program by gaining confidence in her instruction through constant feedback from the instructors, collaboration with other teachers in the program, and use of questioning strategies observed in MIX. This aligned to the study that suggested teachers need supportive conditions to achieve their full potential (Wilson, 2016).

Overall, I found that all participants (n=23) felt encouraged during the MIX sessions to collaborate with other teachers in the program who taught at various campuses and districts. They enjoyed creating lessons with their teaching partner and were able to inquire during the training sessions on how to incorporate teaching strategies they learned into their own lessons. The participants showed willingness to grow by implementing best practices. I found new teachers coming into the program after a year could identify research-based best practices, however they struggled to implement them into their own classroom instruction. The results were not surprising since previous studies have suggested new teachers have different needs and PD must be ongoing for there to be changes in their classroom instruction (Gomez-Zwiep & Benken, 2012).

Some participants stated that the MIX PD program helped them to build confidence in their instruction, which ultimately led them to advocate for best practices and to take on leadership roles at their own campus. Participants reported mentoring teachers and showing new teachers research-based best practices that they learned in the MIX PD program. Participants also reported moving into team lead and department chair positions while others considered moving into administration roles. The roles varied among participants but they all seemed to agree that participating in the MIX PD program gave them the skills they learned to be better teachers in their field and to eventually lead others.

Recommendations

All stakeholders need to understand the need for high quality PD that is long-term and intense for improvement in instructional quality and subsequent improvement in student performance and career/college ready graduates. Teachers must participate in PD that is long term (over more than one year) and intense (over 140 hours/year) in order to see teacher leadership growth. Educators need to understand the importance of PD programs such as MIX whose goal is to enhance their professional development, rather than practicing another new short-term strategy introduced by their district. Teachers also need different types of support when it comes to PD since not all teachers are at the same professional level (Schleigh et al., 2011).

Limitations of my Study

Limitations to my study included using a mathematics focused framework for understanding teacher leadership stages in an integrated mathematics and science PD program. Although science and mathematics have very similar qualities, MIX instructors discovered differences within instructional strategies and definitions. Perhaps a science focused framework could have been created and validated to gather information from a science perspective that may be different from that of mathematics.

MIX's focus on the 3 LPPs is comprised of starting a lesson from a known concept to an unknown concept, moving a lesson from concrete to pictorial/representational then to abstract concepts, and teaching only one concept per lesson. My Teacher Leadership Survey did not inquire how often the participants moved their lesson from concrete to pictorial/representational to abstract concepts. Understanding how often they reported using each of the 3 LPPs would have provided me with further data in their usage of best practices. My study could have also investigated how long it takes for new teachers to advocate for general best practices or MIX identified best practices.

Administering a survey at the beginning and end of the MIX program would have been another source of information to collect on their teacher leadership growth. My survey did not inquire what leadership role the participant initially held at the start of the MIX program. Documenting the stages of their personal growth would have provided me insight into how they progressed within the program. Administrators could have also been queried regarding their perceptions of their teachers' impact and growth.

Although gathering enriched details from my four Stage 3 teacher leaders was important in understanding how they progressed, my study did not take into account how long the process occurred for each case. Due to time constraints of this study being within an M.S. program and the MIX program ending, further investigation is needed on how new teachers in the profession were progressing into leadership stages. With Stage 2 teacher leadership making a positive impact outside the teacher's classroom, future studies may investigate the steps needed to nurture teacher leadership growth in an integrated mathematics and science program.

The link between long term and intense PD based on the outcomes of my study on teacher leadership growth provides further evidence that schools must implement teachers in the leadership process (NRC, 1996). It is essential that teachers be included in educational reform (EL-Deghaidy et al., 2015). Teachers who are included in leadership roles on their campus can ultimately lead to overall school improvement. (Nicholson et al., 2016). York and Barr (2004) found teachers serve various leadership roles on their campus, which was similar to the findings within my study. An integrated mathematics and science approach can initially be uncomfortable for educators, but the benefits of students developing a deeper understanding of the content can be long-lasting (NCTM, 2000). My study sought to investigate teacher leadership growth in a mathematics and science integrated professional development program and I discovered teachers were not only implementing best practices but advocating for them at various stages.

