**Institute Partnership: Mathematics Teacher Leadership Center**

## 1. Vision, Goals, and Outcomes

> *Our **vision** is of a highly qualified, culturally competent, and pedagogically effective cadre of Colorado and Wyoming mathematics teachers, local teacher-leaders, and university teacher-educators.*

The proposed *Mathematics Teacher Leadership Center (Math TLC)* is an integrated partnership of universities and school districts to improve mathematics achievement in middle, secondary, and post-secondary education in the north Rocky Mountain region. Weaving together existing and new research, teacher expertise, and culturally responsive professional development, our plan offers a *virtual master's degree program* for secondary teachers and a *mathematics teacher-leader program* for 4th through 12th grade teachers. Offered jointly by the University of Northern Colorado (UNCo) and the University of Wyoming (UWy), the *Math TLC* master's program provides 32 credits of coursework (225 hours face-to-face, 150 hours online) for 75 in-service teachers, while the leadership program has 24 credits of coursework and professional development (168 hours face-to face, 150 hours online) for 40 in-service master teachers. These programs develop content proficiency, cultural competence, and pedagogical expertise for teaching mathematics. In fact, the goals of the center are based on the recommendations from *Adding it Up* (2001). The *Math TLC* also engages in a *Research Program* to produce evidence-based contributions to the teaching and learning knowledge base.

Goals for the *Math TLC*

Goal 1: Develop a shared vision of mathematics as a culturally rich subject in which K-12 mathematics proficiency is defined by shared community standards (e.g., state, NCTM policies).

Goal 2: Expand mathematical content knowledge in ways that broaden exposure to mathematical ideas and deepen understanding of topics that extend K-12 mathematics content.

Goal 3: Increase pedagogical content knowledge by examination of how students think and learn about mathematics and, for teacher-leaders, about how teachers learn about teaching.

Goal 4: Empower participants as lifelong professional learners who regularly reflect on themselves, students, and community context to improve teacher practice and student learning.

Goal 5: Produce a research-based and tested model for master teacher and teacher-leader development based on the above goals that improves mathematical achievement for *all* students.

Key Outcomes for the *Math TLC*

Outcome 1: Establish a cadre of culturally competent master teachers and teacher-leaders equipped to work locally, regionally and nationally to improve teacher practice and student achievement.

Outcome 2: Generate a body of research and evaluation that documents effective practices in developing master teachers and teacher-leaders.

Outcome 3: Develop sustainable models for the virtual master's and teacher leadership programs offered jointly by UNCo and UWy.

## 2. Why Master Teachers AND Teacher Leaders? Why Colorado and Wyoming?

**2.1 Master Teachers and Teacher Leaders.** Based on experience and research, we separate the development of master teachers from that of teacher-leaders. In on our experiences with the successful master's program for secondary teachers, the master's for middle level teachers, and a pilot teacher-leader program for middle grades at UNCo, graduates take leadership positions in school districts around the state. We expect the same from the proposed joint master's program because it too focuses on developing master teachers. Meanwhile, much of what is required of teacher-leaders is not addressed in a master's program (e.g., working with adult learners, negotiating change in a complex system, creating and delivering mathematics professional development, shepherding a curriculum adoption, working with principals). In fact, teachers need to be in an appropriate place in their professional and personal lives to take on leadership (York-Barr & Duke, 2004). Master teachers' first-hand experience of classroom practice and awareness of their school's culture are a source of expertise and credibility when they become leaders who share their knowledge

and classroom skills with teacher peers (Paulu & Winters, 1998). In the *Math TLC*, teachers become content specialists in their own practice in a master's program. Then, in the teacher-leader program they become specialists in helping their peers and in working at the district and state levels to improve mathematics instruction for all. By separating the two strands of professional development, we create two access points for different types of commitment to leadership development.

> **Teacher leadership** is the process by which teachers, individually or collectively, influence colleagues, principals, and other members of school communities to improve teaching and learning practices with the aim of increased student learning and achievement. It involves three intentional development foci: individual, collaboration or team, and organizational development (York-Barr & Duke, pp. 287–288).

The National Council of Teachers of Mathematics ([NCTM], 1991) acknowledged the need for teachers to implement reform practices in schools and the need to support teachers in those endeavors. A primary reason to focus on *teacher-leaders* is that their expertise in teaching and learning fosters a unique contribution to educational improvements (Yarger & Lee, 1994; Yow, 2007). There is also a nationally recognized need for content-based professional development. The research-based characteristics of highly effective professional development are based on attending to both mathematical content and related pedagogical content knowledge (NCSM, 2006). The master's program in the *Math TLC* provides for these key components through combining content courses with an innovative set of integrated content and pedagogy courses while the leadership program addresses these through rich practicum experiences grounded in the master's classes for teachers serving as a laboratory for teacher-leaders.

**2.2 Colorado and Wyoming.** The Rocky Mountain west is a vast and sparsely populated region. The challenges of distance, isolated pockets of teachers, and limited faculty to serve the need necessitate a collaborative and virtual program. Only with innovative technology use across multiple universities will there be the faculty capacity and teacher participant numbers for a successful and sustainable *Math TLC*. UNCo and UWy are the respective teacher education leaders in their states. The expertise to establish and sustain a mathematics leadership center is in place, with principal investigators who are well versed in such partnerships through their collective experience with NSF Centers for Learning and Teaching (see §4). The partnership of UNCo and UWy is the start that can grow to include universities serving the entire Rocky Mountain region with virtual programs for mathematics and science teachers. Conversations about scalability with the Western Interstate Commission for Higher Education (WICHE) and 6 universities in the region informed the *Math TLC* design.

