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An effective model of developing teacher leaders in STEM education

Heidi Sublette

Pepperdine University

Graduate School of Education and Psychology

AN EFFECTIVE MODEL OF DEVELOPING TEACHER LEADERS IN STEM EDUCATION

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Heidi Sublette

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June Schmieder-Ramirez, Ph.D. – Dissertation Chairperson

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Heidi Sublette

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Doctoral Committee:

June Schmieder-Ramirez, Ph.D., Chairperson

James DellaNeve, Ed.D.

JL Fortson, Ed.D.

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DEDICATION

This dissertation is dedicated to my mother, Susan Hawkins, who has always been a true example of a leader in my life. She modeled the way for me and her stamina inspired me to push myself beyond the ordinary, she is my inspiration.

ABSTRACT

In the last 5 years, industries have begun to recognize a growing gap in the production of college graduates in areas of STEM. Researchers in various industries believe this gap will create a significant loss of competitive edge in the STEM fields, which will leave the United States pursuing STEM graduates from foreign countries and may ultimately leave the US behind in the industry of science, technology and innovation. This qualitative study analyzes the value and impact of STEM teacher leaders in secondary education. A phenomenological study was conducted with 10 secondary school science and math teacher leaders in order to gain a better understanding of teacher leaders' perceptions, classroom practices and the role of a STEM teacher leader. This study addresses the following research questions: 1) What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the Center for Math and Science Teaching system? 2) What success strategies, among teacher leaders of the Center for Math and Science Teaching program, have enabled further development of teacher leadership? 3) What is the best model in developing teacher leaders, according to literature from 2005 to present? 4) What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education? This research aims to explore teacher leaders' perceptions of their role as a teacher leader based on strategies learned from CMAST and past experiences. Findings from this study provide critical data for making informed decisions on including important elements when implementing an effective STEM teacher leader system or program, and the impact it can create on science and math teaching and learning in secondary education. The

investigator concludes this study with the development of a STEM teacher leader model that merges these findings with existing research.

Chapter 1: Introduction

As we move through this highly technological evolving time, there is a need for change in education, but specifically in teaching and learning of science, technology, engineering and math (STEM) disciplines in our current K-16 systems. STEM education offers students the necessary skills needed to form inquiry-based learning strategies and critical thinking through thought-provoking projects; STEM is becoming a primary focus in education and industry in the US. For the growth of the US as well as national security, it is imperative that STEM fields and the STEM education pipeline gain the necessary awareness and tools needed. The demand for scientists and engineers is expected to increase by four times the rate over the next decade (California Space Education and Workforce Institute, 2008). Our STEM educators will now have the weight on their shoulders as they focus on producing our future STEM leaders and engineers.

In the Executive Report under President Barack Obama, *Prepare and Inspire: K-12 Education in Science, Technology, Engineering and Math the President's Council of Advisors on Science and Math Education for America's Future*, The President's Council of Advisors on Science and Technology (PRESIDENTS COUNCIL OF ADVISORS ON SCIENCE AND TECHNOLOGY) stated the education system in the US must provide a strong foundation in STEM disciplines (President's Council of Advisors on Science and Technology, 2010). Following this Council are many small and large organizations, state, federal and local leaders spearheading a STEM movement in the US. These proponents of STEM education, as well as industry leaders, believe that increasing math and science requirements in schools, as well as embedding technology and engineering concepts, will better prepare students for advanced education or careers in STEM fields. This would result in the US rising as the world leader of science innovation once again.

The STEM fields have been gaining attention due to the current career gap; there are not enough people to fill the current job market and for the jobs being filled, the skills needed are not meeting industry standards, leading to less than adequate performance. These lack of skills are due to the education and industry gap. The industry standards in engineering are becoming so highly technological and advanced that some universities have not grasped the expansion. It would be highly beneficial for STEM educators to embed laboratory or field experience in their own learning as this change in STEM education evolves.

Due to the demands of the STEM fields, there are emerging groups all over the US providing assistance to K-12 schools, creating awareness and leading change. These groups are an essential piece in the success of STEM development, as they are creating an opportunity for a movement of change in education, and a voice for highly technological students who are ready for a new type of classroom learning experience. Global Employment Trends (2011) reported 77 million youth around the world are unemployed partly due to the lack of necessary skill development. Due to these lack of skills needed in the workplace, businesses and foundations have been pulling together to create new opportunities for both teachers and students, creating opportunities for skill development and designing pathways for a bright future for degree holders.

New Generation Science Standards (NGSS) have emerged from the National Academy of Sciences to build a rich and in-depth curriculum of inquiry based instruction where students build science knowledge year after year, beginning in kindergarten. These standards offer a new look into science and offer students a breadth of discovery among various areas, including engineering and technology. The NGSS were created to better prepare students in STEM by enhancing and integrating the STEM subjects, as well as adding engineering and technology as necessary components of science development. These standards, similar to the Common Core State Standards in Math and English Language Arts recently adopted by California and most states, focus on a more in-depth learning that pushes teachers and students beyond the surface of learning. Additionally, the standards enable students to be problem-solvers, innovators, and self-directed learners; or as the California STEM Learning Network (2012) describes them, “STEM-capable” graduates. The NGSS have not been implemented in the state of California; however, the addition is expected in the 2013 school year.

> These new STEM standards have another important consequence. They have created a “reset button” for policy, providing states the opportunity to re-think curriculum and high-stakes testing, how we prepare and support teachers, and how we deliver high-quality education. In so doing, they offer the promise of breaking down the walls between the classroom and real-world learning experiences. (California STEM Learning Network Forum, 2012)

With this evolving movement comes the issue of who is leading the efforts in this reform. Current classroom teachers in STEM disciplines need support, time, and money to conduct the needed change that is being demanded of them.   There have been several initiatives presented by the US government and one is to create a Teacher Leader or Teacher Mentor program.

Loyola Marymount University Center for Math and Science Teaching (CMAST)

This section offers a brief description about this unique Center for Math and Science Teaching (CMAST) system founded by Kathy Clemmer, who began a math and science teaching (MAST) program, while working in her school district. Kathy was considered a master teacher and maintained excellence in the classroom. Kathy collaborated with Loyola Marymount University and together they developed CMAST.

The CMAST system assists in preparing the next generation of STEM teachers who "engage and inspire students to achieve and pursue STEM" disciplines and careers. CMAST offers three programs labeled "systems," to teachers wanting to expand their role at their current school sites: MAST support of Common Core State Standards (CCSS), MAST Teacher Leader Certificate, and Los Angeles Math and Science residency (LAMS). It is important to note that these systems are not creating leaders who plan to leave the classroom in the near future. The program administrators and faculty prefer teachers enrolled in CMAST to remain in their classroom, practicing effective teaching methods of which they are coaching to their peers, while building strong STEM pedagogy. This takes a specific participant, which this research further highlights.

History of the Issue

The US has always been a leader in science innovation and industry with the production of aircraft, spacecraft, and technically advanced systems, but this could potentially change. In the last 5 years, industries began to recognize a growing gap in the production of college graduates in areas of STEM. Researchers in various industries believe this gap will create a significant loss of competitive edge in the STEM fields, which will leave the United States pursuing STEM graduates from foreign countries and may ultimately leave the US behind in the industry of science technology and innovation.

The government has established and confirmed the need for STEM focused programs in the US. The need is evident among most industries by the number of unemployed and the number of jobs available in the US. It demonstrates clear distinction in the lack of skill development in those emerging into the workforce. With this recognition came legislative proposals to assist funding of STEM programs. In, 2007 President Bush signed the America Competes Act, which was passed by the 110th Congress (Kuenzi, Mathews, & Mangen, 2006). This act was a bipartisan legislative response to recommendations detailed in the National Research Council (2007), *Rising Above the Gathering Storm* and the Academy of Science (2007) *Innovate America* report (Thomas & Williams, 2010). The America Competes Act of 2007 was amended and resigned by Obama in 2010. The Act of 2007 was “to invest in innovation and research and development and to increase the competitiveness of the US”(America Competes Act USC, 2007, p. 146). The 2010 Act has added several more components to increase funding and expand authorization of committees involved in STEM and business fields.

There have been several initiatives presented by the US government, and in addition to the America Competes Act, another is to create a teacher leader or teacher mentor program, called STEM Master Teachers Corp (President’s Council of Advisors on Science and Technology, 2010). “The President’s plan would begin with 2500 teachers, 50 in 50 sites across the country and locations over the next four years until there are ten thousand teachers in this sector” (President’s Council of Advisors on

Science and Technology, 2010). This initiative has shed some light on individual states and currently California is part of the 100 thousand in 10 initiative and movement led by the federal government. This movement is to create one hundred thousand effective STEM teachers in ten years (California STEM Learning Network Forum, 2012). Many states have also jumped on this movement and there are websites, campaigns, and ads throughout the US advertising this movement. It is now reaching businesses and industries in need of graduates.

The business community has become more and more active in the last few years, because they claim that the nearly 200,000 students who graduated in STEM disciplines in 2004 are not an adequate amount to meet the demands of the science and technology industry. The concern is growing due to hundreds of thousands of students graduating in the STEM disciplines; thousands are not adequately prepared or have the skill development needed to perform the job (Elrod, 2010). Skill development reflects on the university programs educating students in STEM disciplines.

According to Tsupros, Kohler and Hallinen (2009), “STEM education should be instructed using an integrated method of science, technology, engineering, and mathematics in contexts that connect school, communities, and global enterprise for developing STEM knowledge.” A STEM curriculum should be facilitated by presenting real-world problems, driving students to apply STEM learning to create and engage in rich experiments, analyze and interpret data, and deliver authentic findings (Wineberg & Grossman, 2000).

Statement of the Problem

There is a strong need for education reform in science and mathematics throughout the US. The US has been the leader of science innovation for the last century, and other countries may soon overtake it if STEM education does not become a major concern throughout this country. According to the STEM Education Coalition 2008 Report Card over the last decade the percentage of ACT-tested students who stated they had an interest in majoring in engineering has dropped from 7.6 to 4.9 percent, and those majoring in computer science has dropped from 4.5 to 2.9 percent (California STEM ED Coalition, 2008). It has also been discovered that students most likely to major in STEM fields in college and earn a degree, are well prepared in high school with challenging classes and college-level science and math coursework (California STEM Ed Coalition, 2008). This means that students should ideally identify and follow a science path prior to middle school.

In a study conducted using a data set collected by the National Center for Educational Statistics, it was found that students who reported a career interest in a science-related field in eighth grade were two to three times more likely to earn a STEM degree ten years later (PLTW.org). In a national survey of over 4,000 scientists and graduate students in the fields of chemistry and physics, researchers found that nearly 70% reported that they first became interested in science in middle school (National Research Council, 2007, p. 10).

Rigorous and engaging coursework will most likely lead to a successful outcome in the STEM disciplines and fields during high school; however, it has been discovered that many science teachers today are still using 19th century teaching methods for STEM disciplines. There is a need for change with such technological advances. Our current education system still highly focuses science and math in secondary education as single instructed subjects, but there is a call for integrating technology and engineering in the current science and math frameworks. STEM students need inquiry based instruction methods, allowing them to gain conceptual knowledge along with the development of critical thinking skills; these skills may be better developed when the subject of science is merged with engineering, technology and math. There are currently an abundance of science and math teachers using textbooks as the primary learning tool, rather than an inquiry-based or reasoning model and an opportunity for exploration and discovery.

In a recent 2011 study, conducted by 27 graduate students in a STEM leadership program, students questioned their teacher colleagues and administrators on defining STEM. A survey was utilized and resulted in approximately half of 200 teachers surveyed were able to identify the STEM acronym, half of all administrators could define STEM education, and about 60 percent of science teachers could describe STEM education (Brown, Brown, Reardon, & Merrill, 2011). This raises an issue of a lack of awareness among educators on the STEM focus in the US as well as a clear definition of STEM.

Statement of the Purpose

The purpose of this study is to research the Loyola Marymount CMAST system, focused on science and mathematics teaching and learning methods in secondary classrooms. The research developed from this study provides an analysis on secondary math and science teachers emerging as teacher leaders to change and sustain STEM-based instruction. Engaging teachers as teacher leaders to impact student learning and create sustainable change, is an area with minimal research. This study will identify an effective model of leading and preparing secondary teachers of STEM disciplines in the state of California to better prepare students to enter STEM disciplines and fields.

The research further examines the education of our current secondary teachers with an opportunity to further develop their knowledge of STEM teaching and learning methods through teacher leaders. This research will provide depth on how we can better equip current secondary classroom STEM teachers with opportunities for professional development and leadership. The outcomes of this study will enhance the development of the teaching and learning of STEM in secondary classrooms and may assist STEM teacher preparation development among other post-secondary institutions.

Recent Statistics on the Topic

The National Academy of Science, National Academy of Engineering, and Institute of Medicine of the National Academies, (NSF, 2006) has tracked data from many countries on the amount of university degrees awarded in STEM fields. This data concludes the US has one of the lowest rates of STEM to non-STEM degree productions in the world. “STEM degrees accounted for 16.8 percent of all university degrees awarded in the US compared to 46.7 percent in China, 37.8 in South Korea, and 28.1 percent in Germany” (NSF, 2006). The international average of this same ration was 26.4 percent in 2002.

The American Council on Education Fellows, all with backgrounds in STEM fields, has created a mission of preparing the next generation of STEM leaders. The STEM pipeline narrows significantly from 9th grade through college graduates. A study conducted by the National Science Board followed a 10 year pipeline and began with STEM engagement in 1997 with 3.8 million 9th graders, narrowing to 2.7 million high school graduates in 2001 to 1.7 million college freshman to only 233,000 STEM graduates in 2007 (National Science Board, 2010). This shows that about 70% of STEM focused students who enter college as freshman have changed their major out of STEM disciplines upon graduation.

Further statistics from Global Employment Trends 2011 reported 77 million young adults around the world are unemployed partly due to the lack of necessary skill development. Due to these lack of skills needed in the workplace, businesses and foundations have been pulling together to create new opportunities for both teachers and students, creating opportunities for skill development, and designing pathways for a bright future for degree holders. Furthermore, a recent report developed and published by a national nonprofit research group called Change the Equation, stated California has nearly 1.5 open jobs in STEM fields for every qualified job seeker. California additionally has the third highest unemployment rate in the nation (California STEM Learning Network, 2012).

In addition to the lack of skilled STEM employment candidates, "California students are among the lowest performing and least-funded, with fewer students earning degrees in STEM fields when compared to other states." California has nearly one million STEM workers and an expected 19 percent growth rate in STEM jobs over the next decade; however, the state is only producing an estimated 21,000 STEM bachelor's degrees annually, with only one in 10 degrees or certificates awarded in STEM fields (California STEM Learning Network, 2012). Among these statistics, are an extremely low percentage of minors and women represented in STEM fields and/or disciplines.

Research Questions

STEM integration into our current math and science classrooms is urgent and necessary. This study will explore additional research needed to gain understanding on identifying the attributes that create effective secondary STEM classroom teachers. The following research questions will guide this study:

1. What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the Center for Math and Science Teaching system?
2. What is the best model in developing teacher leaders, according to literature from 2005 to present?
3. What success strategies, among teacher leaders of the CMAST program, have enabled further development of teacher leadership?
4. What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education?

Significance of the Topic

The current STEM movement has reached a state and national level. For this reason, it is necessary to keep the momentum of this trend and to spark the necessary education reform in US classrooms. Additionally, the US is approaching a large displacement of teachers due to upcoming retirement plans of Baby Boomers. This is a perfect opportunity for STEM education reform to occur as universities begin placing future teachers in US classrooms.

The significance of this study is based on a great need to improve teacher recruitment, preparation, retention, and renewal. The Science, Technology, Engineering and Math Collaborative Action Plan (STEM CAP) was designed by government, academia, and industry leaders to strategically identify STEM priorities. This collaboration resulted in an analysis of influential STEM related state and national reports written and commissioned by the Business-Higher Education Forum, US Department of Education, Business Roundtable, National Science and Technology Council, Council on Competitiveness, Congressional Research Service, National Governors' Association, US Department of Labor, National Science Board, National Action Plan and others, as well as the results of the three California Space and Engineering Workforce Institute forums and the STEM CAP focus groups (California STEM Ed Coalition, 2008). At its August, 2007 meeting, the STEM CAP Advisory Group reviewed the recommendations from the 22 most cited National and State reports on STEM. One hundred plus recommendations were placed into ten categories, with the focus on teaching and student learning as the top two:

1. "Teacher recruitment and preparation
2. Teacher retention and renewal
3. Student recruitment
4. Curriculum
5. Promising practices/data
6. Strategic communication/marketing
7. State policy/leadership
8. Business collaboration
9. Coordination/articulation
10. Finance" (STEMCAP, 2008)

California has had an immense decrease in the number of students majoring in teacher education. More than 20,000 K-12 teachers have been laid off in the last several years, which have led to enrollments in teacher preparation programs down by half over the last three years (California STEM Learning Network, 2012). The high number of K-12 teachers laid off has created a deterrent for college graduates to enter the teaching field. There are currently a number of university programs pulling prospective STEM teachers from the math and science majors, providing incentives to enter the teaching workforce to increase the quality of STEM education. The state of California educates nearly one in eight students nationally, and despite fewer resources, achievement levels among California's six million students have been increasing steadily (T. Torlakson, personal communication, October 16, 2012).

This research provides critical data for making decisions about the direction for STEM teacher education programs both at the teacher level or master's level, the undergrad level, and STEM teacher professional development programs. The results also present to practitioners, administrators, researchers, and policymakers the role of STEM in science and math education reform in the coming years. This study is critical to how we measure classroom learning with STEM based practices, and this is an area of research that hasn't been assessed in the past.

Key Definitions

Several new terms may arise in the remaining chapters of this study and may have interpreted meanings. The following are key definitions of these terms to guide the reader:

STEM education. According to CMAST, STEM education refers to the design of how education is delivered, but primarily recognizes the common element among the four disciplines (science, technology, engineering and math) of creating inquiry through reasoning.

Teacher leader (TL). A teacher leader facilitating learning to other groups of teachers through collaboration, guided instruction, and observation.

Master teacher. A teacher evaluated and deemed highly effective in his or her practice of teaching and learning or pedagogy.

STEM teacher leaders. Teacher leaders working collaboratively to assist in the development of teachers and pedagogy in the STEM disciplines, such as science, technology and math.

Common core state standards (CCSS). These are the newly adopted standards that all children are benchmarked with every grade level in Kindergarten through twelfth grade. The CCSS have been adopted in California.

New generation science standards (NGSS). These content national standards will be released in the Fall of 2013.

STEM fields. STEM fields are also known as STEM careers in science, technology, engineering or math.

100K in 10. Nationwide initiative to have 100,000 highly effective STEM teachers in classrooms in 10 years.

Key Assumptions

Classroom teachers continue to be held to high standards under strict guidelines from public districts and parents. It is up to higher education institutions to produce high quality teachers through effective STEM teacher education curriculum, providing them with the tools they need to meet these high standards. Therefore, teacher quality is also examined to identify what outcomes universities are striving to meet. It is further assumed that the teacher leaders participating in this study are highly effective teachers and are a model for STEM pedagogy.

The sample studied was representative of the total population of teacher leaders and faculty of the CMAST system. The participants in this study answered all of the interview questions openly and honestly. Responses received from the participants accurately reflect their professional opinions and perceptions.

Delimitations of the Study

This section clarifies the researchers delimitations to indicate the narrowing of the study's scope. The delimitations noted here are primarily based on the nature of the study and the criteria of the study. The following delimitations are detailed as: 1) The time of the study is a narrowed time frame to complete the research, Spring, 2013; 2) The location of the study was narrowed to the regional area of Southern California, interviewing a small sample in small school districts; 3) The sample of the study is limited and represents a small portion of the population of STEM teacher leaders; and 4) The researcher chose to focus on selected samples to interview.

Summary

The remainder of the study is organized into five chapters, appendixes and a bibliography in the following manner. Chapter Two presents a review of literature creating a framework for the study with background on STEM, expansion on evolving trends of STEM teacher leaders, STEM pedagogy and adult learning. Chapter Three delineates the research design and methodology of the study; instrumentation, procedures, data analysis are also described. The data analysis and research findings are illustrated in Chapter Four. Chapter Five includes conclusions, a conclusion and further recommendations. The study concludes with a bibliography and a list of appendixes.

Chapter 2: Review of Relevant Literature

Taking the following research on the critical role of the teacher leader and applying to it to how STEM (science, technology, engineering, and math) disciplines should be taught and learned is critical in the advancement of STEM. The intent of this study is to create a framework for further research and to highlight previous research and theories related to the topic of teacher education models and teacher leaders in STEM. Aligned with this purpose, this chapter will focus on five frameworks: 1) Historical Overview of STEM; 2) STEM Pedagogy; 3) Teacher Leaders; 4) STEM Teacher Leaders; and 5) Adult Learning. This research will provide depth and insight to further understand how teacher leaders can impact STEM disciplines by engaging colleagues to further develop effective STEM learning experiences for students.

Historical Overview of STEM Education

STEM history dates back to the late 1700s with the emersion of scientists and theorists who made pivotal impacts in education. These scientists and education leaders have created a path for the current STEM movement two hundred years later. The impact of their innovation and passion for learning influences how STEM education is conducted in classrooms to this day.

The Dewey School was formed in 1896 when John Dewey created a leaning laboratory where he could test his theories, and additionally initiated school reform; his philosophies and research helped benefit STEM education and what is known today about pedagogy (Goodchild, 2012). Furthermore, in 1931, Dewey wrote and published a pamphlet, *The Way Out of Educational Confusion,* which paved the way for integrating curriculum in classrooms the through the 1950s. Dewey didn't believe that disciplines shouldn't be separate, but rather brought to life through real-world application (Dewey, 1931). Like Dewey, Thomas Huxley was an education pioneer and in 1899 he concluded that science education was essential for understanding the modern world (Association of Higher Education, 2011). Additionally, he recommended that science should be taught at an early age, while using physical real-world objects rather than books for learning.

The Smith-Hughes Act of 1917 was another event that led to reform in education and created an evolution for vocational-focused education. This Act provided federal and state funding for teacher training in secondary vocational education settings (Scott & Sarkees-Wircenski, 1996). This Act led the way for future education funding, and sparked innovation after World War I, where technology really paid off with bomb-dropping planes. The idea of these warplanes was desperately needed after the attack on Pearl Harbor.

The attack on Pearl Harbor had a large impact on science education. Not only did the emerging war cause many deaths and casualties of young scholars pursuing STEM disciplines, the war identified a lack of quantitative reasoning skills and illiteracy among Americans through the drafting process (Scott & Sarkees-Wircenski, 1996). This event, created a needed awareness that education standards were not being met; furthermore, it led to future legislative activity.

The National Science Foundation (NSF) Act, signed by President Truman in 1950, led a large movement toward the progression of science and math education (Appel, 2000). The NSF began creating funding and grants to support science education and science innovation projects associated with the government. This foundation was a staple in the development and enhancements in science in the United States.

The focus on science and technology education in the US during the second half of the 20th century was a reaction to the Soviet Union's launch of Sputnik in 1957, along with the Cold War creating an increased demand in science and technology (Thomas & Williams, 2010). This continuous educational, and slow-moving trend led to significant public and governmental support for enhanced STEM education in the 1980s. This support led to specialized STEM schools, like math and science charter schools, which were created to address concerns about the US economic competitiveness and possible deficiency of STEM leaders and talent.

STEM specialized schools have a long history in the US The first STEM specialized high school, Stuyvesant High School, was founded in 1904 and the New York Bronx High School of Science, in 1938 (Presidents Council of Advisors on Science and Technology, 2010). These two schools alone set a standard for the US and these types of specialized schools offered a great education as well as opportunities and graduates went on to produce generations of STEM leaders. These schools continue to provide a meaningful and rich learning experience in STEM disciplines, however according to Presidents Council of Advisors on Science and Technology (2010) there are around one hundred current STEM-focused schools. This means in the last one hundred years, one hundred STEM focused schools have been developed and continue to thrive; the federal government has an initiative to create one thousand STEM-focused schools in the next decade (Fajemidagba, Salman, & Olawoye, 2010). The schools focus on STEM disciplines, but more importantly bring students together to collaborate in inquiry-based learning through advanced STEM content.