APPENDIX SECTION

A. CLASSROOM OBSERVATION FORM

B. TEACHER LEADERSHIP SURVEY

C. MIX IT UP: CORRELATED MATH OBSERVATION FORM DATA

APPENDIX A: CLASSROOM OBSERVATION FORM

Date:

TQ "*Mix It Up*": Correlated Science and Math
OBSERVATION FORM

Teacher: Grade Level: Class Size: Room Size:
District School: Principal:
Date of Observation: Lesson objective: TEKS:
Cohort- Began T=Teacher S= Student Ss=Students
Time:
Recommendations:

Effective Strategies	**0-3, N/A**	**Comments**
Enhanced Context (real world, science fair, problem/case based, use tech. to bring in real world, relating learning to students' previous experiences, knowledge or interests, Problem/Project Based Learning, field trips, use schoolyard for lessons, hurricanes, or climate change, encouraging reflection)		
Collaborative Learning (arrange students in flexible groups w/ assigned roles to work on various tasks, use Cooperative Learning, e.g. conducting lab/field activities, investigations, group science fair projects, discussion, heterogeneous.)		
Questioning (varying time, positioning, or cognitive levels of questions, e.g. increasing wait time, adding pauses at key student-response points, including more high-cognitive-level questions, stopping visual media at key points and asking questions)		
Inquiry (student-centered, inductive instructional activities, e.g. using guided or facilitated inquiry activities, students plan & conduct their own investigations, guided discoveries, inductive lab activities, indirect instruction. Using Descriptive, Comparative/Correlational or Experimental designs.)		
Manipulation (opportunities to work or practice with physical objects, e.g. operating apparatus, developing skills using manipulatives, drawing or constructing something)		
Testing (changes in frequency, purpose, or cognitive levels or evaluation, e.g. providing immediate or explanatory feedback, using diagnostic testing, formative testing, retesting, testing to master)		
Instructional Technology (use tech. to enhance instruction, e.g. using computers, etc. for simulations, modeling abstract concepts, and collecting data, showing videos to emphasize a concept, using pictures, photographs, or diagrams, wikis, pod casts, blogs)		
Enhanced Material (modified instructional materials, lessons or labs, e.g. rewriting or annotating text materials, recording directions, simplifying lab apparatus to meet student needs)		

Direct Instruction (teach a process or a skill, how to use equipment, techniques, complete a chart, etc.)		
Student Engagement (>80% actively engaged in discussions, investigations or activities)		
Learning objective aligned w/standards (lesson provided depth of content w/ significant, clear and explicit connections made to TEKS, national standards, big picture, activities clearly link to learning objective, 1 concept /lesson)		
Language accuracy (Consistent use of accurate academic vocabulary that is not misleading, conveys misconceptions or is vague, use nouns instead of pronouns. No sloppy language.)		
Overall Impression: 0 - 1 - 2 - 3		

Enhanced Context:

Collaborative Learning:

Enhanced Materials:
Manipulation:

Integration for Math
Math/Science Integration (using science content/natural world phenomena examples, using science equipment, analyzing science data, referencing relevant science experiences, using the proper science language)

1. Was concept integrated?
2. Was the concept appropriate to integrate?

Integration for Science
Math/Science Integration (using mathematics in science instruction, using mathematics manipulatives when appropriate, using mathematics in the same manner as is taught in the mathematics classes and not undermining conceptual understanding by teaching mathematics tricks, using the proper math language.)

1. Was concept integrated?
2. Was the concept appropriate to integrate?
3. Best Practice checklist/rubric: Best practice instructional strategies are measured on a 3-point scale ranging from being observed 0 (not at all) to 3 (greatest extent) or N/A.
4. Interview with Teacher:

A. How was this lesson a typical science or math lesson? B. Was the same lesson taught in previous years? 1. What are some examples of integrated lessons you used in your classroom? Integrated Math lesson (using science content/natural world phenomena examples, using science equipment, analyzing science data, referencing relevant science experiences, using the proper science language) Integrated Science lesson (using mathematics in science instruction, using mathematics manipulatives when appropriate, using	

mathematics in the same manner as is taught in the mathematics classes and not undermining conceptual understanding by teaching mathematics tricks, using the proper math language.) 2. How well did it/they work? How did you measure its effectiveness? Will you teach it again? How would you change it to teach again? 3. How many integrated lessons have you &/or your team done this year? 4. If none, then why? 5. How else can we help you integrate science & math? 6. How else can we help you to use more Best Practices? 7. What did your Principal do to help	
C. What was the most valuable part of the *Mix It Up* program for you?	
D. How can the *Mix It Up* program be improved?	