## 3. Key Features

**3.1 Partnership Driven.** Both universities have committed infrastructure through their Mathematics and Science Teaching institute (MAST at UNCo) and Science and Mathematics Teaching Center (SMTC at UWy) to support collaborations with school districts. The *Math TLC* builds on existing professional relationships among faculty in the mathematics departments and teaching centers at both institutions and extends it to the School of Education Research, Leadership and Technology (UNCo) and Department of Secondary Education (UWy). MAST and SMTC are regional centers that offer professional development for science and mathematics through grant supported projects and master's courses for in-service teachers. SMTC has 70 affiliate faculty members across four colleges who serve as resources, advisors, and instructors for in-service teachers in Wyoming. The *Math TLC* senior personnel have worked on Colorado teacher enhancement projects and distance delivery: **Jodie Novak** has led several state funded MSP projects, **Shandy Hauk** has worked as researcher and **Rob Powers** as teacher-educator on those projects, **Bill Blubaugh** was MAST director, and Rob, Bill, and **Heng-Yu Ku** have expertise in distance delivery. At UWy, **Robert Mayes** is the Director of the SMTC, which has run teacher professional development through state level MSP projects over the past five years, and **Bryan Shader** chairs the UWy math department.

***School Partners*:** In Colorado, we further ongoing collaborations with Weld County District 6, Morgan County School District (MCSD), NE BOCES, and Centennial BOCES, begun in 2003 through state funded MSPs; our plan also initiates new partnerships with Poudre School District (PSD). District liaisons to the project are participants in previous partnership activities. **Matt Christiansen**, co-PI, is mathematics coordinator in District 6, graduate of the UNCo master's program for secondary teachers, and helped coordinate two previous state MSPs. **Linda Frasco**, middle school math and science teacher turned math coach at MCSD, was involved in two state MSPs. **Kate Canine**, K-12 Math Curriculum Facilitator for PSD, is currently a student in the UNCo master's program. The *Math TLC* will add to and create new partnerships with Wyoming school districts. The Wyoming core partners are Laramie County School District 1 (**Kristin Williams**) and Carbon County School District 1 (**Marilyn Vercimak**). Four other Wyoming districts are supporting partners: Park County District 6, Platte County Districts 1 and 2, and Sublette District 1.

### 3.2 Teacher Quality, Quantity and Diversity

***Quality**:* The project improves teacher quality by deepening content knowledge and enhancing cultural competence in pedagogical content knowledge through both the master's and leadership program courses/activities. Since *Math TLC* teacher-leaders will engage in leadership activities in their districts, we impact the quality of teachers and experiences of students across both states. Currently, teachers in Wyoming cannot advance towards a master's degree or gain leadership skills without leaving their home region. By exploring alternative delivery formats, we make the *Math TLC* accessible to rural teachers. We plan to extend application invitations for the teacher-leader and master's programs to rural teachers each year (40% of each cohort; see §5).

***Quantity**:* We address quantity not by recruiting more teachers into the workforce, but by working to retain those we have. First, we provide opportunities to deepen content knowledge and improve practice through participation in a master's program specifically designed for secondary mathematics teachers. Second, by preparing mathematics teacher-leaders, we provide support to new and continuing teachers with the research-based expectation that it will increase retention of the current workforce. (Crowther et al., 2002). The work of teacher-leaders is particularly valuable to novice teachers, those still being inducted into the profession. Without local and accessible leadership from senior colleagues, half of these new teachers will quit teaching within five years (Portner, 2005).

***Diversity***. Our teacher population does not match the diversity of the student population in the region. The Hispanic population in Colorado and Wyoming is growing, as is the Somali population in northeastern Colorado, and we have a significant American Indian presence at the Wind River Reservation in Wyoming. In addition to cultural and ethnic diversity, both states have diversity in socio-economic status. So, while we will actively recruit a diverse set of teacher participants, our main goal is to help teachers gain cultural competence with diverse students. Current research and practice literature suggests five key areas of teacher learning that increase teaching effectiveness, particularly culturally and ethnically diverse students (Gay 2002): (1) developing a knowledge base about cultural diversity, (2) learning mathematical content from ethnically and culturally diverse origins, (3) participating in and building a caring community of learners – this includes developing ways to calibrate teacher intentions with student perceptions, (4) seeing personal communication patterns and using that awareness to learn to communicate effectively with diverse students, and (5) responding supportively to socio-economic, cultural, and ethnic diversity in the delivery of instruction. Offering academic knowledge and skills "situated within the lived experiences and frames of reference of students" (Gay, 2000) leads to more personally meaningful experience and more readily and thoroughly learned

> **Culturally competent** teaching involves using the cultural experiences, characteristics, and perspectives of the students in the room as generative sites for shaping teaching and creating opportunities to learn that are *perceived* by students to *be* opportunities (Gay, 2002).

mathematics. *Math TLC* university teacher educators, responsive to the professional worlds of the teachers in their classes, *model and teach* the five components in master's classroom instruction. Moreover, the teacher-leader program and *Math TLC* research plan are built around the five tenets.

**3.3 Challenging Courses and Curricula.** The master's program includes 18 hours of course work in mathematics and 12 hours in mathematics education (§5 and see Supplementary Documents for course descriptions). The math courses extend teachers' content knowledge beyond what they customarily teach; the math education courses focus on expanding teachers' culturally competent pedagogical content knowledge. The content courses provide substantial theoretical underpinnings for many high school classes (e.g. *Continuous Mathematics* for algebra and calculus and *Modern Geometry* for geometry), explicit experience with the process standards (*Mathematical Problem Solving*), as well as a depth of experience in culturally responsive mathematics and mathematics education. The courses develop the proficiencies needed for school teachers: understanding of the culture of mathematics as a discipline, extending and exploring mathematics with learners, connecting mathematics with and across domains, building on concepts to anticipate future topics, and organizing mathematics for teaching not only logically but also psychologically (Ball, 2003).

Academic year online courses and summer 6-week courses will be re-developed from their current UNCo and UWy formats by content-pedagogy faculty teams. This recasting of the courses for virtual delivery will maintain an advanced perspective on what is taught in high school. The integrated master's courses represent one of the truly innovative aspects of the program. Also, all courses address the NCTM principals and standards: teachers experience as learners the kinds of instruction recommended for K-12 students. For example, technology is integrated into class time learning while group work and collaborative learning are implemented in class and supported through a variety of action research based activities.