Since there are such limited number of STEM specialized schools, it is important to bridge the gap between schools and STEM experts. Further investigation into K-12 schools connecting with science experts proves beneficial; the Teacher Institute, which began in 1978, connects K-12 schools throughout the country with universities (President's Council of Advisors on Science and Technology, 2010). This allows teachers to further collaborate on various disciplines and gain further depth. An example of this is National Lab Day, an ongoing network of teachers, STEM partners, and more than 200 partners who come together to bridge STEM education with critical influences (National Lab Network, 2013). This is one of many programs that must develop and unite STEM teachers with industry and key steak holders in STEM fields.

Project 2061 is a science program that began in 1985 and is running strong to this day. The American Association of the Advancement of Science (1993), dating back to 1848, is running this program and its purpose is to enhance STEM education in the United States. Project 2061 focuses on curriculum, professional development, and training and produces a publication focusing on these components. Additionally, Project 2061 began just after the visibility of Hailey's Comet to further develop science literacy among Americans.

The National Research Council created the National Science Education Standards (NSES) in 1996 to promote and expand the importance of elementary and secondary science education (National Research Council, 2007). These standards are critical because they guide teacher learning, student learning, and the integration of science in general education. The Next Generation Science Standards (NGSS) were created in 2011 and are to be implemented in schools in the state of California in the fall of 2013.

The President's Council of Advisors on Science and Technology wrote a report in 2010 called, *Prepare and Inspire: K-12 STEM Education for America's Future,* which outlines the coming initiatives in STEM education. The following conclusions and initiatives are outlined as: 1) Standards: support the current state-led movement for shared standards in math and science; 2) Teachers: recruit and train 100,000 teachers in the next decade who can prepare and inspire students in STEM; 3) Teachers: recognize and reward the nation's top five percent of STEM teachers, by creating a STEM Master Teacher Corps; 4) Educational technology: use technology to drive innovation, by creating an advanced research projects agency for education; 5) Students: create opportunities for inspiration through individual and group experiences outside the classroom; 6) Schools: create one thousand new STEM-focused schools over the next decade; and 7) Ensure strong and strategic national leadership (Presidents Council of Advisors on Science and Technology, 2010). Having these federally funded initiatives are valuable to know as the movement progresses in the coming years.

The United States, once the leader in science and math innovation, is now in a position of creating a STEM movement, trailing other countries in STEM fields and innovation. The history of science and math education extends to centuries beyond the current time, yet there is a new demand for more reform and focus on science. There is some speculation that due to the demands of No Child Left Behind and the heavy focus placed on reading and math literacy, science was somehow left behind and not a primary concern for future education (Corneliussen, 2011). This long history of STEM in the

United States indicates the breadth of possibility to bring this movement full circle and place the United States back in the lead for science innovation. This history provides a basic framework around the knowledge of STEM education; furthermore, guides this research and the importance of understanding the experiences of STEM teacher leaders and their impact on improving STEM pedagogy and leadership in the classroom and school community.

STEM Pedagogy

STEM pedagogy is critical to this framework as a factor in the importance of how effective STEM methods transfer to learning. "Key hypotheses debated over the past decade is that teacher quality is positively affected by (a) a teacher's possession of a degree or licensure, (b) more years of experience working as a teacher, (c) greater subject matter or pedagogical knowledge, (d) knowledge of how to align standards and curriculum to assessment requirements, and (e) individual characteristics such as verbal ability and competence. All agree that teacher preparation itself plays a role in teacher quality" (Knapp, 2003).

STEM pedagogy can be defined as trans-disciplinary, offering students an opportunity to use project-based learning to define real world problems; furthermore, it is proposed by previous research, in a STEM lesson, the teacher is the facilitator, not the content driver (Aleman, 1992; Darling-Hammond & Youngs, 2002; Fajemidagba et al., 2010; Glasgow, 1997; Nikirk, 2012). STEM is possibly seen as the integration of these four content areas (science, technology, engineering, and math) in ways that are inquiry-based, project-based, and set in real-world applications. Much of the learning occurring in and out of the classroom is discovery. Students are active participants in building new content understanding (Nikirk, 2012; O'Neill, Yamagata, & Togioka, 2012). STEM pedagogy uses the integration of these content areas to empower learners with a sense of being in control of their own learning, engaging their intrinsic desire to learn. Creating a project based curriculum may mean teachers give up some control in the classroom. Instead of teachers dictating the what, where, how, and when of learning, students determine much of the learning through inquiry and discovery (O'Neill et al., 2012).

One study conducted with three teachers willing to participate in an opportunity to transform from math or science teachers into STEM teachers (O'Neill et al., 2012). The study proved that students at a certain point in their education experience are conditioned to student-directed learning, where they are told what to do and fully guided on their learning process. The students assumed the teacher would provide the correct answers as the students reported to the teacher. This made the transformation difficult, as the students felt lost at the midst of the transition.

The STEM learning process in this study started with creating a new environment for students, where discovery was immediately encouraged. Teachers were expected to leave a familiarity with previous teaching experiences and elevate to a new kind of teaching style. A style that promotes learning and motivation for learning (O'Neill et al., 2012). Over time, this study proved that this type of learning environment can create confident students who are capable of independent research and no longer expect the teachers to validate an answer. In the end, the teachers stated the students were rarely directed and did not even want the teachers to provide answers. This is common and supported by experts, who state, "the answers are not important, but more how the students arrived at discovering an answer is what matters" (Wang, Thompson, & Shuler, 1998). The teachers collaborated on this study and together concluded the "students demonstrated greater levels of engagement, willingness, and ability to engage in critical thinking as well as problem solving; higher overall academic achievement as marked by subject test scores and end of year grades" (O'Neill et al., 2012). The teachers further concluded that STEM pedagogy is difficult, but it highly affected the students and their learning experiences and made them better teachers; therefore, better students.

Several themes emerged within this study on STEM pedagogy that highly supports the teacher leader model. First, teachers must be willing to leave their comfort zone in their current teaching methodology. Second, teachers can't immediately change their practices fully without guidance. O'Neill (2012) served as the instructor for two summer classes on STEM pedagogy and how to implement from a STEM perspective. O'Neill additionally served as the teacher leader through classroom observations and continued support and communication for a period of three years. Third, students are already trained to learn a certain way; therefore, STEM teachers must drive new ways of learning and thinking through real-world problems creating meaningful connections (Darling-Hammond & Youngs, 2002; O'Neill et al., 2012). With these three components all of the teachers engaged in this study firmly believe that student motivation, engagement, and academic performance were highly increased, due to the STEM pedagogy they implemented in their classrooms.

It is agreed by many researchers that the STEM educator or teacher is the facilitator, playing a guiding role when students are engaged in multiple forms of learning in the classroom or science and math laboratory (Darling-Hammond & Youngs, 2002; Kuskie & Kuskie, 1994; Nikirk, 2012). It is further recommended that students be fully engaged in learning at all times while in the classroom, if not then teachers become managers of students (Glasgow, 1997). Aleman (1992) believes that students should consistently be "working in cooperative groups to solve problems in a culturally, technologically, and socially evolving environment" (p. 97). These researchers are united in the natural discovery of students and note that continued learning and problem solving are every day occurrences in life and "problems should reflect a bigger picture to the conditions found outside the classroom" (Glasgow, 1997, p. xviii).

Laboy-Rush (2012) states, "integrated STEM education programs should apply equally to the content standards and objective of two or more of the STEM fields." Additionally, it should be noted that when students are exposed early on to math and science in an interactive and engaging environment, competent and confident students will emerge in STEM disciplines (Laboy-Rush, 2012). It is becoming more apparent that STEM educators will need "to allow more time for in-depth and cross-disciplinary learning, for more challenging forms of hands-on work, and for greater opportunities for team teaching and team planning" (Darling-Hammond & Youngs, 2002, p. 6). These strategies will allow students to stay motivated and create a spark for engagement as well as create a student-centered learning environment.

A student-centered or learner-centered classroom creates an opportunity for students to meet learning objectives and outcomes such as critical thinking skills, oral presentation, organization and research, the art of exploration, interpretation, interpersonal skills, and inquiry (Boser, 1993). Additionally, a student-centered classroom allows students to inquire on open-ended questions, providing their own reasoning in their discovery (Wang et. al., 1998). Since STEM teachers are no longer simply delivering or regurgitating information to students, this new role will allow students to take responsibility for their learning. For example, everyone in a small group is held accountable for the successful learning of his or her group members, this leads to the idea of collaborating group work or cooperative learning groups also part of a student-centered or self-motivated learning environment (Ejiwale, 2012).

Shapiro (2004) states, “self-motivated children expect to succeed and set high goals for themselves.” Self-motivated children complete projects they begin, find new and creative ways to stay interested and can delay immediate fulfillment in order to meet their goals (Richberg & Fletcher, 2002). Goleman’s “marshmallow test” showed that some students have a high level of motivation when they were able to wait twenty additional minutes for two cookies versus just receiving one cookie immediately (Goleman, 1996). Self-motivation may rely on others to spark the motivation within those children lacking in this competency.

Nikirk (2012) states this Millennial Generation, also known as the Digital Natives, have always had technology integrated into their lives and really do not recall life without a computer or such technology. This age gap ranges from current school students to adults, seven to thirty years old. Nikirk further implicates that this generation of people think differently and their brains are even wired differently, with technology not being an “add-on to life” like those beyond age 35; his group of people have a different king of learning need.

Nikirk (2012) recommends ten strategies to effectively implement methodology reflecting a STEM learning environment:

> 1) Show graphics first; students react and learn from visuals more quickly than reading text; 2) Start with the end in mind; based on Steven Covey's habits, teachers should begin with the objective and students should know the objective; 3) Start with the concrete concepts, and then move to the abstract; this should be accomplished by using real-world examples so students can relate to the abstract concepts; 4) Integrate technology into teaching; use interactive instructional strategies by incorporating technology through storytelling, virtual labs, games, software, blogs, digital cameras, and audio devices; 5) Teach behavior appropriate to business and industry needs; presenting data through graphs and charts, meeting and greeting professional groups, demonstrating business etiquette, speaking in the active voice; 6) Transition from a teacher-centered to a learner-centered classroom; 7) Transition from group-work to team-work; this teaches students about the power of a vision and working toward a common goal, rather than only producing a product; 8) Fostering a learning environment which values creativity and independent thinking; 9) Engaging students through interactive curriculum; learn to evaluate and utilize technology in a meaningful way; 10) Engage student as teachers, project leaders, technology support, and 'mega-brains' (problem solvers); this is accomplished by recognizing the individual strengths of every student in the class. (Nikirk, 2012, p. 13)

The chances of some students being more skilled on a computer than the teacher, is highly possible with the Digital Native generation.

It is difficult to argue any of the ten strategies Nikirk has described, as they all seem highly relevant and important in every classroom in America, and related to this research more importantly in STEM classrooms. How STEM teachers deliver content and offer inquiry-based learning is critical and has the potential to highly impact this STEM movement. Mastering STEM pedagogy is critical to be able to reflect and utilize a selection of strategies and methods for enhancing math and science education. Part of this mastery is being engaged daily and being prepared to ask students the right questions, which ultimately promotes critical thinking and the ability to think independently.

It will further be concluded through research, that these STEM teaching and learning methods can be established more effectively with the inclusion of STEM teacher leaders. Driving STEM pedagogy is the overall purpose of including STEM teacher leaders in schools; STEM teacher leaders' perceptions will assist in developing further understanding of how STEM teaching and learning ultimately impacts this current STEM movement in the US.

Teachers Leaders

For many decades the "traditional" leaders in K-12 education are the principal and superintendent, one person, whose roles are more managerial than leadership based. They are consumed with parents, control of curriculum, and budgets; principals are in fact so tied to district or superintendent demands that there is little room for the title "leader." This cycle of leadership in education, which has weakened over the last 50 years, has created a new but positive responsibility on educators to take the title of teacher, to teacher leader (Neuman, 2000).

The idea of "I am just a teacher" is no longer acceptable, and the idea of teacher leaders has been developing since the early 90's (Helterbran, 2010). Wasley (1991) suggested the need for teacher leadership for all around school improvement, and this could have begun a movement; however, there was no research or work to support this brilliant theory. Wasley's theory was established based on previous theories that verified a need to establish teacher leaders in schools that remained in the classroom. Now, several decades later there is an ever-expanding body of literature, research and developed theories on the idea of teacher leadership and the impact on student learning. This idea of teacher and leader together is no longer a complex idea.

There has been an extensive societal and demographic change over the last 50 years with increasing diversity; economic demands causing poor funding, and a dire need for a highly educated graduate with a teaching credential (York, 2006). Times have changed and the way America educates and unites in schools has not. Over the last 10 years there has been an expansion of the idea viewing the school as a community, and the role of teacher has increasingly evolved into a role of leadership.

The term leadership is no longer viewed as a particular age, role, or high-level job title of one person. Neuman (2000), along with her team conducted a study using the Annenberg Institute, which provides professional development of leadership strategies, to the school community. The result was intended to infuse a community of leaders. Neuman uses a term distributive leadership also known as shared leadership, which “calls on everyone associated with schools - principals, teachers, school staff members, district personnel, parents, community members, and students - to take responsibility for student achievement and to assume leadership roles in areas in which they are competent and skilled” (Neuman, 2000). Neuman (2000) contributes that “leadership is a characteristic less of an individual than of a community and is a responsibility assumed with the consent of the whole community, with learning as the primary focus.” Change is evident in this progressing STEM movement, Bolman and Deal (2002) state, “when an organization is over-managed but under led, it eventually loses any sense of spirit or purpose” (p. xvi).

Katzenmeyer and Moller (1996), have worked with thousands of teachers and further state, “America’s schools draw vitality from the creativity and commitment of their teachers” (p. vii). They define teacher leaders as “leading within and beyond the classroom, influence others toward improved educational practice, and identify with and contribute to a community of teacher leaders” (p. 6). They are able to see the value of this role if sustainable change is going to occur in schools.

The goal of developing teacher leaders is to facilitate adult learning, and for many it will become a transformational learning experience. An experience where teachers have to raise their level of teaching and expectations, and this develops from goal setting (Drago-Severson, 2006). There are many approaches in developing leaders, and fewer in developing leaders in a non-leadership role. One strategy created by Drago-Severson is Learning-Oriented Leadership, where the leader fosters learning to then create growth among a team with a high level of support. The community benefits from this, as the first of the four pillars in this approach is "supporting the practice of teaming." There is a high importance in teaming in schools because the role of a teacher can become very isolating. Teaming also supports the idea of collaboration and creating a safe place for adults to provide a context with which to experiment and brainstorm, questioning the different philosophies of teaching and learning. This collaboration additionally allows innovation and creativity to occur and go beyond the individual classroom.

The second pillar to Learning-Oriented Leadership is to provide leadership roles. In this strategy or approach Drago-Severson (2006) opposes the thought of "distributive leadership" in contrast to assigning tasks, but instead offers supports and challenges so a teacher can grow and develop as a leader. "The roles invite teachers to share authority and expertise as they work toward creating a community, enriching practice, and developing change individually and as a team" (Drago-Severson, 2006).

The third pillar, collegial inquiry, creates an arena for teachers to practice in the context of supportive relationships and encourages an evaluation of one's development, which in turn improves the individual and school. Overall, collegial inquiry facilitates opportunities for adult learning to occur and provides positive institutional results.

Mentoring, the last pillar addressed by Drago-Severson (2006), claimed to be the oldest method to support adult learning, but still one of the most important. Mentoring allows for direct practice and is more private and less public. It works on a specific skill or need usually over a period of time. Drago-Severson's and Newman's description of the focus on teams relates closely to the team leadership theory.

Leadership teams are organizational groups composed of interdependent members all sharing a common goal, and must coordinate their activities to accomplish these developed goals (Northouse, 1997, p. 153). The idea of team leadership theory is designed for business organizations, project managers, etc., but the model fits perfectly in the case of describing how teachers should work collectively to assist in academic progress. Hackman and Walton (1986), who specializes in leading groups in various organizations, describes the characteristics of an excellent team: clear and engaging, an enabling performance situation, and adequate material resources. There would also need to be a level of trust and candidness to also enhance the group's functionality.

Kogler Hill (1997) also addresses several components to developing a leadership team that would also apply to teacher leader teams: develop clear, elevating goals, create an atmosphere with results driven, competent members of a team, unified commitment, standards of excellence, a collaborative climate, external support and recognition, and principled leadership. These are all important in assisting the team and developing a leadership team, however the individual teacher must want to act as a leader in their role.

A developed vision is a key building block to becoming a teacher leader and this vision should be created in the pre-service teacher program (Phelps, 2008). The old, "all children will learn" saying is nice, but imagine what can happen for a teacher while in their preparation program if they learned the value of being a leader and created a vision that enables them to develop as a strong, capable teacher. The teacher-leader cannot implement their vision until they have discovered the value of being a leader, “Teachers who lead expand their influence beyond their individual classrooms” (Phelps, 2008). One person cannot lead the contributions needed in and around the community alone; it is a school or team effort.

Special education teachers have been evolving as highly competent and school leaders and further review of this model may be needed as part of the discovery of what attributes are needed of STEM teacher leaders, since special education teachers remain a vital role in the learning environment or classroom. Many special education teachers are leading IEP meetings with administration and parents, which may be a contributor to the developed leadership skills. A focus group formed on this study, and the findings were surrounded around the numerous roles special education teachers play in the school. Eight major findings were discovered:

1. Extensive and overlapping roles and responsibilities
2. Complex and dynamic patterns of daily work
3. Predictable annual cycles of work with peak times were not well accommodated
4. Vision and relationships as the foundation for effective practice
5. High levels of professional competence in the instructional, communication, and management domains
6. Site and central office administrative understanding and support
7. Collaborative partnerships for program implementation and support

8. Resources that enable special educators to leverage time and expertise (York-Barr, Sommerness, Duke, & Ghere, 2005).

It was identified that the special educators had levels of organizational and collegial support. Based on these findings it is clear special education teachers have to go above and beyond the call of "teacher" to leader. They have to step around the barriers to ensure the children they are providing a voice for are earning the education in which they are entitled. It can be concluded that these teachers are striving to achieve higher standards, broader goals, in a "context of greater diversity, inclusivity and accountability" (York-Barr et al., 2005). In this case, for special education, it does "take a village to raise a child" and this thought is beginning to move toward the STEM movement.

Walker and Carr-Stewart (2004) write about the ability to learn leadership through Appreciative Inquiry (AI). Walker, Carr-Stewart state, "AI is the art of helping systems create images of their most desired future," and there are seven basic assumptions of appreciative inquiry:

> In every society, community, or group something works well, or is positive; what many focus on becomes the reality; reality is created in the moment, and there are multiple realities; the act of asking questions of an organization or group influences the group one way or another; people have more comfort to journey into the future when they carry positive forces of the past; there is great importance to valuing differences; the language people use creates their reality. (Yoder, 2005)

There is also an assumption that most people want to see the school or organization in which they are currently working, succeed or at least move in that direction. Using these assumptions, the AI model can be carried out quite well using the four basic principals of AI: appreciation, application, provocative proposition, and collaborative interaction and action (Pancultural & Associates, 1999). AI is a change model primarily used in a business setting, however Walker and Carr-Stewart prove it can be implemented in the educational setting through a variety of studies with leaders.

Cooperider, Sorensen, Whitney, & Yaeger (2005) use a similar model and describes it as the 4D model: Discover, Dream, Design, and Destiny. This too can be applied toward the school setting; to discover is to have members within the school describe and explain exceptional moments they have had within the school year, or setting. This allows the members to focus on the positive experiences and dialog about what is working well already, focusing on the strengths of each member. This gives valued learning through inquiry as members begin engaging in the story being told by other members. To dream is to extend new knowledge into the application of *what is possible* based on the discoveries of what is working well (Pancultural & Associates, 1999). This engages members to embark on a new journey focusing on the strengths of the members. Design is to rely on systematic management analysis to help the members construct an effective vision or future according to their dream, one way of doing this is creating an action plan. Destiny is using the action plan for increased success, by ensuring the inquiry and its content along with the members are all one and must remain committed throughout the process. The last step of this process is having the longing to understand and providing "life" to the educational system and accepting that change is an iterative process (Walker & Carr-Sterwart, 2004, p. 73). So, designing and implementing ways to create the future is easier "said" than done of course.

Gaining trust in others and self is a large part of being able to develop as a leader. Teachers seem to have a lack of trust in the "district system" as they are let down time after time with funding support, lacking in resources, and are spending their own hard-earned money on classroom materials. Trust is developed over time, and the teacher-leader may learn that in order to achieve progress in student achievement, leading the way is what it takes in a school community. Principals can help endure trust with the recognition that all teachers can be leaders and foster and acknowledge the leadership of others by encouraging and coaching their staff to assume responsibility (Dinham, 2007). Teach for America is a program consisting mainly of college graduates or those in the work force, and developing them into teacher leaders who enter the profession, like so many other graduates, trusting the system (Wetzler, 2010).

Teach for America was founded 20 years ago to create a positive movement in education by directing the capacity and leadership of top recent college graduates as well as career professionals (Wetzler, 2010). Teach For America recruits, trains, and supports these teacher leaders who pledge to teach in urban and rural public schools for a minimum of two years. Over the span of the 2 years, they are expected to lead their students to make significant academic progress in order to begin narrowing the achievement gap. There is controversy over this program; many claim those training these new teachers aren't clear about the demands of the urban classroom, where most are placed, so there may be a lack of sustainability. Teach for America does however have a teacher leadership model that is meant to work effectively and was created by highly successful and experienced teachers. Wetzler (2010) describes the Teach for America model reveals six patterns of teacher-required actions:

1. "Set big goals
2. Getting students and those who influence or support them invested in the goals

3. Planning purposefully
4. Executing effectively
5. Continually increasing effectiveness
6. Working Relentlessly"

This seems like an effective model, but with it in place and the 20-year history, the achievement gap has yet to budge. However, the model must be somewhat beneficial since it is reported by Hannaway, Xu and Taylor (2009), "in a 2009 independent survey, 90 percent of principals who work with Teach For America corps members rated equally as effective as the existing teaching faculty in their schools, with respect to their impact on student achievement, and two-thirds rated them as more effective than other beginning teachers in their schools." This also seems to be one of the only largest nonprofit companies striving to turn and train people into leaders teaching America's children.

Dutton, Quinn and Cameron (2003) use the term "positive deviance" to describe remarkable leaders. When comparing positive deviance and AI the two correlate, as they are both out of the norm. A simple description of positive deviance is embarking on a new path to positive action. Within AI, positive deviance is clearly visible with commitment from the members of the process. Positive deviance describes those intentions stepping out of the box to go beyond the issue at stake and create a positive stand of "honorable" behavior (Dutton et al., 2003, p.208). This behavior is observable in many educational settings, but all too often is overlooked, as it seems much of the control surrounding change takes place at the state and district levels. It was observed through the research of superintendents that anything is possible and AI is an acceptable process beginning at the top.

It seems to many that the idea of positive change is exaggerated, or it is a non-realistic view of what is possible. There is a wealth of research from the lab to the field welcoming a focus on the reality of these possibilities. (Dutton et al., 2003, p. 239). The focus on appreciative inquiry and positive organizational scholarship gives immense opportunity for creating new knowledge, as those interested in the field and organizational behavior move to discover the best of the positive core in organizations. The endless opportunities in the field of education are also an area for consideration when it comes to adopting positive models. The field of education is filled with people who truly find meaning at work and are waiting for more positive movement, especially in public education.

Public education and its decline in producing adequate test scores and over-crowded classrooms, leave parents seeking a private education, charter school or magnet school for their child (Lieberman & Miller, 2004). In the book titled Teacher Leadership, Lieberman and Miller advocate for new forms of accountability from teachers. In this book, the authors challenge teachers to “step-up” and face the facts of the public school system and the need for change. Teacher leaders can challenge that tests be the sole criterion for success and achievement in school, and introduce alternative ways of measuring that promote learning, not just measure learning. The authors also address that teachers should use their experience and knowledge of what occurs in the classroom and enter into the national conversation. Teachers can be innovators of the norms of achievement and levels of expectations of students, which prepare citizens to work in a complex and democratic society.

An interesting view portrayed are the two opposites we see in American schools: "policies that prescribe curriculum, instruction, and testing and policies that enable schools to build the capacity of teachers to seriously engage in transforming their school community" (Leiberman & Miller, 2004). The all encompassing view on teacher leadership as looking through a microscope, "it is the teachers who are creating learning communities that include rather than exclude, that create knowledge rather than merely apply it, and that offer challenge and support to both new and experienced teachers as colleagues." The teacher leader also leads thru the community, with resources and support.

