Abstract Title:
Defining Effective Mathematics Teachers: How Can Professional Development Promote Evidence-Based Definitions?

MSP Project Name:
West Texas Middle School Math Partnership

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Strand 2

Summary:
The theoretical model that underlies the West Texas Middle School Math Partnership addresses: (1) conceptual understanding of the math taught in middle school, (2) knowledge for teaching math; (3) teaching self-efficacy; and (4) culturally and linguistically sensitive instruction. Thus, effective teaching in mathematics from this perspective involves a focus on conceptual understanding utilizing instructional practices that address students' cultural and linguistic needs as well as interaction patterns that promote positive student self-efficacy of mathematics content learning. Evidence in support of the theory of action was found. Teachers' conceptual mathematical knowledge, content knowledge for teaching, and self-efficacy has grown consistently. Improvements in culturally and linguistically sensitive instruction have lagged behind. Implications are discussed and lessons learned are presented.

Section 1: Questions for dialogue at the MSP LNC
What role does depth of knowledge and content knowledge play in effective teaching of math in the middle school? How can ongoing professional development support acquisition of content knowledge for teaching? How can ongoing professional development support differences in initial teaching self-efficacy, learning needs, and curriculum constraints? How can self determination theory address differences in teachers' learning needs during professional development activities? How should follow-up training sessions be organized to support transformational learning?

Section 2: Conceptual framework
The TIMSS study (Stigler & Hiebert, 1999) has revealed that "a focus on teaching must avoid the temptation to consider only the superficial aspects of teaching: the organization, tools, curriculum, and textbooks. The cultural activity of teaching—the ways in which the teacher and students interact about the subject—can be more powerful than the curriculum materials that teachers use" (Stigler & Hiebert, 2004, pp. 17). Although the results of the TIMSS study resulted in increased research and dialogue about best practices in mathematics, very little attention has

been given to interactions between the teacher and student during mathematics instruction that leads to or impedes mathematical thinking and problem solving. The evolving conception of effective mathematics teaching for the WTMSMP embraces this fundamental principle. Standardized curricula simply cannot predict every potential student response to instruction; responses from which teachers base their moment-by-moment interactions with students. Even curriculum materials that include highly cognitive tasks are insufficient to for promoting mathematical reasoning (Stein, 2009). Drawing on a substantial body of work from the learning sciences (socio-cultural and situated learning theory), we contend that it is through these moment-by-moment interactions with students that teachers can develop critical thinking skills, particularly mathematical reasoning (Aguirre-Muñoz, 2011). Both deep conceptual knowledge and careful planning of instructional moves are necessary to make in the moment decisions that foster reasoning and sense making in mathematics.

Thus, the West Texas Middle School Math Partnership (WTMSMP) is based on a theoretical model that focuses on addressing not only the conceptual understanding of the math taught in middle school and the knowledge for teaching of such math, but also on culturally and linguistically sensitive instruction and the development of self-efficacy of participating teachers and their students. The importance of deep conceptual understanding of the content and knowledge for teaching that content has been well documented (e.g., Shulman, 1986; Hill & Ball, 2004). Self-efficacy research has demonstrated that it positively affects teachers' instructional practices and, ultimately, the mathematics achievement of their students. That is, we believe that a teacher's level of competence and confidence affect the attitudes and achievement levels of her/his students. Thus, effective teaching in mathematics from this perspective involves a focus on conceptual understanding (Grouws & Smith, 2000) utilizing instructional practices that address students' cultural and linguistic needs as well as interaction patterns that promote positive self-efficacy of mathematics content learning. Following this perspective, the theory of action includes four key program inputs: challenging mathematics courses and curricula, training on self-efficacy building, training on instructional practices for culturally and linguistically diverse students, and ongoing support through web-based resources (wiki and Facebook pages).

Challenging mathematics courses are needed due to the recognition that a focus on conceptual understanding requires that teachers have a profound understanding of the mathematics they teach. Thus, the mathematics courses engage teachers in complex math problems to forge transformative learning and instructional change. Further, an assumption we made (and tested) was that increasing teacher knowledge will in turn increase their self-efficacy to teach mathematics. Increasing teachers' self-efficacy is important because it has been associated with their students' self-efficacy which, in turn, has been linked with students' mathematics achievement. Therefore, self-efficacy building training is included to assist teachers to promote their students' mathematical self-efficacy.

Research on effective instructional strategies for teaching content to linguistically and culturally diverse students has identified the following concepts: scaffolding instruction, providing visual displays of information, making links to prior knowledge and experience, verbally interacting with students throughout the learning process, as well as incorporating higher order thinking skills. Effective instruction for English learners involves mediation between students' current linguistic levels in English and their commonsense understandings of the content concepts, on the one hand, and academic language and expert knowledge of the subject on the other hand. Unfortunately, teachers are ill-prepared to provide such instruction. Therefore, training on instructional practices for culturally and linguistically diverse students is also included in our model.

Support during the academic year is important in translating course content to instructional practice, therefore, academic year support is provided through the establishment of the WTMSMP web site and Facebook page supporting a virtual community of educational professionals. These online resources facilitate communication between teachers separated by great distances.

The combination of these components is expected to increase teachers' conceptual mathematical knowledge, develop culturally and linguistically sensitive instruction as well as develop high teaching and mathematical self-efficacy. These proximal outcomes are then expected to facilitate teachers' application of new knowledge and skills while addressing students' cultural and linguistic needs. Once these intermediate effects are reached, increases in student mathematics self-efficacy are expected which, in turn, leads to improvements in achievement across all groups.

Section 3: Explanatory framework

After three intensive summer courses, we have found evidence in support of the theory of action as it relates to the three proximal outcomes. That is, we observed an increase teachers' conceptual mathematical knowledge and content knowledge for teaching, an increase in instruction that is culturally and linguistically sensitive (after the first course) as well as an increase in participating teachers' teaching and mathematical self-efficacy which correlated to increases in content teacher knowledge in complex ways.

Evaluation/Research Design.

The evaluation design is comprised of two phases that will determine the extent to which the program is meeting its intended outcomes, categorized as proximal, intermediate and distal effects. In **Phase I**, conducted in Years 1 and 2, the evaluation focused on obtaining information regarding context as well as determining the success of the program in achieving its proximal or initial effects. Baseline data for each of the research questions was collected prior to program activities to determine the relative magnitude of the impact. In this phase, survey instruments and measures were also piloted. In **Phase II**, years 3 through 5, Phase I data will be collected for the second cohort; however, the focus will be on gathering information to determine the extent to which intermediate and distal effects that occur as participants advance through the project activities are achieved, in particular the overall increase in students' mathematics self-efficacy and ultimately mathematics achievement, especially that of minorities.

In Year 3, profile analyses of teachers were used to evaluate the parallelism, equality of levels, and flatness of profiles for participants' total teaching self-efficacy scores as well as each subscale (i.e., instruction, engagement, and classroom management) and conducted using SPSS 18.

Self-Efficacy & Project Activities.

The WTMSMP activities were associated with increases in teachers' self-efficacy, but this relationship is complex. The most recent findings demonstrate that teachers do arrive at professional development opportunities with existing differences in self-efficacy and those differences are related to their mathematical background. In our case, teachers with a stronger mathematical background ended the course sequence with greater content knowledge than those with a background of only algebra or less; however, net gain comparisons were effectively equivalent. The self-efficacy growth of the teachers with a weaker mathematics background was much smaller, which did not appear to be the result of a ceiling effect; however, this group of teachers did have less room to grow, because they started out with very high self-efficacy. Despite the differences observed in teaching self-efficacy between the two groups of teachers divided by mathematical background, both groups experienced self-efficacy declines at the third time point. That is, immediately following professional development, teaching self-efficacy increased for both groups but upon returning from teaching a full school year, they declined. This suggests that real world challenges may create considerable obstacles that prevent teachers from incorporating knowledge and skills gained from professional development into their teaching.

Teacher Perceptions of Course Activities

Further, factor analysis on a q-sort task targeting teachers' perceptions of the course content revealed the presence of three factors, which were interpreted to represent three distinct types of learners and appear to be consistent with the three key basic needs identified by Self Determination Theory: relatedness, competence, and autonomy. That is, teachers appeared to interact with course strategies and activities in a manner that met underlying needs for learning. Participants in the relatedness group favored activities that emphasized social interaction; participants in the competence group favored items that emphasized understanding; and participants in the autonomy group favored items that emphasized his/her ability to seek out learning opportunities. Despite these differences, participants from the three preference types did not significantly vary in characteristics, such as gender, background in mathematics, or the number of years teaching. Teacher perception did not differ across the four university locations where they completed the course. Most importantly, participants from the three preference types did not differ in their knowledge gain scores from pre-test to post-test. This finding underscores past research showing that variation in course strategies and activities may be necessary to meet the varied learning needs of mathematics teachers.

Teacher Practice

Observations of a small sample of teachers indicate significant growth between Time 1 (pre-test) and Time 2 in teacher conceptual explanations to students as well as the total score of the observation instrument. The other two dimensions of the observation instrument (self-efficacy and culturally sensitive instruction) was not statistically significant, however the overall means did increase. Time 2 to Time 3 observations revealed no statistically significant growth in any of the dimensions of the observation instrument. This is partially due to the lack of self-efficacy training during the second mathematics course as well as additions made to the observation. To better capture our evolving definition of teaching effectiveness, additional dimensions were added at Time 3 that may have made the instrument too cumbersome at Time 3. Thus, the results may be due to an instrumentation issue. Raters noted difficulties with the judgment procedures.

Another possible explanation would be that the online support may not be sufficient in eliciting continued change in teacher practice. Indeed this may be a weakness in our design that demands direct attention. Yet another potential explanation is the introduction of a new state-wide curriculum that was mandated in 98% of districts with little to no professional development provided to teachers. Teachers may have perceived the practices emphasized in the courses to be inconsistent with the new curriculum and thus reduced their implementation of practices learned in course content. More probable is that they were simply overwhelmed with the new expectations of the curriculum, and consequently little thought was given to implementing the course content.

Section 4: Lessons learned

Our experience is consistent with other research that suggests that teacher transformative learning is a highly complex issue that may not be fully addressed by an exclusive focus on content knowledge growth. Our results indicate that teachers' conceptual content knowledge has grown significantly. This growth is coupled with significant increases in self-efficacy. However, consistent changes in teacher practice may lag behind if significant support is not provided on an ongoing basis and over time. This lag may be exacerbated when significant and mandated changes are imposed on teachers. Initial support through a topic-specific social network (i.e., Ning) was ineffective in engaging teachers in ongoing discussion about program implementation. The use of Facebook has improved teacher engagement during the academic year; however it has not resulted in consistent increases in effective mathematics teaching. More direct interaction with teachers is likely necessary.

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Abstract Title:
The Role of Vocabulary in "Inquiry" Science Instruction for English Language Learners

MSP Project Name: Minority Student Pipeline MSP

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Summary:
Researchers disagree about how best to introduce vocabulary to English language learners (ELLs) to facilitate inquiry discussions. Some advocate frontloading vocabulary, so that ELLs can express themselves more easily. Others advocate letting ELLs begin discussions using whatever words they have available, and introducing vocabulary responsively, when students request it to express an idea. The data underlying this debate, however, has mostly been teacher reflections and field notes, not videotaped classroom episodes subjected to fine-grained analysis. Our videotaped examples of ELLs engaging in inquiry suggest the ELLs can engage productively in inquiry without frontloaded vocabulary. In fact, frontloading vocabulary can have the unintended side effect of reinforcing students' framing of science as words to learn rather than ideas to hash out.

Section 1: Questions for dialogue

With English language learners (ELLs), some researchers encourage teachers to "introduce key vocabulary in the beginning of lessons" (Lee, Penfield, & Maerten-Rivera, 2009) in order to link prior knowledge to new concepts and to facilitate communication in English. Other researchers advocate deemphasizing vocabulary, introducing it as needed so that ELLs stretch themselves "to absorb and use new vocabulary in order to express their ideas" (Buck, Mast, Ehlers, & Franklin, 2005).

In this session, we want to spark discussion about when and how vocabulary should be introduced in "inquiry" lessons for ELLs. Related questions include: What are the possible unintended side effects of frontloading or not frontloading vocabulary? How does the evidence we see in particular classroom episodes relate to general theories of language acquisition and learning?

Section 2: Conceptual framework

To contextualize our definition of effective teaching, it will help to first describe our MSP project. Our project focuses on keeping underrepresented students in the STEM pipeline through high school and into college. In one strand of this broader effort, we conduct professional development with grade 4-8 teachers aimed at helping them engage their students in scientific inquiry in the classroom. For the purposes of this paper, we focus on two components of effective science teaching aimed at engaging ELLs.

The first component is effectively engaging students in scientific inquiry, by which we mean the pursuit of coherent, causal explanations of natural phenomena. Notice that this definition encompasses not just empirical investigations but also discussions and argumentation centered around constructing causal explanations and spotting/ reconciling inconsistencies among ideas and between ideas and evidence. Effective teaching, for us, is teaching that draws on students' pre-existing intellectual resources to engage them in inquiry as just defined, and that helps stabilize their inquiry in the long run by helping students see the difference between authentic inquiry and simply spewing vocabulary words or doing a hands-on activity disconnected from an exploration of causal mechanisms. Put another way, we think effective instruction helps students come to understand what scientific inquiry *is*.

The second component of effective instruction involves language acquisition/learning; we want teachers to create learning environments in which ELLs don't just learn scientific *words* in a "rote" manner, but gradually gain command over the scientific *discourse* in which that language is embedded (Gee, 2008). The language learning/acquisition community has long thought that gaining command over academic language involves a combination of direct instruction and more naturalistic" acquisition as occurs when young children learn their first language (Krashen, 1981). For ELLs, the debate is over how much to emphasize and frontload direct vocabulary instruction. Our purpose in this session isn't to take a stance on this issue, but to argue that the decision should be based in part of on videotaped episodes of ELLs' discourse in inquiry lessons.

Section 3: Explanatory framework

In this exploratory qualitative work, by analyzing classroom video of English language learners engaging in scientific inquiry discussions, we are trying to see what role the introduction of vocabulary plays in facilitating or hindering students' participation in the inquiry. Our analysis uses tools from discourse and framing analysis (Erving Goffman, 1974; E. Goffman, 1979; Sacks, Schegloff, & Jefferson, 1974; Tannen, 1993) to explicate not only the content of the students' statements, but also probe what kind of activity they perceive themselves to be engaged in (e.g., searching for the "right" answer vs. making sense of a physical phenomenon).

This kind of analysis will enable to explore such issues as

How does frontloading vocabulary affect how students frame the rest of the lesson?
Under what conditions does frontloading or otherwise emphasizing vocabulary hinder rather than facilitate inquiry?
Under what conditions will students spontaneously request to learn vocabulary?

Insight into these issue will inform our day-to-day work with grade 4-8 teachers, helping them gain comfort and skill at facilitating scientific inquiry for all students. It will also help researchers formulate hypotheses to test in future, more systematic study of these issues

Section 4: Lessons learned

This exploratory work has not and will not yield definitive prescriptions for teachers or teacher educators. And we cannot generalize our preliminary results too broadly. With these disclaimers in place, however, we can report the following: Our videotaped examples suggest the English language learners can engage productively in inquiry without frontloaded vocabulary. In fact, frontloading vocabulary can have the unintended side effect of reinforcing students' framing of science as words to learn rather than ideas to hash out.

In one classroom episode, two co-teachers in a 5th grade class of mostly ELLs decided to take alternate approaches, serially, during a discussion of why cooking utensils often have wood (rather than metal) handles. Mr. L de-emphasized vocabulary, and students showed evidence of framing their activity as sense-making based on everyday experiences and intuitions:

J: With the wood, it could catch on fire… you could be cooking and the fire is there.. the wood could catch on fire...

Another student immediately responded to J's concern:

K: I was asking why the spatula was a good tool with the wood handle, it IS because I thought about the wood is not really touching the fire… it CAN burn, but it's not possible... as long as you don't have the wood in the fire.

By contrast, when the other co-teacher focused students' attention on a particular vocabulary word, students adopted a more authority-driven stance ("Help us," "What's the answer?").

In another episode from a 6th grade classroom discussion of how birds, bats, and butterflies all came to have wings, "Theo" took active part, despite trouble expressing his ideas in English. Challenging another student's argument that all three creatures shared a common, winged ancestor, Theo put forth the idea that birds, bats, and bugs started out long ago as separate kinds of creatures, all of whom developed wings:

Theo: Their ancestors were different. They had birds, bats, and bugs. And they keep on going, going, going forever… she said they started from one… but I said they started from THREE…

Soon after, when challenged to defend why "three," Theo walked up to the co-teacher and asked for the word— he thinks maybe "animal" or "mammal" — that labels bats and birds but not insects. Theo's interest in defending his argument, using what he perceives to be the gulf between insects and "animals," motivated his seeking relevant vocabulary.

Of course, frontloading vocabulary is not always problematic, and video such as our can help us find the conditions under which it is helpful. More generally, classroom data such as these examples can help us attend to the particular in-the-moment effects that unfold in classrooms employing different pedagogical approaches.

