Lead Teachers Foster Institutional Changes in Their Schools and School Districts

Introduction

The Rice University Mathematics Leadership Institute (MLI) was an NSF-funded Math-Science Partnership created to provide a coherent sequence of summer and academic-year professional development for 80 lead teachers from September 1, 2004 through August 31, 2009. MLI was extended to August 31, 2011 by a Noyce Supplemental Award. Led by the Rice University School Mathematics Project (RUSMP), MLI united a variety of mathematics professionals from Rice University's departments of Computational and Applied Mathematics (CAAM), Mathematics (MATH), and Statistics (STAT), mathematics educators, high school faculty, administrators, and students from the Houston (HISD) and Aldine (AISD) Independent School Districts. The purpose of MLI was to meet the demand for mathematics instructional support and intellectual leadership by developing the expertise of high school teachers. MLI was intended to serve as a catalyst to initiate change at the grassroots level in local schools to influence the type and direction of mathematics instruction in participating schools and school districts.

Theoretical Framework

Consistent with recent literature on the importance of mathematics teachers' content and pedagogical content knowledge (e.g., President's Council of Advisors on Science and Technology, 2010), the institute incorporated key features identified in high-quality professional development which include deepening subject-matter knowledge specific for teaching; understanding how students learn and associated difficulties in mastery; relating to what teachers are asked to do and building on what they already know and can do; actively engaging teachers; using teams of teachers from a common school to learn, collaborate, and support each other to enact what they learn; aligning with school, district, and national reforms, policies and guidelines; and providing professional development of sufficient duration (American Federation of Teachers, 2002; Desimone, 2009; Guskey, 2002; National Academy of Education, 2009). In addition, the National Council of Supervisors of Mathematics (2008) has highlighted the importance of professional learning opportunities for teachers to explore research on equitable mathematics instruction and to develop lessons that engage all students in rigorous and accessible mathematics. These features are also consistent with research that found teachers who lead instructional innovation and development, generally, possess an in-depth knowledge of their subject area, a thorough understanding of pedagogy, and an enthusiasm for professional growth and development (Feiler, Heritage, & Gallimore, 2000; Silva, Gimbert, & Nolan, 2000; Krisko, 2001). Furthermore, research suggests that when teachers are empowered to lead instructional innovation and development, meaningful and enduring changes that improve student learning are achieved (Harris, 2002).

One facet of leadership is developing and sustaining campus-based knowledge communities. Educational researchers have acknowledged the significance of building a sense of community among teachers as a means of promoting instructional reform and innovation in mathematics teaching and learning. Lachance and Confrey (2003) noted the means by which the use of explorations of mathematical content and collaboration in professional development created a sense of community among teachers. Collaboration becomes a cornerstone in Communities of Practice (CoPs) (Blankenship & Ruona, 2008) and results in the cultivation of feelings of connection and trust, rather than feelings of isolation (which are often experienced among teachers). However, content explorations are not necessarily enough. CoPs or knowledge communities (Olson & Craig, 2001) that specifically focus on reflection of equity in instruction are also needed to facilitate success for all students (Crockett & Buckley, 2009).

Allexsaht-Snider's and Hart's (2001) conceptualization of equity in mathematics instruction is based upon the supposition that diverse groups of students of every race, ethnicity, class, gender, or degree of language proficiency will acquire and employ mathematical knowledge and skills. This, they assert, requires equity in the following areas: distribution of school resources and resources received by students and teachers; instructional quality; and student achievement outcomes. Gutiérrez (2008) elaborates through the articulation of four components of equity: (1) teacher and student **access** to available high-quality resources and support; (2) teacher and student **achievement** as measured by

standardized tests, participation in high-quality educational programs and activities, and student enrollment in a continuum of rigorous courses; (3) teachers' **identities** or cultural perspectives that support students' opportunities to utilize their cultural resources in educational pursuits; and (4) teachers' and students' **power** to reform classrooms and, thereby, the nation through empowering opportunities to experience alternative perspectives for collective social advancement.

Challenging, relevant, engrossing, effective, and equitable mathematics instruction in MLI classrooms was viewed by MLI developers as necessary to improve student engagement and increase student success. Translating MLI's professional development model to the classroom was articulated through a multifaceted definition of student success grounded in theories of learning as a social, student-centered experience (Bandura, 1977, 1997; Vygotsky, 1978) that engages students in strong mathematics explorations that are aligned with students' learning styles (Piaget, 1972, 1990), interests, and real-world experiences. Students' success in mathematics denoted the ability of learners to develop mathematical proficiency through in-depth conceptual understanding, problem-solving skills, and confidence for success on state-mandated high-stakes assessments, in addition to the development of student desire to enroll and succeed in higher-level mathematics courses. Active student engagement in rigorous, student-centered mathematical experiences was understood to be an important precursor to and aspect of student success. The effective teaching practices of lead teachers were expected to encompass classroom activities consistent with this definition of student success.