Teacher leaders can fight to give new meaning to what it means to work collaboratively or in teams. A study by Spillane, Hallette, and Diamond (2000) conducted observations of 84 teachers at elementary schools, found that teachers can create other leaders just by the conversations and interactions that take place. These teachers were subject matter experts who became leaders because of the exposure to cultural, social, and human resources necessary to lead within a school (Spillane, Hallette, & Diamond, 2000). The "natural" teacher leaders led with determination and a common passion and no formal leadership training. This is a great possibility for STEM teacher leaders or mentors and the impact that can be made through collaboration.

It seems some universities find the leader within a teacher so important the entire teacher preparation programs have been created based on the theme. Wright State University, in Ohio, has a degree program called the Teacher Leader Program (Hambright & Franko, 2008). Hambright and Franko describe the program that evolved from an off-campus professional development in the 1970s. The professional development was intended for students interested in administration at some point in their career. This thought drove the Teacher Leader degree and curriculum began changing to meet the new vision. The Teacher Leader degree became a graduate master's program for those who wanted a leadership role in their school and were continuing to teach and lead students. There is an additional route teachers may take to add the administrative credential to their coursework, but many teachers do not (Hambright & Franko, 2008).

Building the teacher leader program with the cohort mode is used to assist in building relationships and the overall experience. There are even cohorts comprised of teachers working at one school site, so the collaboration and relationship building is taken to a whole new level. They also included several online cohorts to assist meeting the varied teacher schedules. This thought of training principals alongside teacher leaders, allows a principal to complete their many missions, while giving the them the needed input that their teacher leaders are needed to make a school run effectively and successfully. It provides insight on both parts to view the success of teaming, again the underlying theme in developing teacher leaders.

Dinham (2007) reports "research findings on the influence of school-based influences on student achievement conclude that leadership has very little influence on teaching, and little effect on student achievement." Part of this problem is the varying definitions of leadership, which makes accurate measurement of leadership almost impossible and definitely subjective. Teacher effectiveness and performance are also difficult to delineate, per the current debate over teacher effectiveness and merit pay debate. In Dinham's study, he chose groups of teachers in secondary education who were considered high performing. The end result was that school staff members and teachers use their personal qualities to build meaningful relationships with other staff members, teachers, students, community members and system officials. This was developed on the basic concern for others (including students) as people.

Dinham's (2007) study used two parenting models of author Diana Baumrind, responsiveness and demandingness. Responsiveness is described as warm and supportive and "parents foster individuality, self-regulation and assertion by being attuned to the child's special needs and demands." Demandingness, which is also the control of behavior, defines more of an authoritative role with demands, confronting and high disciplinary efforts. From these two dimensions for parenting come four parenting styles, uninvolved, authoritarian, permissive and authoritative (Hamner & Turner, 2001). This notion of implementing parenting styles among teachers gave a new light and influence to the term leadership within these schools. Dinham (2007) formulated a "how successful leaders manifest responsiveness" in their day-to-day relationships. The various studies were found to be responsive by:

- Being good listeners and taking an interest in students and staff as people;
- Being warm, supportive and sensitive to individual and collective needs within the school and the wider community; being able to work with a diverse range of individuals
- 'Giving a lot' and 'rolling up their sleeves' when necessary;
- Providing timely and relevant positive feedback;
- Identifying and catering for the professional learning needs of staff;
- Finding ways for all staff and students to experience success and recognition;
- Recognizing the capabilities of others, 'talent spotting', encouraging,

> empowering, trusting and supporting staff to develop new programs, policies and practices; and seeking to develop competent, assertive, self-regulated staff and students. (Dinham, 2007)

A study conducted by Robinson and Timperley (2007) examined how leaders foster school change by leading and participating in teacher professional development, which improve academic and non-academic outcomes. "The final analysis exposed five leadership dimensions that were critical in fostering teacher and student learning by providing educational direction; ensuring strategic alignment; creating a community that learns how to improve student success; engaging in constructive problem talk; and selecting and developing smart tools" (Robinson & Timperley, 2007). The analysis displayed leadership of the improvement of teaching and learning is highly distributed in terms of both who leads and how it is enacted. Robinson and Timperley (2007) agreed with an earlier statement that distributive leadership pays little attention to the outcome of the students, and this also includes transformational leadership. Instead the authors display their focus on the teacher leadership that improves overall student learning outcomes. The study used a backward mapping without educational leadership theories, but instead on teacher professional development. This idea taking the concept back to the Teacher Leader degree, as mentioned in the previous pages.

Robinson and Timperley (2007) concluded that the role of leadership in developing effective teaching and gaining a teacher leader are: "providing educational direction, ensuring strategic alignment, creating a community for improved student success, engaging in constructive problem talk, and through selecting and developing smart tools." Beginning with goals, direction or a vision seems to be the most obvious when discussing leadership in any organization, but without the shared vision of the desired outcome then the chances of various teams going in many directions are high. A shared desire goal also lends itself to a desirable outcome, meaning the task itself will be desirable.

Ensuring strategic alignment maintains an understanding of the leadership improvement initiatives. It can also ensure an alignment of pedagogical goals and principles, it can depend on the goal, but overall this alignment is critical to the coherence of the program and framework with which the teachers are working (Robinson & Timperley, 2007).

Creating a community for improved student success again seems obvious, but important for this study because of the desire to form professional learning communities. Since professional learning communities are relatively a new concept in the last seven years, there isn't a lot of research on student outcomes based on the models; and according to Robinson and Timperley (2007) the evidence available isn't forth standing. They suggest this is due to the lack of promoting teacher learning, which will make a difference to their students versus just a professional learning or gathering time for teachers. The first focus on teacher learning will focus on the correlation between how teachers led and what the students learned, on an individual lesson or entire thematic unit. The second focus for this community was identify and creating "strong norms of responsibility and accountability for student achievement." The study outcome on this component established a collective results group support, which contributed to a consistent increase in student achievement.

Engaging in constructive problem talk was formed to create a space where leaders could challenge each another, in order to build communities that could thrive and learn. It is clear the educational system has flaws and major problems, this engagement of discussing problems allowed these issues to be "placed on the table" in a way that "invites ownership and commitment and an ability to respectfully examine the issues" (Robinson & Timperly, 2007). Teachers have a difficult time accepting that teacher performance is a big issue and want to place blame on parents, students, or the system, this "constructive problem talk" allows teachers to self-reflect and analyze their own practices without becoming defensive. With this theory also creates the ability to respectfully dissect the contributions of teachers' current practices and theories to the problem being questioned.

The last leadership dimension of selecting and developing smart tools, by Robinson and Timperley (2007), suggests that leadership is not only face-to-face but also impersonal "by shaping the situation in which people learn how to do their jobs." "Tools" is conveyed in this study, as the many physical resources with which teachers interact in doing their jobs, from chalk boards to placing furniture, choice of software, attendance and report cards. Robinson and Timperley see teacher tools and their associated routines institutionalize the desired practice continue independently of face-to-face leadership, but should not replace face-to-face leadership. Since the school's primary purpose is to facilitate learning, these five dimensions of leadership with student-focused goals seem highly relevant for teacher leaders and all school leaders. The idea of leadership of teacher learning and teacher leaders effectively sync, since the development for all teachers is the focus.

At any point, teacher leaders and their followers may merge roles. Sirotnik and

Kimball (1996) suggested that adding the term "teacher" to the word leadership does not change its meaning as it is still the effect of influence by a leader over a follower. Anderson (2004) completed a study with teacher leadership defined as setting direction or goals and influencing others to shift toward those goals. The study consisted of the influence of principals on teacher leaders and the relationship between the two. There was a strong awareness of the influence of teacher leaders on principals, and vice versa.

The study conducted by Anderson (2004) also found a negative or con to the idea of teacher leadership with the "potential to create a ranking amongst teachers who are more or less associated to the center of decision-making, which possibly will exclude other teachers and staff members." This was also mentioned by a secondary source, Marks and Louis (1997), and the result was that most teachers are unable to exercise influence, and perhaps were looking for or felt guided by the teacher leaders.

Anderson (2004) created three leadership models that principals were typically guided by when leading teacher leaders: "the buffered model, the interactive model and the contested model." Each model represents a set interaction with the teacher leaders. The Buffered Principal is surrounded by teacher leaders and somewhat isolated to other staff members within the school (Anderson, 2004). This model involves the teachers in a limited way, and almost created teacher leaders as "foot soldiers to protect the principal." The buffered approach will disable collegial membership of teams and possibly disengage some of the staff.

The Interactive Principal will interact with all staff and distribute decision-making where needed, this approach resembles transformational leadership. This model allows for teachers to be highly involved in the decision-making process as teacher leaders and develops a uniformed consensus amongst all teachers in the school. The teacher leaders are provided with both formal and informal leadership opportunities with professional development and team leadership.

The last, contested model, displays the principal and/or primary school leader as "outside the loop" with a lack of leadership skills. The teacher leaders were so strong that they strongly influence the principal. These teachers easily stand up to the principal and the principal conforms to what is directed. The other staff and teachers are typically unable to challenge them or their ideas. The study that evolved from this model or observation only took place in one of the six schools studied. This shows a lack of leadership skill development in all parties involved.

Traditionally, teachers have been primarily guided to service students in only their classrooms, now with a new call to duty, teacher leaders are being requested to improve their schools and districts. Kurtz (2009) analyzed how today's instructional leader (in California) could be viewed as having six roles:

1. Making student and adult learning the priority.
2. Setting high expectations for performance.
3. Gearing content and instruction to standards.
4. Creating a culture of continuous learning for adults.
5. Using multiple sources of data to assess learning.
6. Activating the communities' support for school success. (Kurtz, 2009)

Kurtz created these roles based on Northern and Bailey's (1991) professional competencies apparent in instructional leaders: "visionary leadership, strategic planning, change agency, communication, and role modeling, nurturing, disturbing (implementing change for those who are comfortable)." Current teacher leadership roles include team or department chair, curriculum developers, literacy coaches, professional development leaders, grade-level chair, assessment designers, and parent group leaders. Kurtz (2009) mentions that teacher leaders are most effective in a collaborative school, which correlates to previous views as mentioned in this paper.

Teacher leaders have some characteristics that contribute the school body such as, revealing innovative ways of conducting new procedures, aspire the best in themselves and their colleagues with a positive attitude, and they help others problem. "Teachers desiring to move into leadership positions must identify a change that is needed in their school district, school or classroom and then move ahead on their own; teachers often become leaders after recognizing a need and committing themselves to taking action" (Kurtz, 2009).

Teachers need support in becoming leaders; it is not something that is handed out, especially in the field of education. Leadership comes from doing and being proactive, it comes from taking a risk, but knowing the risk is a shared vision among teachers with a need for bigger and better school reform. This idea is becoming heavily prevalent in the area of STEM education.

Kurtz (2009) listed how administration can effectively assist more teachers in the area of leadership and creating an environment for teacher leaders to work effectively for school improvement. First, teachers need encouragement to lead and stay informed, this can occur through teachers creating a curriculum committee with new ideas of current trends. Second, administrators should create leadership roles for teachers. Administrators cannot run a school alone and not all successful teachers want to become principals, so this is the perfect opportunity to form a team of leaders with a desired vision and passion, even if it is to share instructional practices with the staff. Next, administrators must provide opportunities for teachers to continue their adult learning and be trained as leaders, if that is a desired outcome. Ongoing professional development is essential for teachers to gain the knowledge as leaders and to grow as professionals (Kurtz, 2009). In addition, principals can also ease time constraints, which seem to be the largest complaint made by teachers. There needs to be a time for leadership activities, and this may mean teachers write this time in their weekly planning.

The last step Kurtz (2009) suggests to administrators is to create more connection opportunities for teachers. Teaching is an isolating role, so not only do they need to connect with other teachers, they can highly benefit from connecting with the community to broaden their views of the diverse classroom needs. As Drago-Severson (2006) described, Kurtz (2009) suggests engagement in collegial interactions with colleagues. All of these steps from school and district leaders may lead to the desired change of the American population.

The Formative Leadership Theory created by Ash and Persall (2000) displays that there are many leadership opportunities within a school. This theory is based on the teachers as leaders and the principal as leading leaders. It describes the belief of teachers as creating student learning as well as enhancing adult learning within the school community. The theory places the principal in the role of chief learning officer (CLO). The CLO is focused on creating leadership learning opportunities for highly capable teachers who are inspired with leading and inquiry. The idea of this formative leadership theory is to have the principal highly interactive with teachers and students, with student learning as the primary goal (Ash & Persall, 2000).

Ash and Persall state conventional approaches to teacher leadership may be summarized as the previously described roles of leadership of serving as department head or grade-level chair, planning and providing in-service training for other teacher, mentoring teachers, or developing curriculum. Ash and Persall persist:

> While these are important functions, they fall far short of the level of teacher leadership that current school reform efforts demand and that the new model of teacher leadership embraces the view that the process of teaching itself is a quintessential leadership function. What is required now is a new model of the teacher as leader, as well as new graduate-level programs grounded in formative leadership theory. (Ash & Persall, 2000)

Leadership on the other hand is much more complex because the essence is relationships (Goens, 2009). These relationships dictate follow through and progression at the school level. Additionally Goens states, “The irony is that those “soft” qualities, while hard to assess metrically, are at the core and heart of a person’s ability to bring a group of people together around a common objective.”

There is an assumption that the idea of the teacher leader is the primary solution for the much desired school reform. It would serve highly effective, but the consideration for outside influences such as demographics, socioeconomic status, and the level of parent involvement must not be ignored, but instead embraced into the ideas of the teacher leader to better serve the community as well as the school. This will enhance the primary goal, student learning.

The last 10 years has had dedicated focus to the idea of professional learning communities and the creation of teacher leaders, and the continued study on this topic is needed for decades to come to observe the desirable change the American population is seeking for their children. This idea ties well with forming a “community of practice” where Wenger (1998) identifies the importance of coming together to practice, where the individual and the group is building acute awareness and opportunity. Learning communities are valuable, especially in a teacher leader model where the teacher is utilizing a team to increase results of achievement.

Learning communities also are reflected in learning organizations where change can occur within the system from internal leaders. It is appropriate to include Peter Senge's five disciplines here as a possible model for organizational change, since there is a strong need for reform in a learning organization. Furthermore, the CMAST system was partially created in aligning with the theory of systems thinking. The teacher leaders within the system are guided with the theories of Peter Senge.

Learning organizations only develop through individuals who learn (Senge, 2006). Senge (2006) describes that learning organizations work best when they are built around practicing five disciplines. The five disciplines include systems thinking, personal mastery, mental models, shared vision, and team learning, which allow learning and engagement to occur among individuals, teams, and at a cross-functional levels. Learning organizations utilizing and practicing these disciplines are creative, productive, and are engaged in all areas of developing and progressing in learning.

Senge (2006) writes about learning organizations and analyzing the organization through the five disciplines. The five disciplines, to be accurately engaged, will take a "shift of mind" or a new way of thinking, to get out of "doing it the way it has always been done," seeing parts to wholes. The process of using systems thinking is getting away from reacting to the present, but rather creating or preparing for the future and change can emerge. Senge's theory of change can easily transform to school reform, where change needs to really occur from the inside out versus the outside in. Working from the outside in, where school districts send leaders into schools to create education reform, has rarely been effective in the past and there is plenty of research through organizations that this model creates very little sustainable change (Bolman & Deal, 2002).

Personal mastery is defined as one of the disciplines of personal growth and learning, as well as approaching life from a creative stance rather than a reactive viewpoint (Senge, 2006) and this idea fits well with the teacher leader. 'Learning' in this context does not mean soaking up more information, but rather maximizing the possibility to generate the results we truly desire in life. The term mastery is meant to describe a high level of proficiency in all aspects of life, both personal and professional. Further, Senge (2006) states that people with a high level of personal mastery have established a clear vision, which they identify with as a calling versus just a good idea. The idea behind personal mastery is not a possession of a title, but rather a lifelong discipline. In the case of this research, personal mastery is further development as a teacher leader. "Those with a high level of personal mastery are aware of their ignorance in life and their incompetence in certain functional areas; in addition they have a high level of emotional intelligence and are extremely self-confident people" (p. 133).

Mental models are our cognitive view of how something occurs, and Senge (2006) describes these as our internal pictures of how the world works. Negative assumptions will form negative mental models and these prevent us from proceeding in certain areas of our life, both professional and personal. Teachers have to eliminate their mental models of what teaching "looks like" in the past in order to create a new mental model for future teaching methodology (S. Mitra, personal communication, October 16, 2012).

Team learning is reflected when a group is aligned, working in the same direction toward a purpose and energy is in sync (Senge, 2006). Team learning should occur through the teacher leader process, as the teachers are committed to working together toward a shared purpose or vision. There is synergy, a shared vision and a level of understanding on how to complement one another's strengths and efforts (Rath, 2007). Senge (2006) states "that individuals do not sacrifice their personal interests to the larger team vision; rather the shared vision becomes an extension of their own vision." A vision is important when considering the development or leading of a team on a particular initiative. This idea relates well to the idea of emerging teacher leaders and how they can utilize a common vision to progress and make notable differences as a team within their school community. This reflects CMAST as working as system versus a program being offered.

It is concluded through this review of literature on teacher leaders that they need immense support and guidance in the development of this role. It takes a full team of people at several levels to meet this objective; guidance, feedback and accountability are several areas that emerged in this section. Existing teacher leaders, external programs, and administrators are a few of the critical roles and members needed to support the emergence of leadership in the school. In addition to a support team, the environment and school community must be equipped to support the teacher leadership initiative.

Teacher leaders enhance student learning; furthermore, a school will work more effectively as a learning organization to achieve the best results. Utilizing various leadership theories, such as Senge's Five Disciplines, Parsall, Goens, Cooperider's Four D's, and many other theorists proves the teacher leader model can be effective if the right tools and leadership strategies are implemented (Appendix A Matrix of Leadership Theories described in this section). Leadership is a key role in this research and understanding the perceptions of the experienced teacher leaders will establish this in greater depth.

Throughout the reviewed literature on teacher leaders, there are many shared beliefs, but also some contradicting beliefs about where and how teacher leaders can grow and develop as leaders and mentors. There is a common goal and belief among these studies, a desperate need for education reform and STEM influence, with an undertaking by the entire school community. Gaining insight in this research from the experienced teacher leaders will provide greater knowledge on the topic of certified STEM teacher leaders.

The following section describes the role of teacher leaders in STEM fields as a critical element in the STEM movement. This section sheds light on past studies as a framework for further research and development of STEM teacher leaders, which is the focus of this research study.

STEM Teacher Leaders

There is a large gap in literature surrounding this area, which creates plenty of space for research. Additionally, if the knowledge surrounding STEM pedagogy is combined with what is known about teacher leaders, the STEM teacher leader emerges. There is, however, some research to further validate the framework and need for this study to contribute in the field of education, since the current reports on the overall status of teaching in STEM fields are of significant concern. There is evidence that STEM teachers primarily teach as they were taught; the approach is limited and not supportive of a learning theory or backing research on cognitive development (National Research Council, 2007).

Bell and Gilbert (1996) researched the need teachers have for inquiring and desiring professional development to build classroom teaching methodology; furthermore addresses the “science for all,” regardless of language, ethnicity, achievement level, and readiness, lessons that provide exposure to science and their needs are met. A study launched by Bell and Gilbert called the Learning in Science Project, at the University of Waikato, which was a three- year ongoing teacher development program. This program sought to challenge teachers to experience a constructivist’s view of learning at the secondary level (although primary was also included). The qualitative study included forty-eight teachers ranging from all levels of gender, experience, and cultures and defined different areas of teaching and learning of science.

Bell and Gilbert (1996) identified that teaching can be seen as human development, being social, professional and personal development. It is stated that social development is the idea of renegotiating what it means to be a teacher of science, personal development is “constructing, evaluating and accepting or rejecting the newly constructed views about teaching science” and managing the feelings toward science educating when defending it against the old methodology (Bell and Gilbert, 1996, p. 13). The professional development may be the learning of science and developing new teaching strategies or activities.

Bell and Gilbert (1996) conclude that the social development aspect in teaching of science is critical and crucial for professional and personal development to occur. The authors state that several roles must emerge in this development: “teacher as learning facilitator in the classroom, as member of a school staff, as a member of a professional community, and an employee” (p. 13). This couples with the role of teacher leader and the trend of creating teacher leaders as a “hat” every teacher can wear.

One of a handful of studies addressed teacher leaders in science. This study conducted by Howe and Stubbs (2003) aligns with the theory proposed by Palus and Drath (1995) on a model of leadership development, which boosts the “individual’s ability to actively participate in the leadership practices in the community for which he or she belongs.” The model follows three stages for development: 1) readiness for development; 2) the process for undergoing developmental change; and 3) places new meaning into action (Howe and Stubbs, 2003). Along with Bell and Gilbert’s (1996) theory, Howe and Stubbs created a science integration program called SCI-LINK, where science teachers, grades seven through twelve, were merged and collaborated with environmental scientists.

The purpose of the SCI-LINK program was to explore the application of external business-type leadership development to teacher leadership development. Additionally, Howe and Stubbs (2003) wanted to “identify components of a specific professional development program that led to the development of science teacher leaders, and consider the implications of the finding for the professional development of science teachers as well as those in other subject areas” (p. 288,). Utilizing five stages by Palus and Drath (1995), Howe and Stubbs began the study with only three teachers, and the outcomes were significant. The findings presented a combination of confidence and new abilities; one teacher conquered her fear of public speaking, but it was clear she needed to be heard and her practices shared. This is one example of many to come, on the importance of teacher leadership in STEM and how a unified and effective system in place can work to develop teacher leaders.

Many current US secondary STEM teachers were educated in lecture halls by STEM undergraduate instructors who had very little, if any, education on instructional practices (Seymour & Hewitt, 1997). In the undergraduate environment students complain about the poor quality of STEM teaching where there is little dialogue, the classes are crowded, it is heavily lecture based, and students are expected to be passive learners (National Research Council, 2007). These STEM graduates become secondary teachers later down the road, and they too haven't had extensive experience or positive examples. Luckily, they have had some instructional methodology training, but often by content experts.

It is easy to see how there is a current STEM issue in the US where the classrooms have become and established as a cycle of lecture-based models where students utilize textbooks. STEM teacher leaders have the difficult role of changing the behavior, methodology and mindset of STEM teachers. Through partnerships between universities and districts, this change is evolving. Studies on these partnerships (although limited) do show the positive impact on teacher quality and effectiveness in STEM disciplines (Bruckerhoff & Popkewitz, 1991; Dresner & Worley, 2006; Gut, Oswald, Leal, Frederiksen, & Gustafson, 2003; Garmon & Mariage, 2003).

One area of the partnership to review is the idea of secondary teachers connecting with scientists. This brings the teacher to the field of science experiences, where they are more involved in the inquiry and participation of scientific research (Dresner & Worley, 2006). This allows teachers to bring a similar experience to the classroom, applying the new methodology of science learning to the teaching of science.

There is a new trend of universities blending with schools, where the experts are coming to the classrooms to enhance learning. One particular program in Vermont focuses on adding depth to an elementary school math program and the teaching of math in upper grades (Galley, 2004). This program requires teachers to attend two-week long sessions each summer and three weekend sessions each summer, as well as a session during each semester over the course of the three years. Concluding the program the teachers are able to earn a master's degree and teach all classes. The evidence resulted in the participating teachers gaining a new perspective toward with increased enthusiasm (Galley, 2004).

There is a critical need for further research on STEM teacher leaders and the impact they have in secondary schools. This is a reduced section due to the lack of research in this field, therefore prescribing a need for further research. It can be concluded based on this review, there have been several effective studies that establish the need for further research on STEM teacher leader, but the results lead to be effective. Bell and Gilbert (1996), Howe and Stubbs (2003), and Palus and Drath (1995) all created results that lead to a positive result on this study. These studies all took place more than a decade ago; therefore, the new perceptions uncovered in this research from the CMAST experienced teacher leaders will shed new light on the critical addition of STEM teacher leaders in school communities.

An important component of teaching and guiding the future STEM teacher leader is the theory of adult learning. Adult learning is described in the next section and it is a critical part of the teacher leader model and what is known about how adults learn. Adult learning in higher education programs must be utilized to best meet the needs of adult learners, especially as teacher leaders are further multiplied in math and science disciplines.