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Abstract Title:
Infusing Issues in Sustainability Science Across the Curriculum to Motivate Improved Teaching and Learning in STEM

MSP Project Name: (ES)2

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Summary:
Improving science education is essential to improving global human sustainability. Sustainability Science, which spans the interface of natural and social systems, provides creative new methods for analyzing human*Earth ecosystems, and engineering a 21st Century green economy. Our theory of action extends these approaches into the domains of STEM education. Our project will create a network of 10 school districts and 5 IHE's in southeastern PA organized into Professional Learning Communities PLC's and woven into a matrix of IHE course offerings, certificates, and a Master's Degree in Sustainability Science Education for teachers that will design and implement new and innovative curricula that infuses project-based sustainability issues into STEM courses across the curriculum. We suggest that these infusions will cause students to learn because learning is driven by motivation to learn, and sustainability is relevant, engaging, interdisciplinary, and brings a novel approach to learning in STEM. We present five case studies of this approach that emerged from our NSF MSP START (08-32049) grant for undergraduate courses in environmental science, biology, chemistry, and math, and for a graduate "green externship" course for in-service high school teachers. We are currently seeking funding to implement our full design across grades 4-16 among our SD and IHE partners.

Section 1: Questions for dialogue at the MSP LNC

(A) In our survey of teachers from our NSF MSP START grant, teachers expressed great interest in sustainability issues and in teaching their students about sustainability. However, "standards" and other curricular constraints on courses and programs often prevent them from following through on these intentions. This reveals a disconnect between what is being taught and what teachers feel is important. We view this as an important opportunity to capitalize on the motivating nature of sustainability issues (a) to engage teachers in the challenging work of community-based professional development and curricular improvement, and (b) to improve student learning by engaging them in project-based curricula in sustainability science at the exciting nexus of STEM solutions to the grand challenges of our time – while preparing students with cutting-edge career skills. The question is how?

(B) Research suggests that Professional Learning Communities (PLC's) can create, adapt, diffuse/ spread, and institute innovation to affect systemic reform in STEM education, improve student STEM learning, and move partner institutions (school districts and IHE's) toward sustainability. This is believed to occur through two constructs, (a) diffusion of innovation (relative advantage, compatibility, low complexity, trial-ability, and observability, Rogers 2003), and (b) community-based collaborative knowledge construction motivated by outcomes alignment & learning reciprocity (social agency/ support networks/ metacognition). How can we design a framework and operational structure of PLC's spanning Faculty and Administrators across grade scales (grades 4-12, and IHE's) and STEM disciplines? Further, we want to combine face-to-face meetings with e-meetings and wiki's to create searchable archives of findings that will propel innovation in our own network and beyond.

(C) How can we design and manage a "Mega University" as a "mega" learning community across IHE's and school districts to organize, catalyze, and propagate systemic reform through curricular offerings (degrees and certificates), workshops, and professional learning community engagement, across the landscape of diverse and distinct IHE's and school districts? Given that no one IHE possesses all of the attributes and capacities necessary for large scale systemic K-16 STEM educational reform, how can we combine our talents, pool our efforts, and maximize our impact?

(D) How can we engage teachers and school district Administrators in the development and refinement of university-school district-community-business collaborations to promote student acquisition of 21st Century skills and a "greener" more sustainable society? Students need to feel not only that there is hope for a sustainable future but more importantly that they themselves can become the critical agents of change that will engineer this transformation. How can we design PLC's that will create greener schools, communities, and local businesses by combining professional expertise in operations, sustainability, and student learning in STEM?

Section 2: Conceptual framework

Effective teaching in STEM is the careful design and execution of concepts and pedagogy that will not only motivate students to engage in scientific thought but will serve to build an important foundation upon which to address important societal problems. We believe that sustainability is such a compelling and authentic issue of widespread interest that it will serve as the "hook" to engage individuals and educational institutions to undertake the challenging and exciting work of reforming practice. Our theory of action and overarching research hypothesis is that by infusing issues of sustainability into STEM courses, students will be more motivated to learn core STEM concepts because sustainability is:

a. Relevant and links to people's lives in many ways
b. Well-suited to active learning and service learning pedagogies
c. Inherently interdisciplinary, a feature that is essential for engaging diverse learners
d. Novel. The novelty decouples many "lower" performing students from their prior failures in STEM, thus, enabling new expectations of learning success to germinate and thrive.

Section 3: Explanatory framework

From our MSP START Project, our next steps for full implementation are to create a network of 10 school districts and 5 IHE's in southeastern PA organized into professional learning communities (woven into a matrix of IHE course offerings, certificates, and a Master's Degree in Sustainability Science Education for teachers) that will design and implement new and innovative curricula that infuses project-based sustainability issues into STEM courses across the curriculum. Preliminary findings from our PLC's and pilot courses over the past 3 years are both tentative (small samples) and tantalizing. We have found that by infusing sustainability issues into mainstream undergraduate science courses (spanning environmental science, biology, chemistry and math) and in a small number of pre-college courses from a pilot group, IHE faculty and high school teachers are excited about trying new innovations in sustainability issues in their teaching, improving their skills at classroom research on teaching and learning to measure the effects of these innovations on STEM learning, and engaging in professional learning communities to actualize the diffusion of innovation. These findings are clearly consistent with extensive research (Ames & Ames 1984, Brophy 1987, McMillan & Forsyth 1991, Schunk 1991, Pintrich & Schunk 1996, Bandura 1997, Bransford *et al.* 2000, Pajares & Schunk 2005) showing that teachers teach better (curriculum, instruction, assessment) and students learn better when each is motivated to do so. The next steps of this program (pending funding) involve extending our models of teacher and IHE faculty professional development to broader contexts of learning progressions across grades 4-16 and STEM curricula.

Section 4: Lessons learned

From our MSP START Project, we learned that IHE faculty and teachers believe that important topics such as those covered in sustainability science represent important opportunities to engage students in learning STEM content, yet, sustainability science in any form is generally absent from the curriculum. To a large extent this disconnect stems from the paucity of opportunities for professional development and scarcity of scaffolding of teacher learning as to how to meet these dual challenges of STEM learning and broader issues in global environmental sustainability and civic engagement for their students. The results of this survey and our analyses are currently being organized for publication. At this point, numerous research directions have emerged for our project and we look forward to the realization of means and capacity to pursue them.

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Abstract name:
Bridging Research and Knowledge to Application in an Effort to Refine Strategic Goals, Program Implementation, and Evaluation Methods

MSP Project: Project MAST

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Summary:
The Mississippi Academy for Science Teaching (Project MAST) is a professional development program intended to provide high school science teachers with the content and pedagogy necessary to teach the state's physical science standards. Halfway through the project, MAST staff and evaluators revisited their original strategic plan; an activity termed the Teacher Effectiveness Action White Paper Project. The TEAWPP defines what MAST is, based on the strongest alignment between the proposed theory of action, the professional development literature, and empirical evidence of the program's implementation and outcomes. Locating the program within the larger literature base helped illustrate the critical components of MAST that lead to better teaching. The TEAWPP protocol can serve as an evaluation model and help inspire program revisions.

<u>Section 1: Questions for dialogue at the MSP LNC</u>
What are some strategies for bridging research to project implementation, and aligning strategic plans, theoretical plans of action, and current empirical evidence to build a much stronger conceptual framework of effective STEM teaching and professional development?

How should strategic plans and theoretical plans of action change based on: relevant literature and empirical findings of the past, what projects on STEM teaching are actively finding, and current empirical evidence and literature?

How can a collaborative white paper project and literature review, during program implementation, be included as part of all STEM education programs on teacher professional development and effective teaching?

<u>Section 2: Conceptual framework</u>
Our project defines "effective science teaching" as engaging students in content-rich science inquiry, guided by teachers with a deep understanding of the subject matter. The Mississippi

Academy for Science Teaching (Project MAST) brings together high school teachers from across the state to learn from a variety of experts and then immediately apply what they've learned into the classroom.

Teachers learn science content during four weeks of graduate-level training (over a three week period), teaching skills through lectures and hands-on activities designed for a high school audience. The teachers that participate in these workshops are trained primarily by Jackson State University faculty, and educators from other universities and school districts outside the state. In addition, they receive relevant science materials for their classrooms to help engage and teach their students. The combination of graduate courses, instructional materials and classroom visits from Project MAST programmers are expected to lead to improvements in teachers' content knowledge, teaching practices, and growth in student content knowledge and positive attitudes toward science.

At the beginning of our NSF grant, Project MAST staff and evaluators prepared a strategic plan outlining the project's theory of change, as well as its goals, activities, outcomes, and evaluation. Halfway through the project, we are revisiting that strategic plan through an activity we call the Project MAST Teacher Effectiveness Action White Paper Project. The TEAWPP, by definition, seeks to define what MAST is, based on the strongest alignment between the proposed theory of action, the professional development literature, and empirical evidence of the program's implementation and outcomes. Over the next few months, we will review current and past MAST projects and evaluation reports along with theoretical and empirical literature on effective science teaching and professional development. We will then locate our program within the larger literature base in order to define the critical components of Project MAST that lead to better teaching. This reflective process allows us to revisit our NSF strategic plan and make any changes based on two years of program implementation, and literature on effective practices.

<u>Section 3: Explanatory framework</u>

This evaluation and writing process by the TEAWPP that Project MAST has adopted will reveal insights into how our definition of effective STEM teaching and professional development should be changing. The following serves as our TEAWPP protocol (, highlighting specific guidelines that we have created and followed during this reflective writing process:

Project MAST Teacher Effectiveness Action White Paper Project (TEAWPP) Protocol:

1. Defining Goals and Framework
2. Literature Review and Acquiring Information
3. Organization of Content
4. Write
5. Review and Revise
6. Publish

Below are descriptions of each section.

<u>Defining Goals and Framework</u>

During this initial phase, project evaluators reviewed the goals of this White Paper Project, and sought to demonstrate that Project MAST is effective in improving STEM teaching and learning, and successfully addresses the need to give teachers more hands on science content training. We also discussed the purpose of this collaboration, and who our audience will be. Brainstorming sessions took place, as well as various team meetings to discuss the project plan and purpose. A team was then assembled that included the Project MAST managing Director and Lead Investigator, a MAST Program Manager, and two third-party Evaluators.

Project MAST staff and external evaluators revisited, and reflected upon, the original strategic plan and proposed theory of action midway through the 2011-2012 school year. The goals of this reflective process were to clarify the project's strategic plan and proposed theory of action, while aligning the findings of Project MAST with current literature on effective STEM teaching and student outcomes. In addition, the goals of this phase in evaluation were to help staff and evaluators provide a framework for the variety of current research on effective STEM teaching, and alignment of claims and components in the literature, relevant to the five critical features of professional development for effective teaching: "(a) content focus, (b) active learning, (c) coherence, (d) duration, and (e) collective participation" (Desimone, 2009, p. 183). This particular phase of evaluation will provide insight as to how Project MAST's definition of "effective STEM teaching" should be changed and refined based on what has been empirically proven in the past, what the project's current evidence is showing, and how effective PD contains certain elements that are grounded in current PD literature.

<u>Literature Review and Acquiring Information & Organization of Content</u>

This phase involved a review of the original Project MAST proposals, reports and relevant documents, as well as extensive research and a thorough review of current literature on teacher professional development. We began by sharing the literature used to frame our evaluation, especially our professional development observation protocol (Bass & Mushlin, 2010). We then consulted the last three years of top-tier journals such as the American Educational Research Journal (AERJ), Educational Researcher (ER) and the Journal for the Association of Research on Science Teaching (JARST) for more recent literature on the characteristics of effective teacher professional development. Our goal was to construct a collection of 8-10 key papers, which we could use as anchor points, in an effort to frame and justify Project MAST's theory and practice.

Two Project MAST staff and two evaluators read, coded, and discussed eight research papers that covered a range of themes, including: pedagogical content knowledge, student learning, teacher professional development, and research methods for evaluating effective STEM teaching and practice. The rationale for selecting the research papers was an important consideration for beginning the white paper writing process. This criterion was of critical importance, because it provided a means for staff and evaluators to quickly engage in the research results. Overall, the papers stimulated intense discussion. The staff and evaluators that participated in the white paper writing process were successful in identifying the main research questions, key findings, and ways in which the current PD literature validated, or invalidated, Project MAST outcomes and their own beliefs about effective STEM teaching. One key way that staff and evaluators aligned current literature to Projects MAST's goals and objectives, and attempted to connect research to project implementation, was to qualitatively code the current literature.

In this stage of assessment, Project MAST staff and evaluators extracted and evaluated the information in the literature that met their inclusion criteria. In other words, all articles were qualitatively coded. To begin, each reviewer devised their own system for extracting data from the articles. The type of codes created, by this extraction of data, was determined by the themes and frameworks that are relevant to Project MAST and the program's goals and objectives. For example, if one of the four reviewers came across the topic of professional development or effective STEM teaching (two over-arching themes in Project MAST), they would create a code (one or two words) that best defines that particular phrase or section and decide how to best integrate those themes and outcomes to the project's current model.

Whether the procedures for coding or extracting the data are included in a master code list, or included within the body of the white paper report, the level of detail should be such that, actually or theoretically, a second person could arrive at more or less the same results by following the group's protocol. It is also valuable to see the discrepancies amongst some of the codes to help encourage dialogue related to coherence and alignment between the research and Project MAST's objectives. The literature review, during Project MAST's midpoint, will require the coding of data that may influence research outcomes, and help bridge the knowledge-application gap. Examining previous literature reviews, before, during, and after the duration of Project MAST is helpful to understand the scope and organization of the project, and may serve a model for how to best evaluate STEM teaching and professional development.

Hart (1998) points out additional reasons for reviewing relevant literature, including: distinguishing what has been done from what needs to be done, discovering important variables relevant to the topic, synthesizing and gaining a new perspective, identifying relationships between ideas and practices, establishing the context of the topic or problem, rationalizing the significance of the problem, understanding the structure of the subject, relating ideas and theory to applications, identifying the main methodologies and research techniques that have been used, and placing the research in a historical context to show familiarity with state-of-the-art developments (p. 27) . Writing a collaborative literature review will provide a framework for relating new findings to previous findings. Without establishing the state of the previous research on effective STEM teaching and professional development, it is impossible to establish how the new research advances the previous research. Following a thorough literature review and an alignment of the original strategic plan and goals, the professional development literature, and empirical evidence of the program's implementation and outcomes, the collaborative writing process will begin.

Beginning in the fall of 2011, Project MAST staff and evaluators began piloting the Teacher Effectiveness Action White Paper Project with the hopes of updating our strategic plan to reflect current trends in the literature. This model is being designed collaboratively to assess research and outcomes aligned to teacher professional development, STEM education, and how to best improve student outcomes in STEM subjects and keep students engaged in the sciences. Project MAST will help inform our thinking for the implementation of a new evaluation and development system that meets the needs of all teachers, schools and administrators, with the potential for district-wide implementation throughout Mississippi and related programs.

As part of this new evaluation project there will be one White Paper released during the 2011-

2012 school year. The White Paper will cover different topics ranging from Project MAST's purpose and design to the project's progress and results. The paper will serve a dual purpose—open sharing about this pilot evaluation procedure to related STEM education programs and as a basis for stimulating discussion about teacher evaluation and development among educators and school districts.

Section 4: Lessons Learned

So far, the Teacher Effectiveness Action White Paper Project has been an excellent forum for staff members and evaluators from diverse backgrounds to share their conceptions of Project MAST and its ties to published literature. The team includes project staff who have been a part of MAST since its inception, as well as evaluators who are new to the group. The project has given us a shared language for describing MAST activities and the opportunity to think about where MAST has been and might go in the future. It also has helped us treat our strategic plan as a living document that can and should be revised over the course of our five-year grant. By working on the TEAWPP, project programmers and evaluators can reference current literature, as well as the projects' empirical evidence and outcomes, to modify any areas of project implementation that needs improvement (i.e. teacher training, teacher professional development, etc.). We have learned that this process takes time and commitment from project staff, which can be a challenge in the midst of the practical demands of the project. Once we've made the time, we've found that the reflective benefits are well worth the effort.

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Abstract Name:
Refining Learning Progressions in Astronomy and Plate Tectonics

MSP Project Name:
Middle Grades Earth and Space Science Education Partnership

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Strand 1

Summary:
The Middle Grades Earth and Space Science Partnership defines effective STEM teaching in terms of three criteria: 1) it targets big ideas in science, not topics; 2) it is organized around a coherent content storyline; and 3) it engages students to develop understandings of both science content and the practices of science. As part of the project's effort to define effective teaching we are developing learning progressions in Astronomy, Plate Tectonics, Climate and Energy. Learning progressions are "empirically grounded and testable hypotheses about how students' understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction". We are in year two of our project.

Section 1: Questions for dialogue at the MSP LNC

- How can we best promote meaningful evaluation of and recognition of effective STEM teaching for K-16 teachers and faculty members? How should this process differ (if at all) across the varied K-16 contexts?
- How do we represent learning progressions that are empirically-based in ways that retain the valuable complexity of the school and classroom contexts in which the data were gathered?
- How can learning progressions contribute to effectiveness of STEM teaching practices across K-16 teaching contexts?

Section 2: Conceptual framework

Overall, we define effective teaching in terms of three criteria: 1) it targets big ideas in science, not topics; 2) it is organized around a coherent content storyline; and 3) it engages students in discourse practices that develop understandings of both science content and the practices of science.