Participant Demographics

The 80 MLI lead teacher positions were filled by 79 teachers (including one lead teacher who left the program and later returned) during the course of the grant. The majority of lead teachers were female (76%). The largest proportion of lead teachers was African American (46%), followed by white (24%), Asian (18%), and Latino (9%). At least 72% of the lead teachers held undergraduate degrees in Science, Technology, Engineering, and Mathematics (STEM) fields, with over 50% in mathematics or the mathematical sciences. Thirty-five percent held masters' or doctoral degrees. In addition, 44% of the lead teachers obtained their educator certifications through traditional certification programs. Equal proportions of lead teachers (24% each) obtained certifications through alternative programs and deficiency plans, while others obtained their certifications while earning Masters of Arts in Teaching (6%). This heterogeneous group of lead teachers was charged with meeting the needs of diverse, ever-changing student populations.

AISD experienced an 11.2% student enrollment growth, while HISD's student enrollment declined by 3.6% during the implementation of MLI. The combined student enrollment of the participating districts was 263,000 (Texas Education Agency, 2010). Approximately, 90% of the students were Hispanic or African American. Nearly 30% were limited in their English proficiency, with over 90 languages spoken in their homes. Free and reduced lunch statistics indicated 80% of students across the districts were economically disadvantaged. Through the grant, leadership programs were established in 37 high schools, which included 27 in HISD and 10 in AISD. At the conclusion of the grant, leadership programs were still active in 27 high schools, 18 in HISD and 9 in AISD, with 54 active lead teachers in MLI schools. From the initial 30 schools that were served by the grant, schools entered and left the program for a variety of reasons. Reasons for schools discontinuing participation included changes in campus administration, the movement of lead teachers to positions at other schools, and promotions of lead teachers to positions outside of the classroom. Nine lead teachers entered administrative positions which required their removal from classroom instruction and, therefore, from eligibility for MLI participation. In fact, program attrition was exacerbated by the expertise lead teachers gained through the program, which opened new avenues to leadership opportunities.

Program Description

MLI developed three cohorts of lead teachers who received intensive professional development to strengthen their mathematics proficiency through an in-depth understanding of mathematics concepts and mathematics knowledge for teaching necessary for success with diverse populations of high school

students. The MLI curriculum augmented and surpassed the state's curriculum and provided lead teachers with a practical framework of the "big picture" of mathematics to develop their understanding of their high schools' curricula in the context of the mathematics continuum. MLI also endeavored to strengthen lead teachers' instructional leadership skills and strategies for working with teachers, administrators, and parents to ensure high-quality learning opportunities in mathematics were provided for all students. Summer institutes were provided for four-weeks each summer during two consecutive summers. The institutes were grounded in social constructivist approaches, with teachers engaged in collaborative groups. Using a problem-solving approach, mathematics content was focused on algebra and geometry during the first summer, followed by combinatorics and statistics during the second summer. Each summer, extensive attention was given to the mathematical knowledge essential for teaching. Through interactions with Rice University mathematics educators and faculty, post-docs, and graduate students from CAAM, MATH, and STAT, lead teachers' examined mathematics concepts and problems from an advanced perspective appropriate for graduate-level mathematics studies. Participants received four hours of graduate credit in Natural Sciences after successful completion of each summer institute.

In addition to developing lead teachers mathematics content knowledge for teaching and capacity for instructional leadership, MLI sought to increase lead teachers' understanding of the current research in mathematics education including issues of ethnic and gender diversity as they relate to STEM. Issues of diversity were explored through panels, lectures and discussions, research groups, and book-study involving the lead teachers, Rice graduate students, faculty members, Noyce scholars, and RUSMP directors. Discussants included MLI Co-PI, Richard Tapia, who shared his work in increasing the number of students from underrepresented minorities who pursue education in STEM fields and Rochelle Gutiérrez, who shared her research and insights on successful urban high schools. Sociological and educational issues in mathematics and STEM were identified and studied by groups of lead teachers. A series of explorations and ongoing dialogue on diversity and equity afforded lead teachers opportunities to focus beyond their perspectives on racial and ethnic issues and to examine variations in the levels and types of motivation, abilities, and needs of their students, colleagues, and school administrators. Participants discussed the many faces of diversity and how diversity issues shape teacher' interaction with students and colleagues. They connected this to classroom practice by discussion on how to make mathematics relevant and interesting for all students.