APPENDIX B: TEACHER LEADERSHIP SURVEY

Teacher Leadership Survey
Name ___________________________________

Please fill in the response that best represents the characteristics you possess.

1. Willingness to grow.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

2. Possess strong pedagogy.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

3. Intrinsically motivated.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

4. Possess strong content knowledge.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

5. Have a positive attitude.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

6. Have principal support.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

7. Have confidence.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

8. Trustworthy.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

9. Collaborate with others.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

10. Highly organized.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

11. Have a vision for your own personal growth.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

12. Have a vision for your Mathematics/Science department or campus.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

13. Support your team.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

14. Attend non required professional development.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

15. Work with your community.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

16. Achieve student growth in your classroom.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

If so, how do you monitor growth in your classroom?

____

17. Implement Mix's known to unknown in your lesson plans.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

18. Implement Mix's abstract-pictorial/representation-concrete in your lesson plans.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

19. Implement Mix's one concept per lesson in your lesson plans.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

20. Practice 3 second wait time during questioning.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

21. Call on a non-volunteer when asking a question.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

22. Familiar with the national mathematics and/or science standards.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

23. Integrate mathematics and science into your lesson plans.

- ○ A. Always
- ○ B. Often
- ○ C. Not very often
- ○ D. Never

24. Understand the importance of mathematics and science integration in your lesson plans.

- ○ A. Strongly Agree
- ○ B. Agree
- ○ C. Disagree
- ○ D. Strongly Disagree

APPENDIX C: MIX IT UP: CORRELATED MATH OBSERVATION FORM DATA

TQ Number	Date of Observation	Best Practice Overall Score	Integration of Science and Mathematics Score	Total Individual Observation Score	Average Score of all Observation	Global Score:
548107	9/28/16	3	N	4	4.5	Clear
548107	10/25/16	3	Y	5		
548107	2/17/17	3	Y	5		
548107	4/28/17	3	N	4		
548210	9/27/16	1	N	2	3	Clear
548210	10/20/16	2	N	3		
548210	2/1/17	2	Y	4		
548210	10/11/17	2	N	3		
548210	10/26/17	2	N	3		
548210	11/29/17	2	N	3		
548210	12/13/17	2	N	3		
548210	2/3/18	2	N	3		
548109	9/29/16	2	Y	2	3.9	Clear
548109	12/5/16	3	Y	5		
548109	2/23/17	3	N	4		
548109	5/9/17	3	N	4		
548109	10/6/17	3	N	3		
548109	10/31/17	3	N	4		
548109	11/7/17	3	N	4		
548109	12/5/17	3	Y	5		
548109	2/15/18	3	N	4		
548110	9/28/17	2	N	3	4	Clear
548110	10/18/17	3	N	4		

548110	11/9/17	3	Y	5		
548110	12/14/17	3	N	4		
548110	2/9/18	3	N	4		
548111	10/4/17	1	N	1	3.7	Clear
548111	10/20/17	2	N	3		
548111	11/15/17	3	N	4		
548111	12/12/17	3	N	4		
548111	1/25/18	3	Y	5		
548111	2/14/18	3	Y	5		
548205	10/12/16	2	N	3	3	Some
548205	11/15/16	2	N	2		
548205	2/22/17	3	N	4		
548105	10/12/16	2	N	3	3.25	Some
548105	11/15/16	2	N	2		
548105	2/22/17	2	N	3		
548105	4/5/17	2	N	3		
548105	9/28/17	2	N	3		
548105	10/18/17	2	Y	4		
548105	12/15/17	3	N	4		
548105	2/14/18	3	N	4		
548217	9/8/16		Y		3.9	Clear
548217	12/12/16	1	Y	3		
548217	1/20/17	1	N	2		
548217	3/3/17	3	Y	5		
548217	4/25/17	2	N	2		
548217	9/26/17	2	N	3		
548217	10/23/17	2	Y	4		
548217	11/28/17	3	Y	5		