Effective teaching is defined first and foremost by student learning, which we consider in multiple ways. We attend to the state mandated Pennsylvania System of School Assessment (PSSA) scores as part of the data we collect. In addition, we attend to local assessments designed by teachers. We also work with teachers to develop these local assessments into more powerful formative tools. Over the life of the project we anticipate these formative assessments will become the more valuable form of data for understanding student learning as they will be linked to individual teachers' context in ways that the standardized assessments will not or can not be. They also will be able to address complex science content understandings and science practices developed by students over time, which we describe in the form of learning progressions. We anticipate that effective teaching will impact students understanding of and participation in the norms and practices of science, and these criteria for effective teaching will be best measured by local formative assessments and observations of teaching and learning in partner teachers' classrooms.

In addition to attending to student learning to define teacher effectiveness, it is also critical to pay attention to the teaching itself. We define effective teaching as being organized around big ideas and a coherent content storyline. This means that effective teachers organize their curricula in a way that is coherent and meaningful to students rather than organizing the content as it would be for a science content expert. To be able to examine this criteria for effectiveness we must look at how teachers plan their curriculum and also how they teach in the classroom. Effective teaching also requires teachers to engage students authentic science activities to provide a context for the discussion of science ideas. These authentic activities need not be labs or "hands-on" activities in the traditional sense, but they must be grounded in phenomena with which students are familiar, or can observe, and build toward more abstract scientific models. Finally, effective teaching requires teachers to be able to negotiate the complex task of scaffolding student discourse to help them build rich understandings of phenomena. It is in this orchestration of discourse where much of the student learning around the practices of science (e.g. scientific argumentation) occurs. Attending to the way teachers organize and teach in their classrooms helps us understand the degree to which practices of teacher participants are becoming closer to our definition of effective teaching. Data for the pedagogical component of effective teaching include curricular planning documents, student artifacts, and teacher conversations about planning, which come from our workshops and professional development activities. We also look at samples of teaching practice via video from partner teachers' classrooms. The samples of teaching practice allow us to examine the ability of teachers to organize classroom discourse to lead students toward deeper content understandings.

While the general criteria for describing effective science teaching hold true in both K-12 and higher education contexts, there are some specific questions/considerations for higher education. The most prominent difference between the two contexts is the structure and organization of higher education courses, especially introductory courses, which tend to be large and lecture-based. What does effective teaching look like in contexts where it is more difficult to engage students in authentic tasks and scaffold their discourse toward deeper content understandings? Related to this question is the question of what data is most useful in measuring effectiveness in higher education? While it is clear that some data, such as student assessments, will be useful in both contexts; It is less clear if all of the data suggested for K-12 make sense to gather for instructors in higher education or if there are data that would be more contextually appropriate.

One measure of effectiveness that could be considered in higher education that is less available in K-12 is the amount of support students receive from the academic safety net. Higher education institutions provide things like office hours, review sessions, tutoring, and other forms of support that could indicate how effective the in-class instruction is for students. If a large number of students are accessing the academic safety net, it gives some indication of the effectiveness of the original instruction. This data, however, is not unproblematic as students take advantage of the academic safety net for a variety of reasons, not all of which have to do with the quality of the original instruction. Our project is considering what data will help us understand effectiveness within the context of higher education beyond student test scores.

One of the goals of the project is to support undergraduate faculty in science disciplines to reconsider/reconceptualize their courses using our definition of effective teaching. For these course revisions at the undergraduate level, we are bringing together science education faculty with STEM faculty to do a bottom-up redesign of targeted science courses. We think effective STEM teaching in higher education begins the same way it does in K-12, with well designed curricula from teams of both subject matter and pedagogical experts. An additional goal for the undergraduate courses is to make the science classroom looks more like how scientists work (e.g., students use real data, make claims from the patterns they find in that data, and peer review each other's work), as we know this is more likely to lead to effective teaching.

Effective teaching in STEM encourages students to think, observe, communicate and make connections both *within* the unit of instruction (course, activity) and *across* multiple units (disciplines, years of learning, and sophistication). Effective teaching will enable students to retain knowledge and skills in ways that are useful to their future learning and decision-making, and that will open up pathways for new ideas to be integrated successfully into a strong framework of science content understanding. Effective teaching takes place in an environment where large-scale objectives (e.g., the Big Ideas framework) are identified, developed and discussed intentionally. Effective pedagogies may vary from person to person (both learners and teachers) and from setting to setting (informal education, middle school classroom, or large lecture hall) but the fundamental engagement of students in their own learning appears to be universally appropriate. Effectiveness also relies on pedagogy that begins with real examples of phenomena, is structured around the big idea associated with the phenomena, and develops through a coherent science storyline. These have become organizing principles or tools that help us think about effective teaching at both the middle grades and at the university. While aspects of these approaches were part of our initial definition of effective teaching, they have become central to the shared project definition over the past year.

Section 3: Explanatory framework

We are still in the initial stages of analysis of our first set of data related to the K-12 components of the project. We intend this initial data collection to provide a baseline of students' understanding in the four focus areas from the proposal: Climate (Change), Plate Tectonics, Astronomy and Energy. In our second year (2011-12) we are focusing our efforts on two areas in particular, Plate Tectonics and Astronomy, to develop preliminary learning progressions. Learning progressions are “empirically grounded and testable hypotheses about how students’ understanding of, and ability to use, core scientific concepts and explanations and related scientific practices grow and become more sophisticated over time, with appropriate instruction.” (National Research Council, 2007). We have initial findings about students’ understandings from our preliminary data, and we are using much of what we have learned to guide our second round of data collection.

Data collection in the spring of 2012 will consist of conceptual interviews with students in our target grade band (grades 4-9), supplemented by conceptual interviews with teacher participants. These data will be used to flesh out the learning progressions in the two focus areas and provide guidance for the design of teacher workshops to be held in the summer of 2012. Using the students’ conceptual interviews and associated learning progressions, we plan to support teachers in developing coherent science storylines for their content area within each workshop. Teachers will begin with developing a big idea based on phenomena within the content area (e.g. volcanoes and earthquakes in plate tectonics). Next, the development of a content storyline will help teachers think about how they can develop authentic activities that help students understand the big idea. We will collect video recordings of the teachers during the workshops as they develop their storyline and big idea. In addition to content storylines, teachers will develop formative assessments guided by both the student interviews and the learning progressions. The formative assessments will provide additional data for year three (2012-13), when teachers across contexts will use them during their instruction.

By studying student conceptual interviews and formative assessment artifacts from classrooms in our partner districts and discussing them with teachers during summer workshops, we will be able to get insight into the role instruction plays in determining student understanding. We will also have data about how our professional development workshops impact our partner teachers’ ability to teach Earth and Space Science and how long term professional development leads to changes in their teaching practice.

As a final piece of data, we will collect video of teacher practice from teacher leaders in our partner districts. We will collect the first round of video data in the spring of 2012. The purpose of this video in the first year will be to get a baseline on the current practices of teacher participants and to inform later hypotheses about the relationship between student learning and teaching practices. We will also use the video as part of the professional development workshops to help support professional conversations around changes in practice.

In year three of the project (2012-13) we will collect a second set of conceptual interview data, as well as formative assessment artifacts from students in partner teachers’ classrooms. This data collection will specifically focus on the relationship between the teaching in partner classrooms and student learning. We will do more intensive video recording of classrooms to be able to clearly link instructional practices with students’ developing understandings as measured by interviews and formative assessments.

In terms of the higher education components of the project, we have focused on institutional change, and thus much of our data are around the changes to teaching and the culture of teaching at the university level. However, this year we are working in two introductory courses, one in Astronomy and one in Earth Science, to develop coherent content storylines that are appropriate for those courses. We intend to collect conceptual interview data with students in those courses in an effort to flesh out the upper section of the Astronomy and Plate Tectonics learning progression as well as to understand the impact of instruction on university students' understandings in our two science content focus areas.

We intend all of this data collection and analysis to inform our learning progressions, which in turn will inform all aspects of our ESSP MSP project. Specifically, the learning progressions and associated research will help us develop coherent content storylines for all our workshops, help teachers and faculty develop coherent content storylines for use in developing their own instruction, and inform the field of science education about the nature of students' conceptual understanding and how it changes with instruction in the two focus areas of Plate Tectonics and Astronomy.

Based on all the data collection across the multiple contexts (K-12, higher education, and teacher professional development) we anticipate significant progress on two learning progressions by summer 2012 along with multiple manuscripts and conference presentations that will focus on the initial development of the learning progressions in Astronomy and Plate Tectonics from student data.

Section 4: Lessons learned

We have learned lessons across the multiple contexts of the project work. They are broken down by general area of focus.

Impacting Middle Grades:

The teacher participants in the project's workshops have a huge range of curricula they are working with and that constrains them in local districts. Establishing something that would be coherent across all of the teachers, while still supporting their local teaching needs, has been difficult. We must design professional development workshops and on-going teacher professional learning communities that recognize this diversity of contexts. On the negative side, we have learned more about the challenges facing middle grades teachers in the current political / educational environment in Pennsylvania, including, but not limited to, losses of funding impacting professional development, changes in standardized exams, larger class sizes and teachers teaching outside of their content area.

We have learned that in order to make progress in the complex systems that make up public schools and universities, we must work on multiple fronts in order to have any impact. Teaching in individual classrooms is a result of many influences, including both national and state standards, local curricular constraints, student course selection, and access to resources and support, to name just a few. We have learned that we have to work on as many pieces of this system as possible, all simultaneously. This means we are working top-down via engagement with the commonwealth department of education, school boards and administration at local school districts, and individual building principles. This means we are working bottom-up by engaging individual teachers via professional development, identifying teacher leaders and providing support and resources to help them build local capacity via the establishment of professional learning communities. Finally, this means we are working in higher education by engaging STEM faculty in thinking about their science teaching to both majors and non-majors and Education faculty to make science teacher preparation rigorous and create multiple pathways for excellent science students to become teachers.

Impacting higher education:

The STEM faculty members in the project did not realize how much STEM faculty have been excluding Education faculty from our internal discussions about our own teaching practice, and how dated our "new" reform ideas are by educational research standards. We now more clearly see how higher education faculty continue to model less effective teaching practices for the preservice science teachers in our classes. However, we also see that the interest in effective STEM teaching at the university level is both more widespread and deeper than we previously thought. We see a growing interest in good teaching and in the development of effective new teachers within the STEM colleges. That statement does not mean teaching practice has changed or will change immediately, but we are in a stronger position to effect and support change than we realized (or than existed) at the time of writing the proposal.

Developing Learning Progressions:

We have learned from our initial data collection and the process of data collection planning for learning progressions work that even preliminary learning progressions will take significant time to develop. The complexity of the task of developing and representing learning progressions in ways that are productive for their multiple audiences (K-12 educators, researchers, curriculum development groups, etc.) makes the process daunting. We have also learned that currently published work on learning progressions work does not adequately represent the complexity of the research process or provide access to the investigators' underlying thinking that is so critical to engaging in this research. Thus, it was initially unclear the best strategy to develop learning progressions and combine that effort with enhancing partner teachers' pedagogies that intellectually engage students and promote deep conceptual understanding. Our emerging understanding of learning progressions based on literature and on our work with advisory board member, Julia Plummer, revealed methods that will be used to develop a lunar phases learning progression for Astronomy: Berkeley Evaluation and Assessment Research (BEAR) and Rasch Modeling. This is one avenue where we are building on prior work in both learning progressions and on students' conceptual understandings. We hope to develop ways of representing the learning progressions that are productive, but also make the process behind their development more transparent, in an effort to advance the field methodologically and theoretically.

Abstract Title:
Assessing the Impact of Cross-Cutting Science Concepts on Teacher Effectiveness in the 3-8 Classroom

MSP Project Name:
Boston Energy in Science Teaching (BEST)-BSP Phase II

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Strand 3

Summary:
The Boston Energy in Science Teaching (BEST) project is researching the impact that concept-based professional development (PD) has on teacher effectiveness compared to the discipline-based PD that was offered through the Boston Science Partnership (BSP). We have recruited grade 3-8 teachers who participated in BEST PD, BSP PD, and both. We will analyze data collected through teacher interviews and surveys, energy assessments for teachers and students, and classroom observations. We will compare data across groups to determine if there are differences in instruction and student achievement that correlate with the PD that teachers participated in. We therefore will be able to say if helping teachers make connections across science disciplines via concept-based PD results in more efficient and effective instruction.

Section 1: **Questions for dialogue at the MSP LNC**
What evidence is needed to convince stakeholders to teach with the big ideas in mind?

What evidence should we look for when documenting changes in teachers' ability to teach with the big ideas in mind?

How might their ability progress/improve over time, and how should measures to describe such changes evolve accordingly?

Section 2: Conceptual framework
As a project, BEST defines effective teaching in science as facilitating opportunities for learners to explore concepts and make connections to those concepts across science disciplines. Our project's strategy is to use the cross-cutting concept of energy to facilitate these opportunities. These opportunities are explored through student-centered, inquiry based learning experiences that result in students gaining the capacity to learn information and apply it in novel ways.

Through these hands-on opportunities, students begin to own their learning and become deeper engaged in what they are doing. The nature and extent of students' engagement will be ascertained through a combination of observations of, and interviews with teachers. Students' understanding of energy concepts will be measured through pre-post assessments. Our theory of change—dating back to the original Phase I project of the Boston Science Partnership—is that if you increase the quality of teachers' instruction, then improved student achievement will follow. We focus on improving the quality of teachers' instruction through professional development (PD). The BEST PD opportunities are based on the original Phase I BSP professional development strategies (Vertical Teaming, Contextualized Content Courses, and Collaborative Coaching and Learning in Science). However, we have adapted these to go from disciplinary-based to concept-based [energy]. Vertical Teaming has helped to identify where energy is taught in the BPS curriculum—which will be used to inform our other strategies—and our Energy I Contextualized Content Course has increased teacher conceptual knowledge about energy. The design of our Energy II course is a blend of Vertical Teaming (VT), Collaborative Coaching and Learning in Science (CCLS), and a Contextualized Content Course (CCC). In Energy II, teachers go deeper into energy content across the major science disciplines and look at how these concepts are translated into a K-12 classroom through the sharing of video lessons. The teachers then use the CCLS model to discuss where energy is in the lesson, how it can connect to other lessons, and how it can be leveraged for future learning.

Our research design reflects the project's assumptions about the nature of evidence needed to demonstrate progress toward more effective STEM teaching. We will be recruiting three different cohorts of research participants: grade 3-8 teachers who have participated in only BEST PD, grade 3-8 teachers who have participated in only BSP PD, and grade 3-8 teachers who have participated in both BEST and BSP PD. Each research participant will take the teacher assessment, complete a survey, administer an assessment to their students, participate in an interview; and some will be observed in their classrooms. The energy assessment for teachers is a 40-question multiple choice assessment that covers energy from each of the science disciplines and is rooted in energy transformations, conservation of energy, energy systems, and energy resources. A similar 15-question assessment has been developed for students. The data collected will help us to answer key research questions, including understanding the relationship between concept-based PD on teachers' ability to identify and focus on the big idea (of energy) in their instruction, and if these changes are associated with changes in their students' achievement on the BEST assessment and on particular questions found in the state's standardized science achievement test.

Section 3: Explanatory framework

We are hoping to determine if there are key differences in student and teacher outcomes among the three cohorts that are participating in the research aspect of the BEST project. Our hypothesis is that teachers who participated in BEST PD (1) refer to energy concepts more frequently, (2) make more connections to energy concepts across multiple science disciplines during their lessons—both observed and self reported—and (3) score better on our energy assessment than their colleagues who took discipline-based PD. We also hypothesize that the students of BEST teachers will answer more questions correctly on our energy assessment, and answer more energy-related questions correctly that appear on the state's standardized math assessment compared to students of teachers who did not take concept-based PD. We then will look to see if there is a correlation between the nature and extent of teachers' participation in BEST and BSP PD, their changes in instruction, and student achievement, after we control for teacher and student demographics. These findings will shed light on whether—and under what conditions—investments should be made in concept-based PD versus discipline-based PD, if we want to see improvements in student achievement. These findings also will enable us to have a better idea if professional development, which is one of the most popular ways for teachers to improve their instruction and content knowledge, can lead to changes in student achievement because professional development that is grounded in cross-cutting concepts is the intersection of student achievement and teacher effectiveness for this project.

Section 4: Lessons learned

The research design of our project has shifted twice during the first year because of the obstacles we have had to overcome. These obstacles have provided us with new learnings about measuring effective teaching that we did not anticipate during our proposal.