The *Math TLC* plan uses small-scale action research to connect coursework with practice, giving teachers a tool to systematically examine their practice, improve their pedagogical content knowledge, and explore changes in student achievement. Our adaptation is to modify Lesson Study (Education Development Center, 2007; Fernandez & Yoshida, 2004; Lewis, Perry, & Hurd, 2004) to a form of *Lesson Experiment* (Hiebert et al., 2003) where one or two teachers are teamed with a teacher-leader. Lesson Experiment harnesses the efforts of those becoming master teachers with that of teacher-leaders. It relies on the successful structures of Lesson Study: development of content and anticipatory knowledge through individual planning, instructing, and reflecting activity along with the community-building dimension of co-observations. Lesson Experiment team members observe each of the other members teach a related topic (this is where it differs from Lesson Study – not the exact same lesson), allowing flexibility for responding to the myriad classroom demands of physically isolated teachers in rural areas.

**Pedagogical content knowledge (PCK)** is the collection of knowledge teachers have about the challenges learners encounter, strategies for helping students, ways to listen to hear not only learners' thoughts but also their thinking processes, and skills for regulating one's own practice. Teachers acquire PCK in many ways: grading, examining their own learning, observing and interacting with students, reflecting on practice, and discussing it with others. (Ball & Bass, 2000).

**3.4 Evidence-Based Design and Outcomes.** The *Math TLC* is based on two premises for improving teacher quality in mathematics education. First, teachers must become content experts in the kinds of mathematics and pedagogical content knowledge needed to teach effectively (Ball, 2003; CBMS, 2000; Ma, 1999). Second, teachers need support in their teaching endeavors to effect change (NCTM, 1991), which is best accomplished through support from teacher-leaders (Barth, 2001). Project research and evaluation will investigate the effectiveness of *Math TLC* programs on teacher growth and the impacts on student achievement. Results will be disseminated through a variety of venues. See Sections 4, 5, & 6 for more details.

### 3.5 Institutional Change and Sustainability

***Institutional Change***. Both UNCo and UWy will undergo institutional change through negotiation and implementation of the *Math TLC* affiliation agreement (see §8). The outcome will be a true partnership offering a virtual master's and leadership program to teachers in their home regions. This will impact school district structures by creating/augmenting district leadership, supporting Lesson Experiment-based learning communities, and increasing teacher's knowledge of culturally relevant content and culturally competent pedagogy.

***Sustainability***. The *Math TLC* plan in Year 1 is for negotiating and finalizing affiliation agreements between UNCo and UWy that institutionalize the partnership for jointly delivering the master's and teacher-leader programs. *Our successful experiences with the NSF-funded multi-institutional Centers for Learning and Teaching has taught us to set aside this year for negotiation and course development to ensure the long-term institutional commitment to sustain what is initiated in this grant project* (see §4). UNCo and UWy both have a history of owning and supporting master's programs developed through grant funds. For institutionalizing the teacher-leader program, we are engaged in conversations with our respective mathematics departments, colleges of education, MAST (UNCo) and SMTC (UWy), and partner school district teachers, leaders, and administrators.

## 4. Prior NSF Support and Lessons Learned

**Bush, W., Long, V., Mayes, R., Lee, C., and Howley, C. DGE-0119679, $10,667,090, 9/01-9/08, (CLT: ACCLAIM)**. The Appalachian Collaborative Center for Learning, Assessment, and Instruction in Mathematics (ACCLAIM) is an NSF Center for Learning and Teaching constituted by the University of Tennessee, University of Kentucky, University of Louisville, Ohio University, Marshall University, West Virginia University, and Kentucky Science and Technology Corporation. ACCLAIM's mission is to cultivate indigenous leadership capacity for the improvement of school mathematics in rural places. The center has developed a model of collaborative university decision-making and its mathematics education Ph.D. program has had 50 participants in three cohorts to date. ACCLAIM has become a nexus and clearinghouse for rural mathematics education research, including *The Rural Mathematics Educator* journal and an active web portal. The center has supported over 15 studies, published nearly 100 working and occasional papers, and created the Appalachian Association of Mathematics Teacher Educators, an AMTE regional affiliate.

**Hauk, S. DGE-02030225 $50,000, 1/02-1/03** (***Mathematical Cognition and Affect During Non-Routine Problem Solving***). Funding for PI and 2 grad mathematics education researchers through four studies aimed at understanding and addressing acculturative stress in collegiate mathematics. Main results pointed to culturally responsive teaching and problem-posing as keys to student success.

***Lessons Learned.*** The principle investigators for the *Math TLC* have extensive experience in developing and researching collaborative mathematics education graduate programs offered at a distance. We have been key players in two NSF Center for Learning and Teaching (CLT) proposals: ACCLAIM (Mayes, coPI) and CLT-West (Hauk). ACCLAIM created a virtual Ph.D. in Mathematics Education with a Rural Emphasis. CLT-West developed online graduate math and science education courses that address equity and diversity in the context of increasing K-16 students' math and science achievement. From these CLTs we learned how to establish an affiliation with multiple universities that can be sustained after grant funding ceases; how to establish a common platform for distance learning that provides consistency for students across courses; how to successfully implement a cohort model that results in high retention levels; how to share courses across universities and states; and how to develop innovative courses that integrate mathematics content with culturally responsive pedagogy. We have the expertise to create and sustain a multi-state, multi-university collaborative that serves the needs of Colorado and Wyoming and is expandable as a model for master teacher and teacher-leadership development across the Rocky Mountain region.