Adult Learning

Adult learning is a complex experience that has become more difficult to be simplified into a single statement or definition; instead it is defined in many formats and with each new era there is a new construct added to the idea of adult learning. Knowles (1980) created a definition on adult learning as “a process of adults gaining knowledge and expertise based on their personal goals.” Adult learning does ultimately result around the brain and cognitive processing, however research has expanded to include a multidimensional aspect (Marriam, 2008). Adult learning is important to examine the role of teacher leader alongside the recipient in training.

Research is ongoing, however there are additional components to cognitive development where information is taken in, retrieved and then processed to produce an end result. The added multidimensional components include emotions, the body (physically), and the spirit in addition to the mind (Marriam, 2008). Taylor and Lamoreaux (2008) described that in order for adults to make relevant connections to learning new information, learning should be connected to physical and embodied experiences. Since physical responses are captured in the brain as experiences, which help create memory, there is no basis for constructing meaning without physical responses (Taylor & Lamoreaux, 2008). We simply learn the most by watching what others do and then follow that perceived behavior throughout our lifetime (Zenger, Folman, Edinger, 2009). This is important as we explore how teachers should learn how to teach STEM content.

Successful adult learning relies on how mature the individual is and the experiences that can be drawn upon in the learning process (Mezirow, 1991). Wang, Sierra, and Folger (2003) state that experiences assist adults in becoming independent thinkers, rather than inert information receivers. However, like children, adult learners also need ongoing incentive to sustain learning progress, particularly those that are not busy in a career (Priest, 2000). To achieve motivation, the course curriculum must connect the individual adult's learning needs, interests, abilities and experiences (Lindeman, 1926). This can be applied to the teacher leader and teacher recipient in the motivation to effectively engage students in learning of STEM.

Adult learners might learn more effectively when instruction is designed with their personal needs, characteristics and their life situation (Knowles, 2005). Knowles (1980) "proposed the idea of contract learning as a framework for organizing individual learning experiences" (p.96). Contract learning creates a platform for adult learners to design their own learning based on their individual learning needs, goals, and motivation (Knowles, 1980). Boyer (2003) adds that when the adult learner can create their own objectives and learning outcomes through a contract process, they will be more self-aware and have more accessibility to the course content.

Knowles (1980) states that adults have a "deep psychological need" to be self-directing in learning new information or content. When adults enter a classroom, they tend to revert to their previous schooling experiences (as adolescents) of having the dependent role of "student" (Knowles, 1980). Adults, however, are independent in every other role in their life outside the classroom such as: parent, manager, teacher, or caretaker. Knowles (1980) believes when adults enter a classroom they are conditioned to sit back and think, "Teach me." Adults have to be retrained in their thinking that the role of teacher is now the role of facilitator and the adult learner is an independent role. This is a more constructivist type of learning experience and one that will be further explored as a critical component of teaching STEM.

Constructivist learning evolved from Piagetian and Vygotskian perspectives (Palincsar, 1998), which emphasizes the impact of constructed knowledge on an individual's thinking process, specifically pointing to active and reflective thinking (Ruey, 2010). Vygotsky stresses that socio-cultural systems are important for learning and Dewey (1931) supports this theory in that individual development is dependent on the existing social environment and students should learn from the real world by interacting with others. The constructivist instructional approach will focus on how and why, placing learning into logical explanation and discussion (Scott, 2001). In the constructivists learning environment it is understood that learning will take place through active engagement such as discussion, negotiation, explore new ideas as innovators, and challenged in higher level thinking prompts (Ruey, 2010). There should be ongoing dialogue where the teacher is merely the facilitator and the students are independent, controlling their own learning.

There are many theories on how adults learn effectively, and this is also how teachers should begin teaching children. Through research, it has been discovered that for successful STEM learning to occur there are various instructional strategies to be considered, such as: requiring students to engage in collaboration, applying learning through simulating and assuming the authentic role is real in the authentic learning community (Auyeung, 2004; Maor, 2003). Additionally important is establishing a collective goal and vision to drive students to collaborate and participate (Gilbert & Driscoll, 2002) and require students to be in control of the discussion. Since it is known that adults learn best when being able to apply new information to past experiences, which is also called authentic learning, there must be a format for this type of learning to occur (Huang, 2002).

Self-regulated learning is viewed by Garcia (1995) as the link from motivation to cognition; ongoing motivation is key for learning to occur, which is why it is important the learner has developed a vision and their own learning goals. Karabenick and Collins-Eaglin (1995) include success expectations and different levels of cognitive engagement in learning in their definition. Knowles (1980) states adults are self-directed and self-regulated when they take on a challenge of learning something new on their own. If effective teachers in the STEM classroom environment can create a vision and their desired learning goals, this self-regulation can be automatic when delivering material in the same way to their own students.

Connecting to Vygotsky's social learning theories, Wenger (1998) studied social presence, which leads to the idea of communities of practice. Communities of practice are also known as learning communities. Wenger further describes the community of practice as a place where beliefs, ideas, knowledge, and behaviors are both shared and acquired to create rich learning experiences. Bransford, Brown, & Cocking (1999) state that knowledge can't be separated from practice and practice is inseparable from the communities in which it occurs. Therefore, social learning theories should be addressed in any learning environment. Lave and Wenger (1991) state that learning is situated and should be displayed in authentic context.

It is further practical application that creates real and valid learning experiences (Knowles, 2005). Real learning does not occur until the implementation process begins, therefore creating and identifying the proper strategies for taking action is key and then moving forward to execute the plan will follow. The last component is coaching, as guiding the learning process. This role mirrors that of a servant-leader, such as: 1) creates opportunities for the members to find their own answers; 2) challenges the members to learn from one another's perspectives and mistakes; 3) refrain from imposing views and knowledge; 4) provide difficult feedback to members; 5) ask critical questions; and 6) frame mistakes as future learning opportunities (Marquardt, 2011). The action learning coach guides the team through thoughtful questions as a reflection of performance and leadership skills. Coaching will address the group on how they were at listening, framing the problem, scoping the problem, providing feedback to one another, and planning and working.

Adults, for the most part, like exploring and dissecting information on their own, and higher-level learning is a result of this process (Knowles, 2005). To facilitate with this process and set learners up for self-directed learning, Knowles' *Theoretical Foundation of Adult Learning* is one way the teacher leaders can formulate a process. The foundation will be part of the initiative to create learners throughout the team and if the members have a framework, they will be able to create a plan, identify their learning process and recognize and evaluate their own success. These foundations will allow the leaders to determine their own learning needs, create and implement their own learning, and evaluate their learning. In the evaluation process of the plan, the members should collect enough evidence to determine if learning has occurred.

In a learning team all members are considered adult learners; therefore, teacher leaders should embed the andragogy core learning principles to ensure the groups communicating are in sync (Knowles, 2005). These principles will create a foundation to ensure the needs are met of the members in a learning environment of practice. Although the principles identify individual learning, it should additionally be applied to both individual and group learning. This will allow the leaders to pinpoint learning goals for their learning sessions or meetings and apply the principles. This idea directly correlates to that of a STEM teacher leader. It is critical for STEM teacher leaders to include all of their learners in the learning team to dissect and create new ideas around teaching and learning.

An important component of teaching and guiding the future STEM teacher leader is the theory of adult learning. Adult learning is described as leading adults through a learning process, and in the STEM teacher leader model it can be concluded the new learning is developed through guiding and creating opportunities to further develop and enhance past teaching and learning methods. Adult learning is a critical part of the STEM teacher leader model and what is known about how STEM driven teachers learn. Adult learning in higher education programs must be utilized to further enhance the needs and objectives of adult learners, especially as teacher leaders are further multiplied in math and science disciplines.

Summary

In review, this chapter has created a framework for further research on the study of STEM teacher leaders. A historical overview, STEM pedagogy, teacher leaders, and STEM teacher leaders all serve this study and align to the research questions, which will provide greater depth to what is already known about these areas and future research. Identifying the perceptions of the CMAST certified teacher leaders align with each of these literature topics in this chapter. The theories, authors, and studies reviewed in the literature suggest there is a need for further developing the STEM teacher leader in school communities and further creates a space to develop more work around this topic.

Current US science education and science standards fail to meet the expectations, skills and conceptual depth needed to sustain a STEM workforce. Science, technology, and engineering filter through every aspect of life and are demanded during the most urgent current and future challenges (National Academy of Sciences, 2012). Throughout the research on STEM pedagogy, STEM teacher leaders, teacher leaders and adult learning, the term engineering was used infrequently. The integration of engineering in science education in K-12 is forthcoming in the NGSS and as reviewed in this literature, it is an important link to science education and how science is taught. Several key areas emerge as important components for further research in this study of STEM teacher leaders: 1) STEM pedagogy; 2) professional development; 3) supporting and guiding the teacher leader process; 4) leadership strategies and tools. Each of these components plays a critical role in STEM teacher leader development and aligns with the following research questions framed for this study: 1) What attributes define an effective STEM teacher leader? 2) What success strategies, among teacher leaders of the Center for Math and Science Teaching system, have enabled further development of teacher leadership? 3) What is the best model in developing teacher leaders, according to literature from 2005 to present? 4) What is an optimal model of developing STEM teacher leaders within secondary education? The four components, which emerged throughout the literature as critical elements, serve as a guide to further design research instrumentation, and contribute to the framework for this study on STEM teacher leaders.

This literature review and the themes that have emerged within the review will assist in identifying the results for this research on STEM teacher leaders, and the impact of teacher leaders in a school community. The information in this review has established the need for further research in this field and has created a guide for establishing research areas within the study. STEM teacher leaders is a current desired topic in the STEM movement that exists today, and the research on this literature concludes a prominent need for further research on this topic.

Chapter 3: Methodology and Procedures

Chapter three provides a detailed description of the methodology, research design and overall processes and methods to answer the following research questions:

1. What attributes de fine effective STEM teacher leaders, according to teacher leaders who have completed the CMAST
2. What success strategies, among teacher leaders of the CMAST, have enabled further development of teacher leadership?
3. What is the best model in developing teacher leaders, according to literature from 2005 to present?
4. What is an optimal model of developing STEM teacher leaders within secondary education?

This chapter will further describe the design for a phenomenological study including a sample description, instrumentation used with descriptions of reliability and validity, data collection strategies, and a proposed data collection analysis. Chapter three proposes the methodology for the research to be conducted on evaluating a STEM teacher leader model.

Research Design

This phenomenological study is reflective of the participants' experiences through the teacher leader model provided by CMAST at Loyola Marymount University. This study will follow a qualitative research method using forms of interpretive research using the psychological approach (Creswell, 2009). The psychological approach will be used to determine what the experience means for the participants who have had the experience in the CMAST teacher leader certification system; furthermore, participants are willing and able to provide a comprehensive description of their experience (Creswell, 2009). General or universal meanings are derived from the participants' descriptions, by analyzing and interpreting the interview (Moustakas, 1994). This design will allow more in-depth research to occur, along with what is already grounded in the existing literature on teacher leaders. The interview questions are broad, more general allowing the participants some latitude to construct the meaning of the situation. The researcher then interprets the findings to make sense of the shared experiences among the participants (Creswell, 2009).

The researcher will draw an inference from the study, concluding the attributes of an ideal model STEM teacher leader program. The inference will additionally create further implications for sustainability and replication of similar programs interested in this field. Ultimately, this study will broaden the field with what is known about teacher leaders and their ability to enhance STEM education.

Data Sources Description and Procedures

CMAST creates a partnership with educational organizations to lead and implement a teacher leadership model that enhances math and science education by training, supporting and developing a team of veteran teachers who collaborate and lead the transition to CCSS within the schools and district (Loyola Marymount University, 2012). This process can be developed through professional development, observation, in-class instructional guidance, and other collaborative processes, where the ultimate goal is creating a strong math and science curriculum engaging students. Additionally, this system creates teacher leaders within the school to continue the process of teaching and learning excellence.

A second system CMAST currently offers is a teacher residency program, which develops current math and science teachers with effective hands-on curriculum to support an immediate need for development. These teachers are called LAMS residents and they will spend a full academic year in an urban public school, developing teaching and learning methods under the guidance of a mentor teacher (Loyola Marymount University, 2012). These residents then go from a co-teacher to lead-teacher the following school year and the mentor teacher can earn a Teacher Leader Certificate through this process.

The third system CMAST offers is a high quality professional development that supports math and science teachers in dissecting their teaching and learning methods. This process is conducted through aligning their methods to the new CCSS while maintaining rigorous classroom practices. This opportunity enhances STEM knowledge in order to created a classroom where students are competent and confident in math and science.

These three systems offered by CMAST assist in the process of developing math and science teachers in this current STEM movement, while offering rich instruction practices to teachers who are motivated and passionate about classroom math and science teaching. This system was developed on the premise of passion and engagement of math and science and its progress has proven to be well received with high results.

The purposive sample in this study includes participants who have successfully completed the CMAST teacher leader system and have earned a certificate as a teacher leader. A proposed population sample of 15 certified teacher leaders would be interviewed. Approval and access has been granted to this group of teacher leaders and have been identified by the CMAST director; furthermore, these are the total number of certified teacher leaders from this system thus far.

The 15 teacher leaders selected for the interview are all secondary STEM teachers working in six different school districts and or systems, both private and public, throughout Los Angeles County. Fourteen teacher leaders teach either math or science courses and one teaches multiple subjects. Eight of the teacher leaders currently teach at middle schools and seven teach at high schools. The teacher leaders will be interviewed in a natural setting at various school sites. The schools have similar demographics, which adds to the validity to the study. All interviews will occur in the school or school office setting to maintain a consistent environment, which allows participants to remain comfortable and offer reliable responses.

Instrumentation

Due to the qualitative nature of this study, this section will describe in detail the instrument, containing interview questions, interview schedules, validity and reliability, and inter-rater reliability used to conduct the research in the study. The instrument will guide the researcher through interviews, which will engage the researcher with the sample population. The interview questions will align directly with the four primary research questions. The instrument will engage participants and assist in structuring the research outcome. The interview questions (Appendix B) are designed to gain the perceptions of experienced certified teacher leaders. The interview questions were constructed to be short, easy to understand, and allow for expanded responses from the participant. Each question was thematically created to contribute to the knowledge surrounding their experience as teacher leaders, as well as form good rapport among participant and researcher.

The following matrix contains the instrumentation aligned with each of the research questions for the study. Additionally, each of the research questions aligned with the theoretical framework characteristics highlighted in the chapter two summary: 1) leadership strategies; 2) ongoing support from existing school leaders; 3) professional development and adult learning; and 4) STEM pedagogy.

Research Questions	**Interview Questions**
1. What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the Center for Math and Science Teaching system?	1. What is your role as a certified STEM teacher leader? 2. What leadership qualities do you possess as a teacher leader? 3. What aspects of the CMAST system prepared you to be an effective teacher leader?
2. What success strategies, among teacher leaders of the Center for Math and Science Teaching system, have enabled further development of teacher leadership?	4. What kind of continuous learning and development is necessary to maintain the efficacy of teacher leaders in schools? 5. What school-wide support system is necessary to optimize the success of teacher leaders?
3. What is the best model in developing teacher leaders, according to literature from 2005 to present?	The answer to research question three will arise from analyzing existing research within the literature review that reinforces the teacher leader and STEM teacher leader model, from current and relevant literature.
4. What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education?	Based on the coded responses to interview questions and a detailed analysis of the literature review, which provides detailed answers to research questions one, two and three, an optimal model of developing STEM teacher leaders should emerge and be further developed.

Validity of Data Gathering Instrument

The instrument will be validated through distributing the interview questions to a director not affiliated with the study. This will allow the researcher to field test the instrument for the following items: understandable instructions, clear wording, adequate answers, sufficient detail, irrelevant questions, length, and convenience (Roberts, 2004). It is proposed the leaders and gatekeepers of the study, to assist in validating relevancy, interpretation, and research outcomes, will review the interview questions. These leaders play a key role in guiding and connecting the researcher to the participants in the study and they have the most knowledge about the study, but will not act as participants in the study.

Plans for Reliability

Reliability is a strong area of concern for any researcher due to bias and poor interpretation. This study will use triangulation as a primary reliability method to corroborate evidence from those participants involved in the study. Member checks will be conducted on an ongoing basis throughout the study to maintain accuracy of the interpretations written. Peer review will be used to eliminate bias and collaborate on definitions and meanings throughout the study; peer-debriefing sessions will be used as part of the peer review process (Creswell, 2009).

A peer-to-peer coding strategy will be utilized to increase reliability through the data analysis phase. Two of the researcher's colleagues will verify and collaborate in the coding process to ensure data is accurately transcribed and interpreted. This process is critical to the reliability of the research outcome and theory development. The colleagues, as doctoral candidates, will verify and confirm the coding process to be effective and meaningful collaboration of data.

Data Collection and Data Management

To provide a valid and fully representative analysis of this study, the researcher will utilize numerous and diverse amounts of data in order to draw inferences (Creswell, 2009). The data collection aligned to result with answering the four main research questions: 1) What attributes define an effective STEM teacher leader, according to CMAST? 2) What is the best model in developing teacher leaders, according to literature from 2005 to present? 3) What success strategies, among teacher leaders of the CMAST, have enabled further development of teacher leadership? 4) What is an optimal model of developing STEM teacher leaders within secondary education? Along with interviews, archived documents of student-assessments will be utilized to gain the greatest result in the study.

The following sequence will be used to collect data for the greatest result in this study: teacher leader interviews and documentation of student assessment data. Teacher leader interviews provide the most relevant analysis for the study analyzing the value of the CMAST system and its attributes in creating teacher leaders. Data analyses of student performance-based assessments of students instructed by the teacher leaders, offer inferences on the validity of the CMAST system, a unique characteristic to the value-added in education.

Asynchronous email communication will serve as the primary method of contacting participants. The email will serve as an introduction to the study, as well as its purpose (Appendix C). Gaining trust via the first email of contact is key, which will impose no threat to the participants. A third-party, such as the executive director of the program, will facilitate the introduction of the participants. The researcher will suggest a telephone conversation with the participants, or even a face-to-face meeting to initiate the context of the research, providing further relevance and next steps if it requested. This meeting will allow the researcher to verify the participants' anonymity as well as further expectations of the study.

The interviews and observations will be arranged at a convenient time for the participants concluding his or her workday, and in his or her natural work environment. The interviews will be conducted in a timely manner, no more than thirty to sixty minutes long, so there is no exhaustion of resources and participants' responses are not skewed. The research will conduct a structured, open-ended interview, utilizing both transcription and an audiotape, which will later be transcribed (Creswell, 2009). Please see Appendix A for the instrument containing the interview questions to be asked to each participant.

The researcher will gather, maintain and organize documents throughout the study to provide relevant sourcing of information. The following documents will be collected: keeping a journal during the research study, collecting data from participants, analyzing public documents, such as assessment scores, and archival material or files, and possibly analyzing existing videotapes of participants (Creswell, 2009). These materials will follow an organized and structured data analysis plan to effectively interpret and narrate the research. The data will be housed in a locked safe, if it can't be held on a locked, password-locked computer. This data will remain confidential and no participant names will be utilized. All participant identification will be excluded from the assessment data. The data analysis plan is further discussed in the next section.

Proposed Data Analysis Process

There are many strategies for analyzing data, and the researcher has chosen to use several methods proposed by several authors in order to collect and analyze data most effectively through a holistic analysis (Creswell, 2009). A narrative analysis will be written on each of the interviews, at the same time piecing the information and begin establishing patterns and generalizations. These patterns are established through the coding processes, where themes will emerge to assist in dissecting the data for analysis. Coding will be the primary analysis strategy for reaching a valid and reliable response to each of the research questions.

The research will gather the proposed data and further conduct analysis through first sorting all data and reading through all data to begin a sorting out process and to gain insight on the data set (Creswell, 2009). The researcher will then utilize a sorting out process that will further allow the researcher to take additional reflective notes as the researcher begins the summary process and organization of data. The organizing of all data collected is an important step in reducing the data, as not all data may be needed in a qualitative study (Walcott, 1999).

Within this process will be the strategy of coding, where the researcher will begin developing categories to sort the data and begin the process of recognizing patterns from the responses of interviews. Significant statements, phrases, or quotes will be categorized to assist in identifying the participants' experiences. Each category will be identified through a white-boarding strategy, where codes can be identified under each category and color-coded. This strategy will further develop into a "short list of tentative codes that match a text segment or theme" (Creswell, 2009). It is further recommended by Creswell to not exceed 25 to 30 categories of information, which will later be reduced to five categories. To aid in the coding process and reliability of the coding process, two colleagues will also assist with coding the narratives. This ensures the researcher is not the only one decoding adding confirmation to the results. Further proposed strategies in reducing data will include translating ideas into metaphors, creating displays, tables, diagrams or graphs as needed (Creswell, 2009). The research will further be developed to analyze within a computer software, theory-building program, this will reinforce the categorizing of data by the researcher and colleagues.

NUD-IST is a software program that will be proposed for use during the analysis phase of the research process (Richards & Richards, 1994). NUD-IST allows researcher to collaborate data by storing and organizing files, searching for themes, crossing themes, diagramming, and creating templates. Creswell, not only supports the proposed program, but the program has had proven success for qualitative researchers. The program has many features that guide the researcher through creating comparison tables, levels of abstraction or complexity, and assists in the process of theory development (Creswell, 2009). The researcher will spend time collaborating with colleagues, aided in the coding process, to best disseminate the research into organized templates and diagrams.

To gain a thorough result of this study, the researcher added a review of literature into the study as a research question: What is the best model of developing teacher leader leaders according to literature from 2005 to present? The result of this research will be to further analyze and develop a new theory by collecting the emerging themes and highlighted theories within the literature on teacher leaders. This review of literature will further guide the development of an effective model for developing teacher leaders, as well as serve as a guide for the conclusion of the study.

Plans for IRB

The researcher will propose an exempt review from the Institutional Review Board, since there will be no psychological repercussion as part of the outcome in this study and participants will not be identified or disclosed within the study. All participants will receive an informed consent document (Appendix D) ensuring their privacy and protection throughout the study and research outcome. The document will further outline to the participants the voluntary nature of the study to offer their perspectives or perceptions requested; furthermore, the informed consent will conclude that confidentiality is maintained through the process of coding.

Limitations

The major limitation of this study is sample size. Sixteen total participants were selected for this research and a total of 10 were interviewed. Three did not respond to correspondence and two were no longer living in the same city. There are a limited number of participants due to the unique program of study. All participants were from the same program, so a larger population sample from several programs and several states may offer more significance. Additionally, the researcher conducted observations, which increases the chance for bias to occur. The researcher also has a teacher leader background, but is not associated with the program, or any of the districts in any way.

Chapter 4: Results

Introduction

Chapter four provides a detailed analysis and the findings of the study on the STEM teacher leader model of Loyola Marymount, CMAST certificate system. The following research questions guided this study:

1. What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the CMAST system?
2. What success strategies, among teacher leaders of the CMAST system, have enabled further development of teacher leadership?
3. What is the best model in developing teacher leaders according to literature from 2005 to present?
4. What is an optimal model of developing STEM teacher leaders within secondary education?

This chapter will provide detailed answers to the research questions one through three and provide further insight on developing an effective model of teacher leaders in STEM education. This phenomenological study was conducted using interview questions to gain depth and insight on the perceptions of ten participants who earned a certificate from the CMAST system at Loyola Marymount. The findings in this chapter support the conclusion, recommendation, and suggestions for further research made in Chapter Five.

Overview of the Study

This study was conducted to gain an in-depth understanding on the perceptions of STEM teacher leaders through coding and analyzing the responses to interview questions.

These perceptions and responses provide greater depth on the desirable attributes of STEM teacher leaders, which will assist the development of further STEM teacher leader programs or systems. The investigator interviewed ten STEM teacher leader participants in secondary education engaged in teaching and leading of math and science. The interviews consisted of five questions, which resulted in gaining further understanding on the role and leadership qualities of the STEM teacher leaders, as well as perceptions on program components, ongoing learning and development, and necessary school-wide support.

All interviews took place in a face-to-face format at the participants' school sites and lasted no more than thirty minutes. Each response was answered with deep thought and consideration. Participants were engaged and actively involved throughout the interview. The ten participants consisted of four men and six women, which provided a positive gender sample. The investigator retrieved the total number of years teaching from each of the participants as an additional descriptor for analysis. The average number of years of total teaching for all participants is 8.9 years. The participants were primarily located in charter schools, with only three located in secondary public schools.