- *Energy is mysterious:* When writing the proposal, we assumed that all Boston Public Schools grade 3-8 teachers would want to take at least our Energy I course because these teachers are already teaching kits from across different science disciplines throughout the year. Furthermore, we assumed the teachers who already took Energy I as part of the BSP would be really excited to take Energy II to work on incorporating this great theme into their own instruction. However, energy PD is not as attractive to the average teacher as the discipline based PD because there isn't a specific kit, course, or curriculum that matches what we are doing through BEST. It has made our project question our assumptions about effective teaching, gain insight into what our teachers believe is necessary for effective teaching, affirming that we believe that effective teaching includes making connections across science disciplines, and has resulted in our being more proactive in bringing this level of awareness to teachers before we provide them with PD.
- *Thinking Outside the Silos:* As we continue to do more research on what others have done around energy education and energy education research, we find ourselves realizing that we are thinking about energy in a very different way than others. Energy tends to be anchored in the physical sciences when it is discussed in curricular contexts. It is nearly impossible to find a physics textbook that will make extensions to chemistry when discussing kinetic energy. However, we are focusing on using energy as a connector between the different science disciplines so that students and teachers begin to focus on how the energy discussed in biology is the same that is discussed in chemistry. This has implications for teachers' implementation of BEST PD when working with "siloed" instructional materials, and for measuring student learning in the same context.
- *Small Changes:* We think that what we planned with our concept-based PD in our proposal is having an impact on teachers. However what do we do if those changes are small, not observable in classroom instruction, and/or slow to emerge? This is the situation we have found ourselves in because our PD is not as closely connected to one kit or one discipline as it was during the BSP. Even during the BSP, it was determined that it would take usually 3 years for changes in instruction to be demonstrated.
- *Finding good, existing instruments:* In our original proposal, prior to clarifications, we thought that we would develop and validate our own instruments. However, it was suggested to us that we use already existing instruments to test teacher and student

conceptual knowledge of energy. After we selected an instrument, we quickly realized that what we are doing—not just teaching energy as a concept but using it as a cross-cutting concept in science—is very different than what others are doing right now and the pre-existing instruments could not capture changes in conceptual knowledge for our teachers. Instead, we have decided that it is more important to have an instrument that matches the changes we anticipate seeing in classrooms, and will therefore develop it ourselves rather than use a pre-existing instrument.

- *Knowing where to look:* Measuring the frequency and quality of energy connections teachers make after participating in BEST PD is not easily captured. As mentioned above, the opportunities for teachers to implement changes in their instruction may be rare, making it a challenge to know when our 2-3 observations should be planned. And it may be that a teacher may never articulate energy connections during an observation but, as always, we cannot know for certain whether the lessons observed are typical of one teacher's instruction. Additionally, it is always difficult to attribute the particular impact of a PD experience on teachers' instruction when we know teachers' participate in a variety of such experiences.

Abstract Title:
Development and Implementation of a Year-long High School Engineering Course

MSP Project Name: UTeachEngineering

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Strand 2

Summary:
The UTeachEngineering Program has developed a year-long high school Engineering Design and Problem Solving course that can be used to satisfy part of the science requirement for students graduating from high schools in Texas. The course is now in its second year of pilot testing in a diverse group of high schools. This session will describe the curriculum, the development and testing of the curriculum, and the professional development provided to teachers delivering the curriculum. Plans for continued modifications and dissemination of the curriculum will also be described.

Section 1: Questions for dialogue at the MSP LNC

What are the core learning objectives for a high school engineering course?

How should these learning objectives be scaffolded?

What supporting strategies are most appropriate to help students achieve these learning objectives?

What constitutes an enhanced capacity for engineering teaching?

What supporting strategies are most appropriate to help teachers develop this capacity?

What are the critical elements of professional development to prepare teachers to effectively teach a high school engineering course?

Section 2: Conceptual framework

The high school engineering curriculum developed by UTeach*Engineering*, titled *Engineer Your World*, responds to a national need for a high-quality, low-cost, broadly based high school engineering course. The UTeach*Engineering* team that designed this innovative high school course comprised university engineering faculty, clinical engineering faculty (professionals with experience as both practicing engineers and secondary classroom teachers), engineering research fellows, and learning sciences faculty. With input from high school teachers and secondary curriculum specialists, the team defined desired student learning objectives, documented the constraints of a high school classroom, and identified course design principles based on research in the learning sciences. The team then developed a scaffolded course framework that builds a narrative of engineering and its role in the world with project themes ranging from the personal to global. Finally, the team developed and refined a scope and sequence for each project-based unit before writing day-by-day lesson plans and supporting materials.

To define student success and teacher effectiveness, *Engineer Your World* has defined the following core learning objectives and supporting strategies:

Objective (students and teachers): Develop greater engineering awareness (*i.e.*, engineering practices, engineering career opportunities and pathways, impact of engineering on society and the global context of engineering).

Strategies: Introduce students to multiple disciplines and a variety of career paths within engineering; design course materials that include a variety of challenges, each of which makes explicit the inherent multidisciplinary nature of engineering; frame challenges as addressing societal needs; and introduce students to the Greatest Engineering Achievements and Grand Challenges of Engineering.

Objective (students and teachers): Develop engineering habits of mind (*i.e.*, systems thinking; systems understanding and quantification, including understanding/application of domain-specific science and mathematics knowledge; understanding/application of engineering tools and techniques; creativity; collaboration; communication; ethics; safety and reliability).

Strategies: Provide opportunities for students to learn and practice engineering habits of mind in the context of engineering design challenges, scaffold student learning of the engineering habits of mind, provide opportunities for students to work in teams of various sizes, and provide opportunities for students to use realistic engineering tools and techniques common in engineering practice.

Objective (students and teachers): Successfully apply the engineering design process to solve challenges.

Strategies: Develop and model explicitly the UTeach*Engineering* design process; provide opportunities for students to execute each step of the engineering design process through challenges that incorporate engineering habits of mind; scaffold student learning of the design process through increasingly complex design challenges; provide opportunities to experience engineering design in the contexts of original design, redesign, and reverse engineering; provide opportunities to experience different degrees of open-endedness in engineering design, including ill-structured tasks; provide opportunities to iterate and learn from failure; and highlight that engineering design and problem solving are skills that can be learned, practiced, and improved.

Objective (teachers): Demonstrate an enhanced capacity for engineering teaching (*i.e.*, heightened engineering and engineering teaching knowledge, heightened awareness of design challenges as a way to promote science and math learning, knowledge of strategies for creating teams and facilitating collaborative work, development of a growth mindset with regard to learners and strategies to facilitate learning for diverse learners, and heightened confidence in both engineering and teaching ability, including comfort with the uncertainty inherent in engineering design.)

Strategies: Include research-based practices and activities in professional development experiences. In particular, present relevant learning theory frameworks; facilitate reflection on teaching strategies; engage teachers in an analysis of engineering education standards and frameworks; explicitly model project- and problem-based learning/instruction; present research on collaborative learning, model grouping and group facilitation strategies, and reflect on group functioning; and discuss stereotype threat, gender and cultural differences in STEM learning.

Section 3: Explanatory framework

Engineer Your World is being piloted with more than 230 students in eight high schools during the 2011-2012 academic year. The pilot schools range from rural to suburban to urban, with student populations between 200 and 2800 students. The smallest pilot class has just seven students, while the largest has more than 30. Project faculty, staff, researchers and evaluators are gathering and documenting student performance and teacher feedback from the pilot to inform course revisions. In particular, the project staff is visiting pilot classrooms to document course implementation; the project evaluator is conducting focus groups to gather teacher feedback about course design and support; and pilot teachers are returning to the project red-lined lesson plans, sample student artifacts and student pre- and post-tests that will be used to evaluate both teacher implementation and student learning. Additionally, project researchers are considering how the course facilitates effective argumentation, how it influences student perceptions of engineering, and how it influences teacher perceptions of engineering.

Preliminary lessons learned are based on pilot teacher feedback and student interviews. Evidence from the student interviews informed course redesign activities that resulted in the development of the materials being piloted this year. Evidence from teacher feedback is informing both curriculum revisions and planning for professional development for teachers beyond the pilot group. In particular, the project team is now developing a focused professional development for in-service teachers who will implement the course as part of a regional rollout in 2012-2013. This blended professional development will be designed with the project's learning objectives and supporting strategies in mind, and its ability to enable effective teaching will be evaluated during the 2012-2013 project year.

Section 4: Lessons learned

One of the challenges of developing and delivering high school engineering courses is preparing teachers for the uncertainty of engineering design projects, particularly vis-a-vis open-ended design experiences. Over the past three years, our program has provided professional development for hundreds of teachers and we will summarize some of the main lessons learned in developing effective professional development. These include the need for just-in-time and ongoing support, and flexibility in the curriculum to allow for teachers to customize the curriculum to the needs of their classes.

Abstract Title:
Promoting Effective Elementary STEM Teaching Through Engineering Design in Grades 3 Through 6

MSP Project Name:
Science Learning through Engineering Design (SLED)

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Strand 2

Summary:
The Science Learning through Engineering Design (SLED) Partnership is a new targeted project aimed at improving student learning of science and math at the elementary/intermediate school level through the integration of engineering design-based activities. The SLED project seeks to develop a framework for effective STEM teaching through engineering design to support educational change and innovation among 200 inservice and 100 preservice teachers and 5,000 students over five years. Progress to date has focused on creating the SLED community through shared information on instructional and curricular issues, development and implementation of content-rich design tasks, professional development for inservice teachers, creation of a design-based methods course for preservice teachers, and preliminary interactions within/across the community.

Section 1: Questions for Dialogue
The *Science Learning through Engineering Design (SLED) Targeted Math Science Partnership* research team seeks to learn more about effective science teaching through engineering design at the elementary/intermediate school level. We posit the following discussion questions:

1. What are key elements that must be included in a framework for developing effective elementary STEM teaching through engineering design?
2. In what ways does teaching through engineering design contribute to productive student learning of science?
3. What constitutes effective professional development for teachers to teach science using engineering design?
4. How can a framework for effective STEM teaching through engineering design be sustained?

Section 2: Conceptual Framework

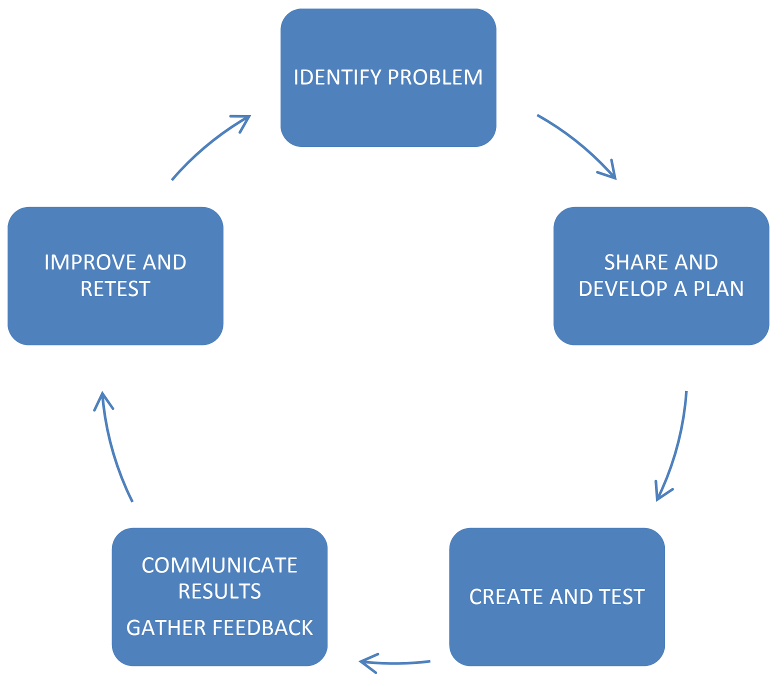
The SLED Partnership will answer the overarching question: Given the necessary tools and resources, cross-disciplinary support, and instructional time, could elementary/intermediate teachers work as a community of practice and effectively improve elementary school students' science achievement through a standards-based, design-oriented, integrated curriculum built around the use of the ***engineering design process***? Engineering, science, technology, and education faculty from Purdue University will work directly with 200 elementary /intermediate inservice teachers, 100 preservice elementary teachers, and 5,000 students in the four partnering Indiana school districts.

SLED Definition of Effective STEM Teaching Effective STEM teaching is instruction that results in student learning of science through engagement in coherent, design-based activities situated in real world STEM contexts. This teaching is enabled by high quality standards- and design-based curricular materials that are jointly constructed and owned by all SLED partners (i.e., STEM disciplinary faculty, teachers, and researchers). Effective teachers within the SLED project develop and organize lessons whereby there are clear and explicit connections made between the teachers' focus questions, the science ideas, the activities, the follow up discussions of the activities, and the lesson closure. SLED teachers use engineering design activities to anchor purposeful attempts that build students' learning of science by making connections between the science ideas, and the engineering design task, resulting in students using science accurately to inform or explain their designs.

SLED Design Model

The design model is based upon five interactive processes that students use to solve an ill-structured problem. Students work in teams to first identify the overall context of the problem, including the overarching problem and needs of a particular user. Second, students individually generate possible ideas or solutions using what they know about the problem as well as using relevant scientific knowledge. Then students share their ideas within their design teams and mutually agree upon one detailed plan and/or solution. Third, design teams create and test their plan or model. During this process, emphasis is given to recording results from testing and using existing scientific knowledge to explain what is happening. Fourth, design teams share their ideas with either one other team and/or the entire class. Finally, design teams gather feedback from other teams and return to their original design to revise, improve, and retest their original model.

Figure 1. The five processes of the SLED Engineering Design Model



There are several assumptions underlying our working definition. First, science teachers must have the science subject matter knowledge and pedagogical content knowledge necessary to deliver effective instruction to promote students' learning of accurate and appropriate science concepts (Abell & Lederman, 2007). Second, teachers with integrated knowledge will have greater ability than those whose knowledge is limited and fragmented to plan and enact lessons that help students develop deep and integrated understandings (Magnusson, Krajcik, & Borko, 1999). Lastly, integrating engineering design is somewhat novel for most SLED teachers and teachers who grapple with this type of innovation are likely to do so more successfully if they are part of a community of practice (Borko, 2002, 2004; Kahle, 1997).

It is hypothesized, that if elementary school teachers are given the necessary tools, resources, and support, they will implement, and possibly innovate and invent, their own instructional ideas for integrating the engineering design process in diverse ways, giving priority to different pedagogical or conceptual features (e.g., science content, academic standards, and processes).

The SLED Project's Design

The SLED project has created an integrated model for science teacher professional development and preparation. This includes the development and implementation of Indiana's first elementary engineering design-based methods course; a comprehensive, content-rich inservice teacher professional development program; a STEM faculty design team network; and an interactive national and state SLED repository of all best practices, curricular resources, and assessments.

The SLED project is in its first full year of implementation and its partners have focused on the following initial steps to support and facilitate effective science teaching among teachers and faculty in the following ways:

- Establish and maintain the partnership through active involvement of in-service and pre-service teachers, university STEM faculty, and university education faculty;
- Establish an interactive STEM faculty network of three multi-member design teams that meet on a regular basis to discuss ideas, brainstorm possible design tasks, and consult with SLED teachers on implementation of tasks;
- Facilitate bi-annual STEM faculty retreats for faculty to share and pilot test their tasks with STEM colleagues and gather feedback;
- Deliver intense, content-rich summer institutes and follow up sessions for in-service teachers;
- Model best practices by education and STEM faculty in all professional development activities;
- Develop an engineering-design focused science methods course for pre-service teachers;
- Promote co-teaching among SLED preservice and inservice teachers and STEM faculty;
- Facilitate ongoing collaborative lesson reflection sessions driven and directed by SLED teachers;
- Identify SLED master teachers who direct the implementation and assessment of best practices among all SLED teachers;

Rationale for the design of the SLED Partnership

Quality K-12 classroom science learning depends on equipping inservice and preservice teachers with a proficient knowledge base in science content, high-quality pedagogy, and effective methods for recognizing and supporting student learning (Abell & Lederman, 2007; Appleton, 2007; Koriala & Bowman, 2003; Lonning & DeFranco, 1994). However, it is also becoming increasing important for teachers to effectively blend disciplines (Lederman & Niess, 1997) and integrate math and science as a means of building student understanding of and appreciation for both content areas (AAAS, 1989; NCTM, 1989; NRC, 1996).

The STEM education community has responded in recent years with well-documented problem- and project-centered approaches that allow students to learn content from multiple disciplines in the context of authentic problems (Carlson & Sullivan, 1999; Kolodner, et al., 2003; Krajcik, et al., 1998). One project-based approach in particular, the engineering design process, has been heralded by science education researchers as a strong mechanism to facilitate integrated curriculum and instruction (Fortus, Dershimer, Krajcik, & Marx, 2004; McRobbie, Stein, & Ginn, 2001; Roth, 1996). Engineering design encourages students to construct refinable solutions to real problems using inquiry and cooperative learning processes that allow students to explore for new understandings and to relate those understandings to other concepts (Mooney & Laubach; 2002).

Currently over twenty states have adopted engineering-related standards at the K-8 level. More recently, engineering standards have become an integral part of the newly proposed *Conceptual Frameworks for New Science Education Standards* (NAS, 2011). According to the National Academy of Sciences, “engineering and technology are featured alongside the natural sciences in recognition of the importance of understanding the designed world and of the need to better integrate the teaching and learning of science, technology, engineering, and mathematics" (NAS, 2011, p. 1-1). These reform efforts require K-12 teachers to have the knowledge, skills, and resources necessary to prioritize instruction and student learning in science through design.

Explanation about the SLED project's Design in Relation to the Conference Strand

To support teachers, the SLED Partnership pairs both preservice teachers and STEM faculty with practicing teachers in effort to help teachers mobilize and adapt new curricular resources. These curricular resources are co-generated by STEM faculty and practicing teachers through ongoing collaborative design team meetings. The design team members identify key academic science and mathematics standards that align with the expertise of STEM faculty and the curricular needs of the SLED teachers. Each team carefully and critically examines the standards and develops a mutually agreed upon interpretation of each standard. Then the teams work in concert with SLED teachers to develop, field test, and revise grade appropriate, engineering design-based science lessons.