Originated by the NSF-funded Rocky Mountain Secondary Teacher Education Institute (RMSTEIN, 1995) project, the UNCo master's degree program for secondary teachers is an institutionalized success. The *Math TLC* project enhances and expands the reach of the UNCo master's curriculum through a combination of online and face-to-face interactions to create a virtual program offered through the UNCo and UWy (see §5.1). Similarly, the *Math TLC* teacher-leader program builds on the success at UNCo of state-funded middle school teacher-leader initiatives – to extend teacher-leader development up and down the grades. As in the existing UNCo middle school teacher-leader model, the *Math TLC* integrates the master's and teacher-leader programs: master's classes serve as practical laboratories for initial teacher-leader experiences. In particular, teachers in the leadership program apprentice with university teacher-educators and act as facilitators in the master's courses before moving to leadership fieldwork activities in school districts (see §5.2). Another integrative layer of the *Math TLC* is that research and development with the master's and teacher-leaders programs are sites for the cultivation of leaders in mathematics teacher education among university faculty, post-docs, and doctoral students at UNCo and UWy (see §5.3).

## 5. Research and Implementation Framework

**5.1 Master's Program Implementation.** The *Math TLC* creates a rigorous virtual master's program jointly offered by UNCo and UWy. We are committed to a 2-site delivery system while developing and researching delivery methods for the program. Jointly delivering a master's program between two universities in two states requires serious planning to ensure a good experience for students. Thus, in Year 1, we establish the infrastructure required for implementing the *Math TLC*. The master's program, with its math and math education courses designed specifically for secondary mathematics teachers, consciously addresses adult learning issues of relevance and supports the building of content knowledge, cultural competence, and PCK simultaneously through attention to course design. Research-based characteristics (Loucks-Horsley, et al., 2003; NRC, 1996; 1997; 2005) will guide course design (see Table 1).

Plan for Initial Year

1. Negotiate the affiliation agreement between UNCo and UWy to ensure a seamless delivery of the program and its long term sustainability.
2. Research the knowledge base on teaching and learning about using video and online delivery technologies and choose a common platform on which to deliver the program.
3. Advertise for 1st cohort by October 1, 2009 with applications due December 15 and decisions for admittance by January 15, 2010. This allows time for pre-participation data collection among participating teachers, including observations, surveys, and assessments of content knowledge. The 1st cohort will begin classes in Summer 2010.
4. Begin development of online math/math education paired courses during Year 1, Fall 2009. Continued development in Spring and Summer 2010 includes field-testing by master teachers. Ready for implementation with 1st cohort in Fall 2010.
5. Regional and National Advisory Boards meet.

*Table 1. Research-based course design characteristics.*

(a) Employ a research-based instructional design, modeling learning strategies that promote effective classroom learning and teaching, and that teachers can also use with their students. (Bybee, 2006)
(b) Build new knowledge upon teachers' prior knowledge.
(c) Support learning through interaction among teachers about mathematical ideas
(d) Convey clear purpose and outcomes. (NRC, 1999, 2005).
(e) Incorporate a variety of learning activities to engage teachers, appeal to different learning styles, and explore the cultural capital of teachers and the students they teach (Bourdieu, 1986; Civil, 2002; Kuhn, 2005; NRC, 2000).
(f) Assess teacher understanding frequently.
(g) Situate learning within meaningful, relevant contexts (e.g., action research; Nentwig & Waddington, 2005).
(h) Cultivate a safe, non-threatening, low-risk environment for teachers to express new ideas and try out new approaches, such as incorporating collaborative learning strategies within course designs.

The goals of the master's program are to:

M1: Extend teachers' content knowledge beyond the content they customarily teach to students.
M2: Engage teachers in actively building their pedagogical content knowledge (Shulman, 1987), enabling them to enlarge their repertoire of pedagogical methods, skills and knowledge congruent with *Principles and Standards for School Mathematics* (NCTM, 2000), the *Colorado Model Content Standards* (CDE, 2007) and the *Wyoming Mathematics Content and Performance Standards (WDE, 2003)*.
M3: Support teachers to evaluate and improve their teaching practice by regularly engaging in lesson experiments and small-scale action research projects.
M4: Develop teachers' knowledge, skills and disposition to effectively teach math in a culturally diverse classroom.

To address Goal M1, the master's program includes 18 hours of mathematics courses with 7, 3-credit courses available. Goal M2 is met both by the 12 hours of math education courses and by the design of all courses in the program (Table 1). There are 6 math education classes to choose from, all are 2-credit courses except the first, which is 3 credits. Some content courses pair naturally with math education courses, such as Geometry with Teaching Geometry. These pairs will be jointly developed and delivered by a mathematician and a mathematics educator to explicitly link the content being learned with its connection to the high school classrooms and culturally competent pedagogical strategies to teach the content.

Math Courses (choose 6 of 7)
- Continuous Mathematics (required)
- Modern Geometry (required)
- Problem Solving
- Discrete Mathematics
- Applied Probability and Statistics
- Abstract Algebra and Number Theory
- Mathematical Modeling

Math Ed Courses
- Introduction to Research in Mathematics Education (required)
- Assessment Practices in K-12 Math
- Teaching Algebra and Trigonometry
- Teaching Geometry
- Teaching Data, Probability, & Statistics
- Teaching Discrete Mathematics

Goal M3 is met in two ways. First, we incorporate lesson experiments (small scale action research projects) into each math education course. Second, we offer 3, 1-credit classes in which teachers engage in a larger scale action research project, putting what they have learned in their mathematics education courses into practice. The results are written up as the master's thesis.

Meeting Goal M4 is the *most challenging* because doing so asks teachers to address intellectually and personally many assumptions about who succeeds in mathematics and why. We address this goal in both math and math education courses. Math courses will challenge the Euro-centric view of mathematics in that each instructor will devote at least 10% of course time to exploring the historical and cultural nature of "modern" mathematics. For example, students might explore the evolution of the idea of algebra from ancient Greek geometry and Hindu numeration, through its development in the medieval Islamic world, into its representations in Mediterranean trade and its re-discovery and reshaping by Renaissance European physicists. Or, they might explore the complex kin system of the Warlpiri, in Australia's Northern Territory (Ascher, 1991) to discover that the logical structure of the system is a dihedral group of order 8. Math education courses will take steps to help teachers build cultural competence for the cultures students bring to their classrooms. This includes such approaches as readings on issues of equity and diversity in math education (e.g., Civil, 2002; Gay, 2000), building anticipatory knowledge related to cultural competence in teaching diverse student populations, and organizing panels of parents to talk with teachers about their experiences with districts, schools, and teachers. In addition, as we did in piloting the middle level teacher-leader program, we have budgeted for teacher-leaders to be involved in the development and delivery of the master's program.