Summer institutes were followed by academic-year support for the duration of the grant in the form of job-embedded professional development designed to enhance and support the implementation of the knowledge, skills, and strategies developed during the summers. The MLI developers made site visits to MLI schools to mentor lead teachers and to support their campus-based instructional and leadership activities. Lead teachers developed skills in creating flexible student groups, differentiating and individualizing instruction, motivating disenfranchised students, meeting the needs of gifted students, using different modalities of instruction, and integrating technology and manipulatives to enhance instruction. This personalized professional development was supplemented by monthly academic-year meetings that brought together all lead teachers from active cohorts. In addition, lead teachers in each cohort voluntarily participated in Rice University's advanced mathematics courses and activities. Lead teachers also received encouragement to obtain and support in preparing for the advanced, regional Texas Master Mathematics Teacher (MMT) grades 8–12 educator certification through a state-sponsored accreditation program. This certification process required the completion of a year-long preparation course to further develop lead teachers' mathematical proficiency and pedagogical content knowledge. The courses were offered following each cohort's second year of MLI participation. During the final academic-year of the program, lead teachers participated in a book study of *Stuck in the Shallow End* (Margolis, 2008). Through this book study, lead teachers explored the impact of diversity on academic-rigor and their role in motivating and supporting students to enter and remain in educational programs that would prepare them for STEM careers.

One of the findings from MLI is the importance of developing lead teachers' skills in supporting their colleagues in providing high-quality mathematics instruction for all learners, in particular, those traditionally underrepresented in STEM (McCoy, Hill, Sack, Papakonstantinou, & Parr, 2007). Lead

teachers were charged with developing and nurturing professional mathematics learning communities at their schools. To that end, lead teachers shared their knowledge of mathematics content and pedagogy and mathematics education reforms with mathematics teachers on their campuses during the academic year. MLI lead teachers were expected to model teach, observe and support their colleagues, facilitate curricular planning sessions, and share best practices in mathematics education. Lead teachers also disseminated information and resources to their colleagues at local, state, regional, and national conferences for leaders in mathematics education to help educators' enhance their content knowledge, instruction, and leadership.

Program Results

"As a result of participating in the MLI, teachers increased their mathematics and pedagogical content knowledge as well as their understanding of mathematics education reforms and diversity issues related to STEM" (McCoy, 2011, p. 88). External evaluation of MLI showed statistically significant gains in lead teachers' knowledge of the content strands explored in the institute and statistically significant differences between lead teachers' students' and comparison students' performances on the state-mandated mathematics assessment, except for one group of students. In addition, survey responses of lead teachers and their mathematics colleagues on their campuses indicated that lead teachers had positive impacts on the campus-based mathematics instructional leadership, colleagues' mathematics content knowledge and mathematics instructional strategies, and colleagues' students' mathematics content knowledge. Furthermore, recent interviews with administrators and survey responses of lead teachers reveal sustained district-level and school-level impacts of MLI on collaborations among administrators and teachers, instructional planning, mathematics instruction, and professional development models. The following delineation of results of the program reveals institutional changes in MLI schools and districts.

Mathematics Content and Knowledge for Teaching

Table 1 presents results of the external evaluation of lead teachers' pre and post-test scores in geometry, algebra, statistics, and combinatorics for MLI's three cohorts following their instruction in the summer institute (McCoy, 2011). The findings reveal statistically significant increases in all four content strands addressed during the institute. Their highest scores on the pre- and post-test were in geometry. The greatest gain in lead teachers' content knowledge was in combinatorics, followed by probability and statistics and algebra. After instruction, the lead teachers' mean score on the post-test in combinatorics was second highest to their mean score in geometry, indicating substantial growth in the content area with the lowest pre-test score (combinatorics) as well as considerable growth in the content area with the highest pre-test score (geometry).