To support faculty, the SLED Partnership facilitates ongoing reflective sessions for STEM faculty to generate and pilot innovative, subject specific learning activities. This is complemented by bi-annual STEM faculty design team half-day retreats whereby design teams share drafts of their tasks with faculty and teachers, gather feedback, and revise their tasks in preparation for piloting.

Underpinning each of these components is: 1) a shared understanding of the instructional and curricular problems, issues, and concerns across the system (in this case, the partnership); 2) a mutual interest in innovation; and 3) a collective creation of shared instructional products (Morris & Hiebert, 2011). SLED faculty and teachers understand that teaching elementary science through engineering design is both challenging and important. All partners understand that policy (i.e., new science academic standards for design) dictates what can or must be generated; however, the partners can determine how this is created and manifested. This, in turn, provides an opportunity for innovation. In the SLED project, faculty and teachers possess and contribute different kinds of knowledge. Collectively they develop high quality standards- and design-based challenges for teachers to enact in their own classrooms. SLED teachers participate in these tasks and then transfer newly acquired knowledge from their practical experiences into action-oriented implementation plans that directly impact students. Hence, SLED products are jointed constructed and owned by all SLED partners (i.e., faculty, teachers, and researchers), which in turn results in increased use of the products and increased commitment to improve them over time. Consequently, these active teacher-faculty networks have revitalized existing teacher networks within and across SLED partner schools.

Section 3: Explanatory Framework

The SLED Partnership is guided by the following research questions related to effective STEM teaching:

1. How do elementary and intermediate school science teachers conceptualize design?
2. In what ways do elementary/intermediate school science teachers construct and implement design-based science tasks that capitalize on the strengths of their existing curriculum and/or currently available curriculum resources?
3. What design-informed pedagogical methods do they employ?

4. How do teachers reflect on, develop, and sustain their design-informed methods?
5. What classroom-based challenges do teachers encounter and how do they solve them?
6. In what ways do teachers collaborate with one another and with other members of the community of practice to reflect on their challenges, ideas, and solutions?
7. What differences exist in teacher-identified challenges in implementing an engineering design challenge when comparing teachers of rural school settings with non-rural school settings?

Measures of effective STEM teaching

The following measures are used by the SLED research team to assess effective STEM teaching: individual and focus group interviews, classroom observations, and surveys. These will elicit teachers' knowledge and conceptual understandings. Other measures, such as collaborative reflection sessions, will reveal any similarities and differences among the teachers' pedagogical attempts, instructional challenges, and shared curricular resources. Additional measures including faculty focus group interviews and supporting documents will convey factors that facilitate or impede the development effective science teaching practices and shared instructional products generated across the community of practice.

Interviews: Individual interviews identify teachers' conceptualizations of design and how they reflect on their engagement in design-based professional development activities. In addition, individual interviews help researchers characterize teachers' knowledge and instructional plans for implementing design tasks. Focus group interviews among inservice and preservice teachers capture teachers' shared experiences with learning to teach science through design. These interviews allow researchers to identify any products, resources, or materials created and adapted by teachers as a way of building effective science teaching. STEM faculty focus group interviews identify steps the design teams have taken to build a community of practice within the partnership, establish a collaborative network, generate innovative design tasks, and provide support to practicing teachers.

Collaborative reflection sessions: School-based cohorts of SLED teachers are established for the primary purpose of promoting teacher collaborative reflection. Within the SLED project, there are up to five teacher cohorts within each school building. Each cohort meets after the implementation of a design task to reflect on their attempts, identify challenges, and propose purposeful action strategies for facilitating student learning.

Classroom observations: Classroom observations allow SLED researchers to examine, in real time, how design tasks are implemented and how students engage in these respective tasks. Observations allow us to assess the fidelity of the treatment (i.e. do teachers implement activities as expected?). We also expect to observe evidence of students working in teams, using design-informed language and/or vocabulary, and attempting to apply scientific concepts.

Surveys: A series of formative and summative teacher surveys are administered as a way of determining teachers' existing conceptions and expectations for the partnership; teachers' needs to improving science teaching; and teachers' overall satisfaction with the SLED partnership.

Supporting documents: Supporting documents such as teachers' implementation plans, newly developed curriculum resources, and student work (i.e., notebook entries, artifacts, and assessments) are analyzed for purpose of determining how teachers sequence and organize key science concepts; elicit students' ideas about science and engineering design; and check for students' understanding of science.

Section 4: Lesson Learned

As SLED research team begins to analyze preliminary data, we have learned that SLED teachers who demonstrate best practices in integrating engineering design in the elementary science classroom are teachers who:

- Express accurate conceptions of the engineering design process
- Develop comprehensive plans that include purposeful links between science concepts and design;
- Plan and enact lessons that provide opportunities for students to use science content to inform their designs and testing of their designs;
- Anticipate student ideas and difficulties and respond in ways that help students move forward in their science understandings using the design process;
- Find pathways to integrate design into existing curriculum; and
- Provide valuable input for STEM faculty design teams.

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Abstract Title:
Several Models of Preparing and Supporting STEM Faculty to Teach Effectively

MSP Name:
Boston Science Partnership (Phase I) and Boston Energy in Science Teaching (Phase II)

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Strand 2

Summary:
The Boston Science Partnership (BSP Phase I &II) has provided a variety of forms of preparation and support for STEM faculty at institutions of higher education centered on effective teaching. Many of these forms can be considered types of Professional Learning Communities (PLCs), some for STEM faculty only, and some also involving K-12 teachers. Evaluation findings have shown that STEM faculty involved in these activities report increased understanding of teaching practice, interest in and ability to implement student-centered learning practices and greater awareness of the entire STEM educational pathway from K-12 to college. They report changes in student performance and changes to departmental culture related to issues of pedagogy.

Section 1: Questions for Dialogue at the LNC

a) What activities engage faculty in discussions of pedagogy?

b) What short and long term outcomes can be expected?

Section 2: Conceptual Framework

Defining high quality teaching in science at the higher education level presents more challenges than it does for K-12 settings. Because pedagogy is at the center of the training, support and expectations of K-12 teachers, a long history of attention to classroom practice, professional development to support that practice and research on the nature of learning in children supports K-12 science teaching. Included in the assumptions of the Boston Science Partnership are that all instructors at every level of teaching must attend to the needs of their students and to their methods of instruction in order to achieve their instructional goals. Better teaching practice leads to better student outcomes (i.e., course grades, persistence, increased number of majors, fewer people changing majors out of science, more graduates from science majors) in the critical area of science, especially for non-traditional learners at the campus. In order to advance teaching practice, we designed a range of opportunities for faculty to learn about current thinking of STEM education, reflect on their practice as educators, and exchange ideas with both peers at their institutions and with those from other institutions, including K-12.

Our formats for strengthening faculty instruction shared elements of PLCs familiar to K-12 teachers. Most were a series of meetings with groups of instructors, with an agenda related to an element of instructional practice, and which allowed instructors to deepen professional relationships with their colleagues around topics related to instructional practice. At times the goals were driven by upcoming teaching responsibilities, such as in the case of the CCC instructor workshops; other times they were left more open-ended. As the chart below indicates, in some cases faculty from different institutions (including K-12) came together to exchange ideas and perspectives about teaching.

The BSP addressed a number of barriers in order to establish a range of types of professional learning communities during both the Phase I Phase II. Reported here are findings from the evaluation report for which data were collected through surveys of STEM faculty, interviews with some faculty, and observation of BSP activities in which faculty participated.

Section 3: Explanatory Framework

The BSP training and support activities around effective instruction for STEM faculty include the following:

Type of activity	Short Description (Including the n of IHE faculty)	Audience			
		Original BSP (Phase I)	Includes K-12 teachers	Years 3-6 inclusion of RCC	BEST (Phase II)
Training and Orientation for CCC instructors; co-teaching with K12 teacher leaders	Workshops (first 2 years), formal, and informal discussions about teaching high level content to 6-12 teachers. Faculty worked closely with k-12 master teachers on integrating the 7E's, assessments, co-teaching. (n=32)	•	•	•	•
Faculty Seminars by COSMIC and Center for STEM Education	Monthly informal meetings among interested faculty at UMB and NEU to discuss issues of pedagogy. Formats and topics varied each year and at each institution.	•			•
Vertical Planning	Series of meetings with teachers and faculty from every subject and	•	•	•	•

	grade band to examine the vertical alignment of content from elementary to college freshmen. (n= ~25)				
Articulation Teams	Teams of three: high school AP teacher, RCC instructor of Freshmen, UMB instructor of Freshmen. Examined differences and similarities in syllabi, expectations and outcomes. (n=4)		•	•	
Univ. Colloquia	Annual lecture given by a nationally recognized expert on STEM education.	•			
Energy Course	Graduate course using the cross cutting theme of energy. Taught by three faculty and a master 3-8th grade teacher. (n=9)	•	•		•
Joint Course Development	At RCC and NEU, faculty are working on undergraduate courses through the Phase II.			•	•

Each of the major strategy activities in which STEM faculty participated included professional development that focused on issues of teaching and learning, and gave them a chance to reflect on their own instructional practices. In addition, those involved with CCC and VP also had the opportunity to learn from BPS teacher leaders. These activities led to a wide range of changes to teaching and attitudes to K-12 outreach activities.

Recruitment for these events was through a combination of word of mouth, direct invitation and, in the case of the CCC instructor workshops, required.

In this session, we will discuss two of these in depth: Articulation Teams, Faculty development at NEU. As well, we will discuss the impact at RCC of engaging faculty in the BSP set of faculty development opportunities.

1. Articulation Teams. The Articulation Teams worked for two years meeting occasionally on a specific topic of investigation that was designed by the teams together. They looked at the similarities, differences and outcomes of among three courses that share the same objective: covering science material that is equivalent to Freshman level, that is, AP science, Freshmen-level at RCC and Freshman-level at UMB. NEU faculty participated in the physics team, and that team therefore had four members. In the first year of study, they looked closely at their syllabi, tests and other course material in order to compare the goals, depth of coverage and breadth of coverage in these courses. For example, the physics team believed that the goal of their work together should be to better stagger and align curriculum so that the content and skills introduced in AP high school and community college courses could support future physics and engineering students in excelling in introductory physics courses at the college level.

2. At Northeastern University, the Co-PI has explored a number of ways to engage faculty and sustain the conversation related to teaching in STEM, and especially in Engineering, the department in which he is faculty. Topics ranged from course development to establishing networks within the university.

3. A supplemental funding request to the BSP provided funds to include Roxbury Community College faculty in the BSP. The faculty were invited to become part of the Vertical Planning Teams, co-teach two CCCs with the UMB and BPS teachers, and to join attend Colloquia. (There were other activities not related to this abstract). As well, the funding allowed the project to launch the Articulation Teams, and to host an annual lecture at RCC for all faculty on teaching and learning issues in STEM. Through the Phase II, they became a core partner. They are developing an undergraduate course on Energy and participating across the professional development activities at the Universities.
    - Learning about the knowledge, skills, and abilities students possess when they enter RCC
    - Making connections with BPS and higher education faculty
    - Learning new teaching strategies and approaches from BPS teachers
    - Seeing the alignment and gaps in the science curriculum and assessments
    - Hearing about differences within and across BPS schools—for example, differences in curriculum and foci across BPS middle and high schools

Section 4: Lessons Learned

1. Involving STEM faculty with BPS teachers was mutually beneficial.
   Partnering STEM faculty with BPS teachers on instructional teams for intensive courses and professional development was helpful for everyone involved, specifically providing STEM faculty with exposure to high-quality pedagogical approaches and K–12 education involvement.
   In addition to increased respect for teachers' professional expertise, STEM faculty indicated an increase in their interest in, and understanding of, K–12 curriculum and teaching strategies. Furthermore, many STEM faculty reported changing their own college-level teaching to include more active student learning and other research-based approaches, with positive results for their students (see (d) in list below).
2. Bringing BPS teachers and Community College and University faculty together to vertically and horizontally align and articulate the curriculum can strengthen the STEM education pathway.
   Vertical Planning workshops brought K-12 teachers together with Community College and University STEM faculty. Articulation Teams also brought together Advanced Placement teachers, RCC, and UMB STEM faculty who teach similar course levels to clarify ("articulate") expectations of learning from each course. Each activity prompted insights about how to better teach and coordinate the science learning experience for students. For STEM faculty, especially those not also involved with CCC courses, these experiences provided a much fuller picture of the prior science educational experiences of their students, both in content and learning styles.

3. Professional Development especially targeted for STEM faculty can help them focus on teaching and learning, and improve their teaching methods.
Special seminars and discussion groups for STEM faculty can provide an effective environment for introducing faculty to research about teaching and learning, and increase their interest in these issues. According to evaluation findings, STEM faculty involved with these activities (who responded to the survey) have increased their interest in issues of teaching and learning (77%), and have more discussions with STEM faculty about these issues (57%). Many have considered and often adopted (52%) new, research-based teaching methods. These new practices include strategies for motivating and engaging students, formative assessment practices, and efforts to help all students learn. Results of STEM faculty teaching changes as reported by the evaluator's survey include:
    - Lecturing—30% of respondents place less value on lecturing, while 5% place more value on lecturing during classes.
    - Active student involvement—respondents place more value on: student engagement during class, 61%; inquiry-based activities, 57%; class discussion, 43%; small group work, 43%; student presentations, 25% (5% value student presentations less)
    - Informal/formative assessment activities—valued more by 43% of respondents
    - Activities that are differentiated according to student abilities—valued more by 38% of respondents
    - Review of prior student knowledge—valued more by 36% of respondents

4. STEM faculty involvement in activities designed to improve their teaching notice changes in their students.
Some STEM faculty noticed positive changes in their students as a result of BSP-inspired changes to their teaching:
    - Student level of understanding of science content—somewhat better, 75%; much better, 8%
    - Student ability to use scientific method—somewhat better, 67%; much better, 11%
    - Level of student satisfaction with the course—somewhat better, 54%; much better, 8%
    - CCC instructors reported the greatest changes in student outcomes, with 100% reporting a somewhat or much better level of understanding of science content by their students and 100% reporting a somewhat or much better ability to use the scientific method.

5. Impact over time can include changes to departmental and College culture related to the importance of teaching and learning issues.

   At UMB, where the largest number of STEM faculty were involved with a variety of BSP-sponsored activities, faculty respondents indicated changes in the culture of their department over the core years of the BSP:

- Department places more value on K–12 science education-related activities at UMB (39% of respondents)
- Department places more value on the quality of undergraduate- and graduate-level teaching at UMB (56%)

6. Involving community college faculty in events based at the universities can revive interest in deepening STEM education methods at the college.

   Roxbury Community College has deepened the connections for its faculty to engage with peers on topics of pedagogy through the BSP and BEST. Faculty have reported greater feelings of professionalism, appreciation of opportunities to connect both to the university faculty and to K-12 STEM teachers, and greater interest in on-going professional development opportunities.

7. STEM Seminars on teaching and learning may need to take different forms to overcome common problems
   BSP PIs who sponsored STEM seminars at UMB and NEU have varied their format and approach each year in order to enable and entice participation by their colleagues. Some of these formats have included: anywhere from 1 to 3-hour meetings, sometimes over lunch (with lunch provided) and using a range of formats (formal lecture, discussion sessions, very informal, participant-chosen discussion topics); 1-time colloquia on these topics for each STEM department; asking faculty to plan a cross-disciplinary introductory course for non-science majors together; and a series of talks by junior faculty about their research and its inter-disciplinary connection, followed by discussions including issues for teaching and to which members of other departments were encouraged to attend.

Abstract Title:
How Can STEM Faculty Become Effective in the Advanced Training of Teachers?

MSP Project Name:
Arizona Teacher Institute

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Lotfi Hermi, University of Arizona
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Strand 2

Summary:
The Arizona Teacher Institute has developed a three-year part-time master's degree for middle school teachers, which includes content courses in mathematics and education and two final projects, an action research project and a mathematics research activity. The mathematics courses are taught by postdoctoral and faculty members in the Mathematics Department at the University of Arizona. As this degree shifts from one that is externally funded as part of a special program (ATI) to one that is a regular graduate degree option in our department, the courses will need to become part of the mainstream mathematics courses at a research institution. As part of this shift, a variety of mathematicians need to be prepared to teach mathematics content courses to practicing middle school teachers. In this presentation, we will report on our efforts to prepare mathematics faculty to effectively teach these non-traditional mathematics students.