The master's program will not be developed in isolation. Each year we will hold a meeting of our Regional Advisory Board (appointed in Year 1) to evaluate progress, update goals and objectives, and ensure that we are meeting the needs of students, teachers and districts. The Regional

Advisory Board will include state mathematics leaders from Colorado and Wyoming, master teachers from Colorado and Wyoming, and graduates from UNCo's masters' in mathematics for secondary teachers and middle level teachers (for grade band communication). The National Advisory Board will meet in person in Years 1, 3, and 5 and online in Years 2 and 4. While the Regional Board will focus on *Math TLC* progress, the National group will focus on vision for the future of the *Math TLC*.

Recruitment and Selection of Master's Participants
- *Priority to teachers in core partner districts*
- *Invitations sent first to teachers in high-diversity schools and those in rural areas*

Application Package must Document:
- Math Teaching: middle or high school certification
- Math Content Preparation: transcript showing at least 30 hours of undergrad math
- Professional Goals: Application essay
- Recommendation Letters: 1 from school administrator, 1 from colleague
- Letters of Commitment: from participant and district

Meeting school districts' needs for master teachers in mathematics in Colorado and Wyoming requires addressing issues of distance. To allow equitable access for rural teachers without compromising quality, we will explore and research a variety of delivery formats while maintaining a face-to-face component during the summer and an online component during the academic year. We will offer online math courses, blended math/math education courses in both formats, and three 6-week summer courses that teachers take at UNCo or UWy. Summer courses will be delivered live at one institution and through streaming video at the other. We will explore other summer alternatives such as offering classes in a 4-week session (e.g., options include 2 math courses or 1 math and 1 math education course). We will also explore 2-week summer session options such as a math-for-teaching course to address the challenges in teaching algebra to students who have not had previous success in math or students who need more than a year's progress in a one-year course so they can "catch up" mathematically.

Master's Program Outcomes
*Practical*: content projects and assessments in math courses and pedagogy projects and lesson experiments in math ed courses.
*Transforming*: action research thesis.

Through face-to-face courses, teachers experience a pedagogical method, such as collaborative learning, as a student. This gives them insight into how one might use a method in the classroom. For this reason, we retain face-to-face classes in our program. The question is: what portion of the program should be offered face-to-face? And, how do we balance that with rural teachers' needs for accessible programs? We will explore our answers to these questions through research, evaluation, and discussion with Educational Technology project expert Heng-Yu Ku and the Advisory Boards. If a 4-week/2-week summer session is effective, it introduces flexibility for teachers. The trade-off is that it takes 2 years plus a summer to finish the degree instead of 2 years. Thirty students will take courses together during the summer. Teachers in their first year will take Introduction to Research in Math Ed and 1 other math ed course. In their second year, they will take a math course in fall with its paired math ed course in spring and two credits of action research. During the academic year UNCo and UWy will each offer two courses (see Table 2 below).

### 5.2 Implementing the Teacher Leadership Program

The goals of the teacher leadership program parallel those of the partnership master's program. Specifically, the goals of the *Math TLC* are that participants will:

L1: Develop a shared vision of mathematics teacher leadership;
L2: Enhance mathematics content knowledge;
L3: Expand understanding of how teachers build knowledge for teaching mathematics;
L4: Increase pedagogical content knowledge about adult teachers learning mathematics and who are learning to teach mathematics to diverse populations;
L5: Develop an understanding of the role of equity and culture in mathematics in schools and districts;
L6: Build self-efficacy as teacher-leaders of mathematics

***Math TLC Curriculum.*** The courses in the Teacher Leadership Program (TLP) address objectives for developing teacher leadership knowledge, skills, and dispositions consistent with those identified in the literature (e.g., Sherrill, 1999; Yow, 2007). Each TLP experience will focus on mathematics content that will elicit aspects of teacher leadership. The TLP will span a cycle of two years and total 24 credit hours of graduate-level work. During the summer, teacher-leader cohorts will complete two 1-week seminars; each is equivalent to a 2-credit course. The primary purpose of the seminars is to promote the knowledge mathematics teacher-leaders need to be successful, including an understanding of theory and research about mathematics teaching and learning, cultural competence for teaching, and about adult development.

Recruitment and Selection of Leadership Participants
- *Priority to teachers in core partner districts*
- *Invitations sent first to teachers in high-diversity schools and those in rural areas*

Application Package must Document:
- Math Teaching: middle or high school certification and at least 5 years math teaching experience
- Math Content Preparation: Master's in math, math ed, or equivalent in PD and experience, including at least 40 hours of undergrad math or equivalent (undergrad and graduate transcripts)
- Professional Leadership Goals: Application essay
- Recommendation Letters: 1 from school administrator, 1 from colleague
- Letters of Commitment to Leadership Development: from participant and district

During the school year, teacher-leader cohorts will participate in two interrelated activities: online courses and weekend retreats. The primary purpose of the 3-credit online courses is to develop mathematics-centered teacher-leadership skills. These courses include a practicum component that addresses development of individual, collaboration or team, and organization and supports TLP participants' learning in ways that directly sustain their leadership work. The practicum may not necessarily be synchronous with the online course; for example, a teacher-leader may co-facilitate in summer master's courses in the secondary or middle level teacher programs. In addition to online courses, teacher-leaders will participate in one weekend retreat per semester. These 1-credit retreats begin at noon on Friday and end at noon on Sunday. The primary purpose of the retreats is supporting positive dispositions of math teacher-leaders about themselves as leaders and their fellow teachers (Sherrill, 1999). These sessions will build community among members of two cohorts at a time and are planned to promote growth among colleagues (Lieberman et al., 1988). Tentative titles for the seminars, online courses, and weekend retreat sessions:

Teacher-Leader Program Outcomes
*Practical*: observations, stakeholder surveys, lesson experiments.
*Transforming*: teacher-leader professional portfolio.

| **Teacher Leader Plan** | Year 1 | Year 2 |
|---|---|---|
| Summer Seminars | • Diversity and Equity in Math Ed<br>• Developing and Delivering PD for Math Teachers | • Adult Learning Theory in Practice<br>• Changing Complex Systems |
| Fall Online Course | Facilitating Lesson Experiments | Culturally Responsive Teaching |
| Fall Retreat | Time Management | Facilitating Change in Mathematics Education |
| Spring Online Course | Clinical Supervision | Data Driven Instruction |
| Spring Retreat | Coaching Peers | Developing Leadership Skills |

Table 2 gives the 2-year plan for teacher-leader and master's program cohorts. Each summer a 1-week seminar for the TLP is followed by a 6-week period of courses for master's candidates and then a second 1-week seminar for the TLP. This is to provide the opportunity for a master's course practicum for teacher-leaders. During the academic year, teacher-leaders are active in online courses and weekend retreats while those in the master's program do online math or math ed courses.

*Table 2. Math TLC Timeline for Teacher Leader and Master's Program Cohorts*

| Term | Duration | Year 1 | | Year 2 | |
|---|---|---|---|---|---|
| Summer | 1-week | TLP Seminar 1 (2) | | TLP Seminar 3 (2) | |
| | 6-weeks | | MATH Course 1 (3)<br>MATH Course 2 (3)<br>MATH Course 3 (3) | | MATH Course 4 (3)<br>MED Course 2 (2)<br>MATH Course 5 (3) |
| | 1-week | TLP Seminar 2 (2) | | TLP Seminar 4 (2) | |
| Fall | Semester | TLP Online Course 1 (2) | Math Ed Research (3) | TLP Online Course 3 (2) | MATH Course 6 (3)<br>MED Research (1) |
| | Weekend | TLP Retreat 1 (1) | | TLP Retreat 3 (1) | |
| Spring | Semester | TLP Online Course 2 (2) | MED Course 1 (2)<br>MED Research (1) | TLP Online Course 4 (2) | MED Course 3 (2)<br>MED Research (1) |
| | Weekend | TLP Retreat 2 (1) | | MTL Retreat 4 (1) | |

**5.3 Research Plan.** Research and evaluation will use naturalistic/qualitative and quasi-experimental quantitative designs to investigate *Math TLC* participant knowledge around two key institute themes: (1) examining and using students' mathematical thinking to shape teaching and (2) strategies for generating culturally responsive teaching. Evaluation will analyze in detail the impacts of *Math TLC* activities on the learning of participants and on the learning of their students (also see Supplementary Documents: Evaluation Chart). For example, before beginning *Math TLC* activities, the teachers in each cohort will complete pre-participation measures of their knowledge and beliefs about students' thinking in mathematical contexts (using existing instruments). To evaluate the effectiveness of *Math TLC* activities, specifically to distinguish between what one might expect teachers to learn by virtue of teaching and what they might learn from *Math TLC* participation, we plan a quasi-matched comparison method. We will use instrumentation and results from currently published reports of teacher practice (without PD) for comparison to *Math TLC* participants. Like the teachers reported on in the literature, *Math TLC* teachers, teacher-leaders, and university teacher-educators will participate in periodic documentation of their planning, instructing, reflecting, and PD practices. As a measure of the effectiveness of *Math TLC* activities on mathematics learning (of teachers, teacher-leaders, teacher-educators, and their respective students), data on participant and students' mathematics learning, including exam scores and written work on open-ended problems (where possible), will be collected for participants and their students as well as for students of non-participants. Note that much of the data collected will be used in both research and evaluation.

**Research Goal 1.** Advance knowledge about the *content and impact* of professional development of mathematics teachers by researching the mathematical understandings, pedagogical content knowledge, and practices among *Math TLC* participants (teachers, teacher-leaders, and university teacher-educators), as well as the achievement of K-12 students.

*Question 1.1. Teacher Change*. What mathematical understandings, pedagogical content knowledge, and teaching practices do teachers, teacher-leaders, and teacher-educators have at *start* and *end* of each year of participation in the *Math TLC* project?

*Question 1.2. Instructional Content*. What mathematical and pedagogical content knowledge components are addressed in *Math TLC* courses and activities?

*Question 1.3. Student Achievement*. What is the relationship among *Math TLC* participants' *activities*, *teaching contexts*, and *student achievement*? In particular, we will investigate the nature of change in K-12 and master's student achievement given experiences of:

*1.3.a*. Teachers and teacher-leaders in rural contexts compared to suburban/urban situations,

*1.3.b*. Teachers and teacher-leaders in socio-culturally diverse and homogeneous contexts,

*1.3.c*. University teacher-educators teaching at a distance compared to teaching face-to-face – where student achievement is that of graduate students.

*Question 1.4. Instructional Format.* How do changes in mathematical understanding, PCK, practices, and K-12 student achievement correlate with aspects of *Math TLC* participation?

*1.4.a.* Teacher, teacher-leader, and university teacher-educator participation in technologically rich instructional environments (e.g., online courses and workshops during academic year, distance delivered summer master's courses),

*1.4.b.* Teacher and teacher-leader participation in summer-intensive experiences,

*1.4.c.* Teacher and teacher-leader participation in laboratory leadership experiences (e.g., within master's classes, school/district in-service day workshops)

*1.4.d.* Teacher-leader and university teacher-educator participation in *Math TLC* retreats.