Table 1

Pre- and Post-Content Tests Scores of MLI Lead Teachers

MLI Measure	Mean	N	Std. Deviation	Std. Error Mean	Sig. (2-tailed)
Geometry Pre-test	20.785	79	9.391	1.057	0.000
Geometry Post-test	34.190	79	10.424	1.173	
Algebra Pre-test	14.867	79	7.635	0.859	0.000
Algebra Post-test	29.506	79	8.505	0.957	
Probability and Statistics Pre-test	13.930	71	10.600	1.258	0.000
Probability and Statistics Post-test	30.113	71	10.089	1.197	
Combinatorics Pre-test	10.563	71	7.365	0.874	0.000
Combinatorics Post-test	32.662	71	9.313	1.105	

Forty-six (58%) of the 79 lead teachers pursued additional professional development through intensive preparation for the MMT examination to increase their conceptual understanding of

mathematics and mathematics knowledge for teaching. Approximately one-fourth (n= 21) of the lead teachers obtained MMT certification. The initial goal was to increase the number of MMT-certified teachers in the state by 20%. However, MLI lead teachers increased the number (n=27) by nearly 78%.

In a follow-up program survey conducted in the spring of 2011, nearly a year after the conclusion of the program, 48 former MLI lead teachers were queried and 37 (77%) responded. Of the respondents, 95% agreed MLI had a positive influence on their mathematics content knowledge and 89% affirmed MLI had made a positive impact on their mathematics knowledge for teaching. In addition, respondents reported MLI's favorable influence on their students' understanding of mathematics (89%), on their students' understanding of the importance of studying advanced mathematics (78%), and on their students' interest in studying advanced mathematics (65%).

Mathematics Instruction

During the lead teachers' participation in MLI, external evaluators' observations of mathematics classes taught by MLI lead teachers provided insights into lead teachers' instructional practices and interactions with students during mathematics lessons. Generally, the instructional strategies employed by lead teachers reflected their own deepening subject-matter knowledge specific for teaching. Lead teachers were observed providing meaningful, high-quality mathematics learning opportunities to diverse student populations in ways that demonstrated a solid understanding of how students learn and an awareness of methods to address students' difficulties in concept mastery. Lead teachers provided their students with encouragement and practical alternatives that built upon what students already knew and were interested to explore.

Table 2 presents the percentages of the 192 mathematics lessons observed where lead teachers and their students engaged in the identified behaviors, activities, or interactions with regard to propositional knowledge (or knowledge of the facts), procedural knowledge, lesson implementation, and classroom culture (McCoy, 2011). In approximately 99% of the classes, teachers demonstrated a solid grasp of the subject matter or presented fundamental concepts of the subject to develop students' propositional knowledge. In 65% of the lessons, teachers made connections to other content disciplines or explored real world phenomena. In addition, in 73–76% of the lessons students used multiple ways to represent their understandings of concepts, engaged in activities that required higher-order thinking and critical assessment, or students' and teachers' behaviors indicated they valued challenging and intellectual rigor to develop students' procedural knowledge.

Students in nearly 58% of the classrooms developed procedural knowledge through making predictions, generating hypotheses, etc. Additionally, students participated in demonstrations of lessons in 93% of the classes and provided input to lead teachers' lectures in 96% of the classes. In 71–92% of the classes, the lessons implemented by lead teachers engaged students, incorporated technology, or provided opportunities for independent student-work or student engagement in learning communities. In 30–70% of the lessons, lead teachers incorporated manipulatives, interactive activities, or a variety of materials to develop the concept, or triggered divergent modes of thinking among their students. The culture in lead teachers' classrooms in 93–96% of the observed lessons was characterized by respect and/or patience or lead teachers served as a resource person or listener who supported student investigations.

Table 2

Classroom Observation Results: Percentages of MLI Lead Teachers' Classes that Engaged in Identified Instructional Behaviors, Activities or Interactions

Behaviors, Activities or Interactions Observed	Classes
Propositional Knowledge	
Teacher had a solid grasp of the subject-matter content inherent in the lesson.	99.0%
Lesson involved fundamental concepts of the subject.	99.5%
Connections with other content disciplines or real world phenomena were explored and valued.	65.1%
Procedural Knowledge	
Students were actively engaged in thought-provoking activities that often involved the critical assessment of procedures.	76.4%
Intellectual rigor, constructive criticism, and challenging ideas were valued.	75.6%
Students used a variety of means to represent concepts.	73.1%
Students made predictions, estimations, or hypotheses and devised means for testing them.	57.8%
Lesson Implementation	
Teacher demonstrated without having students participate.	6.8%
Teacher lectured without much input from students.	3.7%
Students appeared to be engaged in the lesson.	92.2%
Students worked independently.	89.5%
Teacher presented a lesson that was designed to engage students as members of a learning community.	85.2%
Teacher incorporated technology.	71.4%
Teacher used hands-on, interactive activities to develop the concept.	58.8%
Students used a variety of material (not just worksheets or textbooks).	38.6%
Teacher incorporated manipulatives.	29.8%
Classroom Culture	
In general, the teacher was patient with students.	97.4%
Teacher acted as a resource person, working to support and enhance student investigations.	95.8%
The metaphor "teacher as listener" was very characteristic of this classroom.	94.0%
There was a climate of respect for what others had to say.	93.1%
Teacher's questions triggered divergent modes of thinking among students.	70.1%