Section 2: Conceptual framework

Consistent with leading research in the field (Ball, Thames & Phelps, 2008; Hill, H., Ball, D. L., & Schilling, S. 2008), we assume that various domains of teacher knowledge support effective mathematics instruction, including subject matter knowledge (e.g., knowledge of common and specialized content) and pedagogical content knowledge (e.g., knowledge of curriculum, of student thinking about content, and teaching strategies for content). For example, effective mathematics teachers have sufficient content knowledge to design lessons that describe mathematical ideas in multiple contexts and representations: graphical, numerical, and analytic. Additionally, effective mathematics teachers understand how students reason about and learn particular concepts, and they are familiar with a range of pedagogical tools for supporting students' thinking.
While the mathematics knowledge for teaching framework is most often used to describe the kind of knowledge that elementary or middle school teachers need to be effective

mathematics teachers, we contend that the framework is also relevant to other teaching contexts, such as mathematics faculty teaching content courses to practicing middle school teachers. For example, to effectively teach K-8 teachers, STEM faculty must have a deep understanding of the relevant content, the ability to anticipate potential confusions, and knowledge of various pedagogical strategies for supporting and extending teachers' understanding. While STEM faculty generally have very strong subject matter knowledge, including common and specialized content knowledge as well as knowledge at the mathematical horizon, many faculty who teach courses for in-service teachers are unaccustomed to working with teachers and may not immediately know how to organize and teach mathematics content so that it is accessible and relevant to a K-8 teacher audience.

Section 3: Explanatory framework

In our presentation, we will speak on these issues and the experiences the faculty have had in teaching content courses. Our speakers will include mathematicians who have taught the mathematics content courses along with those who have co-taught an educational research based class on student learning, Research on the Learning of Mathematics. As mentioned above, we will first outline a series of *key issues* related to STEM faculty teaching courses for middle school teachers; namely, identifying mathematical content that is likely to be useful to teachers ("mathematical knowledge for teaching") and encouraging faculty to engage teachers in the process of doing mathematics rather than teaching by direct instruction.

Next, we will include examples of the *innovative support* faculty members have received when preparing for and teaching the content courses. Such support includes sharing curriculum, having faculty who are experienced at working with teachers share expertise with people new to the courses, having a high school math specialists (high school teachers) help prepare and co-teach the course, and developing knowledge among faculty of research on mathematics learning and teaching. Additionally, the project has prepared mathematics faculty for the teaching of experienced in service teachers in several ways: We have course notes and class materials for instructors to use in preparing and teaching the course.

Mathematicians teach the mathematics content teamed with an experienced High School Teacher to facilitate classroom discussions of the mathematics and the pedagogy. Mathematics faculty members with previous experience in teaching these content courses discuss the course expectations and goals with new faculty before they are given the assignment

We will also address some of the *challenges* we have faced, such as developing content for the math courses that is relevant to K-8 teachers, teaching content in such a way that the knowledge transfers to classroom practice, and developing institutional structures that encourage and reward faculty for engagement in teacher education. One particular challenge an instructor faces in teaching such a course is that students often vary widely in mathematical background and ability. Therefore, instruction must be designed to appeal to students whose levels of prior understanding of mathematical content may be quite different.

The first cohort of the program has just competed the first full year beyond their master's degree. In the executive summary of the ATI program two evaluators observed the teachers using the Reformed Teaching Observation Protocol (RTOP). Here are some of their findings:
For one of the observers, the overall range of improvement ranged from 2 to 71 points. Of the three areas measured the area with the greatest improvement was in content, indicating that the teachers were doing a better job of understanding and teaching the mathematics content.

Each of the two evaluators have commented that classroom observations indicated more confidence in teaching mathematics on the part of the participants as well as the content knowledge.

When the participants of Cohort I were asked about the benefits of the program comments included:
"Feeling more confident" and "having a better understanding of the content".
Teachers also indicate an appreciation of getting to know other teachers of mathematics and being able to share ideas.
All but one of the teachers in Cohort I have taken and passed Arizona Education Proficiency Examination in mathematics. It is clear that participants have demonstrated changes in their teaching strategies, demonstrated more confidence and increased their mathematics knowledge.

Section 4: Lessons Learned

Preparing mathematicians to teach mathematics to in-service K-8 teachers requires convincing them that they can lower their expectation of the preexisting mathematical knowledge of their students without lowering their expectations about what those students can learn about the mathematics the students already teach.

Dedicated middle school teachers are very interested in learning more about the mathematics they teach; however, for many their mathematics background makes this a difficult task. Finding good instructors with an understanding of challenges their teacher-students will face is vitally important for a successful outcome.

Improved content knowledge in active teachers can be quite ephemeral. The improvements gained after an intensive course can begin to dissipate over time. In particular, topics beyond the grade levels and specific curricula educators teach are very venerable. Continued professional development especially, in a vertically integrated setting, is important in maintaining teachers' knowledge bases.

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Susan Mundry *What experience has taught us about professional development.* (edited by Martha Boethel) The Eisenhower Mathematics and Science Consortia and Clearinghouse Network June 2005

Abstract Title:
Supporting In-Service K-8 Mathematics Teachers: The Vermont Mathematics Partnership's Frameworks for Strengthening Content Knowledge, Instructional Practice and Systemic Collaboration

MSP Project Name:
Vermont Mathematics Partnership

Presenters:
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Strand 2

Summary:
The Vermont Mathematics Partnership (VMP) has developed a conceptual framework and set of protocols to inform planning to support teachers and leaders at the classroom, school, and system levels. The planning protocols are based on three antecedents: the Professional Development Model and accompanying materials developed by Kenneth Gross and the Vermont Mathematics Initiatives; the VMP Equity Framework based on Rachel Lotan's work related to equity and complex instruction; and the Diagnostic Classroom Observation materials and protocols developed by Nicole Saginor of The Vermont Institutes and Paul Decker and Amy Johnson of Mathematica, Incorporated. These are described and related to lessons learned through intensive work with successful and less successful school and district partners.

<u>Section 1: Questions for dialogue at the MSP LNC</u>
1. What is the role of mathematics content knowledge in the preparation of and support of STEM teachers and teacher leaders?

Mathematics is a sequential discipline and the mathematics taught at the secondary level and in college is based on the mathematics learned at the elementary grades. It is imperative that elementary and middle school math teachers have broad conceptual understanding of mathematics content beyond what they are teaching. In the Vermont Mathematics Initiative, described below, teacher leaders complete a comprehensive set of mathematics courses, including two three credit courses in calculus.

2. What is the proper balance among modeling exemplary instructional practice and explicit direct instruction related to pedagogy in preparing teachers and teacher leaders?

The balance depends upon the math background and teaching experience of the individual participants as well as the profile of the cohort as a whole.

That said, in general we follow a recursive model that is modeled daily in the professional development setting. This model is based on Gradual Release of Responsibility and is colloquially as: I do, you watch; I do, you help; you do, I help, You do, I watch. The model is recursive in the sense that it repeats throughout the session: at any given time participants and facilitators may be at any or all of the stages of the model in terms of the math content. In terms of the pedagogy, the balance is more heavily placed on modeling in the first and last stages, and more heavily to direct instruction in Stages 2 and 3.

3. What techniques are most effective to engage teachers to analyze their classroom practices in terms of a defined set of elements such as the Diagnostic Classroom Observation?

The initial engagement emphasizes teachers' understanding of what is being looked for. In the case of the DCO this requires careful unpacking of the teaching practices in four areas: Planning and Organization, Implementation, Content, and Classroom Culture. At this stage techniques include "unpacking" the descriptors in each area, generating examples and non-examples, and recognizing the practices in one's own classroom.

The next stage requires teachers to make judgments as to the degree to which each descriptor is evident in the classroom. Videotape review works very well here since participants and trainers can stop the video, discuss, and replay as needed. A next step is self-assessing and rating one's own classroom performance. Again video can work very well especially if the teacher is given the only copy of the video.

The final phase involves achieving inter-rater reliability. It is useful to established a "gold standard" panel whose ratings can be used to calibrate over time.

<u>Section 2: Conceptual framework</u>

The Vermont Mathematics Partnership (VMP) has developed and implemented a conceptual framework emerging from three antecedents: the Vermont Mathematics Initiative's *Instructional Model*; the Vermont Mathematics Partnership's *Equity Framework*; and the *Diagnostic Classroom Observation (DCO).*

The Vermont Mathematics Initiative's *Instructional Model*

Begun in 1999, The Vermont Mathematics Initiative (VMI) is a comprehensive statewide mathematics professional development program designed to close the gap between insufficient mathematics training of K-8 teachers and the demands of the contemporary mathematics classroom. The program is designed to prepare mathematics teacher leaders through a twelve course Master's degree program based in deep understanding of mathematics content.

The VMI Instructional Model is grounded in four goals: 1) Building a strong and deep knowledge and understanding of mathematics content; 2) Demonstrating effective mathematics instruction; 3) Conducting action research, and 4) Providing leadership that supports school-wide improvement of mathematics teaching and learning.

Goal 2 is at the heart of the VMI Instructional Model. The model has four parts:

1. Modeling effective pedagogy. Mathematicians and math educators collaborate to provide

engaging instructional practices that translate into the classroom and school. Multiple forms of instruction throughout the day include problem-solving activities, cooperative group work, and blending of inquiry-based learning and direct instruction.
2. Emphasis on problem-solving and active engagement of the learner.
3. The VMI Instructional Model, which includes individual support and encouragement. Each course boasts an instructional team comprised of a lead instructor and several facilitators who provide individual and small group support throughout the instructional day.
4. The VMI has developed high quality course materials on topics including arithmetic, algebra, geometry, number theory, probability, statistics, and calculus that take teacher knowledge far beyond the demands of the elementary curriculum. These materials are used in the courses themselves and also as resource materials as they implement peer professional development in their schools.

The Vermont Mathematics Partnership's *Equity Framework*
Developed in partnership with Rachel Lotan of Stanford University, the Equity Framework contains five elements of effective STEM teaching and is utilized in development of all professional development offerings and classroom applications in VMP. They are:

1. Classroom Organization including norms of participation and collaboration
2. Intentional focus on language demands and literacy strategies
    - Specifically address language challenges and build strong understanding of vocabulary
3. Ongoing formative assessment to inform instruction and to provide continual feedback to the learner
    - Exit questions and study groups to review homework
4. Complexity of the curriculum, as per the Stanford Complex Instruction Model
    - Focus on important mathematical ideas – simultaneously building skills ad concepts – in meaningful contexts
    - Infuse course with research on how students learn mathematics related to the course content and where they commonly have misconceptions
5. Instructional strategies that equalize participation and access to challenging curricula
    - Engage participants in complex problem solving that requires interdependence and contributions from everyone
    - Delegate authority for learning – require independent research and application

The Diagnostic Classroom Observation
Based on foundation work of Horizon Research and SAMPI, and validated in partnership with Mathematica Policy Research, Inc., ***The Diagnostic Classroom Observation*** is a comprehensive system for providing teachers with feedback as to instructional effectiveness in the classroom. The DCO is also utilized as a tool for program evaluation. The DCO was published by Corwin Press in 2010.

The DCO is comprised of materials and protocols that address these aspects of instructional practice:

1. Planning and organization of the lesson
2. Implementation of the lesson
3. Content of the lesson

4. Classroom culture

Each section describes standards of behavior for both teachers and students.

Taken together these three aspects of the VMP conceptual framework provide a comprehensive set of planning materials to develop and implement content-based, focused learning experiences for students, classroom teachers, and teacher leaders.

Section 3: Explanatory framework

VMP has utilized a "loosely coupled – tightly coupled" process for work with school partners. Elements of each partner school's implementation plan directly relate to goals of the project and pathways through the VMP Logic Model (tightly coupled). However, each site's particular path is structured by project and site-based leadership to ensure that program implementation is appropriate in the context of the site (loosely coupled).

Evaluation of the efficacy of this design utilizes a two-tiered, mixed methods evaluation plan guided by the project goals and logic model. Sources of teacher (Tier 1) impact data include:

- Classroom observation
- Pre-post tests of teacher pedagogical content knowledge
- Course evaluations
- Inventory of prior and current professional development
- Site-based focus groups
- Administrator interviews

Sources of student (Tier 2) impact data include:

- Student performance on the New England Common Assessment Project (NECAP) for the years that NECAP has been utilized as the statewide assessment.
- NECAP results of VMP schools are compared to state results for all students and for subgroups based on poverty and special education eligibility (the two equity areas of most concern in Vermont).
- Evaluators also compare NECAP results at VMP sites with matched districts (matched on size, income, demographics, and comparable performance on the New Standards Reference Exam (the statewide test prior to NECAP).

In our initial five years of work with partner sites and the two subsequent years of data collection we found that the school level factors that most influenced teaching and learning at VMP sites include:

- **Shared Leadership** - A strong shared leadership model that includes teachers, building administrators, and district administrators provides focus and continuity.
- **Administrative Involvement** - Active support of principals in alignment of curriculum, instruction, and assessment, and in planning and implementation of student level interventions.
- **Learning Community focused on mathematics content and education research**
  - Primary importance of mathematics content in professional development for teachers of mathematics.

    - Building belief in and commitment to education research, including research on how children learn mathematics.
- **Teacher Collaboration Related to Student Results** - Teachers and administrators collect, analyze and use student performance data to build on assets and strengths (appreciative inquiry) as well as identify and address areas of need.
- **Student Intervention Strategies** – Specific, research-based intervention strategies that incorporate specific curricular content, frequent progress monitoring and coordination with mathematics instruction in the classroom.

The two VMP sites which showed the greatest gains in student achievement on the statewide NECAP committed to intensive, sustained effort in all five areas. For example, at one of these, a suburban school of approximately 1000 students, from 2005 to 2008 the percentage of 3^{rd}-6^{th} graders who scored proficient or higher in mathematics increased from 65 to 69 percent. Most compelling is the increase in the percentage of students receiving free or reduced lunch rates, from 33% proficient in 2005 to 48% in 2008 and a narrowing of the achievement gap in that timeframe by 11 percentage points. For comparison, in the state of Vermont as a whole, the percentage of all students meeting or exceeding the standard in that timeframe increased from 63% to 66%, but the achievement gap held steady at 25 percentage points. With support of VMP, this school identified math teacher leaders who worked with their colleagues across grades K-6, revised the schedule to make time for teacher collaboration, offered on-site graduate level mathematics courses, developed formative and common grade level assessments in order to better understand and support student learning, and established an intervention program to offer additional instruction for students who struggled during regular math classes. Classroom coaching and modeling allowed teachers to observe their students performing well beyond expectations. The courses and workshops were formats for teachers to engage with challenging mathematics and experience differentiated instruction and formative assessment.

Other VMP partner schools also made gains in student achievement. These schools implemented heavily in a few of the areas. For example, at a K-8 city school of approximately 900 students which offered onsite courses and classroom mentoring for teachers, emphasized formative assessment practices, and expanded its mathematics intervention center, the percentage of students scoring proficient or higher in mathematics from 2005-2008 increased from 53%-61%. For the sub-group of students who received free and reduced lunch rates at this school, the percent proficient went from 41% to 48% in that timeframe. While the rates of proficiency increased for both those receiving free and reduced lunches and those who did not, the achievement gap increased by five percentage points. Compared to the school in the previous example, in this case administrators were marginally involved in improvement efforts and teacher leadership was concentrated in a few individuals, resulting in less opportunity for teacher collaboration, and systemic reform.

Section 4: Lessons learned

Synergy in developing a systems approach to instruction.
We learned that our systems approach to our work with teachers and teacher leaders strengthened as we incorporated multiple models into our planning and delivery systems. In particular, grounding all professional development and technical support in mathematics content (a la VMI) formed the basis for all of our interventions. The Equity Framework became an indispensable planning tool that led us to continually loop back to the individual learner. The DCO provided a vocabulary and common research base for dialogue about classroom practice with teachers, teacher leaders, and administrators.

Interdependence of key factors that support effective mathematics instruction.
Our experiences in VMP have shown that effective mathematics teaching is fostered through proactive and shared school leadership that engages the adults in the system in ongoing professional learning and systematic use of student data to address student learning needs. Shared leadership, administrative involvement, professional learning, analysis of student performance data for decision-making, and intervention strategies for struggling students are each important and no single one is enough by itself.

Abstract Title:
Evolution of a Partnership Engagement Project in the Appalachian Mathematics and Science Partnership: Lessons Learned

MSP Project Name:
Appalachian MSP

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Strand 2

Summary:
The AMSP's model of STEM K-12 /Higher education engaged partnership, the Partnership Engagement Project (PEP), is in its sixth administration. Using NSF's DIO Cycle of Evidence of formative evaluation, seven modifications have been incorporated into the current model. The modifications include: assistance in writing professional development plans, analyzing data, creating a toolkit for programmatic evaluations, development of a district needs survey, and locating STEM higher education faculty to collaborate in planning and implementation. Due to geographic isolation inherent in rural districts and the difficulty of making IHE connections, we propose to use the AMSP local master teacher as an intermediary between IHE faculty and school districts. The intermediary serves as a bridge between these two cultures and offers a support mechanism for the reform effort.

<u>Section 1: Questions for dialogue at the MSP LNC</u>
Do most disciplinary and education STEM faculty believe that K12 STEM faculty have the knowledge and skills to use various sources of data to identify barriers and deficiencies in the effective teaching of math and science in their classrooms?

What are the most effective ways of identifying mathematics and science teacher needs for professional development?

Do the barriers of geographic isolation affect the opportunities for rural mathematics and science teachers to receive effective professional development, especially if assisted by higher education institutions?

Can Master Teachers serve as effective intermediaries between rural teachers and geographically - isolated higher education STEM faculty?

Section 2: Conceptual framework.