**Research Goal 2.** Advance knowledge of teacher leadership development by researching, through a design experiment, the *Math TLC* leadership development model. The goal of this model is to develop teacher-leaders who can facilitate professional development of other teachers in ways similar to what is offered through the *Math TLC*.

*Question 2.1*. How do the various aspects of the leadership development model contribute to the development of teacher-leaders?

*Question 2.2*. How are these aspects combined to create a successful leadership development model for mentoring teacher-leaders?

**Methods.** In addressing these questions, *Math TLC* researchers rely on mixed-methods approaches using existing qualitative and quantitative instruments. In some cases, appropriate instrument modifications may be made (accompanied by evaluation of reliability, confirmability, and validity).

*Data Collection*. In each case, data is collected in five categories using appropriate Institutional Review Board approved consent/assent (also see Supplemental Documents – Evaluation Plan):

1) Pre-participation and post-participation survey.
2) Interviews of individuals or focus groups.
3) Observations, video-recorded where possible.
4) Student achievement data (K-12, undergraduate, and master's, as appropriate)
5) Artifacts and documents (e.g., lesson plans, lesson experiment, student work)

*Instrumentation*. Intended use of existing instruments and protocols we have identified (most from MSPnet and Horizon Research sources; also see Supplemental Documents – Evaluation Plan):

1) Surveys on received and enacted curriculum completed by teacher participants and university teacher-educators (Wisconsin Center for Education Research, 2003).
2) Individual and focus group interview protocols already developed and validated under state-funded MSP work at UNCo (Hauk, Deon, Judd, Kreps, & Novak, 2007).
3) Coding rubrics for use in observations to capture the content and quality of mathematics instruction (Horizon Research, 2000; Learning Mathematics for Teaching Project, 2006).
4) Student scores provided by partner districts and schools on state standardized tests along with copies of in-class assessments (school students, master's students, teacher-leaders).
5) *Math TLC* participants: pre-participation documents include application materials from master's, teacher-leader, and post-doc candidates (transcripts, application essays, application interviews, emails). Post-participation documents include: In-class assessments, written reflections, master's students' Action Research Project reports, teacher leaders' Portfolios, post-doc Dossiers (Campbell et al., 2006).

**Research Outcomes:**

1) Publication of broad quantitative and in-depth qualitative research on the *Math TLC* model in developing deep mathematical understandings, culturally competent PCK, and effective instructional practices for teachers, teacher-leaders, and teacher-educators ("effective instruction" is defined as that which leads to increases in student learning).
2) Dissemination of the *Math TLC* model in a research-to-practice format in venues accessible to

teacher-educators, such as *Focus* (publication of the MAA).

3) Publication in teacher- and administrator-accessible ways about how changes in teachers' PCK and mathematical understandings can be manifested in practice. This responds to the call for research connecting PD with instruction and student learning (Ball & Bass, 2000; Boaler, 2002).
4) Publication of the design experiment including in-depth descriptions of how and to what extent aspects of the leadership development model were effective. Such descriptions will give information on how to provide leadership development within specific contexts.
5) Contribution to the literature on teacher leadership by publishing case studies of teacher-leader experience and development.
6) A research-based model for leadership development, disseminated through publications, conferences, and the future work of the *Math TLC* participants.
7) Dissemination through MSPnet and other teaching-focused web sites of our understanding of the effectiveness of the overall *Math TLC* model as indicated by K-12 student achievement data and participant reports.

## 6. Evaluation Plan – Also See Supplemental Documents

The project's external evaluator **Rose Shaw** taught math for 20 years, has the Ph.D. in Applied Statistics and BS/ MS degrees in Mathematics, and has evaluated numerous NSF projects (LSC, CETP, IGERT, RII, NUE, BD, ADVANCE and LSAMP). Rose is highly committed to improving mathematics education aligned to state and national standards, including the findings of the recent National Math Panel. She is currently the external evaluator of Ft. Morgan school district's Colorado Department of Education funded MSP and her MSP program work extends back to 2004 when she served as an invited member of the NSF national site-visit team that evaluated the University of North Carolina-Chapel Hill MSP.

Process evaluation will be applied in a traditional *context*, *input*, *output* and *outcome system* that will be supplemented by the project's research studies findings. *Context evaluation* will involve a description of participating schools, students, parents, higher education faculty, teachers, and communities. *Input evaluation* will focus on the range of resources (human, material, curricular) used for *Math TLC* activities. *Process evaluation* findings will be used by project PI/co-PIs to understand differences in implementation of processes and differential outcomes. Process evaluation will involve ongoing documentation of the nature of implementation of project activities, modifications in the activities based on formative feedback, and achievement of responsibilities according to project timelines and criteria. These evaluation efforts focus on describing project activities and documenting the extent to which proposed activities were conducted as planned and of quality consistent with good PD and learning practices. An important shared responsibility among the researchers, external evaluator, PIs and co-PIs is communication about systematic analysis

Key Evaluation Questions
(1) Are participating teachers acquiring a knowledge base in mathematics that includes concepts, factual content, and research-based procedures?
(2) Is learning of mathematics facilitated through the use of meta-cognitive strategies that identified, monitored, and regulated cognitive processes?
(3) Are teachers learning research-based strategies, approaches to accommodate learning and a shared vision of teaching in culturally diverse classrooms?
(4) What strategies are implemented to motivate teacher formal and informal learning and how is their ability to lead other teachers being shaped?
(5) Did teachers deepen their understanding of content and pedagogy shifts from 5-8 and 9-12?
(6) Did teachers learn how to use frequent formative assessment of student learning to guide instruction and monitor learners?
(7) Did teachers learn pedagogical content and strategies for intervention and remediation?
(8) Did *Math TLC* activities emphasize deep understanding of content and discipline-based methods of inquiry while developing teachers' cultural competence in mathematics PCK?
(9) Did professional development treat teachers as active learners, help them to build on their existing mathematics knowledge, and get them involved in the professional community?

of project activities and outputs, attainment of benchmarks, and findings in order to coordinate and facilitate project improvement and research processes. The *outcome evaluation* benchmarks are summarized in the supplemental materials.