The following comments demonstrate lead teachers' views of the impact their growth as mathematics teachers has had on their students:

> *The program increased my ability to ensure my students success in college-related math skills requirements.*
>
> *More students are actively thinking, making choices, and executing skills than in typical teacher-led lessons.*
>
> *Students are able to handle more complex assignments and do more with higher-order skills.*

The results of the external evaluation of MLI classrooms were summarized as follows:

> *When observed in their classrooms, many MLI teachers worked to engage students using collaborative learning groups. MLI teachers incorporated technology in lessons and teachers used hands-on interactive activities to develop concepts. In addition, most of the observed lessons appeared to be designed to engage students as members of a learning community. Therefore, it was rare to see MLI teachers conduct demonstrations without having students participate or lecture without students' input*. (McCoy, 2011, p. 92)

Diversity and Equity

MLI's developers and the final external evaluation found the institute's activities to expand lead teachers' awareness and skills to address issues of diversity had a great impact on the lead teachers. Lead teachers expressed their appreciation for the validation of their expertise that these discussions provided. The following quote demonstrates one lead teacher's view of MLI's impact on his/her conceptualization of diversity and commitment to equitable mathematics instruction:

> *MLI gave me a new outlook on diversity and its true meaning. I thought I knew and understood the meaning of the word diversity—it seemed easy enough. I realized that diversity refers to many things like gender, religion, age, special education, leaning ability, socioeconomic status, and many other things that make a person distinct. MLI taught me that all students are diverse in their own way, and we cannot teach them unless we acknowledge their differences and accept them and work with those differences to reach the final goal…which is to teach them.*

Leadership Skills

MLI lead teachers and their campus colleagues (i.e., the other mathematics teachers on MLI campuses) participated in a follow-up program survey during the spring of 2011. In addition to 37 former MLI lead teachers, a total of 54 of their campus colleagues responded to the survey. **Table 3** reveals the percentages of respondents who agreed the identified leadership behaviors were exhibited by lead teachers in their campus-level or district-level capacities. Lead teachers' and their colleagues' views of the leadership behaviors exhibited by lead teachers were similar. All lead teachers and their colleagues found that MLI participants exhibited a genuine interest in other teachers' opinions. A total of 94–100% of respondents found lead teachers provided relevant information, supported teachers, interacted openly and honestly, or articulated concerns constructively and without bias. More than 90% of both lead teachers and their colleagues affirmed that each of the identified leadership skills was utilized by lead teachers.

Table 3

Spring 2011 Survey: Percentages of MLI Lead Teachers' and Their Colleagues' Affirming Leadership Behaviors Exhibited by Lead Teachers

Leadership Skills	Lead Teachers	Colleagues
Showed a genuine interest in other teachers' opinions.	100%	100%
Provided other teachers with relevant information.	100%	94%
Interacted with teachers in an open and honest way.	95%	100%
Unequivocally supported other teachers in their work.	97%	98%
Expressed concerns objectively and constructively.	95%	94%
Expressed expectations clearly and transparently.	92%	96%

Table 4 delineates important skills, knowledge, understandings or interests influenced by lead teachers' MLI participation. Differences in lead teachers' and their peers' views ranged from two to six percentage-points regarding lead teachers' influences on their colleagues and their colleagues' students, with the exception of a 13 percentage-point difference in respondents' views of lead teachers' influences on their colleagues' students' understanding of the importance of studying advanced mathematics. Generally, greater percentages of respondents indicated awareness of MLI's influence on lead teachers' interactions with campus educators, lead teachers' colleagues' instructional strategies, and colleagues' students mathematics content knowledge; followed by the percentages of respondents identifying MLI's influence on lead teachers' colleagues' mathematics content knowledge. Fewer respondents indicated MLI influenced lead teachers' colleagues' students' understanding of the importance of studying advanced mathematics as well as lead teachers' colleagues' students' interest in studying advanced mathematics.