In the past, effective teaching was primarily defined in terms of knowledge of content and the pedagogical skills related to student performance. We now recognize that effective teaching is complex and changes from within and without the classroom have profound effects on the profession. The definition of effective teaching has also evolved with teachers' use of inquiry to improve problem solving and thinking skills, knowledge of formative and summative assessment, use of differential instruction for all students, and introduction of state standardized assessment.

The issue of effective teaching now includes three domains: knowledge and confidence of the subject matter to ensure the material is accurate, research-based pedagogical knowledge to provide instructional strategies and ensure learning, and,finally, connection of the human elements with the unique and diverse students, communities and classrooms that provide the setting for the individual teacher.

Some studies have shown that improved content knowledge at levels exceeding the grade level of instruction have a positive effect on the teaching profession and, somewhat, on student outcomes. There is also the issue of pedagogical content knowledge, which in mathematics is tied to the teacher not just knowing more mathematical content but more content as it is tied to the material being taught by that teacher in the primary and secondary grades. Early studies have shown this to have an impact on teachers.

Effective teaching consists of more than just improved student scores on standardized assessments. Effective teaching embodies a dedication to, and a type of enthusiasm about, the content being taught, a desire to imbue children with an interest in the subject, a desire to ensure that all students are learning and are making progress in those areas, as well as having students show mastery of the subject.

The Partnership Enhancement Project (PEP) model, after seven phases of modifications, now has the following three design elements:

(1) involvement of the teachers in designing their own individualized professional development strategies and plans through engaged partnerships;
(2) recognition that professional development for teachers in rural areas, far from higher education institutions, requires special attention and often different strategies;
(3) development of a network of Master Teachers in rural schools that can serve as intermediaries between higher education faculty and isolated rural schools and their teachers.

This new third element of the model addresses the persistent challenge of higher education faculty involvement in geographically isolated schools, often far from the higher education institutions. It represents the synthesis of two successful NSF MSP programs.

To focus this study, a number of sites (schools and/or districts) in Appalachia will be identified where the AMSP has made strong contributions to the nature and quality of STEM teaching and learning, as well as developed a long-term indigenous capacity to continue their own local STEM improvement efforts. In particular, the key strategies of the AMSP work in these places (the PEP's, Master Teacher Program, IHE partnerships, for example) will be studied and how they have, individually and in concert with one another, worked to strengthen STEM education. These will be identified from the quantitative research that has been completed to date and the extension that is planned to carry the impact forward through the 2010-2011 academic year. The sites will be selected in a collaborative and iterative fashion identifying those schools and districts where:

1) data show that significant AMSP work has been done, and there has been a high degree of participation in and engagement with the AMSP over the past nine years;
2) key features of the AMSP (e.g., PEPs, Master Teachers, relationships with IHEs) have been implemented;
3) the quantitative models show that there have been significant improvements in student learning and classroom instruction; and
4) personal knowledge of AMSP leaders and staff indicate that the site is likely to be an illuminative and rich example of AMSP contributions.

The study will include a gathering and thorough review of a number of previous studies and a wide array of existing data *vis-à-vis* the study sites. The study will involve site visits and an up-to-date examination of documents and other data at the selected sites in order to document their long-term evolution. In these AMSP focal schools/districts we will examine existing data, and gather additional data through interviews, surveys and site visits around the following key evidence of AMSP successes and contributions to the following:

a. student achievement as measured by test scores;
b. student experience and learning (as documented by observers, journals, *etc*.);
c. improved quantity and quality of learning experiences (in and out of classrooms) (observations, survey data, interviews);
d. improved teacher capacity (attitude, skills, practices, relationships);
e. immediate and sustained improvements in programs, practices, policies (e.g., new curricula, new professional development, new assessments);
f. derivative improvements that were supported by the AMSP contribution (further grants, curricula adoption, new programs, new partnerships);
g. improved long term system capacity for further improvements (improvement capital of various forms — knowledge, leadership, social, political);
h. broader regional improvement capacity.

Inverness Research Associates and SRI have been engaged to develop a comprehensive framework for rating each of the districts along the dimensions listed above. For each school/district, they will compile the existing data around each of the dimensions outlined and create a plan for collecting the additional data needed. Site visits, telephone interviews, and surveys will be used to gather additional data. They will create a template with rating scales and rate each focal school/district on each of the above dimensions which will result in a profile of each AMSP district that shows 1) the degree to which there is evidence in each dimension, and 2) the strength of that dimension in the focal school, and 3) the ways in which and extent to which AMSP program components and strategies contributed in each dimension.

<u>Section 3: Explanatory framework</u>

The AMSP partners have found that a “top-down” approach to K12 mathematics and science teacher professional development will not work in the rural mountains of Appalachia. The

K12/higher education partnerships must be of an engaged, personalized type. This is the partnership vehicle that most ensures the increase in teacher content and effective classroom instructional practices that has led to effective teaching. The Partnership Enhancement Project (PEP) model has resulted in greater teacher participation in focused and individualized professional development that has supported improvement in student achievement. Acceptance of strategies to effect needed change in content and pedagogy was evident in the teachers' attitudes and partnership involvement as a result of the engaged partnership approach that confers co-ownership to the teachers. When teachers feel ownership of the changes needed for effective teaching they will be more effective teachers than if they are given a model to adopt. (Design element 1). It has also been statistically demonstrated that the overall interaction of all of the many programs of the AMSP has led to greater student achievement in mathematics in certain grades. Research in this year will further clarify the role of individual programs, school characteristics, school teachers and administrators, and other internal and external factors on this demonstrated student achievement.

A mentor pool of IHE faculty from STEM content disciplines and science and mathematics education will serve as partners for the Master Teachers. (Design Element 3) Expected outcomes of this model will be increased retention of high quality mathematics and science teachers, additional strengthening of the mentoring networks and partnerships in Appalachia, integration of content and instructional methods (emphasizing formative assessment and differentiated instruction), improved professional development in mathematics and science education, and continuing research on the reform of rural mathematics and science education.

The future AMSP research and evaluation will also examine the effectiveness of the AMSP's Master Teachers in serving as intermediaries between higher education faculty (source of continuing professional development) and the K12 mathematics and science teachers in isolated rural schools.

Section 4: Lessons learned

Lessons Learned from the Nine Years of the AMSP

"At a time when local expertise and individual teacher knowledge have been disconnected, devalued and even dismissed, the AMSP has taken a decidedly different stand – seeking out, honoring and cultivating the local voice. One of their operating assumptions was that a top down theory of action would not take root in the mountains of Appalachia. By most accounts, the AMSP was on to something. People respond when they feel heard and respected." External Evaluator, Inverness Research, Inc. The partnerships between K12 and higher education STEM faculty are most effective when they are individualized to a personal level. For example, the AMSP originally proposed these partnerships in the form of summer institutes, creation of challenging courses, and school level-professional development. However, through partner feedback, a more direct and personal form of partnership was created, the Partnership Enhancement Project (PEP) program.

The PEP program is a micro-investment for professional development designed to provide support to locally identified and developed mathematics and science education projects. These projects establish and cultivate significant working partnerships between individual K12 teachers/school districts and individual faculty/institutions of higher education (IHE). The projects are models of collaboration that recognize that essential knowledge and expertise resides in the teachers and school districts as well as in the IHEs. The projects are particularly effective at partnership building because of their primary goal of giving the district partners a voice and role in identifying local needs. The K12/IHE partners co-develop the type of intervention that might involve pre-service or in-service teacher enhancement, as well as school improvement/program enhancement, research and evaluation. Using NSF's DIO Cycle of Evidence of formative evaluation, seven modifications had been incorporated into the current model. The modifications include: assistance in writing professional development plans, analyzing data, creating a toolkit for programmatic evaluations, development of a district needs survey, and locating STEM higher education faculty to collaborate in planning and implementation.

Further feedback from teachers and school administrators has led to the identification of the need for an eighth modification to the model professional development program. This addresses the persistent concern about the difficulty of sustained involvement of higher education faculty in geographically distant and isolated rural schools of Appalachia. Master Teachers, developed from the teacher cohort in the rural schools, will serve as effective intermediaries between K12 STEM faculty and higher education faculty that are often unable to travel the large distances to rural schools.

Abstract Title:
Teacher Motivation in Professional Development – Results from a National Sample

MSP Project Name:
Math and Science Partnership - Motivation Assessment Program II (MSP-MAP II)
Teacher Motivation in Professional Development

Presenters:
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Strand 2

Summary:
Teacher professional development (PD) is an essential feature of instructional interventions in general, and for the improvement of students' math and science learning and achievement in particular. The more motivated teachers are to participate and engage in PD, the more likely they will be to profit from the experience. When teachers benefit, they are more likely to enact the PD approaches, content, and skills in their classrooms. Informed by theory and research on student and teacher motivation, a national study of teachers (*n* = 552) examined the level of teachers' motivation for PD (PDM), teachers' experiences in PD, and perceived benefits of PD, as well as associations with features of PD programs, teacher factors, and contextual factors.

<u>Section 1: Questions for dialogue at the MSP LNC</u>

- How do MSPs consider teacher motivation when designing PD?
- To what extent do MSPs see teacher motivation as an issue in their projects?
- How have MSPs been successful at supporting teacher motivation?

<u>Section 2: Conceptual framework</u>

Teacher professional development (PD) is an essential feature of instructional interventions in general, and for the improvement of students' math and science learning and achievement in particular. The more motivated teachers are to participate and engage in PD, the more likely they will be to profit from the experience. Teacher motivation in PD is directly linked with classroom enactment of PD approaches, content, and skills, and indirectly related to increasing the likelihood of desirable student outcomes.

Teacher motivation is central to most definitions of effective teaching, both in and out of STEM. Across MSPs effective teachers are assumed to be motivated to teach and to improve their practice. As a RETA, this project provides a much-needed test of these assumptions by assessing the quality of teacher motivation in PD contexts. While motivational concerns are often alluded to (e.g., participation incentives or teacher confidence) the motivational processes in teacher PD remain an understudied component of MSP interventions. MSP-MAP2 is systematically applying current work on teacher motivation to the domain of teacher PD with the following goals: (1) Develop a knowledge base of theory, research and assessment of motivation and the PD process; (2) Develop and make available a suite of motivation-related reliable and valid assessment tools for MSPs to use for formative and summative evaluation; (3) Collaborate with MSPs to test and refine features of a proposed model of motivation and teacher PD; (4) Facilitate the incorporation of the model and motivation-related PD assessment tools into existing and future MSP logic models and evaluation designs; and (5) Disseminate the motivation and PD model and assessment tools to the broader teaching and research community. MSP-MAP II is accomplishing its goals with surveys of large samples of teachers at various stages of PD. This LNC session describes the findings from the most recent national survey.

Informed by theory and empirical evidence from research on student and teacher motivation, and by a model of teacher motivation to participate in PD (PDM), a national study of teachers (*n* = 552) examined the level of PDM, teachers' experiences in PD, and their perceived benefits of PD. Also examined were how perceived experiences and benefits were associated with features of PD programs and teacher and contextual factors.

<u>Section 3: Explanatory framework</u>
MSP-MAP II has completed five of six planned studies of teacher motivation to develop refine, and use instruments to measure teacher motivation in PD. To address the theme of the LNC, the project will address one component of effective teaching explicitly stated or implicitly assumed in most, if not all, MSP definitions of effective teaching in STEM—teacher motivation. We will present the latest findings from a national sample of teachers on their motivation in PD.

Among the most noteworthy findings — On average, teachers reported being positively motivated to participate in PD. Approximately 40% of the teachers indicated they were highly motivated, whereas only 7% indicated they were not at all motivated. Most teachers reported having participated in PD during the previous school year, and those with higher levels of PDM were more likely to have participated.

Teachers Who Participated in PD

A majority of the teachers (64%) reported that PD experiences were either positive or extremely positive, whereas only a small proportion (13%) reported having had a negative experience. Approximately half of the teachers (45%) indicated that past PD experiences made them more motivated to participate in PD in the future and relatively few (16%) reported they were less motivated. A majority (62%) judged PD useful for increasing their teaching effectiveness, although 18% considered it useless. More specifically, teachers indicated that PD helped them to improve students' competence in the following: subject area(s) taught, motivation to understand the material in depth, interest in and value for the subject area(s) taught, and improvement in motivation to work with classmates to study, seek help when needed, perform well on state tests, attend class, and do their homework. Improvement in all areas was directly related to teacher PDM. PDM was higher for teachers who indicated that the PD they experienced: required a significant amount of work to implement teaching strategies, earned continuing education credits, fulfilled state licensing and renewal requirements, required them to bear some of the cost, included a stipend for attendance, and enhanced their job security. PDM was *lower* when PD fulfilled a district or school requirement. PDM was unrelated to whether PD took up a significant amount of teachers' personal time, conflicted with other scheduled school events, conflicted with their class time, involved considerable travel time, or was part of their evaluation.

Teachers' Preferred Features of PD

Teachers' most preferred PD formats consisted of a single workshop with teacher participation, a series of workshops with participation, and PD delivered completely or partly online. Less preferred were summer institutes, professional learning communities (PLCs), and lectures. Of these formats, the more that teachers were motivated to participate in PD the more they preferred a series of workshops with teacher participation. Teachers' desire to participate was directly related to whether PD would: make their lessons more engaging and more effective for student learning, improve their students' achievement, improve the degree to which their students learned the required material, capture students' interest in the subject they taught, show students they truly cared about them, and establish positive relationships with students. Teachers' PDM was directly related to all of these ratings. Teachers indicated they would want to participate in PD to the extent they expected participation to do the following: improve their subject-matter knowledge, be enjoyable and fun, enhance their career, and not require too much time and effort,. Teachers reported a preference for PD when other teachers in their school were participating and when their principal encouraged them to participate. Teacher PDM was directly related to all of these PD characteristics.

Teacher Characteristics and School Context

Teachers who considered themselves more personally responsible for student achievement, student motivation, relations with students, and for quality teaching were more motivated to engage in and had more positive experiences with PD. Those who reported more positive emotions (e.g., excitement and satisfaction) and with less negative emotions (e.g., anger and feelings of burnout) in their teaching were more motivated to participate in PD. Teachers with higher PDM also reported more positive principal relations and collegial leadership, felt a sense of personal accomplishment, experienced fewer school problems, emotional exhaustion, and stress. Those with higher PDM were more likely to adopt a mastery approach to instruction that focused on individual student improvement and had high expectations for their students. To a lesser extent, PDM was related to the adoption of a performance approach to instruction that focuses on student ability and interpersonal student comparisons.

Section 4: Lessons learned

Conclusions and Links to the PD Literature

Results from this study support the inclusion of motivation in definitions of effective teaching and highlight the importance of considering not the *quantity* of teachers' motivation, but rather the *quality*. It is not enough to specify that effective teaching requires teachers to be motivated. All the teachers in this sample reported being motivated. Paralleling the research on student motivation, this research shows that the focus should be not on whether teachers are motivated (they are) but on the reasons they have for participating in PD and the value they place on activities designed to improve their practice.

Teachers in general indicated they were positively motivated to participate in PD. Most in this national sample reported having participated in PD in the previous year, and a majority of those felt that PD was useful for improving their teaching practice, student learning, and student motivation. Teachers reported they are open to a variety of PD formats, especially those structured as workshops (as opposed to lectures) that included teacher participation. Overall, teachers who participated in PD reported moderate to high levels of motivation, even when participation involved a considerable investment of time or resources.

Abstract Title:
MOSART: Examining SMK and PCK with Modern Psychometric Analysis

MSP Project Name: MOSART-LS

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Phillip M. Sadler, Harvard

Authors:
Nancy Cook Smith, Harvard
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Strand 2

Summary:
Our conceptual framework of effective teaching begins with teachers knowing the content of the science they teach and the misconceptions that their students are likely to have. Prior research of teachers' knowledge of student misconceptions enhances students' gains in understanding the science represented in items. New analyses of our MOSART test items use Item Response Theory (IRT) to examine the relationship of students' answers to the proficiency of students ranging in performance level. These analyses further extend the power of MOSART tests to support the work of MSPs to enhance teacher SMK and PCK. A recent study used MOSART items for assessing the gains of teachers participating in various professional development activities.

Section 1: Questions for dialogue at the MSP LNC

1. What can MSPs learn about participants' knowledge through administering MOSART assessments' test items?
2. How can various item response patterns inform understanding of the power of misconceptions as distractors in MOSART test items?

Section 2: Conceptual framework

Our conceptual framework of effective teaching begins with teachers knowing the content of the science they teach and the misconceptions that their students are likely to have. Teachers' responses to the same questions given to their students are a measure of Subject Matter Knowledge (SMK), while their identification of common misconceptions is one efficient measure of Pedagogical Content Knowledge (PCK). New analyses of our MOSART test items use Item Response Theory (IRT) to examine the relationship of students' answers to the proficiency of students ranging in performance level. These analyses further extend the power of MOSART tests to support the work of MSPs to enhance teacher SMK and PCK.

The definition of student success in MOSART describes a continuum of cognitive development. Students may move to the completely accurate response, but many students particularly those whose performance falls in the middle range move from a completely incorrect response to the most common misconception. Our research (particularly the IRT analyses) reveals that a misconception is often a necessary step before students completely grasp the concept.