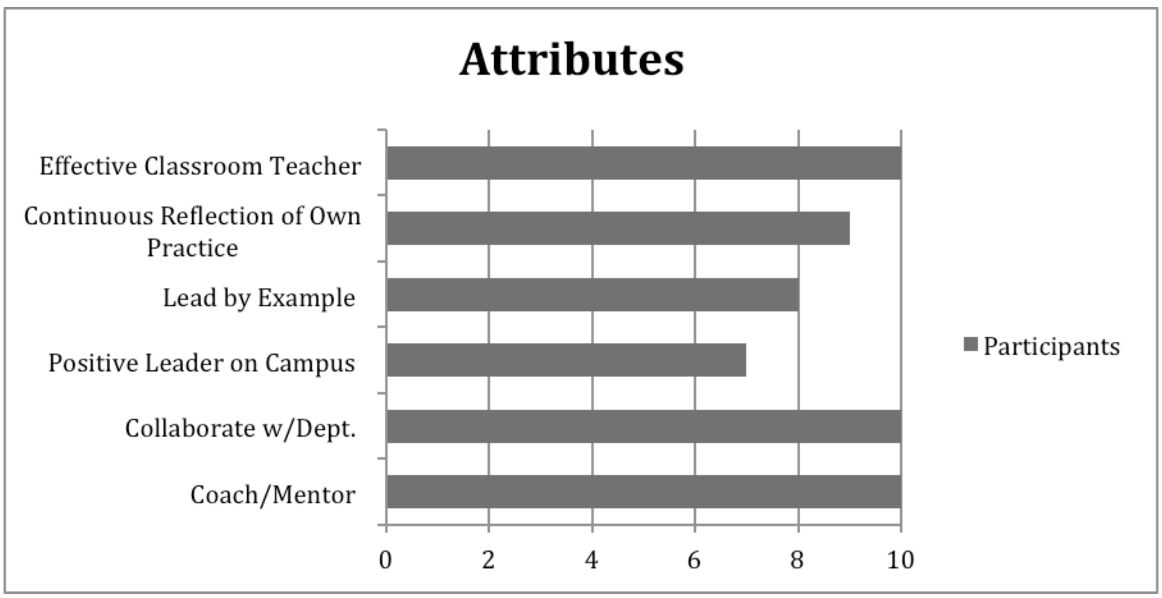
Results

This section will describe in detail the findings of the study with a response to each of the five research questions. As discussed in Chapter Three, creating themes based on responses from the interview was the methodology and analysis method used for this study. Transcriptions of audio files of recorded interviews served as the primary data for the analysis. The analysis of the interviews combined typological and inductive analysis to identify themes. After the eighth interview was conducted the investigator reached redundancy and saturation as no new themes emerged from the remaining two participants. However, the remaining two participants offered some descriptive evidence that offered further support of the remaining themes.

Research question one: What attributes define effective stem teacher leaders, according to teacher leaders who have completed the center for math and science teaching system? The attributes of teacher leaders were discovered by the investigator through the interviews conducted with each of the ten teacher leaders.

Table 1.0

Attributes with Corresponding Participant Responses



These attributes were identified through the emerging themes based on coding of the first two interview questions: 1) What is your role as a STEM teacher leader? 2) What leadership qualities do you possess as a STEM teacher leader? The following themes emerged under these two questions:

1. The primary role of the teacher leader is to coach and mentor prospective and existing teachers in the math and science departments, while maintaining their own classroom teaching.
2. The participants, as a majority, felt they had a prevalent leadership role on campus.
3. The participants identified leading by example while sharing a common vision as the prevalent leadership quality.
4. Continuous self-improvement and reflection on teaching practices is necessary for ongoing success.

The primary role of the teacher leader is to coach and mentor prospective and existing teachers in the math and science departments, while maintaining their own classroom teaching. After coding and analysis surrounding this theme it became apparent that the role of a STEM teacher leader was to coach and mentor teachers based on their knowledge of teaching math or science, through providing feedback derived from continuous observations and data. The following table aligns the participants' responses as a prevalent attribute to this role.

Table 1.1

Coach/Mentor Attribute and Participant Response Patterns

Interview Question 1	Coach/ Mentor Prevalent Role/Attribute	Response Patterns	Number of Participants Providing a Correlating Response
What is your Role as a STEM teacher leader?	Observe and provide feedback	"I observe, script, coach, I do not evaluate" "Observe and then give feedback" "I support every other teacher on campus teaching math" "Onsite coaching" "After each observation, we meet to collaborate"	9
	Lead Professional Development	"I am training most of my department in MAST" "Planning and executing PD (professional development)" "I conduct one PD session a month"	7
	Department Chair	"Acting as a current resource for the other teachers in the department" "It also involves community outreach, maintaining partnerships with media, aerospace, anyone who could better enhance our program and support our students."	5
	Classroom Teacher	"…creating team cohesion and community within the department and first and foremost is to teach (his or her own classroom of students)." "Just be a good teacher in the first place."	10

Observing and providing feedback was a common response among all participants as a description of the teacher leader role. The participants also stated he or she mentored and coached student teachers, also known as residents. The residents, like student teachers, were in the teacher leaders classrooms full-time. These teacher leaders possibly carry a little more of a workload than those without a full-time resident.

Participants continued to report the role of teacher leader as leading professional development sessions for teachers in their department in various topics. Topics ranged from adopting CCSS and NGSS to MAST, based on CMAST strategies. While speaking of this role of leading professional development sessions, it seemed as though the participants were comfortable being the leader and also being the participant of ongoing professional development. It was mentioned by more than half of the participants that the CMAST faculty (some of which are current teacher leaders) conducted ongoing monthly professional development sessions at the school sites to teach the science and/or math teachers about new trends in education, such as CCSS.

Under the theme of coaching and mentoring teachers, emerged the title of "department chair." This was the title described by four of the participants as he or she described his or her role. The department chair was described as leading the department through department meetings, ongoing collaboration on curriculum and planning, and being a close resource for the other teachers. There seemed to be a need of being current with the trends, as one participant described it as, "acting as a current resource for the other teachers in the department." Another interviewee stated that this role also included staying active with the families and the community, "it also involves community outreach, maintaining partnerships with media, aerospace, anyone who could better enhance our program and support our students."

Last, as an effective coach or mentor, the participants are STEM classroom teachers leading their own group of students. A common theme as well as a critical component to the teacher leaders is to stay current classroom teachers, leading his or hers' students, which allows for continuous development of his or hers' individual practice. One response describes the role as, "…creating team cohesion and community within the department and first and foremost is to teach (his or her own classroom of students)." The teacher leaders all teach at least one period of math or science, leading their own students. Since this is a common theme, this component will be readdressed later in this chapter.

The participants, as a majority, felt they had a prevalent leadership role on campus for the math and science departments. The investigator identified this leadership role as a theme due to the descriptive words of the participants identifying themselves as "A leader on campus." Table 1.2 displays the participant responses correlating to the role of leader on campus. The table includes the response patterns by the participants, which convey additional leadership qualities and perceptions on their leadership role.

Table 1.2

Leader on Campus Attribute and Participant Response Patterns

Interview Question 1	Leader on Campus Prevalent Role/Attribute	Response Patterns	Number of Participants Providing a Correlating Response
What is your Role as a STEM teacher leader?	Leader on Campus	"I am more like a leader on campus this year" "…we are something more than a teacher, but definitely something less than administration." "…master practitioners to our teachers"	4
	Attend Leadership Meetings or Collaborate with Leadership	"I attend Leadership meetings to discuss issues." "I'm good at working with administration to work cooperatively with a common vision for the science department."	3

The teacher leaders were clear about their role as a leader on campus, as stated by the participants. Additionally, it was interesting to listen as teacher leaders were so committed to this leadership role that they identified the other teachers as his or her teachers with a sense of ownership, "I am training most of *my* department," "…observe *my* science teachers," "…master practitioner to *our* teachers," and "…mentor to *my* residents." This was purely viewed by the investigator as a high-level of commitment to the role by the teacher leaders in the development of the other teachers in the department.

The participants were also clear about attending ongoing leadership meetings on campus as part of his or her role. The leadership meetings were ongoing with administration and/or CMAST faculty to primarily align goals with a common vision for the math and science departments. Interviewee responses were descriptive in this theme as well, as seen in Table 1.2.

The participants exemplified leading by example while sharing a common vision. Leadership qualities emerged as participants were prompted with identifying these qualities. Leading by example formed as the common theme as the idea of modeling was stated repeatedly by the participants. The participants also identified sharing a common vision as an important quality. Table 1.3 identifies the response patterns correlating with leading by example while sharing a common vision.

Table 1.3

Leading by Example/Sharing Common Vision Attribute & Participant Response Patterns

Interview Question 2	Leading by Example Sharing Common Vision Prevalent Role/Attribute	Response Patterns	Number of Participants Providing a Correlating Response
What leadership qualities do you possess as a teacher leader?	Model the Way	"In order to get people to follow, then you have to be doing it." "…leading by example." "…be positive and always focus on the students, model, be on my A-game all the time." "…be inspiring and make them want to be on-board."	9
	Share a Common Vision	" Relationship building, setting a vision, creating a vision and getting others to buy into that vision." "I am good at having a shared vision and a clear vision of what my school site wants to achieve."	5

One of the interviewees stated he or she was "goal oriented" as part of his or her leadership qualities. This aligns well with Drago-Severson's theory of the learning experience of a teacher leader being transformational and raising their level of teaching and expectations, which is developed from goal-setting (Drago-Severson, 2006).

Under the theme of leading by example, the investigator noted additional qualities that further align with this premise: being consistent, motivating others, following through, staying positive, and being flexible. These qualities, identified by the participants, are all behaviors teacher leaders can lead by example for those they are leading. One interviewee stated, "I try to exhibit all CMAST instilled, initiate, motivate, encourage, and follow through." The CMAST system borrows these skills from the Army manual as a way to assist leaders in their development.

Continuous self-improvement and reflection on teaching practices is necessary for ongoing success. This theme became the most prevalent in all of the responses from the participants and was consistently stated throughout the interviews as many responses to the prompts, not only in the question addressing leadership qualities. It was clear this was a critical component to their role as a teacher, teacher leader and a component of CMAST. The following Table 1.4 displays the response patterns, which validate the presence of this attribute. This theme will be further addressed later in the chapter as the components of CMAST are discussed.

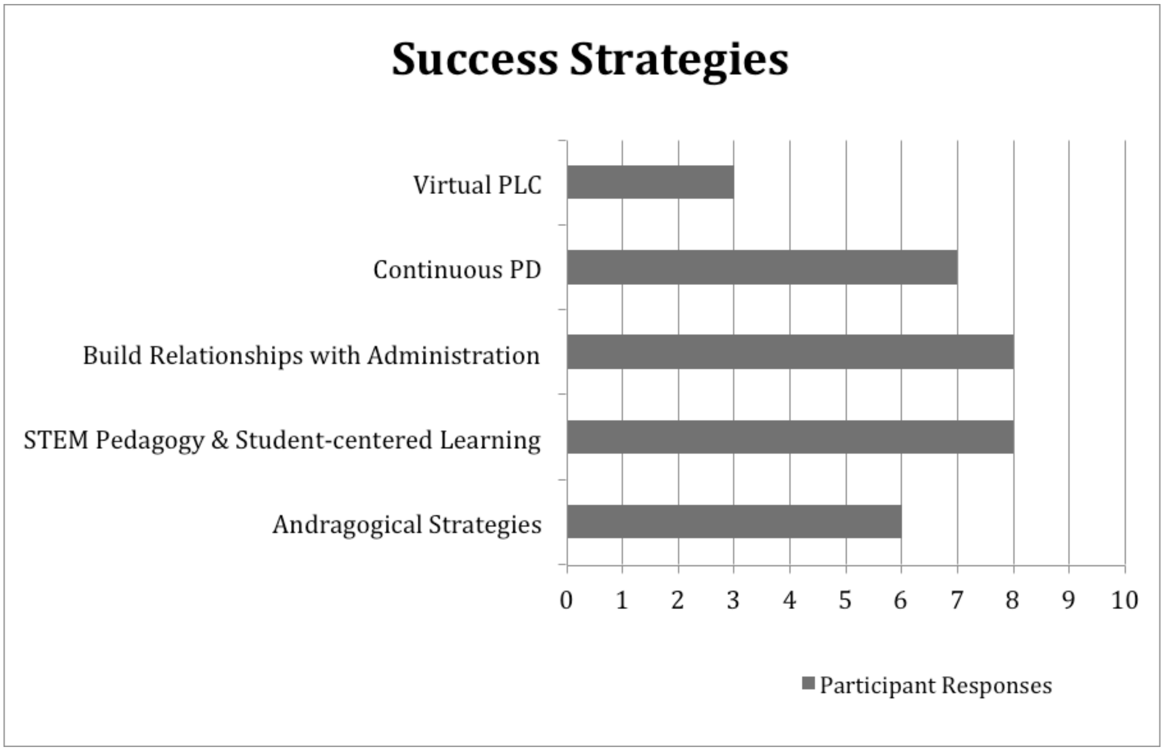
Table 1.4

Continuous Self-Improvement and Reflection Attribute and Participant Response Patterns

Interview Question 2	Continuous Self-Improvement and Reflection Prevalent Role/Attribute	Response Patterns	Number of Participants Providing a Correlating Response
What leadership qualities do you possess as a teacher leader?	Self-Improvement and Reflection on Practice	"Even now I question myself, how do I know I am an effective teacher?" "I get my department to self-regulate." "Continually seeking self-improvement." "…critical of our own teaching." "..teach through modeling of your own curriculum and then you are reflective of yourself." "…always evaluating our own teaching."	10

Research question two: What success strategies, among teacher leaders of the center for math and science teaching system, have enabled further development of teacher leadership? Success strategies were identified by the investigator through analyzed data and themes based on the responses of the ten teacher leaders or participants. Table 2.0 displays the results with the concluded success strategies utilized and needed by effective STEM teacher leaders.

Table 2.0
Success Strategies Correlating to Participant Responses



The success strategies emerged through the coding and themes based on the following interview questions: 1) What aspects of the CMAST system prepared you to be an effective teacher leader? 2) What kind of continuous learning and development is necessary to maintain the efficacy of teacher leaders in schools? 3) What school-wide support system is necessary to optimize the success of teacher leaders? The following themes emerged from the responses to the three interview questions:

- The study of andragogy or strategies for teaching adults is beneficial for a teacher leader's success.
- STEM pedagogy, focusing on student-centered learning is part of the coaching experience, and a necessary skill for a STEM teacher leader.

- Support from administration is critical for maintaining the success of a teacher leader.
- Ongoing professional development through professional learning communities is required for longevity and efficacy of teacher leaders.

The study of andragogy is highly beneficial for a teacher leader's success. The participants were asked to respond on the aspects of CMAST, which contributed to their development as a STEM teacher leader. More than half of the participants stated that the number one component they found most beneficial of the program were the courses they learned on andragogy. They reflected on the ability to work with adults and how it differs from working with children, and elaborated on how to coach and mentor adults as an important skill in this role as teacher leader. This skill involves the teacher leader learning various approaches on how to initiate collaboration with the teachers. The teacher leaders are facilitating the group of department teachers with a team-learning approach; they are learning along side the teachers and allowing the teachers to discover their own practices versus telling the teachers how to teach.

Table 2.1
Strategies of Andragogy with Correlating Response Patterns

Interview Question 3	The study and application of andragogical strategy Prevalent Strategy	Response Patterns	Number of Participants Providing a Correlating Response
What aspects of the CMAST system prepared you to be an effective teacher leader?	Andragogy and learning how to work with adults	"I am no longer the expert, but I am learning along side other teachers." "I want them to realize the correct way for them, not just tell them my way, let them discover it." "…it is really focused on teaching adults versus teaching students." "This shifted me to teaching adolescents to teaching adults." "The course that made a difference for me was on andragogy." "A lot of the training I did at LMU was actually on how to talk to an adult and we used research based on andragogy." "Working with adults and building trust and communication are part of the classes that really helped."	10

Studying andragogy strategies led them to the identified coaching and mentoring role. It was apparent that working with adults and the approach to address their peers was a necessary and valuable skill they learned in the CMAST system and continue to find this a memorable and long-lasting component.

STEM pedagogy, focusing on student-centered learning is part of the coaching experience, and a necessary skill for a STEM teacher leader. This theme continued to surface as the investigator coded responses on the components from the CMAST system that contributed to their success. STEM pedagogy, based on the information provided in the literature review (Chapter Two), is critical to student achievement and engagement in science, technology, engineering, and math. It became apparent that CMAST was addressing classroom strategies for the teacher leaders to implement as they continued to focus on the personal mastery of teaching STEM; this is exemplified in Table 2.2.

Table 2.2
STEM Pedagogy Correlating to Response Patterns

Interview Question 3	STEM Pedagogy Prevalent Success Strategy	Response Patterns	Number of Participants Providing a Correlating Response
What aspects of the CMAST system prepared you to be an effective teacher leader?	Focus on STEM Pedagogy and Student-Centered Learning	"I really figured out how to teach and keep students engaged." "I discovered what are the things I should be looking at so students are advancing in a classroom, where the teacher is implementing those necessary strategies." "How do you know the teacher is engaging students or providing opportunities for students to grow and achieve in STEM, what are the markers that show that?"	10

The investigator was most moved by some of the responses provided by participants in this theme, due to the excitement and passion exhibited by the teacher leader during the interview. Several interviewees expanded on this topic:

> "I used to lecture in front of the kids, the shift has changed from me to the students, my classes have become student-centered, the students are making choices on their level of practice, choosing the activities they want to do; everything I do has a meaning and a purpose and it is to meet achievement and engagement."

> "I was afraid of everything coming at me, and then I actually began to implement things they (CMAST) were telling me, then I got to see the kids faces, then it was like, ok, there is a reason we do it this way. We can see the engagement and achievement is way better than it was before. I would learn it one night (in class) and then try it the next day, this was really important for me. Once you see it works you want to keep doing it, and that is a lot of the hook and the IBE (investigation before experimentation), it gets the kids engaged immediately and they see ah-ha moments."

> "The goal of MAST (math and science teaching through CMAST) is to have students responsible for their learning so it is not direct instruction that you would usually find, it is direct collaboration the teacher has with the student. They are looking at what they know, they are assessing what they know, and you are having a conversation. What are the things you know, what are the things I can help you with? A constant back and forth conversation you are having with the student to the point you are getting the students to take ownership for their learning. They will come in on their own to ask for help or challenge you on your ideas, that is the best part when they challenge you, and they come in and say, "I disagree with you and I found something on the internet," or what ever it is, I say perfect lets talk about that."

> "CMAST teaches a very cohesive and connected lesson structure. In order to teach it to someone else you need to fully embrace it in the classroom; hooking the kids with pop culture, motivational video games and songs, whether it being an analogy or comparison. Actually having the kids driving their own learning in the classroom."

All of the statements regarding student learning were very powerful and exemplified through passion and facial expressions; meaningful student engagement and achievement are critical to these teacher leaders. He or she almost had a sense of pure gratitude for learning these strategies, identified as Action Learning, through CMAST and were fully committed to ongoing facilitation and coaching of these strategies. Knowles (1980) states, adults are self-directed and self-regulated when they take on a challenge of learning something new on their own. If effective teachers in the STEM classroom environment can create a vision and their desired learning goals, this self-regulation can be automatic when delivering material in the same way to his or her own students.

Support from administration is critical for maintaining the success of a teacher leader. Administration was the number one form of support needed for school-wide support to be an effective teacher leader. The term administration was used 35 times in responses to the investigator's prompt, and nine of the ten participants stated administration as primary to any other type of support. The participants felt that if administration was not "on-board" that the teacher leader was extremely limited in how they could fully contribute in their role. Part of the teacher leader role is to have ongoing dialogue with the administrative team, if administration wasn't supportive then they lose not only the credibility of their peers, but their role becomes weakened with the support they can offer to other teachers. Participants voiced their expression and conviction of administration being a necessary component of the process, as seen in Table 2.3.

Table 2.3
Administration Support is Critical Correlating Response Patterns

Interview Question 5	Support from Administration Prevalent Success Strategy	Response Patterns	Number of Participants Providing a Correlating Response
What school-wide support is necessary to optimize the success of teacher leaders?	Administration Support	"Administration support is really important, without them on board it is really difficult, just because as a leader you are trying to lead a department in one direction so they need to be on board with that." "Administration giving the freedom and the help, I think that is the most important thing because without the help of administration it is difficult." "Administration completely involved in the process of the leadership process, if they don't have your back, it will be impossible to implement." "100% need administrator buy-in." "Administration has to trust you, there has to be a high level of trust and the relationship." "We now all have a common prep period to collaborate, and administration is key in aligning this."	9

Since administrators are leading the school community, this necessary support wasn't a surprise to the investigator; however, the investigator was surprised when there was a lack of support from administration, which occurred from several examples created by the participants.

It can be concluded that with strong support from school administration other critical components contributing to the success of teacher leaders will be more easily established. Several of the participants communicated that the support from peers or the teachers they were coaching, parents and students were all important for optimal success of a teacher leader. If the administrators were not supportive, it would be difficult to have buy-in from anyone else involved in the leadership process. Interviewees responded, “You need buy-in from everyone,” “The peer-to-peer relationship is the foundation of this program,” and “The actual student is very important because you have to be able to have the student buy-in to the process that you are trying to teach.” Additionally, participants mentioned community as part of the school-wide support, since so many outside industries are contributing to the success of their math and science programs. Without administration, these connections would be difficult not only to initiate, but also maintain, since many of the teacher leaders act as the liaison between the industry and the classroom.

Ongoing professional development through professional learning communities is required for longevity and efficacy of teacher leaders. The responses to the question referring to the necessary ongoing learning and development that is needed to maintain efficacy of teacher leadership, all surrounded ongoing professional development. The term PD or professional development was used 24 times total and at least once by each of the 10 participants. Participants felt that they not only received strong professional development from the CMAST system, while they were enrolled as students, but they were also engaged in the ongoing professional development CMAST was continuing to provide at their school sites. Table 2.4 displays the prevalence of ongoing professional development correlating to participants' success strategies. The ongoing professional development they were receiving as teacher leaders were primarily focused around the adoption of CCSS and NGSS. These professional development opportunities were being addressed to the math and science department teachers only.

Table 2.4
Ongoing Professional Development Success Strategies

Interview Question 4	Ongoing Professional Development Prevalent Success Strategy	Response Patterns	Number of Participants Providing a Correlating Response
What continuous learning and development is necessary to maintain the efficacy of teacher leaders in schools?	Ongoing Professional Development (PD)	"There is a common core shift right now, the way we are teaching in the classroom needs to shift. I think that is one of the major component s for growth, how do you teach or lead PDs that involve such a drastic change in the classroom? How do we help our teachers deal with the anxiety, there is a lot of anxiety?" "We are getting our monthly PDs." "PD is one of the most important parts of MAST." "Collaborate with CMAST."	6
	A Desire for More PD	"In some ways there is not a structure in place to keep us together and connected." "A piece I think the program needs is to coach one another as TLs (teacher leaders)," "We talked about meeting once a month and I think that could be something very beneficial."	4
	Attending External PD or Reach out for External Resources	"I am going to a conference next week and three of the PDs I am attending are on teacher leadership. Since my training has been through one source it will be interesting to hear others opinions on the topic." "I go to a conference at X university once a year, you have to constantly look at other resources to grow." "I am always reading and hearing things and getting things to present; I act as a resource with an open mind."	4

(continued)

Table 2.4
Ongoing Professional Development Success Strategies Continued

Virtual PLC (professional learning community)	"On the virtual PLC, TLs post their plans and ideas on there. So, if I am looking for something new, or if my teachers are looking for a new idea, then I can use that as a resource, and that is almost like Facebook where I can connect with other TLs too." "There is also the PLC which is one extra step in place."	3

It was evident that not all of the teacher leaders were receiving this same type of ongoing professional development. One interviewee explained, "I want to be on top of it, but I don't go to class (at LMU), we need a monthly meeting; I think this would be beneficial, because my resident (student teacher) is getting all of this brand new info coming out (CCSS) and she comes to me and I don't know what she is talking about." Based on the responses, it seems some teacher leaders are receiving the ongoing professional development support and others need additional support. Furthermore, there is a critical component that still needs some refining and that is maintaining the community of teacher leaders. Several teacher leaders expressed the need to have ongoing dialogue with other teacher leaders. Three participants felt there was a strong need to have monthly or quarterly meetings to have some ongoing professional development, communication, and meeting time. Interviewees expressed their desires for more professional development, as displayed in Table 2.3.