548217	12/15/17	3	Y	5		
548217	1/22/18	3	Y	5		
548217	2/12/18	3	Y	5		
548209	9/8/16		Y		3.7	Clear
548209	12/12/16	3	N	4		
548209	1/19/17	2	N	3		
548209	3/3/17	3	Y	5		
548209	4/25/17	2	Y	4		
548209	9/26/17	2	Y	4		
548209	10/23/17	2	Y	4		
548209	11/28/17	3	N	4		
548209	12/8/17	3	N	4		
548209	1/18/18	2	N	2		
548209	2/12/18	2	N	3		
548112	10/4/17	3	N	4	4	Clear
548112	10/25/17	3	N	4		
548112	11/8/17	3	N	4		
548112	12/14/17	3	N	4		
548112	2/19/18	3	N	4		
548222	9/15/17	2	N	3	3	Some
548222	10/16/17	1	N	2		
548222	11/30/17	1	N	2		
548222	12/14/17	3	N	4		
548222	1/22/18	2	N	3		
548222	2/9/18	2	Y	4		
548213	9/13/16		N		2.4	Some
548213	12/6/16	1	N	2		
548213	1/19/17	1	N	1		

548213	4/6/17	1	N	2		
548213	4/28/17	3	Y	5		
548213	9/28/17	1	N	2		
548213	10/24/17	1	N	2		
548213	11/16/17	1	N	1		
548213	12/5/17	2	N	3		
548213	1/18/18	2	N	3		
548213	2/12/18	2	N	3		
548221	9/14/17	2	N	3	2.8	Some
548221	10/17/17	1	N	2		
548221	11/17/17	1	N	2		
548221	12/7/17	2	N	3		
548221	1/18/18	2	N	3		
548221	2/12/18	3	N	4		
548212	9/9/16		N		3.5	Some
548212	12/5/16	2	N	2		
548212	1/24/17	2	N	2		
548212	3/30/17	3	Y	5		
548212	4/28/17	2	N	3		
548212	9/14/17	2	N	3		
548212	10/17/17	3	Y	5		
548212	11/16/17	1	N	2		
548212	12/15/17	3	N	4		
548212	1/19/18	3	Y	5		
548212	2/8/18	3	N	4		
548203	9/9/16		Y		2.8	Some
548203	12/5/16	1	N	2		
548203	1/24/17	2	N	3		

548203	3/30/17	2	Y	4		
548203	4/28/17	2	N	3		
548203	9/14/17	1	N	2		
548203	10/16/17	2	N	3		
548203	11/16/17	2	N	3		
548203	12/15/17	2	N	3		
548203	1/19/18	2	N	3		
548203	2/12/18	2	N	2		
548219	9/4/17	2	N	3	3.5	Some
548219	10/17/17	1	N	2		
548219	11/30/17	3	N	4		
548219	12/14/17	3	Y	5		
548219	1/22/18	3	N	4		
548219	2/8/18	2	N	3		
548218	10/16/17	1	N	2	2.4	Some
548218	11/16/17	2	N	3		
548218	12/5/17	1	N	2		
548218	1/18/18	2	N	2		
548218	2/9/18	2	N	3		
548220	9/27/17	1	Y	3	2.8	Some
548220	10/24/17	1	N	2		
548220	11/17/17	1	Y	3		
548220	12/7/17	1	N	2		
548220	1/19/18	2	N	2		
548220	2/8/17	3	Y	5		
548214	10/5/16		N		4	Clear
548214	12/1/16	3	N	4		
548211	9/28/16	1	N	3	3	Some

548211	10/25/16	1	Y	3		
548211	2/2/17	2	N	3		
548211	5/17/17	2	N	3		
548214	10/5/16	2	N	3	3.5	Some
548214	12/1/16	2	Y	4		
548108	10/21/16	1	N	2	2.5	Some
548108	12/2/16	1	Y	3		
548108	2/7/17	1	Y	3		
548108	5/17/17	1	N	2		
548215	11/17/16	2	N	2	3.25	Some
548215	12/5/16	2	Y	4		
548215	2/3/17	2	N	3		
548215	3/3/17	3	N	4		

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