Table 4

Spring 2011 Survey: Percentages of MLI Lead Teachers and Colleagues Affirming MLI's Impact on Lead Teachers, Lead Teachers' Campus Colleagues, and the Colleagues' Students

Skills, Knowledge, Interactions, Understanding and Interest	Lead Teachers	Colleagues
Lead teachers' leadership skills	97%	-
Lead teachers' interactions with campus colleagues	86%	-
Lead teachers' interactions with campus administrators	81%	-
Lead teachers' colleagues' mathematics instructional strategies	89%	85%
Lead teachers' colleagues' mathematics content knowledge	76%	78%
Lead teachers' colleagues' students' understanding of the importance of studying advanced mathematics	57%	70%
Lead teachers' colleagues' students' interest in studying advanced mathematics	51%	57%
Lead teachers' colleagues' students' mathematics content knowledge	-	85%

Lead teachers commonly claim their greatest MLI accomplishment is the growth of the campus-based colleagues they have mentored. Consistent with the previous comments of lead teachers, the following remarks of lead teachers' colleagues' reflect the positive results of lead teachers' commitments to provide effective mathematics leadership:

> *I have always enjoyed my conversations with [lead teacher], as she is a very willing and knowledgeable mentor and coworker. She has many great ideas, good relationships with the kids, and is just a pleasure to work with.*
>
> *Our campus lead teacher was very supportive in [helping] me meet the needs of all students.*
>
> *She did a great job in a tough situation, running Saturday tutorials and taking over for a teacher that had problems.*
>
> *The MLI program was a program that opened my eyes to new and innovative ways of using my knowledge of math to reach the below grade level students who are struggling to pass and the advanced students who are thirsting for knowledge.*

The previous comments are testaments to the vitalization of teaching mathematics experienced by lead teachers and their colleagues. Lead teachers' colleagues valued the commitment, knowledge, information, leadership, and support provided by their lead teachers. The following quotes reveal lead teacher's perceptions of their development as leaders:

> *When the department chairperson job was first offered to me, I was asked how I felt about a role as a coach and mentor. I was able to answer that this is exactly what my MLI training had prepared me to do, to be an academic coach and help teachers become better educators.*
>
> *As an MLI Lead Teacher and a Master Mathematics Teacher, my experience as a presenter for teachers has allowed me to become more comfortable when sharing valuable information with colleagues. I have gained the confidence and the ability to share learned instructional strategies and teaching methods with teachers building-wide, district-wide, and nation-wide.*
>
> *I gained a deeper appreciation for my responsibility as a math leader. I understand that my role is to 'lead,' and not to dictate as I was doing in the past.*
>
> *I have learned to advocate for teachers with administrators. I have learned to work with groups of teachers to learn the math and grapple with issues teachers face.*
>
> *I am a critical consumer of classroom resources and professional development. I am able to match teacher interests to those resources.*

Communities of Practice

MLI lead teachers initiated and advocated administrative and instructional practices that increase student success through CoPs they created in the mathematics departments of their high schools. Further, MLI professional learning communities were achieved within and across schools and partner districts through study groups (including extra-curricular MMT preparation activities), problem-solving explorations, book studies, collaborative planning, co-teaching, and instructional demonstrations. The following excerpt articulates some impacts of MLI's CoP:

> *The MLI Lead Teacher knowledge community has empowered its members to stand up for themselves and for each other in particular ways. It represents a center of refuge when members feel the pressures from the conduit, a place to vent out of reach of the conduit, and a wide circle of support when teachers enter into difficult or challenging professional pathways . . . . Through membership in this community, teachers have raised the bar on standards for learning in their own classrooms and have shown ultimate proof of the value of the MLI MSP through their own students' achievement scores*. (Sack & Kamau, 2009, p. 150)

MLI officially concluded in the fall of 2011with the end of its Noyce Award. However, former MLI lead teachers report a strong and abiding commitment to their MLI-initiated CoP. Many former lead teachers suggest this support system continues to provide professional validation, reliable resources, reality-checks, and advocacy for high-quality instruction and intellectual leadership for them as frontline mathematics educators. Many of the lead teachers who were developed through MLI continue to serve in an array of campus-level or district-level leadership positions in which they were elevated to support institutional changes in the type and direction of mathematics instruction. In the spring of 2012, district administrators and former MLI participants who continued to work in MLI's partner school districts reported the presence of sustained impacts of MLI on the mathematics leadership and instruction in their

high schools and districts. These MLI effects include a heightened, wide-spread awareness among educators of the benefits of ongoing collaborations between district leaders, lead teachers, and teachers. Collaborative decision-making and planning practices promoted through MLI have replaced some of the demeaning, top-down administrative processes which undermine teachers' professionalism.