Most of the participants felt they were getting the support they needed as teacher leaders both from CMAST and external resources. CMAST has created a virtual PLC (professional learning community) to give teacher leaders an opportunity to continue their dialogue outside the school site. One participant related the site to Facebook.

Several other participants responded as the PLC being very helpful and as an extra step they found beneficial from CMAST. It can be concluded with only two participants responding that he or she is actively using the virtual PLC and several of the participants stating they need more networking and teacher leader community and development time, that a face-to-face PLC would also be highly beneficial as an additional component.

Under the theme of ongoing professional development is the opportunity to further develop from external resources. Three of the participants stated they attended outside conferences as a way of gaining further understanding of the teacher leader role. Two of the participants stated he or she acted as the resources by reaching out on his or her own. The expectation that all current resources and strategies were not going to come directly from CMAST was evident from most of the participants; it is up to them to also stay current and proactive.

Concluding the theme of professional development is the reoccurring idea on being critical of one's own practice. As stated earlier in the chapter, the idea of continuous self-improvement and reflection on one's teaching practice surfaced as a response from about half of the participants. This reoccurring theme stresses the importance of the teacher leader continuing to practice strategies in their own classrooms so they can assist others in perfecting the practice. Some participants elaborated on this topic when prompted with the professional development question:

> "Having general PD that pushes curriculum to make you to reevaluate curriculum in your own classroom, trying new things in your own classroom helps you as well because you have to work with your colleagues to keep improving the things that are already there, so having the continuous reflection and need to improve and make things better is ongoing."

> "I think it is really important of keeping them (teacher leaders) in the space of being critical of their own practice. I thought I was doing everything great and I really wasn't, it is a hard spot to be in. How do you lead people when you are not perfect? So consistently working within that space has to be maintained."

Concluding with the evidence from the responses to the interview questions aligned with research question two, what success strategies, among teacher leaders of the CMAST system, have enabled further development of teacher leadership? Strategies that can further develop the success of a teacher leader include:

1. The knowledge and application of andragogy is key in enabling a successful relationship while leading peers.
2. The ability to coach and mentor other teachers on their understanding of STEM pedagogy and student-centered learning, utilizing various strategies, is necessary to optimize achievement and engagement among students.
3. Building connections and relationships with school administration is key, since gaining support from administration is a critical factor in the success and sustainability of a teacher leader.
4. Continuous professional development utilizing both the teacher leader PLC (professional learning community) and external resources for growth and longevity. (It is recommended the PLC occur in a face-to-face arena as well as a virtual space).

Research question three: What is the best model in developing teacher leaders according to literature from 2005 to present? The investigator utilized the literature review in chapter two and research from other existing teacher models, including CMAST, as a response to this question. This section will briefly review some critical literature to reinforce an adequate model based on existing research, which is further described in the next section. Many of the existing models include strategies for developing success within an entire school versus one department.

After reviewing theories, models and various existing literature on the topic of teacher leaders and STEM teacher leaders, there were some significant areas that were common among all of the research located. At least 25 authors within this literature review in Chapter Two placed a significant amount of weight on the importance of leadership skill development among teachers striving for teacher leadership. There were various theories around how leadership development should occur and the most significant theories are expanded on in this section.

The investigator did not find any existing literature contrary to the idea that STEM pedagogy should be inquiry based with hands-on and active learning. More than 12 authors were reported in this literature review, but at least twenty were discovered and validated the referenced literature located in Chapter Two. STEM pedagogy and the much-needed reform in teaching and learning of STEM disciplines are part of the reason for the development and expansion of STEM teacher leaders. STEM pedagogy and reflecting on ongoing practice is part of the investigator's model located in the next section.

The following models and theories were used as significant contributors to the existing teacher leader research. These models carry several important facets necessary for a teacher leader's ongoing success. These models and theories were deemed as the most significant contributors to the current existing research on teacher leaders and STEM teacher leaders.

Teacher Leader Model Standards

The Teacher Leader Model Standards were published in 2012 and are supported by the following entities: state education departments, award-recognized teachers, authors, education companies and industries, and prestigious universities. These standards create a framework for administrators, teachers, and teacher leaders to assist in driving student achievement. The standards are listed as a model and are as follows:

1. Fostering a collaborative culture to support educator development and student learning
2. Accessing and using research to improving practice and student learning
3. Promoting professional learning for continuous improvement
4. Facilitating improvements in instruction and student learning,
5. Promoting the use of assessments and data for school and district improvement
6. Improving outreach and collaboration with families and community
7. Advocating for student learning and the profession (Teacher Leader Exploratory Consortium, 2012)

These standards each are critical to student achievement and offer roles that are dedicated to learning and development for teachers and staff. After researching the STEM teacher leaders, as participants of this study, it is apparent that each of these standards is a need among the professional community of teacher leaders. In comparison, one unique component of the CMAST teacher leader model is that teachers are committed to the profession of teaching and therefore remain in the classroom as classroom teachers. These standards (described extensively on the website) do not state teacher leaders are current classroom teachers.

Center for Math and Science Teaching, Transformational Leader Model

LMU-CMAST has developed a teacher leadership model that supports a plan where CMAST Teacher Leaders (TLs) learn how to:

1. "Create Common Core State Standards (CCSS) demonstration classrooms where TLs can demonstrate effective mathematical and scientific practices that lead to student engagement and achievement in the CCSS and articulate the research-supported reasons behind these practices." (Center for Math and Science Teaching, 2012)
2. "Learn a variety of coaching techniques in order to effectively coach colleagues who are at different places in their attainment of proficiency in teaching with a goal of increasing their student engagement and achievement in CCSS." (Center for Math and Science Teaching, 2012)
3. "Teach colleagues how to develop a classroom and site culture that supports CCSS recommendations within the framework of active learning, shared assessment for learning, and problem solving through reasoning in order to be STEM college and career ready." (Center for Math and Science Teaching, 2012)
4. "Share instructional leadership with their site and organization administrators in order to transform their school site, or other departments, to expand the culture of professional growth and collaboration that will inspire students to study STEM and increase student achievement and engagement to the entire school." (Center for Math and Science Teaching, 2012)

Along with these components of the model are a set of components that address administrators and how they can support the process, leadership, and relationship with the teacher leader. Additionally, there is more to the model in details of roles and responsibilities and these are included in Appendix E on CMAST.

CMAST has a unique model for developing teacher leader models. The CMAST model has student learning at its core and to foster this learning the teacher leader remains in the classroom as a teacher, as well as provides support to fellow teachers as teacher leader. The teacher leader remains in a classroom for a variety of reasons:

- To remain master practitioners who continue to innovate within their practice (CMAST).
- To remain current with trends in education and then practice those trends, enabling an improved coaching experience.
- To remain critical of their own teaching practice so they can act as an effective mentor and coach.
- To remain connected with the love and passion of teaching young students.

This is a unique component to the CMAST system that isn't as prevalent in other models, and one that seems crucial to sustainability and success of the school. This also allows administrators to feel secure in knowing their best teachers will remain in the classroom.

Another distinguishing component of the CMAST system is the focus on STEM teacher leaders. There are many emerging teacher leader programs in universities across the country, but the focus is on a general teacher leader to assist in the facilitation of leadership. Also, these programs highlight the idea of the teacher enrolling in the program should there be a desire to leave the classroom and pursue an administrative title in the future. This opposes the CMAST view entirely, as the research they have shows the impact of the teacher leader remaining inside the classroom.

An extraordinary component to the CMAST system is that it is a *system*. A system is defined as a comprehensive assemblage of facts, principles, or doctrines in a particular field or thought. It is not identified as a program, as CMAST is not using a standard curriculum, which is being transferred to the group of adult learners. Rather, this system is creating a new leader, within each teacher leader, through transformational leadership theory. Transformational leaders can be part of teams, departments, divisions, and organizations as a whole, and these leaders are described as visionary, moving, audacious, risk-takers, and deep thinkers. These leaders are often are very charismatic. This type of leadership theory is important for bringing about major changes. This system also includes CMAST faculty instruction to take place on the prospective teacher leader's school site. The prospective teacher leader is mentored, coached, and guided through their teaching, as well as guided through their coaching. Coaching sessions are observed and they are followed with feedback from the CMAST faculty. This allows for a rich and engaging experience for the prospective teacher leader.

CMAST has tracked their teacher leaders' success through test scores over the last five years. The test score improvements are significant from the model CMAST implements with the teacher leaders. Appendix E includes the test scores from various unidentified schools in California that display the increase in achievement by the math or science department for a particular school.

The CMAST system has identified sessions that are valuable and offer valuable and sustainable strategies for the teacher leader. The teacher leader learns through an active-learning process that enables critical thinking of the process and practice. This active-learning process is carried through to the classroom of secondary students. Further description of the CMAST system is described in Appendix F. This is a system that should be replicated and pursued by other institutions throughout the country.

Learning-Oriented Leadership Theory

One theory created by Drago-Severson (2006) is *Learning-Oriented Leadership*, where the leader fosters learning to then create growth among a team with a high level of support. This approach is focused on developing leaders in a non-leadership role and consists of four pillars; supporting the practice of teaming, providing leadership roles, collegial inquiry, and mentoring. Although this model is not a STEM based model, it promotes effective practice as a teacher leader.

Supporting the practice of teaming is critical since the idea behind creating teacher leaders is to move an entire department or team of teachers toward a common vision. The team atmosphere creates a sense of unity, which is contrary to the idea of teachers being isolated in their practice. Teaming also allows teachers to reside in a space of comfort, knowing they are able to critically analyze teaching and learning. Last, this idea supports creativity and innovation beyond the classroom.

The second pillar is providing leadership roles. This idea offers support and challenges so a teacher can grow and develop as a leader. Additionally, this role invites the teacher to share expertise so they can assist in creating a community, enriching practice, and developing change individually and as a team.

The third pillar, collegial inquiry, creates an arena for teachers to practice in the context of supportive relationships and encourages an evaluation of one’s development, which in turn improves the individual and school. This inquiry leads the individual to discover his or her own strengths and opportunities for growth. Overall, collegial inquiry facilitates opportunities for adult learning to occur and provides positive institutional results.

Mentoring, the last pillar addressed by Drago-Severson (2006), claimed to be the oldest method to support adult learning, but still one of the most important. Mentoring allows for direct practice and is more private and less public. It works on a specific skill or need usually over a period of time. Drago-Severson's and Neuman's description of the focus on teams relates closely to the team leadership theory.

Kurtz Theory of the Role of Teacher Leaders

Kurtz (2009) analyzed how today's instructional leader (in California) could be viewed as having six roles (not a STEM description):

1. Making student and adult learning the priority.
2. Setting high expectations for performance.
3. Gearing content and instruction to standards.
4. Creating a culture of continuous learning for adults.
5. Using multiple sources of data to assess learning.
6. Activating the communities support for school success.

Kurtz created these roles based on Northern and Bailey's (1991) professional competencies apparent in instructional leaders: visionary leadership, strategic planning, change agency, communication, role modeling, nurturing, and disturbing (implementing change for those who are uncomfortable). Current teacher leadership roles include: team or department chairs, curriculum developers, literacy coaches, professional development leaders, grade-level chairs, assessment designers, and parent group leaders. Kurtz (2009) mentions that teacher leaders are most effective in a collaborative school, which correlates to previous views as mentioned in this chapter, and the term collaborative was highly repetitive in responses from participants.

Teacher leaders have some characteristics that contribute to the school body such as, revealing innovative ways of conducting things, aspire the best in themselves and their colleagues with a positive attitude, and they help others problem solve.

> Teachers desiring to move into leadership positions must identify a change that is needed in their school district, school or classroom and then move ahead on their

> own; teachers often become leaders after recognizing a need and committing themselves to taking action. (Kurtz, 2009)

Kurtz (2009) listed how administration can effectively assist more teachers in the area of leadership and creating an environment for teacher leaders to work effectively for school improvement. First, teachers need encouragement to lead and stay informed; this can occur through teachers creating a curriculum committee with new ideas of current trends. Second, administrators should create leadership roles for teachers. Administrators cannot run a school alone and not all successful teachers want to become principals, so this is the perfect opportunity to form a team of leaders with a desired vision and passion, even if it is to share instructional practices with the staff. Next, administrators must provide opportunities for teachers to continue their adult learning and be trained as leaders, if that is a desired outcome. Ongoing professional development is essential for teachers to gain the content and new information as leaders and to grow as professionals. In addition, principals can also ease time constraints, which seem to be the largest complaint made by teachers. There needs to be a time for leadership activities, and this may mean teachers write this time in their weekly planning.

There is an assumption that the idea of the teacher leader is the primary solution for desired school reform, especially in this current STEM movement. It would serve highly effective, but the consideration for outside influences such as demographics, socioeconomic status, and the level of parent involvement must not be ignored, but instead embraced into the ideas of the teacher leader to better serve the community as well as the school. This will enhance the primary goal of student learning.

A study conducted by Robinson and Timperley (2007) examined how leaders foster school change by leading and participating in teacher professional development, which improve academic and non-academic results. "The final analysis exposed five leadership dimensions that were critical in fostering teacher and student learning by providing educational direction; ensuring strategic alignment; creating a community that learns how to improve student success; engaging in constructive problem talk; and selecting and developing smart tools." This is critical not only for administrators, but also the success of teacher leaders. Additionally, smart tools are needed to engage students and assist students in driving their learning.

York-Barr: Teacher Leader Characteristics

Another model the investigator chose to highlight here is a model created around the identity of special education teachers. The role of special education teachers are important because they have a clear role as leader, identified by York-Barr et al. (2005), a focus group was formed and the results of the study created the following teacher leader characteristics:

1. Extensive and overlapping roles and responsibilities
2. Complex and dynamic patterns of daily work
3. Predictable annual cycles of work with peak times were not well accommodated
4. Vision and relationships as the foundation for effective practice
5. High levels of professional competence in the instructional, communication, and management domains
6. Site and central office administrative understanding and support
7. Collaborative partnerships for program implementation and support

8. Resources that enable special educators to leverage time and expertise (York-Barr et al., 2005)

These 8 identifiers align closely to that of a teacher leader and will be considered as part of an effective model.

CLASS Model

A more recent model, although it is not a STEM model, that has been developed on teacher leaders and has been based on research over the last forty years is called the Creating Leaders to Accelerate School Success (CLASS) model. Frank Crowther (2009) wrote about how teacher leaders enhance school success and defined his model as CLASS. This model describes areas for teacher leaders development in several components: “stimulating and nurturing teacher leadership capabilities, developing parallel leadership relationships and strategies, and sustaining leadership into the future.” Much of Crowther’s (2009) work has been focused internationally in Australia and other countries with a high reputation on education, such as Finland.

Crowther (2009) created a basic framework, *The Teachers as Leaders Framework*, that assists in organizing the actions, roles, responsibilities, ideas, and behaviors of teacher leaders. The framework is divided up into six components:

1. Convey convictions of a better world
2. Facilitate communities of learning
3. Strive for pedagogical excellence
4. Confront barriers in the school’s culture and structures
5. Translate ideas in sustainable systems of action
6. Nurture a culture of success (Crowther, 2009)

Each of the six areas includes two to three general strategies of action that a teacher leader should exhibit. This framework was created based on international research of teacher leaders and establishes a good foundation for all models of developing effective teacher leaders. This framework also assumes the administrator role is dedicated to the transformation and delegation of leadership among the school community. This model aligns with what is known about teacher leaders, but further enhances areas of the role as teacher leader with the necessary dedication required to transform a culture among educators.

Research question four: What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education? Using The Teacher Leader Model Standards along with existing general and STEM teacher leader models and theories, the investigator has created a model or framework that encompasses many powerful facets of existing models into one organized model. The investigator identified critical missing components in each of the models described in this study; the following Table 3.0 identifies the models used and the missing components identified by theme. This was a strategic piece in creating a STEM teacher leader model that identifies all necessary areas for developing an effective STEM teacher leader in secondary education.

Table 3.0

Existing Models in Literature Correlation

Roles/ Attribute Models	Remain Classroom Teacher	Leadership Training	Instructional & Curriculum Specialist	Coach/Mentor	Lead by Example	Vision	Collaborate with Dept. Team	Lead Dept. Team/ Dept. Chair (Assess Data)	Resource Provider	School Community Outreach/Families	Community Outreach	Ongoing PD –PLC (F2f & Web)	Add Additional Compensation
CMAST (2007)	X	X		X	X	X	X	X	X	X			
Teacher Leader Model Standards (2012)			X	X			X	X	X	X	X		
Teacher Leader Model Crowther (2009)				X	X		X	X	X	X			
Kurtz Theory (2009)			X				X	X		X	X		
York-Barr Theory Characteristic s (2005)	X		X	X			X		X	X	X		
Learning-Oriented Leadership Theory Drago-Severson (2006)		X		X			X		X	X			

Investigator's Model STEM-I^3

The investigator concludes that a necessary model is displayed by several necessary components for ongoing efficacy of a STEM teacher leader within secondary education. The investigator has created a STEM-I^3 model (Table 4.0), which highlights instruction, inspiration, and inquiry asey components to a STEM teacher leader role.

Table 4.0
STEM- I^3 Model

Instruct	Inspire	Inquire
• Remain Effective Classroom Teacher to Uphold Master Practitioner • Analyze new strategies and approaches in teaching • Model the Way • Focus on Student Learning	• Establish or Share Common Vision • Coach and Mentor • Lead by Example • STEM Curriculum and Instructional Specialist • Collaborate with Dept. Team • Lead PDs • Lead School Community and Parents in STEM • Liaison with Industry Leader • Administration Impact	• Resource Provider • Ongoing Learning & Development of STEM Pedagogy and Practice • Maintain Network and/ or PLC • Inquire about increased Compensation through stipends or grant-writing

These three areas for ongoing effectiveness of teacher leaders were designed for teacher and student learning as well as for longevity of the process and or system to maintain the role. These components should be considered as the foundation for extensive training or preparedness for future STEM teacher leaders. Throughout the study it was concluded by the investigator that the teacher leader participants were hard-working and had incredible balance of all the areas in the their role. It has been established that in the CMAST system there are an abundance of teachers who do not want to leave the classroom but rather have an intrinsic desire to reach a higher population of students through leadership. This teacher leader role enables this desire and passion for teachers to move a school toward achievement and engagement.

There were significant findings within the study that led to the development of this model, and the investigator has highlighted some of the missing components from existing models or frameworks (Table 3.0). First, teacher leaders continue to be critical of their own teaching practice when they remain classroom teachers. This is critical to the development of other teachers and his or her practice because the teacher leader has already established that the strategy, method, or research-based approach works effectively and has perfected the practice. This evolves with a master practitioner approach, which allows for strategic coaching and mentoring. The coaching process from this point is geared toward practice and student learning rather than "let's see how this strategy works in the classroom" verbiage.

Teacher leaders who remain in the classroom also have a team learning approach. They are actively engaged with what other teachers are doing on a daily basis. There is no room for other teachers to judge or view the teacher leaders differently, or administratively. The teacher leader is singled out more for being highly effective in their role rather than being out of the classroom. If the teacher leader is only teaching one period, they are still interacting with their own students, parents and maintaining their practice, but they have an opportunity to fit the other roles and responsibilities of a teacher leader into their day. Additionally, they truly have an opportunity to lead by example, which is an important characteristic of this role. The investigator found no other existing models in literature where the teacher leader *should* remain in the classroom as part of the role.

Another significant finding is the importance of connecting the teacher leader with the external school community. The teacher leader acting as a liaison directly with industries that can contribute and donate with funding and provide learning tools and technology is a valuable relationship. STEM teacher leaders are subject matter experts in science and math and typically have more knowledge on these subjects than the administrator; therefore, fostering the relationship between the teacher leader and industry leader is strongly recommended for science and math focused teacher leaders.

"In 2009, the President launched Educate to Innovate, a public-private partnership that brings together leading businesses, foundations, non-profits, and professional societies to improve STEM teaching and learning" (President's Council, 2010). Change the Equation was also launched to connect CEOs with creating opportunities in the STEM movement. In February 2012, "Change the Equation announced that 24 member companies would expand five effective STEM programs in more than 130 new sites, benefiting nearly 40,000 students nationwide; over half of whom are in low-income schools" (Change the Equation, 2013).

Leading with a common vision is another finding that contributes to the success of teacher leaders; many teacher leader models do not include connecting to a vision as a critical component. This is an important component for teacher leaders, not only to feel like they are part of the development process, but also so they can have a better sense of where they are leading others. Leaders should connect the team goals to a vision. Establishing a common vision needs to become more common among administrators and school leaders.

Having a structured ongoing PLC (professional learning community) of teacher leaders is critical and another finding in the conclusion of this study. The teacher leaders in this study expressed a need for an ongoing connection as a teacher leader upon concluding the CMAST system. He or she recommended there be a monthly or quarterly gathering, or partner connection to stay connected. The leadership role can feel isolating, so having a network and other teacher leaders to unite and reflect with is an important aspect to this model.

The PLC should consist of a face-to-face network as well as a virtual network. Teacher leaders having time and space to improve their knowledge on new trends in education as well as new pedagogy is critical for the success of all teacher leaders and the teachers they are leading. Robinson and Timperly (2007), state "that the first focus on the community of teacher learning will focus on the relationship between how teachers teach and what the students learn on an individual lesson." The second focus for this community of teacher leaders was to identify and creating "strong norms of responsibility and accountability for student achievement" (Robinson and Timperley, 2007). The study they conducted led to enormous gains in student achievement. Professional learning communities are optimal for creating a space to allow participants to be critical of their own teaching practices, while learning from other experiences. These communities of practice are developed for critical thinking, creativity and innovation, and for ongoing accountability. The PLC also holds a level of accountability for progression and longevity of the teacher leader process.

There is significant evidence that teachers are the most important component to student achievement and success, yet teachers are not rewarded or promoted with compensation for their excellence. Although compensation wasn't related to the interview questions within the study, in response to the question on the need for ongoing learning and development, several participants stated, "…this means more time out of the classroom without compensation." This described a need to address this issue as part of the investigator's model. Teacher leaders deserve added compensation for their extended dedication beyond their own classroom, and many teacher leaders are not earning anything more than their general teacher salary. This compensation can come from grants, stipends, non-profit organizations such as Teach+Plus or Alliance for Education, or new federally funded education grants, such as Race to the Top.

In July 2012 Obama announced the initiative of America STEM Teacher Corp. that would launch a STEM teacher leader search to educate and train 100,000 STEM teachers over ten years. The proposal was to dedicate $1 billion in funding and teacher leaders would earn $20,000 beyond their teacher salary. These are the kind of stipends teacher leaders need to not only increase tools, but to sustain their dedication and determination to effectively change STEM education. It is evident that teacher leaders deserve the added compensation based on this proposal headed by the federal government, but more opportunities need to be made available, since there are teacher leaders and teacher leader programs emerging all over the country.

One grant received, March 2013, by Boise State University, Idaho National Laboratory and partner districts to enhance STEM teaching and learning for K-12 teachers. They are training 100 teachers across five locations throughout the state of Idaho during summer institutes. These institutes, called i-STEM, will help teachers build knowledge and confidence in the teaching of STEM subjects through interacting with regional and national STEM experts such as scientists, engineers, etc. (Idaho State Department of Education, 2013). The institutes also equip teachers with knowledge on how to integrate and network with STEM in their local communities. Imagine if this type of grant were possible for every state with 100 STEM teacher leaders taking critical knowledge back to their districts to train other teacher leaders. This would have an incredible impact on the nation and education reform, as it would begin a cycle of teaching and learning across all academic disciplines.

Another option to explore is the title of teacher leader embedded in each district with a certain number dedicated among various schools. The role would add one additional component and that would be working with several school sites. The role of classroom teacher would change to fit this model, where the classroom teacher would teach one period. This would allow a full day beyond the one teaching period to reach as many teachers as possible. The one-to-four model is designed for budget purposes, as the ideal model would allow one STEM teacher leader per school. This is an ideal model for a small district with a limited number of schools, but with enough funding it could expand to a larger district.