Formative evaluation, consisting of implementation and progress evaluations, will provide project leadership with timely, accurate information that can be used to improve the long-term effectiveness of the project by adjusting activities; monitoring the meshing of new ideas with well-established beliefs and practices; improving strategies; sharing accountability, and strengthening communication and commitment among partnership members. The formative and summative evaluations will be results-oriented, defining issues, informing, and providing supporting evidence. All quantitative data will be disaggregated by No Child Left Behind categories (ethnicity, disability status, etc). Summative longitudinal trend analysis will monitor progress toward meeting the project's goal of enhancing mathematics achievement through master teacher and teacher-leader development.

## 7. Partnership Management/Governance Plan

*The Affiliation Agreement.* The ACCLAIM Project is a highly successful Center for Learning and Teaching that provides a model for developing virtual degree programs across multiple university partners. Bob Mayes, a *Math TLC* Co-PI, was a Co-PI on ACCLAIM. A letter of affiliation will be signed by the Chief Academic Officer of the two initial university partners, then negotiations with additional university partners in future years of the grant will include letters of affiliation. The letter provides for an efficient and equitable means of conducting the joint programs across universities. This includes the creation of an Advisory Board made up of faculty and administration from the university partners that reviews the program; determines admission and enrollment criteria for the program accepted by all university partners; sets expectations for coursework including number of mathematics content hours, distribution of course delivery formats, in-state tuition and fee charges, and acceptance of course credit for the programs across the partner universities; makeup of graduate committees across universities for the program; establishment of a common distance education platform for the program; and graduation requirements for the program.

*Partnership Management.* The project will be managed by teams. The PI and project manager will oversee day-to-day operations of the *Math TLC* and will regularly interact with team leaders.

*Table 3. Project Teams.*

| Team Name | Team Membership, Lead in Italics | Responsibilities |
|---|---|---|
| Project Leadership Team (PLT) | *J. Novak*, R. Mayes, M. Christiansen, S. Hauk, B. Shader | Guidance and oversight of *Math TLC* |
| Research Team (RT) | *S. Hauk,* R. Powers, H. Ku, post-doc(s), grad students | Implement the research plan, report regularly to PLT what they are learning through internal, formative assessment, disseminate research; recruit and review post-doc applications |
| MA Team UNCo | *R. Powers*, B. Blubaugh, S. Leth, former graduate | Evaluate and admit participants, manage development and delivery of programs, develop and maintain partnership. |
| MA Team UW | *R. Mayes*, B. Shader, M. Chamberlin, Wyoming teacher-leader | |
| Teacher Leadership Team | *J. Novak*, R. Mayes, R. Powers, M. Chamberlin, M. Christiansen, K Williams | Develop and implement the teacher leadership component |
| Affiliation Team | *B. Mayes,* J. Novak, appropriate representatives from both Math Depts, MAST, SMTC, College of Education (UW) and administrative offices at both campuses | Negotiate an affiliation agreement between UNCo and UWy to ensure smooth delivery of joint master's program and long-term sustainability of the *Math TLC* model |

*Management Plan.* The PLT will meet monthly to discuss ongoing implementation of the project to ensure broad goals are being met. As part of the regular agenda, we will take immediate action on obstacles to delivery. The project will hold yearly full day planning meetings with the PLT and leads for each team in conjunction with the yearly National Advisory Board meeting. In addition, the PI will meet with the lead from each team monthly and with all team leaders quarterly. External Evaluator Rose Shaw reports at least quarterly to the PLT.

**8. Institutional Change and Sustainability**

The *Math TLC* will create institutional change through the creation of collaborative regional programs for culturally competent mathematics education. The UWy and UNCo will enter into an affiliation agreement that institutes a virtual master's program and a leadership program. The affiliation will require that courses are accepted for credit towards a degree across institutions, that teachers can take courses at in-state tuition rates, and that courses are team-developed by mathematicians and mathematics educators across the two universities. Such an affiliation indicates an extraordinary institutional change as the universities move to becoming joint providers of a regional degree program. The *Math TLC* development of these mathematics programs will serve as a model for similar programs in secondary science education, including chemistry, biology, physics, and earth sciences. Expanding the model K-12 science teachers would require an expansion in the university partnership as well, with affiliations across multiple universities in the Rocky Mountain region.

Institutional change will also occur due to the collaboration of mathematicians and mathematics educators who create and implement the courses in the programs. Their interaction with $4^{th}$ to $12^{th}$ grade mathematics teachers will open a dialogue around content and culturally relevant pedagogy issues that will have far reaching impacts on how mathematicians view their role in education. Offering mathematics courses online constitutes another instance of institutional change. Some STEM professors are reluctant to offer mathematics or science online. This project will provide support for their learning about alternate instructional techniques and a safe space to explore the use of powerful online tools to assist them. The long-term result of providing quality online STEM courses to teachers in the field will have a deep impact on professional development in local school districts.

The university affiliation and school partnership are the basis of sustaining the program, increasing faculty capacity to deliver the program and providing access to a pool of teachers. Recruiting across the region allows for large enough enrollments for programs to be self-sustaining. Tuition and fees flow to the university teaching the course; courses will be equally shared across institutions. The increased enrollments will offset accepting course credits from other institutions, making it a profitable model for all the institutional partners.

**Dissemination and Communication Outcomes.** In addition to the research products (see §5.3), the *Math TLC* will establish a web portal hosted through a collaboration between MAST and SMTC. This web site will include a virtual library of links to research and evaluation products as well as to master teacher, teacher-leader, and teacher-educator products (e.g., action research theses, leadership portfolios, professional dossiers by post-docs and university faculty). Also, information about *Math TLC* seminars that are open to the public will be available through this web portal and through MAST and SMTC phone and email support for partner districts.