Principles and strategies recommended by lead teachers, grounded in research on teaching and learning, are used by administrators, mathematics instructional leaders, and teachers to collaboratively develop engaging and challenging student-centered instructional goals and plans to address content delivery, classroom management, and student assessment. In addition, district administrators attest to the districts' reliance upon the lead teachers to construct in-depth mathematics curricula and assessments, and to provide professional development for mathematics teachers as well as teachers of all disciplines. MLI's professional development model has been incorporated at a smaller scale in subsequent professional development provided by MLI's partner school districts and by RUSMP. Inspired by MLI's model, one district has instituted professional development programs focused upon rigorous content knowledge development, effective classroom management to support rigorous lesson delivery, alternative assessment, development of measurable objectives, and the utilization of collaborative instructional planning for concept development. Also, aspects of MLI's model have been adapted for teachers at other grade levels. For example, an MLI-generated problem-solving activity which was constructed around the state mathematics assessment has been utilized effectively with K-12 mathematics teachers in several Houston-area schools and districts. In fact, MLI has been the catalyst for several new institutes and courses for mathematics leaders including RUSMP's Institute for Mathematics Leaders for school and district administrators and academic-year short courses in leadership for mathematics department chairs, skills specialists, and team leaders.

Student Success and Achievement

MLI lead teachers strive to be highly successful mathematics teachers and intellectual leaders through providing opportunities for teachers and students to build strong mathematics foundations. Because of their experiences in MLI, lead teachers expressed an intensified desire and a greater capacity to help students appreciate and learn mathematics. MLI's developers anticipated lead teachers' invigoration would result in their using effective instructional practices to increase their students' academic achievement. From 2005 to 2009, average scores on the Exit Level TAKS assessment given during the 11th grade increased from 2107 to 2282 for students of MLI lead teachers, showing more growth than AISD, from 2184 to 2262; HISD, from 2153 to 2255; or Texas, from 2201 to 2264 (McCoy, 2010; Texas Education Agency, 2010). The following statement summarizes the external evaluator's findings regarding lead teachers' students' mathematics achievement:

> *Each year, mean scale scores for students of MLI lead teachers on the Texas Assessment of Knowledge and Skills (TAKS) increased from the mean scales scores of the same students on the previous year's assessment. In addition, the mean scale scores of students of MLI lead teachers were compared with the mean scale scores of students of a comparison group of teachers. For all groups of students except those initially taught as sophomores by MLI lead teachers in the 2006-2007 academic years, the mean scale scores for the students taught by MLI lead teachers were statistically significantly higher*. (McCoy, 2011, p. 29)

MLI lead teachers thrive on their students' successes, which fuel lead teachers' quests to further enhance their professionalism to meet the needs of all of their students. MLI lead teachers recounted powerful learning experiences they facilitated with their students. Additionally, they express gratitude for opportunities to share their insights and skills with their colleagues. Lead teachers' colleagues who use these instructional models also report experiences of success with their students. In fact, student success is what may entice administrators to re-examine and improve views, expectations, policies, procedures, and practices that are found to impact student success.

Conclusion

MLI developed the mathematics content knowledge and instructional and leadership skills of 79 lead teachers which resulted in students' improved learning experiences and increased student success in mathematics. Lead mathematics teachers and administrators developed through MLI continue to foster institutional changes on their campuses and in their school districts. District administrators and former MLI lead teachers report MLI's impact continues to enrich their schools and districts through lead teachers' provision of model classrooms, introduction of innovative instructional strategies, encouragement of teachers to use new and effective instructional strategies, validation of teachers' work, and other activities to build rapport with and among mathematics teachers throughout the schools and districts. In fact, district administrators report that the districts have sustained all of the changes instituted through MLI, except for "release time" (due to budgetary restraints) for some lead teachers who are classroom instructors. District administrators and former MLI lead teachers attest to lasting improvements in the quality of professional collaboration, instruction, and professional development within the districts. Through increased collaboration, heightened expectations, and improved teaching and learning standards and practices, lead teachers who participated in MLI continue to help advance the academic performance of teachers and students in their districts, to encourage mathematics teachers to participate in professional learning communities, as well as to support them in disseminating their own insights at local, state and national conferences. Moreover, district administrators and former MLI lead teachers indicate the current mathematics programs in their districts and schools are much stronger due to the lead teachers' participation in MLI.

References

Allexsaht-Snider, M., & Hart, L. E. (2001). "Mathematics for all": How do we get there? *Theory into Practice*, *40*(2), 93–101.

American Federation of Teachers. (2002). *Principles for professional development: AFT's guidelines for creating professional development programs that make a difference.* Washington, DC: Author.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*, 191-215.