The last approach to adding additional compensation for teacher leaders is to refer back to the Highly Qualified Teacher initiative that couple No Child Left Behind. This California initiative encouraged all teachers to be fully credentialed with a certain number of years teaching and the required assessments to be taken. The investigator proposes something similar, where state funding and/or grant money is used for a Highly Qualified STEM Teacher initiative. Part of this initiative is providing the appropriate path for the teachers and offering compensation based on completion. The initiative would encourage teachers to become highly qualified through a proposed number of steps, such as:

- Teacher education on STEM pedagogy, an updated model of inquiry
- Teacher as leader and school community contributor
- High performance indicators

These components would drive STEM teachers to better themselves as teachers, but then further qualify them to becoming STEM teacher leaders. Again, this would include compensation increases. Teachers, just like any other business or industry, need some added incentives to go beyond the classroom. Typically, highly effective teachers have the drive, passion, and commitment to maintain effective teaching practices and enhance learning; however, there is a need to spread this effectiveness to surrounding classrooms and it may take more than a dedicated teacher. Business leaders, such as managers, are paid more for their title and responsibilities beyond the basic functions of the job or role; teacher leaders deserve the same recognition. This recognition through added compensation will not only benefit the school, but will increase the demands of this role and teachers just might do what it takes to get there.

Summary of Findings

STEM teacher leaders have incredible stamina, and this can be contributed to the dedication to the subjects they teach and the students they impact. The significant findings are identified based on the overall data analysis. These findings were also identified in depth in the previous section on the investigator's STEM-I^3 model. Additionally, these findings add to the existing research, knowledge, and frameworks already established on the topic. These findings, based on data collected from the STEM teacher leader participants, include:

- STEM teacher leaders should continue their role as classroom teachers to maintain critical analysis of their own practice.
- STEM teachers should be trained or guided to connect with the community beyond the school site to further engage with industries that can contribute to student learning either through pedagogy or funding.
- STEM teacher leaders should establish or share a common vision and lead with that vision.
- STEM teacher leaders should maintain a network or strong PLC (professional learning community) for ongoing success and longevity of the role.
- STEM teacher leaders should have added compensation for their role as leaders beyond the classroom.

The significant findings discovered by the investigator were identified primarily due to the exposure of CMAST at Loyola Marymount University. CMAST requires STEM teacher leaders to remain in the classroom to ensure ongoing mastery of practice. Additionally, CMAST prepares STEM teacher leaders in a variety of leadership trainings, which includes strategies for andragogy as well as transformational leadership. The remaining significant findings were established based on the needs of the teacher leader participants interviewed in this study.

Some of the participants in the study were connected with the community beyond the school site, while others were not. The participants who were directly communicating with outside STEM industries were highly impacted by the experience and confirmed the network as a correlation to the ongoing success of students. This is a significant finding that the teacher leader can associate as a liaison, removing the administrator as the "middle man."

Participants also stated they needed more of an established network once they were proficient in their roles as STEM teacher leaders. The participants validated the existing virtual PLC CMAST was offering, but felt they needed a stronger network for ongoing communication. This was a significant finding due to the ongoing support needed to maintain the efficacy of STEM teacher leaders.

The last significant finding of added compensation was highlighted due to the comments of some of the participants. Compensation could be an added driver to the role, but more importantly, it is deserved for the amount of work expected by the STEM teacher leaders to go above and beyond their classroom duties as a teacher. Each of these findings is elaborated in more detail in the previous section on the investigator's model for effective teacher leaders.

Summary

The results in this study conclude that the role of STEM teacher leaders is critical to maintaining achievement and engagement in the STEM (science, technology, engineering and math) disciplines. Significant findings were discovered upon the conclusion of analysis of data (and described in the previous section). The following research questions assisted in the conclusion of significant findings, as well as the answers to those questions:

1. What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the Center for Math and Science Teaching system?
    a. Effective and Passionate Classroom Teacher
    b. Coach and mentor
    c. Positive leader on campus
    d. Lead by example
    e. Share a common vision within the department
    f. Continuous reflection for ongoing self-improvement
2. What success strategies, among teacher leaders of the CMAST system, have enabled further development of teacher leadership?
    a. The knowledge and application of andragogy is key in enabling a successful relationship among leading peers
    b. The ability to coach and mentor other teachers on their understanding of STEM pedagogy and student-centered learning, utilizing various strategies, is necessary to optimize achievement and engagement among students
    c. Building connections and relationships with school administration, since gaining support from administration is a critical factor in the success and sustainability of a teacher leader

d. Continuous professional development utilizing both the teacher leader PLC (professional learning community) and external resources for growth and longevity (It is recommended the PLC occur in a face-to-face arena as well as a virtual space.)

3. What is the best model in developing teacher leaders according to literature from 2005 to present?
    a. Teacher Leader Model Standards
    b. Transformational Leader Model (CMAST)
    c. Drago-Severson: Learning-Oriented Leadership Theory
    d. Kurtz Theory on The Role of Teacher Leaders
    e. York-Barr Theory on Teacher Leader Characteristics
    f. Crowther: CLASS Model
4. What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education?

These results on data conclude there is a high demand and need for future STEM teacher leaders throughout California and the country. The teacher leaders help teachers build confidence in their teaching practice, as well as coach teachers to engage students in critical inquiry. The teacher leader helps create a community of expert instructors, often an area where administrators have little time or are out of practice. Teacher leaders may not solely be the answer to the STEM education movement, but definitely aid in creating a better future for STEM teachers and students.

Utilizing STEM teacher leaders to increase student achievement and engagement in every math and science classroom is critical. Due to the demands of the STEM fields, there are emerging groups all over the US providing assistance to K-12 schools, creating awareness and leading change. These groups are an essential piece in the success of STEM development, as they are creating an opportunity for a movement of change in education, and a voice for highly technological students who are ready for a new type of classroom learning experience. Graduates are coming to the workforce with a lack of qualified skills. Therefore, businesses, foundations, and universities have been pulling together to create new opportunities for both K-12 teachers and students, creating opportunities for skill development and designing pathways for a bright future for degree-holders. Based on this research, Loyola Marymount University, CMAST is one of these critical institutions assisting to impact this movement and shed light on the necessary component in schools, STEM teacher leaders.

Chapter 5: Conclusion

This study was designed to examine the positive impacts of STEM teacher leaders in secondary education, trained by the CMAST system, and the direct affect they have on teacher practice and student learning. Based on the analysis of the experiences and perceptions of the participants, described in the previous chapters, a framework or model has been developed to display the critical components needed to have a sustainable and effective STEM teacher leader system. In this chapter, the investigator's model will be summarized (a detailed description is located in the previous chapter) in light of the results and connection to the literature. In addition, implications for practice in furthering the development of STEM teacher leaders are explored. Finally, limitations and further recommendations for research will be included.

Overview of Theoretical Framework

The theoretical framework as described in previous chapters, serves as a foundation for this study. There was an evident gap in literature surrounding the topic of STEM teacher leaders, but there is a significant amount of research on the topic of teacher leaders. This existing research, including theories and models, on teacher leaders was used to create a framework for furthering research on STEM teacher leaders. Due to the lack of STEM teacher leader research, there was great opportunity to expand in this area.

Throughout the literature review four themes emerged as critical pieces to gaining more understanding in what we know about teacher leaders; 1) STEM pedagogy; 2) professional development; 3) supporting and guiding the teacher leader process; and 4) leadership strategies and tools. These four areas provided a framework to further develop the research questions. Through the research questions the researcher was able to gain further understanding in these four areas through the interview process. It was concluded by the investigator that there not only was a gap to be filled with further research in the area of STEM teacher leadership, but the responses to the interview questions provided further depth on each of the four themes within the literature.

In the existing literature, the investigator did not discover a model similar to the CMAST model. Each model, although relevant in many ways, all seemed to be missing components that would aid in the success of teacher leaders. The teacher remaining in the classroom is one example of how the CMAST model stood apart from the rest. CMAST seeks to provide teacher leaders with many facets not found in other models, and has a great focus on the leadership and pedagogy development of STEM teacher leaders.

The Connection to Literature & STEM-I^3 Model

This section will review the theories and models used to formulate the investigator's model, STEM-I^3. This model was developed to fill the missing gaps in existing literature, theories and models. The investigator's model is unique, as it brings together the established theories and existing models, including CMAST.

One theory created by Drago-Severson (2006) is Learning-Oriented Leadership, where the leader fosters learning to then create growth among a team with a high level of support. This approach is focused on developing leaders in a non-leadership role and consists of four pillars; supporting the practice of teaming, providing leadership roles, collegial inquiry, and mentoring. Although this model is not a STEM based model, it promotes effective practice as a teacher leader.

Crowther (2009) wrote about how teacher leaders enhance school success and defined his model as CLASS (Creating Leaders to Accelerate School Success). This model describes areas for teacher leaders development in several components: stimulating and nurturing teacher leadership capabilities, developing parallel leadership relationships and strategies, and sustaining leadership into the future. Much of Crowther's work has been focused internationally in Australia and other countries with a high reputation on education, such as Finland.

Another model the investigator chose to highlight here is a model created around the identity of special education teachers. The role of special education teachers are important because they have a clear role as leader, identified by York-Barr et al. (2005), the study created the following teacher leader characteristics:

1. "Extensive and overlapping roles and responsibilities
2. Complex and dynamic patterns of daily work
3. Predictable annual cycles of work with peak times were not well accommodated
4. Vision and relationships as the foundation for effective practice
5. High levels of professional competence in the instructional, communication, and management domains
6. Site and central office administrative understanding and support
7. Collaborative partnerships for program implementation and support
8. Resources that enable special educators to leverage time and expertise." (York-Barr et al. 2005)

Kurtz (2009) created roles based on Northern and Bailey's (1991) professional competencies apparent in instructional leaders: visionary leadership, strategic planning, change agency, communication, role modeling, nurturing, and disturbing (implementing change for those who are uncomfortable).

Additionally, published in 2012, the Teacher Leader Model Standards create a framework for administrators, teachers, and teacher leaders to assist in driving student achievement. The standards are listed as a model and are as follows:

1. Fostering a collaborative culture to support educator development and student learning
2. Accessing and using research to improving practice and student learning
3. Promoting professional learning for continuous improvement
4. Facilitating improvements in instruction and student learning
5. Promoting the use of assessments and data for school and district improvement
6. Improving outreach and collaboration with families and community
7. Advocating for student learning (Teacher Leader Exploratory Consortium, 2012)

These standards are important to consider due to the validity and reliability of their development and foundation. Additionally, leaders within the US Department of Education now promote these standards.

CMAST is the last model used as a foundation for developing and effective model. Upon the conclusion of research, it became evident that the CMAST model was the most detailed and thorough STEM teacher leader model to exist. Not only is the model highly valuable and being utilized by many districts, Loyola Marymount University and the leaders of CMAST have been tracking the teachers who have left their system and finished with a certificate. CMAST has been analyzing and tracking the test scores of their teacher leaders not only to monitor their impact but also to improve practice. The math and science scores at these individual schools have significantly increased since the placement of teacher leaders in these represented schools (the CMAST model can further be explored in Appendix H).

The CMAST model along with the interview of the participants who participated in the research study served as a foundation for the STEM-I^3 model. This investigator's model differs primarily due to the responses of the participants, which shed light on some needed enhancements and additions to sustain the STEM teacher leader role. The investigator pulled out important components, based on the research with the participants, from the different models and theories to develop one cohesive model (Table 4.0).

Summary of Investigator's STEM-I^3 Model

The STEM-I^3 model was created to connect all of the conclusive research on STEM teacher leaders and general teacher leaders into one cohesive model. This model serves a valuable purpose for any institution or school district with a desire to implement a STEM teacher leader program or system. The STEM-I^3 model has three necessary parts: to instruct, to inspire and to inquire. Extensive training in each of the three areas is necessary to gain the necessary leadership skills, find balance among all of the roles, and further establish the need for ongoing inquiry or learning.

Instruct. To instruct or remain a committed effective classroom teacher is critical to this model. This ensures the teacher leader is a teacher first and is committed to mastering his or her own practice. Teaching in a classroom also allows the teacher leader to practice new approaches and strategies, needed in STEM pedagogy, with his or her students first. This removes the guessing game of whether the strategy will or won't work, and it allows the teacher leader to perfect the strategy before leading a professional development on the new practice. Teaching in a classroom also provides an opportunity for the STEM teacher leader to model the way for other teachers of STEM disciplines. Teachers can observe the teacher leader working with his or her own students just as the teacher leader observes the STEM teacher. Last, remaining in the classroom providing ongoing instructions allows the teacher to focus on the most critical part of their role, student learning.

Inspire. A STEM teacher leader can leave a lasting mark on the teachers with which they work on a daily basis. This mark is the catalyst for the *inspire* component of the model. Teacher leaders have a unique opportunity to inspire other teachers, leaders, and students, so the investigator believes this was a significant part to the model. As an inspiring leader the STEM teacher leader should establish or share a common vision to lead a group of teachers toward a common developed goal. This goal(s) might be student achievement through higher test scores, student engagement, evidence of active learning, etc. Establishing a vision is the first step toward creating cohesion, as everyone is united as a team toward one mission. This cohesion is based on a foundation of constant collaboration and communication. This ensures the teacher leader’s commitment to the team and assists in establishing a relationship.

STEM teacher leaders should inspire through coaching and/or mentoring other teachers. They can inspire their team by leading by example as a positive leader who is committed to the vision and/or goals established. Leading by example is also identified with the knowledge base and expertise from which the teacher is leading. The skills as a curriculum and instructional specialist are important, as the leader seeks to find answers to ongoing teacher development. This specialist role also serves as a resource provider through leading ongoing professional development opportunities for teachers in the STEM department of team. The STEM teacher leader seeks outside resources to assist in leading the school community and parents and inspiring them to take part in the STEM education being provided to their students. This may include the teacher leader acting the liaison between industry leaders and the school and classroom. Not only does this empower the teacher leader, but it allows them to directly connect with the industry they are inspiring middle and high school students to directly connect with once they graduate from college.

Administration impact is critical in the role of inspiring, since the administration must be supportive of this teacher leader role. This model strives to have the administrator learning from the STEM teacher leader equally as the teacher leader is learning leadership from the administrator. This relationship must be fostered and built over time, but the ideal model leaves the administrator inspired as well.

Inquiry. STEM teacher leaders must have a lifelong learning outlook to meet the demands of being an effective STEM teacher leader. To be an effective leader, it is critical to remain current and updated on the resources available to your team and/or school. Teacher leaders must have this same approach as they lead a team of STEM teachers. STEM teacher leaders should maintain ongoing learning and development as resource providers to other teachers. This knowledge on STEM and ongoing practice of STEM pedagogy is critical to student achievement. Part of staying abreast with the current trends is maintaining an ongoing teacher leader network or PLC (professional learning community). This allows the teacher leaders to stay connected as well as critique and develop through one another. The PLC should have ongoing meetings both face-to-face and online to not only establish relationships and a community, but to also further develop the practice of the STEM teacher leader.

The last component to inquiry is the added compensation teacher leaders deserve while balancing these many roles. If budget is an issue for the school district or implementing organization, then it may serve the teacher leader to have training on grant writing. Time dedicated to grant writing, may not only increase teacher leader funding, but also contribute to student learning through gaining tools and technology to further develop students in the STEM disciplines. It may be up to the teacher leaders to seek the additional funds or compensation.

The STEM-I^3 model was developed to enhance the effectiveness and sustainability of teacher leaders. This model serves as a framework or foundation for future development of STEM programs or systems, and additionally contributes to the existing research on the topic of STEM teacher leaders.

Implications for Future Development

A school district or institution should plan on the use of these critical roles and responsibilities and components of the STEM-I^3 model when considering the development of a STEM teacher leader program. Each teacher leader should have extensive training and development on the following:

1. Instruction
    - Remain Effective Classroom Teacher to Uphold Master Practitioner
    - Analyze new Strategies and Approaches in teaching
    - Model the Way
    - Focus on Student Learning

2. Inspire
    - Establish or Share Common Vision
    - Coach and Mentor
    - Lead by Example
    - STEM Curriculum and Instructional Specialist
    - Collaborate with Department Team
    - Lead Professional Development
    - Lead School Community and Parents in STEM
    - Liaison with Industry Leader
    - Administration Impact
3. Inquiry
    - Acting as a Resource Provider
    - Ongoing Learning & Development of STEM Pedagogy and Practice
    - Maintain Network and/or Face-to-Face PLC
    - Inquire about increased Compensation through stipends or grant writing

These roles and responsibilities are important in maintaining sustainable progression of the role and will help guide STEM teacher leaders to a depth of understanding their impact in the role. These teacher leaders should also contain the following attributes, as they are deemed important to the connection to this role:

- Effective and Passionate Classroom Teacher
- Coach and mentor

- Positive leader on campus
- Lead by example
- Share a common vision within the department
- Continuous reflection for ongoing self-improvement

These attributes were common among the participants in this study and are descriptor of teacher leaders who will remain in the position.

For further development of a teacher leader program or system, it is also recommended that the following strategies (identified as success strategies in this study) be considered for learning and development or training of STEM teacher leaders:

- The knowledge and application of andragogy is key in enabling a successful relationship among leading peers
- The ability to coach and mentor other teachers on their understanding of STEM pedagogy and student-centered learning, utilizing various strategies, is necessary to optimize achievement and engagement among students
- Building connections and relationships with school administration, since gaining support from administration is a critical factor in the success and sustainability of a teacher leader
- Continuous professional development utilizing both the teacher leader PLC (professional learning community) and external resources for growth and longevity (It is recommended the PLC occur in a face-to-face arena as well as a virtual space.)

Recommendations for Further Research

Although this study is focused on STEM teacher leaders, it was limited to secondary education. The investigator recommends further research be conducted in other areas to further the development and understanding about what is known on the topic of STEM teacher leaders. Areas for further development and research in this section include: analyzing STEM teacher leaders from a district initiated program perspective, research on STEM teacher leaders at the elementary education level, gaining perceptions from STEM teacher leaders or teacher leaders who earn additional income for their role, and further research on a larger population of STEM teacher leaders.

Analyzing STEM teacher leaders from a district created program. Recommendations for further research on STEM teacher leaders from a school district created program may serve the STEM education community on understanding more about how the school district interprets a STEM teacher leader role. It also provides further analysis on how districts can evolve as program developers for STEM teacher leader programs and teacher leader programs. More and more school districts are taking part in the STEM movement, creating many opportunities for student and teacher learning. This would add great depth to the existing research.

Analyzing STEM teacher leaders at the elementary school level. Recommendations for further research on analyzing STEM teacher leaders at the elementary school level would be a great asset to the existing literature. There is a large gap in this area of existing literature and there may not be any previous research on STEM teacher leaders in elementary schools. There is existing data on the lack of strong content preparation in STEM subject. A 2012 National Survey concluded that less than half of elementary school teachers don't feel very prepared to teach science. This may be in part to the fact that in college elementary education majors take a significant amount less of science and math coursework compared to secondary education majors. Due to recent findings, identifying the role of elementary school teachers when it comes to math and science teaching, there is an important unexplored area for research on the elementary school STEM teacher leader.

Gaining perceptions from teacher leaders earning additional compensation. Due to the research conducted in this study and the responses from participants on added compensation for the responsibilities of the role, it is further recommended to explore perceptions of teacher leaders who are being compensated more for their role as a teacher leader. There is a gap in literature on this topic, and what does exist are a lot of opinions and views on compensation. In order to provide substantial evidence and data from further research, it is recommended to explore the perceptions of these teacher leaders who are being compensated, and how they are being compensated. Significant data would provide perceptions from teacher leaders who are earning added compensation from broad categories such as salary, stipends, and/or grants. This would provide government, state, and local entities a broader understanding of how to budget STEM teacher leaders.

Study of a larger population of STEM teacher leaders. This study was limited in the number of teacher leaders interviewed. Additionally, this study only gained understanding from one university or program. It is further recommended that the research on STEM teacher leaders in secondary education continues to a greater population and more than one program. This research is valuable and highly contributes to the existing literature and research on the topic. This research also identifies the impact of STEM teacher leaders on student achievement and increased student engagement in the areas of math and science. Districts need further insight on the impact of leaders at a peer-to-peer level and the positive gains from such leadership.

Contribution to the Field

This study contributes to the existing research on STEM teacher leaders in secondary education. The investigator has identified the STEM-I^3 Model as an effective model that assists in closing the gap in literature and existing research on the topic. This model, which can add more depth on the topic of teacher leaders in existing literature, contains critical components for longevity of the role, program, system and process of developing STEM teacher leaders. CMAST has opened the doors for researcher to further explore the many important facets that are critical for student achievement and engagement in STEM disciplines; it can now be concluded that STEM teacher leaders have a significant impact on student learning.

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Appendix A

Matrix of Theories- School Leadership and/or Teacher Leadership

Theorist	Theory
Hackman and Walton (1986)	They specialize in leading groups in various organizations, describes the characteristics of an excellent team: clear and engaging, an enabling performance situation, and adequate material resources.
Katzenmeyer and Moller (1996)	They define teacher leaders as "leading within and beyond the classroom, influence others toward improved educational practice, and identify with and contribute to a community of teacher leaders"
Kogler Hill (1997)	Also addresses several components to developing a leadership team that would also apply to teacher leader teams: develop clear, elevating goals, create an atmosphere with results driven, competent members of a team, unified commitment, standards of excellence, a collaborative climate, external support and recognition, and principled leadership.
Nueman (2000)	Created a study infusing leadership strategies with teacher and created the term distributive leadership. "Leadership is a characteristic less of an individual than of a community and is a responsibility assumed with the consent of the whole community, with learning as the primary focus."
Ash and Persall (2000)	This theory is based on the teachers as leaders and the principal as leading leaders. It describes the belief of teachers as creating student learning as well as enhancing adult learning within the school community.
Cameron, Dutton, and Quinn (2003)	Positive Deviance- embarking on a new path to positive action.
Walker and Carr-Stewart (2004)	"AI is the art of helping systems create images of their most desired future," and there are seven basic assumptions of appreciative inquiry.
Leiberman & Miller (2004)	The all encompassing view on teacher leadership as looking through a microscope, "it is the teachers who are creating learning communities that include rather than exclude, that create knowledge rather than merely apply it, and that offer challenge and support to both new and experienced teachers as colleagues
Anderson (2004)	Created three leadership models that principals were typically guided by when leading teacher leaders: "the buffered model, the interactive model and the contested model."
York-Barr (2005)	Created a study on special education teachers recognizing they have eight characteristics that align them as school leaders.
David Cooperider (2005)	Created a model and describes it as the 4D model: Discover, Dream, Design, and Destiny.
Drago-Severson	Learning-Oriented Leadership, where the leader fosters learning to then create growth among a team with a high level of support. (3

(2006)	Pillars)
Senge (2006)	Describes that learning organizations work best when they are built around practicing five disciplines. The five disciplines include systems thinking, personal mastery, mental models, shared vision, and team learning, which allow learning and engagement to occur among individuals, teams, and at a cross-functional levels.
Dinham (2007)	Formulated a “how successful leaders manifest responsiveness” in their day-to-day relationships
Robinson and Timperley (2007)	Concluded that the role of leadership in developing effective teaching and gaining a teacher leader are: “providing educational direction, ensuring strategic alignment, creating a community for improved student success, engaging in constructive problem talk, and through selecting and developing smart tools.”
Phelps (2008)	The teacher-leader cannot implement their vision until they have discovered the value of being a leader, “Teachers who lead expand their influence beyond their individual classrooms.”
Kurtz (2009)	Analyzed how today’s instructional leader (in California) could be viewed as having six roles: Making student and adult learning the priority, Setting high expectations for performance, Gearing content and instruction to standards, Creating a culture of continuous learning for adults, Using multiple sources of data to assess learning, Activating the communities support for school success
Wetzler (2010)	Teach for America

Appendix B

Interview Questions

The certified teacher leader interview questions will provide depth on participant experiences while engaged in the CMAST system. The following questions will guide the teacher leaders' interview:

1. What is your role as a certified STEM teacher leader?
2. What leadership qualities do you possess as a teacher leader?
3. What aspects of the CMAST system prepared you to be an effective teacher leader?
4. What kind of continuous learning and development is necessary to maintain the efficacy of teacher leaders in schools?
5. What school-wide support system is necessary to optimize the success of teacher leaders?

Appendix C

Email Communication: Participant Invitation to Interview

Date: February 1, 2012
To: Teacher Leader Participants
From: Heidi Sublette

Dear TL Participant,

I am Heidi Sublette, a doctoral student at Pepperdine University, Graduate School of Education and Psychology, under the supervision of Dr. June Schmieder-Ramirez. I have chosen to complete my dissertation research on identifying effective STEM teacher leader models. Loyola Marymount University has granted me permission to study the Center for Math and Science Teaching system and to effectively complete this objective I am inviting you to participate in this study.

In order to participate in this study, I am asking for 30 to 60 minutes of your time to complete a personal interview. This interview will be conducted at the school site where you work and at a convenient time concluding your workday. The interview questions surround the following topics: a) your role as a teacher leader, b) leadership support, c) CMAST preparation, and d) leadership qualities.
You have the right to refuse responding to a posed question, should you not want to answer. Additionally, the participation in this study is completely voluntary. Should you refuse to volunteer, it will in no way reflect on you or your relationship with any institutions, nor impact your current work status in any way.

The only foreseeable risk associated with participation is the time it will take from your day, by coordinating and conducting time for the interview. Additionally, the interview may cause certain emotions surrounding the experience of teacher leadership.

Although you may not directly benefit from participating in this study, a potential benefit is being able to provide information that may assist in the planning of future teacher leader models.

When the results of the research study are shared, the information you provide will be completely confidential and you will be identified as part of a group under this CMAST system. You will not provide any identifiable information such as your name or contact information. I am required to keep all identifiable information secure, and upon time completion of secure documentation all information will be destroyed.

If you have any questions regarding your participation in this study please contact me, and I am happy to answer your questions. You may either email me or call me. If you have any questions of your rights as a study participant you may contact Dr. Doug Leigh, Chairperson of the Graduate School of Education and Psychology and Professional

Institutional Review Board, Pepperdine University, 6100 Center Drive Los Angeles, CA 90045 (310) 258-2845. Sincerely, Heidi Sublette

Appendix D

Informed Consent For Participation In Research Activities

Participant: ____

Principal Investigator: ____

Title of Project: ____

1. I ____________________________ , agree to participate in the research study being conducted by Heidi Sublette under the direction of Dr. Schmeider-Ramirez.

2. The overall purpose of this research is:
____
____
____
____

3. My participation will involve the following:
____
____
____
____
____

4. My participation in the study will (explain the expected duration of the study). The study shall be conducted in (provide the location of the project)

5. I understand that the possible benefits to myself or society from this research are:

6. I understand that there are certain risks and discomforts that might be associated with this research. These risks include:

7. I understand that my estimated expected recovery time after the experiment will be:

8. I understand that I may choose not to participate in this research.

9. I understand that my participation is voluntary and that I may refuse to participate and/or withdraw my consent and discontinue participation in the project or activity at any time without penalty or loss of benefits to which I am otherwise entitled.

10. I understand that the investigator(s) will take all reasonable measures to protect the confidentiality of my records and my identity will not be revealed in any publication that may result from this project. The confidentiality of my records will be maintained in accordance with applicable state and federal laws. Under California law, there are exceptions to confidentiality, including suspicion that a child, elder, or dependent adult is being abused, or if an individual discloses an intent to harm him/herself or others. I understand there is a possibility that my medical record, including identifying information, may be inspected and/or photocopied by officials of the Food and Drug Administration or other federal or state government agencies during the ordinary course of carrying out their functions. If I participate in a sponsored research project, a representative of the sponsor may inspect my research records.

11. I understand that the investigator is willing to answer any inquiries I may have concerning the research herein described. I understand that I may contact (*insert name and contact information for faculty supervisor or other collaborator)* if I have other questions or concerns about this research. If I have questions about my rights as a research participant, I understand that I can contact (*insert name of IRB chairperson),* Chairperson of the (*insert name of appropriate IRB)*, Pepperdine University, (*insert appropriate contact information*).

12. I will be informed of any significant new findings developed during the course of my participation in this research, which may have a bearing on my willingness to continue in the study.

13. I understand that in the event of physical injury resulting from the research procedures in which I am to participate, no form of compensation is available. Medical treatment may be provided at my own expense or at the expense of my

health care insurer, which may or may not provide coverage. If I have questions, I should contact my insurer.

14. I understand to my satisfaction the information regarding participation in the research project. All my questions have been answered to my satisfaction. I have received a copy of this informed consent form which I have read and understand. I hereby consent to participate in the research described above.

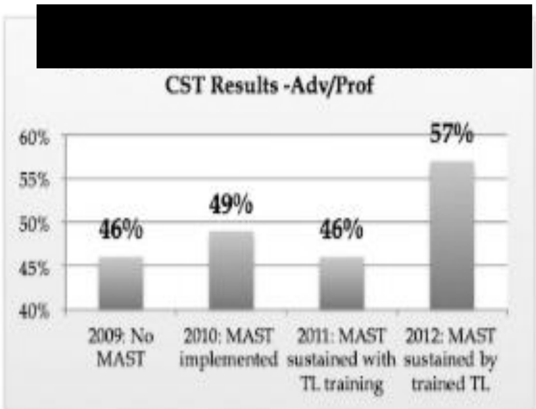
: or legal guardian's signature on participant's behalf if participant is less than 18 years of age or not legally competent.	participant's Signature
Date	Witness
	Date

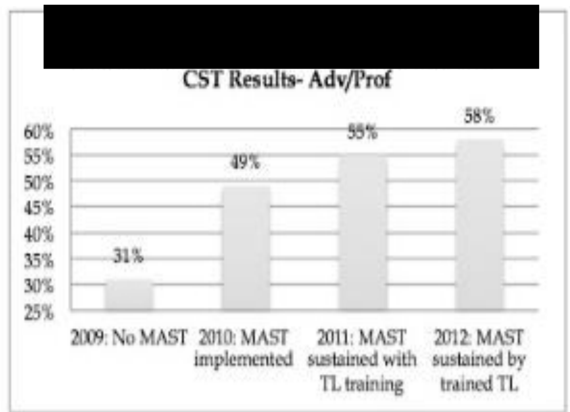
I have explained and defined in detail the research procedure in which the subject has consented to participate. Having explained this and answered any questions, I am cosigning this form and accepting this person's consent.

Principal Investigator	Date

Appendix E

Snapshot of Test Scores after CMAST Teacher Leader Implementation





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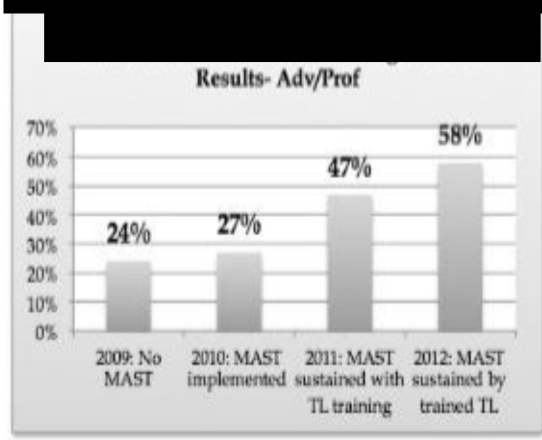

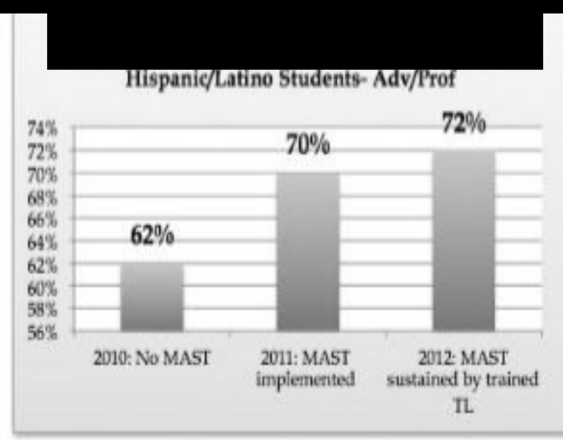

MAST Website soe.lmu.edu/cmast

Appendix F

Loyola Marymount University, Center for Math and Science Teaching

LMU|LA
Loyola Marymount University

Center for Math and Science Teaching (CMAST)

MAST SYSTEM

The Math and Science Teaching (MAST) system institutionalizes an active culture of math and science teaching within a classroom, school and organization. The learning environment is transformed through active learning, active and shared assessment, and learning for long-term retention and cognitive understanding. MAST embraces complexity and the interaction of content and pedagogy with math or science at the core. MAST instills a collaborative culture of shared leadership and accountability to transform student engagement and achievement.

How MAST Works

School leadership and teacher leaders interested in increasing student engagement and achievement in mathematics and science engage in a collaborative dialogue with LMU/CMAST faculty to analyze data surrounding student learning.

LMU/CMAST faculty and school leadership start by conducting a collaborative needs assessment based on observations of current math and science teaching practices and desired MAST culture. Collaborating on a site action plan, they create a timeline for learning and integrating the MAST culture with the school culture, thereby engaging in the apprentice model.

Learning begins with the active observations and collaborative debriefs of teachers on-site. Faculty and school leadership go into each participating teacher's classroom to gather data on how students are being engaged. This is followed by a debriefing with the teacher that includes proposed recommendations for rigorous practice connected directly to observational evidence gathered monthly on current student engagement and achievement. The CMAST faculty then collaboratively works with teachers on-site and off-site to teach MAST within professional learning seminars held monthly. Every month student, teacher and school site data is measured and shared with the teacher and school leadership. In December and June there is a comprehensive data review to inform next steps in institutionalizing MAST.

In the summer, the same teacher comes to LMU for an institute to refine and customize teaching skills that have a direct impact on increasing student engagement and achievement. Teachers are introduced to organizing and presenting information in innovative and active ways that stimulate students' critical thinking processes and long-term retention of academic content; they learn how to effectively implement assessments as motivations for student achievement, as well as develop opportunities for all students to demonstrate comprehension and retention of essential content over time. Teachers also see MAST in action and create an action plan for cultivating a MAST culture in their classrooms. Teachers are selected to become teacher leaders, who engage with CMAST to institutionalize the MAST culture at their school or organization.

Data continues to be collected in all schools where school leadership and teachers have learned to institutionalize MAST within the classroom and throughout the site to increase student engagement and achievement. Teachers become action researchers who collaboratively work with LMU/CMAST faculty to collect and analyze data and inform research.

CMAST Website
http://soe.lmu.edu/cmast

Appendix G

Pepperdine IRB

PEPPERDINE IRB
Application for a Claim of Exemption

Date: 1/5/2013 IRB Application/Protocol #:

Principal Investigator: Heidi Sublette
☐ Faculty ☐ Staff ☐ Student ☐ Other
School/Unit: ☐ GSBM ☒ GSEP ☐ Seaver ☐ SOL ☐ SPP
[redacted]ation ☐ Other:
Street Addres[redacted]
City: R[redacted] State: CA Zip Code:
90275[redacted]
Telephone (work): (310) 936-5146 Telephone (home): (310) 377-283
Email Address: heidi.sublette@pepperdine.edu

Faculty Supervisor: **Dr. Schmieder-Ramirez** *(if applicable)*
School/Unit: ☐ GSBM ☒ GSEP ☐ Seaver ☐ SOL ☐ SPP
☐ Administration ☐ Other:
Telephone (work): ( ) -
Email Address: june.schmieder@pepperdine.edu

Project Title: An Effective Model of Developing Teacher Leaders in STEM Education
Type of Project (Check all that apply):
☒ Dissertation ☐ Thesis
☐ Undergraduate Research ☐ Independent Study
☐ Classroom Project ☐ Faculty Research
☐ Other:

Is the Faculty Supervisor Review Form attached? ☒Yes ☐No ☐N/A

Has the investigator(s) completed education on research with human subjects? ☒ Yes ☐ No
Please attach certification form(s) to this application.

Investigators are reminded that Exemptions will NOT be granted for research involving prisoners, fetuses, pregnant women, or human in vitro fertilization. Also, the exemption at 45 CFR 46.101(b)(2), for research involving survey or interview procedures or observations of public behavior, does not apply to research with children (Subpart D), except for research involving observations of public behavior when the investigator(s) do not participate in the activities being observed.

1. Briefly summarize your proposed research project, and describe your research goals/objectives. The purpose of this study is to research the Loyola Marymount Center for Mathematics and Science Teaching (CMAST) in education program, focused on science and mathematics teaching and learning methods in secondary classrooms. The research developed from this study provides an analysis on secondary math and science

teachers emerging as teacher leaders to change and sustain STEM based instruction. Engaging teachers as teacher leaders to impact student learning and create sustainable change, is an area with minimal research. This study will identify an effective model of leading and preparing secondary teachers of STEM disciplines in the state of California to better prepare students to enter STEM disciplines and fields.

The research further examines the education of our current secondary teachers with an opportunity to further develop their knowledge of STEM teaching and learning methods through teacher leaders. This research will provide depth on how we can better equip current secondary classroom STEM teachers with opportunities for professional development and leadership. The outcomes of this study will enhance the development of the teaching and learning of STEM in secondary classrooms and may assist STEM teacher preparation development among other post-secondary institutions.

The main objective of this research is to answer the following research questions:

1. What attributes define effective STEM teacher leaders, according to teacher leaders who have completed the Center for Math and Science Teaching system?
2. What is the best model in developing teacher leaders, according to literature from 2005 to present?
3. What success strategies, among teacher leaders of the Center for Math and Science Teaching program, have enabled further development of teacher leadership?
4. What is an optimal model of developing STEM (science, technology, engineering, and math) teacher leaders within secondary education?

2. Using the categories found in Appendix B of the Investigator Manual, list the category of research activity that you believe applies to your proposed study. The proposed research activity involves face-to-face, personal interviews with an adult population that is not in an identified group of section 45 CFR 46. The participants may additionally volunteer to allow the investigator observe a teacher to teacher mentor/coaching interaction. Adults will only be involved and the identified pariticipants will not be disclosed. The participants nor identifiers will be used to link a participant's identity to her/his data; the study does not present more than a minimal risk to the participants nor would the disclosure of data outside the study, place the participants at risk of criminal/civil liability or damage to their financial standing, employability, or reputation; and no deception is used. Therefore it is appears this study is exempt based on 45 CFR 46.101(b)(1-5).

3. Briefly describe the nature of the involvement of the human subjects (observation of student behavior in the classroom, personal interview, mailed questionnaire, telephone questionnaire, observation, chart review, etc): To gain the best perspective and not lose any information in the process of the research, personal interviews will be used to conduct the research. The personal interviews will be audiotaped to assist with the best transcription of data. Each interview will last no more than one hour.

4. Explain why you think this protocol should be considered exempt. Be sure to address all known or potential risks to subjects/participants. After reviewing the Code of Federal Regulations Title 45 Public Welfare of the Department of Health and Human Services in Part 46 Protection of Human Services, it became evident this research could fall under exempt status based on 46.101(b)(1-5), 1 directly correlates to my study where "commonly accepted educational settings, involving normal educational practices,such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods." Additionally, the participants nor identifiers will be used to link a participant's identity to her/his data; the study does not present more than a minimal risk to the participants nor would the disclosure of data outside the study, place the participants at risk of criminal/civil liability or damage to their financial standing, employability, or reputation; and no deception is used. Additionally, if assessment scores are to be used, they will not link the participant and due to the documents being public information, they will impose no risk as part of the research: "(3) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that fall under (b)(2)" These assessment are based on education and fall directly under 46.1010(b)(2). Based on these three criteria, this research protocal should be considered exempt.

5. Explain how records will be kept. The personal interview transcriptions will be kept in a file on the computer without identifiers linking the participant by name, only utilized by the investigator. The data will be kept in a locked folder in a password contained computer laptop, only used by the investigator. No identifying documentation will be utilized on the personal interview files. The participant will be labeled to a code and no outside identifying information will link to the participant. All audio recordings will be destroyed once the research is completed. All codes and information will be eliminated or whited out, once research is complete. If existing data is utilized, such as assessment scores, these are public data and will have no link to the participant, but additionally will not impose any risk to the participant.

6. ☐ Yes ☒ No Are the data recorded in such a manner that subjects can be identified by a name or code? If yes:
   - Who has access to this data and how is it being stored?
   - If you are using a health or mental health assessment tool or procedure, what is your procedure for referring the participant for follow-up if his/her scores or results should significant illness or risk? Please describe.
   - Will the list of names and codes be destroyed at the end of the study? Explain your procedures.

7. Attach a copy of all data collection tools (e.g., questionnaires, interview questions or scripts, data collection sheets, database formats) to this form. Be sure to include in such forms/scripts the following information:
   - a statement that the project is research being conducted in partial fulfillment of the requirements for a course, master's thesis, dissertation, etc. (if applicable)

- purpose of study
- a statement that subjects' responses will be kept anonymous or confidential (explain extent of confidentiality if subjects' names are requested)
- if audiotaping or videotaping, a statement that subject is being taped (explain how tapes will be stored or disposed of during and after the study)
- a statement that subjects do not have to answer every question
- a statement that subject's class standing, grades, or job status (or status on an athletic team, if applicable) will not be affected by refusal to participate or by withdrawal from the study (if applicable)
- a statement that participation is voluntary

Please note that your IRB may also require you to submit a consent form or an **Application for Waiver or Alteration of Informed Consent Procedures form.** Please contact your IRB Chairperson and/or see the IRB website for more information.

8. Attach a copy of permission forms from individuals and/or organizations that have granted you access to the subjects.

9. ☐Yes ☒No Does your study fall under HIPAA? Explain below. There is no health implication or threat to health within this research.

   9.1 If HIPAA applies to your study, attach a copy of the certification that the investigator(s) has completed the HIPAA educational component. Describe your procedures for obtaining Authorization from participants. Attach a copy of the Covered Entity's HIPAA Authorization and Revocation of Authorization forms to be used in your study (see Section XI. of the Investigator Manual for forms to use if the CE does not provide such forms). If you are seeking to use or disclose PHI without Authorization, please attach the **Application for Use or Disclosure of PHI Without Authorization** form (see Section XI). Review the HIPAA procedures in Section X. of the Investigator Manual.

I hereby certify that I am familiar with federal and professional standards for conducting research with human subjects and that I will comply with these standards. The above information is correct to the best of my knowledge, and I shall adhere to the procedure as described. If a change in procedures becomes necessary I shall submit an amended application to the IRB and await approval prior to implementing any new procedures. If any problems involving human subjects occur, I shall immediately notify the IRB Chairperson.

Principal Investigator's Signature　　　　　Date

Faculty Supervisor's Signature (if applicable) | Date

Appendices/Supplemental Material

Use the space below (or additional pages and/or files) to attach appendices or any supplemental materials to this application.

Documentation and Tools:

Statement of Requirement:

This dissertation, written by Heidi Sublette under the guidance of a Faculty Committee and approved by its members, has been submitted to and accepted by the Graduate Faculty in partial fulfillment of the requirement for the degree of Doctor of Education.

Statement of the Purpose

The purpose of this study is to research the Loyola Marymount Center for Mathematics and Science Teaching (CMAST) system, focused on science and mathematics teaching and learning methods in secondary classrooms. The research developed from this study provides an analysis on secondary math and science teachers emerging as teacher leaders to change and sustain STEM based instruction. Engaging teachers as teacher leaders to impact student learning and create sustainable change, is an area with minimal research. This study will identify an effective model of leading and preparing secondary teachers of STEM disciplines in the state of California to better prepare students to enter STEM disciplines and fields.

The research further examines the education of our current secondary teachers with an opportunity to further develop their knowledge of STEM teaching and learning methods through teacher leaders. This research will provide depth on how we can better equip current secondary classroom STEM teachers with opportunities for professional development and leadership. The outcomes of this study will enhance the development of the teaching and learning of STEM in secondary classrooms and may assist STEM teacher preparation development among other post-secondary institutions.

Statement of Confidentiality:

All subjects utilized for the purpose of this research will remain undisclosed throughout and upon completing of the research. The investigator will use names only upon initial contact via email to arrange interviews (time and place), however from that point on, the researcher will refer to the participant by code, not linking the participant in any way. Emails will be deleted and destroyed once the interview has been completed. Please see confidentiality form below.

Statement of Data Storing:
In the event interviews are audio-taped, all audiotapes will be kept in a locked safe in the investigators residence until the completion of all research. Once the research is complete, the audiotapes will be destroyed by being shredded and then burned.

Participant Interview Questions

1. What is your role as a certified STEM teacher leader?
2. What leadership qualities do you possess as a teacher leader?
3. What aspects of the CMAST system prepared you to be an effective teacher leader?
4. What kind of continuous learning and development is necessary to maintain the efficacy of teacher leaders in schools?
5. What school-wide support system is necessary to optimize the success of teacher leaders?

Please see forms below confirming confidentiality to participants.

INFORMED CONSENT FOR PARTICIPATION IN RESEARCH ACTIVITIES

Participant:

Principal Investigator:

Title of Project:

1. I , agree to participate in the research study being conducted by Heidi Sublette under the direction of Dr. June Schmeider-Ramirez.

2. The overall purpose of this research is:

3. My participation will involve the following:

4. My participation in the study will (explain the expected duration of the study). The study shall be conducted in (provide the location of the project)

5. I understand that the possible benefits to myself or society from this research are:

6. I understand that there are certain risks and discomforts that might be associated with this research. These risks include:

7. I understand that my estimated expected recovery time after the experiment will be:

8. I understand that I may choose not to participate in this research.

9. I understand that my participation is voluntary and that I may refuse to participate and/or withdraw my consent and discontinue participation in the project or activity at any time without penalty or loss of benefits to which I am otherwise entitled.

10. I understand that the investigator(s) will take all reasonable measures to protect the confidentiality of my records and my identity will not be revealed in any publication that may result from this project. The confidentiality of my records will be maintained in accordance with applicable state and federal laws. Under California law, there are exceptions to confidentiality, including suspicion that a child, elder, or dependent adult is being abused, or if an individual discloses an intent to harm him/herself or others. I understand there is a possibility that my medical record, including identifying information, may be inspected and/or photocopied by officials of the Food and Drug Administration or other federal or state government agencies during the ordinary course

of carrying out their functions. If I participate in a sponsored research project, a representative of the sponsor may inspect my research records.

11. I understand that the investigator is willing to answer any inquiries I may have concerning the research herein described. I understand that I may contact (insert name and contact information for faculty supervisor or other collaborator) if I have other questions or concerns about this research. If I have questions about my rights as a research participant, I understand that I can contact (insert name of IRB chairperson), Chairperson of the (insert name of appropriate IRB), Pepperdine University, (insert appropriate contact information).

12. I will be informed of any significant new findings developed during the course of my participation in this research which may have a bearing on my willingness to continue in the study.

13. I understand that in the event of physical injury resulting from the research procedures in which I am to participate, no form of compensation is available. Medical treatment may be provided at my own expense or at the expense of my health care insurer which may or may not provide coverage. If I have questions, I should contact my insurer.

14. I understand to my satisfaction the information regarding participation in the research project. All my questions have been answered to my satisfaction. I have received a copy of this informed consent form which I have read and understand. I hereby consent to participate in the research described above.

Parent or legal guardian's signature on participant's behalf if participant is less than 18 years of age or not legally competent.

____
Participant's Signature

Date

Witness

Date

I have explained and defined in detail the research procedure in which the subject has consented to participate. Having explained this and answered any questions, I am cosigning this form and accepting this person's consent.

Principal Investigator Date

LMU | LA
School of Education

Center for Math &
Science Teaching

University Hall
1 LMU Drive, Suite 1300
Los Angeles, CA 90045-2659

Tel 310.338.3783
Fax 310.338.5262
www.lmu.edu

Research Consent and Authorization

I hereby authorize Heidi Sublette and those acting pursuant to her authority (Researcher) to:

a) Research Loyola Marymount University's MAST Teacher Leader Certificate program, including permission to interview former candidates; and

b) Cite the Center for Math and Science Teaching, Loyola Marymount University, and our Faculty and Staff in connection with this research; and

c) Keep all data and sources secure, due to confidentiality, upon completion of the research videotapes, audiotapes, and journals correlating to the individual (and destroy once the holding deadline of five years has expired).

All such findings, in whatever medium, are, and shall remain, the property of Loyola Marymount University.
Sincerely,

Kathy W. Clemm

Kathy Clemmer
Executive Director of CMAST
Loyola Marymount University