Bandura, A. (1997). *Self-efficacy: The exercise of control.* New York, NY: W. H. Freeman and Company.

Blankenship, S. S., & Buona, W. E. A. (2008). Exploring knowledge sharing among members of a community of practice. Retrieved from http://eric.ed.gov/PDFS/ED501645.pdf

Crockett, M. D., & Buckley, L. A. (2009). The role of coflection in equity-centered mathematics professional development practices. *Equity & Excellence in Education*, *42*(2), 169–182.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199.

Feiler, R., Heritage, M., & Gallimore, R. (2000). Teachers leading teachers. *Educational Leadership*, *57*, 66-69.

Guskey, T. R. (2002). *Evaluating professional development*. Thousand Oaks, CA: Sage Press.

Gutiérrez, R. (2008). A gap-gazing fetish in mathematics education? Problematizing research on the achievement gap. The National Council of Teachers of Mathematics, Inc. Retrieved from http://www.nctm.org/

Harris, A. (2002). *School improvement: What's in it for schools?* New York, NY: RoutledgeFalmer.

Krisko, M. E. (2001). "Teacher Leadership: A Profile to Identify the Potential." Paper presented at the Biennial Convocation of Kappa Delta Pi, 43rd, November 8-10, Orlando, FL. Retrieved from http://www.eric.ed.gov/ERICWebPortal/contentdelivery/servlet/ERICServlet?accno=ED459147

LaChance, A., & Confrey, J. (2003). Interconnecting content and community: A qualitative study of secondary mathematics teachers. *Journal of Mathematics Teacher Education 6*(2), 107-137.

Margolis, J. (2008). *Stuck in the shallow end*. Cambridge, MA: The MIT Press.

McCabe, C. (2010). The economics behind international education rankings. *National Education Today.* Retrieved from http://neatoday.org/2010/12/09/a-look-at-the-economic-numbers-on-international-education

McCoy, A. (2010). *The Rice University Mathematics Leadership Institute annual report.* RUSMP DN: 10-01.

McCoy, A. (2011). *The Rice University Mathematics Leadership Institute final report*. RUSMP DN:11-01.

McCoy, A., Hill, A., Sack, J., Papakonstantinou, A., & Parr, R. (2007). Strengthening mathematics teachers' pedagogical content knowledge through collaborative investigations in combinatorics. In T. Lamberg, & L. R. Wiest (Eds.), *Proceedings of the 29th Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (pp. 887-889). Stateline (Lake Tahoe), NV: University of Nevada, Reno.

National Academy of Education. (2009). *Teacher quality.* Washington, DC: Author.

National Council of Supervisors of Mathematics. (2008). Improving student achievement by leading the pursuit of a vision for equity. *Improving Student Achievement Series, 3*. Retrieved from www.ncsmonline.org

Olson, M. R., & Craig, C. J. (2001). Opportunities and challenges in the development of teachers' knowledge: The development of narrative authority through knowledge communities. *Teacher and Teacher Education, 17*, 667-684.

Piaget, J. (1972). *The psychology of the child*. New York, NY: Basic Books.

Piaget, J. (1990). *The child's conception of the world*. New York, NY: Littlefield Adams.

President's Council of Advisors on Science and Technology. (2010). *Prepare and inspire: K-12 education in science, technology, engineering, and math* (*STEM*) *for America's future.* Retrieved from http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-stemed-report.pdf

Sack, J., & Kamau, N. (2009). The impact of the lead teacher professional learning community within the Rice University Mathematics Leadership Institute. *The Journal of Mathematics and Science: Collaborative Explorations*, *11*, 141-162.

Schofield, J. W. (1986). Causes and consequences of the colorblind perspective. In J. F. Dovidio S. L. Gaertner (Eds.), *Prejudice, discrimination, and racism* (pp. 231-253). New York: Academic Press.

Silva, D. Y., Gimbert, B., & Nolan, J. (2000). Sliding the doors: Locking and unlocking possibilities for teacher leadership. *Teachers College Record*, 102, 779-804.

Texas Education Agency. (2010). *Texas Education Agency academic excellence indicator system 2009-10 district performance: 2010 district AEIS Report.* Retrieved from http://ritter.tea.state.tx.us

United States Department of Education. (2010, March). *A blueprint for reform: The reauthorization of the elementary and secondary act*. Retrieved from http://www2.ed.gov/policy/elsec/leg/blueprint/blueprint.pdf

Vygotsky, L. (1978). *Mind and Society.* Cambridge, MA: Harvard University Press.

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