Section 3: Explanatory framework

MSPs can identify the SMK and PCK of their teacher participants by examining a pretest diagnostic profile of MOSART item responses and predictions of the most common incorrect responses of students. Our on-line testing capacity can provide staff with that information if teachers take the appropriate MOSART test before they attend the professional development programs. Similarly, pre and post-test results can identify those items where teacher participants benefited from the PD experiences. The relationship between the PD curriculum and those test items illustrates validly and objectively the benefits of the PD. Similarly, lack of gains on non-relevant items provides a reasonable measure of instructional sensitivity. MOSART tests are defined broadly to measure the science content standards while other, more narrowly focused, tests cannot provide information from a nationally representative sample of students and teachers. Our MOSART tests represent a unique perspective as compared to program-developed measures because of the reliability and validity produced by our development and validation process and the peer-reviewed journal publications concerning our assessments.

Item Response Theory has advanced the state of the art in psychometrics, in these days of high-stakes tests for teachers and students. There are other uses for IRT in creating valid tests of science content knowledge and we will share the results of some of these analyses in our session. Typical multiple choice test items are chosen for inclusion in various student and teacher tests on the basis of comparing students who answer correctly to those who answer incorrectly. Analyzing these test items dichotomously (right/wrong) can help select the most powerful items from an item bank. Because of the unique characteristics of MOSART items, more sophisticated polytomous IRT analysis shows the relative power of specific misconceptions as distractors, thus enhancing the information provided to MSPs.

Abstract Title:
STEM Teaching Effectiveness: A Synthesis of Perspectives

MSP Project Name:
Louisiana Math and Science Teacher Institute (LaMSTI).

Presenters:
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Serena Fisher, Louisiana State University
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Strand 2

Summary:
Our presentation includes contributions from the lead designer of the physics curriculum (Slezak), cognitive scientists studying teacher expertise (Fisher, Lane and Matthews), the external project evaluator (Meyer), a teacher who has investigated transfer to classroom practice (Alphonso) and the project director (Madden). We give several different but related perspectives on the problem of delivering and evaluating university-based academic work that impacts the effectiveness of STEM instruction. The perspectives are brought together in our conceptual framework, which identifies the expected pathways of influence from the academic program to the classroom and distinguishes these pathways from other factors that impact classroom work. Partnership activities promote consonance between the academic program and school-based classroom demands.

Section 1. Questions for dialogue at the MSP LNC

Many people suggest that STEM-teacher professional development ought to be a continuum, like the training of physicians, lawyers or engineers, with some components that are primarily academic and university-based (but advised by practitioners), some components that are provided during the initial years of employment under the supervision of mentors, and some components that become available at later career stages and support transitions to varied roles. Is this a viable notion? Are there good models for this in existing partnerships? What variations are there in different implementations of this general idea?

What are the signature features of the most successful content-intensive graduate degree programs for STEM teachers? Can we compile a catalog of the options that have been developed around the nation? What elements do different programs have in common? Do similar elements produce similar outcomes in different settings?

Deliberate practice has been defined as an individuals' prolonged efforts to improve performance while negotiating motivational and external constraints; see (Ericsson et al. 2006).

- Do the findings concerning deliberate practice in other domains of expertise apply to the acquisition of teaching expertise?
- Can teachers engage in deliberate practice in the context of "normal" teaching duties?
- What obstacles do STEM teachers encounter when attempting to engage in deliberate practice?
- What types of aids might assist teachers in getting around these obstacles?
- What is the optimal time in a teacher's career to allocate time to learning important self-regulation skills related to deliberate practice?

Section 2. Conceptual framework

"Effective teaching" is teaching that achieves valued outcomes. Of course, different parties value different things. Administrators have an eye on the performance distribution of student populations on standardized measures. Teachers value aspects of student performance that meet much more complex, multidimensional and individualized criteria. STEM professionals tend to value the skills, knowledge and temperament that contribute to success in the scientific enterprise. Teacher-educators and curriculum developers often view effective teaching in terms of particular models of learning and instruction. Students and their families value teaching that contributes to success in school, career and life. Ultimately, teachers need to harmonize all these views. To do this, they employ deep understanding of the subject being taught and how the fundamental principles of that subject are incorporated in the curriculum, sensitivity to student thinking and a grasp of how students develop mastery of a content area, skill in dealing with people, ability to set and uphold standards, and executive skills in maintaining focus on complex goals and allocating time and resources to meet them.

The Louisiana Math and Science Teacher Institute (LaMSTI) project is designed to establish a master's degree program for middle and secondary school teachers in service of the teaching profession. Funded as an Institute Partnership through the National Science Foundation's Math and Science Partnership (MSP) program, the program is designed to build the capacity of teachers, leading to improved student achievement in mathematics and science. The project builds on Louisiana State University's Master of Natural Science (MNS) program and reflects ongoing communication with partner districts and schools to meet identified needs. Project activities focus on aspects of STEM knowledge that are critical for teaching; skills and orientations that teachers need to serve as leaders among their peers; and development of a master's thesis that allows participants to make a meaningful contribution to the professional knowledge of STEM teachers. Annual cohorts of approximately 24 teachers participate in the LaMSTI track of the MNS program, which offers specializations in mathematics, physical sciences, and biological sciences. The project is led by the Louisiana State University (LSU)

Cain Center, along with core partners, East Baton Rouge Parish School System and Iberville Parish School System.

So far, two cohorts, each of 12 math teachers, have been recruited, one cohort of 12 physics/chemistry teachers, and one cohort of 12 biology teachers. (Additionally, 24 candidates completed the degree in a pilot program prior to NSF funding.) The program is completed in three summers (each of six 40-hour weeks), with additional work in the intervening academic years. All candidates write a thesis based on classroom research or curriculum study.

The academic work of the LaMSTI program focuses on developing certain cognitive and social foundations for effective practice. Taking the conditions of the teaching job into account, we seek to provide an academic experience that complements those things provided by the schools, the districts, the state and the professional teaching community. Cognitive foundations include 1) a coherent framework for conceptualizing the teaching task, 2) specific models (or schemata) for effective instruction that can be employed in classrooms, 3) deep understanding of key concepts that can be called upon to guide planning and decision-making while teaching, and 4) a wide variety of representational resources that can be used to interpret and respond to student-thinking. (Schoenfeld, 2010) provides a framework for thinking about 1), 2) and 3) in the mathematics classroom. A good framework for thinking about 4) in mathematics (albeit at an elementary level) is contained in (Petit, Laird & Marsden 2010); also see (Cuoco, 2000). Foundational references for the physics program are referred to in Section 4.

Assuring the conditions for effective teaching (e.g., a safe, disciplined environment, high-quality learning standards and curriculum materials, organizational support, opportunities for professional interaction on the job and insulation from distractions and gratuitous duties) are all things that one expects to come not from the LaMSTI program, but from the school, district and state levels.

Section 3. Explanatory framework

Based on several years' experience, we recognize several separate foundational domains that the LaMSTI academic program must address:

1. Deep knowledge of foundational concepts and fundamental principles of a discipline;
2. Knowledge of and experience with instructional paradigms;
3. Ability to apply the scientific method to classroom problems;
4. Ability to regulate one's own development as a professional.

This is certainly not an exhaustive classification of all the aspects of the teaching profession that might be addressed in the academic setting, but only those things that we have been able to address in systematic fashion, with clear purpose and with measurable ends in mind. Each domain is addressed by different means, with specific contributions to teacher practice intended.

Developing deep knowledge of fundamental principles is a central theme in all LaMSTI tracks (math, physics/chemistry, biology/chemistry). Within the mathematics track, the chief strategies are: a) to use the Common Core State Standards for Mathematics to define the knowledge domain that teachers ought to master and b) engaging teachers in mathematical activities that embody the standards for practice and provide meaning-making opportunities that resemble the kind of intellectual work that mathematicians do. We pay particular attention to developing appropriate "iconic" knowledge of mathematics, including a range of basic representational resources, standard geometric images, paradigmatic examples and notational, linguistic and procedural conventions.

The Master of Natural Sciences Degree program includes a thesis requirement. The LaMSTI curriculum includes course work that is specifically designed to prepare candidates to investigate a problem of significance to the STEM teaching profession in a manner that a research scientist would find acceptable. The steps include preparing a review of the literature to determine the nature and extent of existing knowledge and to frame the research question in a way that is meaningful to the professional community, developing a clear, testable question, drawing up specific plan for gathering relevant data, evaluating the strength of evidence and writing up a presentation.

Teachers in the LaMSTI program have taken a short course designed by the psychology research team that covers a number of important components of expertise acquisition. Motivated by theoretical and empirical work in cognitive science, the course objectives are:

1) understanding what expert teaching entails and how expertise is acquired,
2) developing the skills and knowledge that allow one to effectively learn from classroom experience and to deal with obstacles that are typically encountered,
3) learning how to solve problems cooperatively and learn from one's peers, and
4) utilizing these skills with a focus on improving student learning.

During the course, teachers set out one or more goals for improving student learning, design a plan for accomplishing these goals, and get feedback about these plans from their peers.

Section 4. Lessons learned

Among the active MSP Institutes, LaMSTI is exceptional in that science and mathematics both participate equally in offering a professional master's degree program for teachers. This has opened our eyes to some profound differences between the culture of science education, as exemplified by the programs that have served as a model for LaMSTI—the physics education groups at the University of Washington, Arizona State University, the University of Colorado and the University of Maryland—and the culture of mathematics education in the models that have guided the LaMSTI math educators—the Vermont Math Initiative, Math in the Middle at the University of Nebraska and PROMYS for Teachers at Boston University. Physics education programs appear to have a more explicit and systematic pedagogical signature than the math programs, and also to be more tightly linked to empirical work that supports the pedagogy. Of course, the mathematics education community interacts with a much greater range of ages and a much more varied student population, which helps to account for some differences. There is much to be learned through comparisons between the practices of educators in science and in math, and much to be gained by closer cooperation.

The Physics team (Slezak reporting) will report on the findings that have emerged in the first two years. "Instructional paradigms" are well-vetted approaches to classroom instruction that are based on explicit principles, include explicit methods and routines and are widely replicated. "Inquiry-based learning" is not an instructional paradigm, because it is an aspect of instruction that may be realized in many different ways. In contrast, the *Physics by Inquiry* curriculum (McDermott et al. 1996) and the *Tutorials in Introductory Physics* (McDermott et al. 2002) are self-contained course materials with a coherent sequence of carefully-defined activities designed for the preparation of elementary, middle, and high school science teachers. The LaMSTI program (physics track) focuses on the development of cognitive foundations by proper selection and implementation of tried and proven approaches when they are available. We separate this focus into stages. In the first summer, we foster meta-cognitive development to positively affect teachers' attitudes towards learning while working towards content mastery. In the second summer, the focus shifts towards the identification and development of cognitive resources for the classroom. To maintain a high level of coherence, the program concentrates on one methodology each year. Two inquiry-based curricula are employed during the 1st summer. *Physics by Inquiry* provides a well-established path to content development and positive attitude change, while the *Tutorials in Introductory Physics* provide the framework for a practicum in which teachers can develop engagement techniques in a coached classroom environment. For the 2nd summer we have chosen a curricular framework within which participating teachers continue their content mastery. Here, the main aim is the modeling of best practices in identifying cognitive student resources and how to best develop them. Initial results indicate comparable conceptual gains in topics approach by inquiry-based instruction and active practicum participation. An overall improvement of attitudes towards active learning was also observed, but the impact on teachers' instructional reform has not been investigated beyond activities linked to their research topic.

The LaMSTI cognitive science (Fisher reporting) team has collected data about the nature of teachers' goals and plans, information about their current teaching practices, and follow-up self-reports about their subsequent experience applying what they learned in the course. We have found that teachers are capable of integrating deliberate practice into their teaching and sustaining a focus on deliberately selected goals. However, there are a number of common obstacles. Not surprisingly, time is a major obstacle, often aggravated by unexpected duties being assigned by administrators. Other issues concerned teachers understanding of how to measure their own and students' progress. We have some data suggesting the "psychology of deliberate practice" course may be more effective for teachers with greater experience. Although the initial data is promising and does have implications for the overall MSP program (see below), future work will necessarily examine the direct impact on student learning. Our work has highlighted the importance of self-regulation skills in the acquisition of teacher expertise (in addition to the typically acknowledged content knowledge, pedagogical knowledge and pedagogical content knowledge). Prior research (e.g., Dunn & Shriner, 1999) has been largely pessimistic about the ability of teachers to utilize deliberate practice as a means of improving their performance. Our results confirm that it is indeed difficult, but that it is in fact possible to use deliberate practice to achieve goals related to STEM student learning. Furthermore, there are specific skills that, if taught, can help teachers improve more rapidly. Some skills, such as learning how to measure the impact of an intervention or how to solve problems effectively with other teachers in a group, are not in the repertoire of many LaMSTI participants when they enter the program.

Perhaps the most critical concern is the impact that LaMSTI course work has on classroom practice. If we cannot identify specific changes, understand why and how they occur and gauge their impact on student learning, then there is no reason for the LaMSTI program. Alphonso will report on a study designed to generate hypotheses concerning this complex problem. Participants' responses to survey questions suggest that viewing familiar mathematics content in alternative ways that deepens understanding of basic concepts is directly relevant to classroom practice. One of the most valued (and presumably most influential) activities was hearing peer teachers report on their practices. The *most* influential experience in summer 2010 was the psychology course, with its goal-setting activities. This suggests asking teachers to select and report on goals for change may be a good strategy. Note that goals set externally might not fare as well.

The external evaluators (Meyer reporting) are concerned with a bigger picture. To frame their contributions, let us set the project goals in a broader framework. LaMSTI seeks to develop STEM teacher capacity, recognizing that various types of teacher capital (e.g., social, cultural, and symbolic) can be developed through opportunities to

- acquire deep knowledge and practical skills,
- engage in community and leadership roles,
- associate with university faculty and other knowledge leaders, and
- successfully complete a rigorous master's degree program.

LaMSTI evaluation is examining the impact on participant teaching using several measures, including: classroom observations in a sample of participant classrooms, collection of teachers' self-report data via survey, and detailed descriptions of practice and factors that influence practice collected via teacher focus groups. We seek to measure the extent to which these types of capital are developed and the extent to which they affect teacher practice, both in the classroom and in other roles in which LaMSTI participants may serve. Because a variety of factors in the district, school, and classroom environments influence classroom teacher practice, we also seek to track these influences. Evaluation of these factors presents several measurement challenges. First, understanding the ways in which less tangible teacher capacities (such as aspects of teacher capital, values, habits, or dispositions) are developed requires measures that are sensitive and highly aligned with the types of capacities being developed. Second, assessment of teacher practice also requires that measures be sensitive to change over time, closely aligned with the domains of practice targeted by LaMSTI curricula and experiences, and valid in the sense that they accurately reflect how teachers typically approach their work. Third, to effectively track contextual factors that affect practice-and may either support or detract from intended outcomes-requires a good understanding of local factors affecting teachers, such as the support provided by their district and school to realize leadership and other roles that are promoted through LaMSTI project activities and competing pressures that may affect their classroom teaching. The evaluator presentation will delineate the approaches to these measurement problems that are being implemented.

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Abstract Title:
Using Teacher Assignments to Measure the Rigor and Relevance of Middle School Mathematics Instruction

MSP Project Name:
Impact of MSP Professional Development on the Quality of Instruction in Middle-School Mathematics Classrooms

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Strand 3

Summary:
This presentation will illustrate the use of teacher assignments for examining the quality of instruction of middle school mathematics teachers who received MSP-provided professional development and similar teachers who did not. The presentation will explain how carefully developed scoring rubrics and the Many-Facet Rasch model can be applied to measuring the quality of teacher assignments and how the scoring process can be effectively managed by using the Access-based Teacher Assignment Scoring System. This presentation will also demonstrate how measures of assignment quality can be properly analyzed using an advanced analytic method – HLM latent variable modeling, and report preliminary findings. We hope that these under-utilized measurement tools will become part of an expanding repertoire of methodological tools for STEM education researchers.

Section 1: Questions for dialogue at the MSP LNC

Do the rigor and relevance of teacher assignments get at the most critical elements of effective STEM teaching, as observed in the classroom setting?

What other evidence should be sought when examining teacher practices?

How useful is feedback like this to a project leadership team?

How can projects use the knowledge about teacher assignment quality?

Section 2: Conceptual framework

As a RETA project, our study is intended to be a source of tools, data, and analytic support to math and science partnerships. In the first two years of our grant, we have been working closely with the Greater Birmingham Mathematics Partnership (Phase II) (GBMP) and supporting an evaluation of its impact on mathematics teaching in middle schools. Focusing primarily on teacher professional development, GBMP offers a series of challenging, content-focused, and inquiry-based summer courses to teachers of middle-grade mathematics in participating schools. In addition to the summer courses, teachers also actively participate in school-based professional learning communities focused on implementing inquiry-based pedagogy and aligned assessment. These challenging courses and curricula and the activities of the teacher professional learning communities reflect GBMP's definition of effective teaching in STEM, which focuses on: 1) deepening knowledge of important mathematical ideas, 2) inquiry and reflection, 3) communication, and 4) productive disposition.

As part of our RETA project, we collected in-class and homework assignments from teachers and used the quality of these assignments as a proxy measure for effective teaching. Classroom artifacts, particularly teacher assignments, offer a promising alternative method to more commonly used classroom observations, surveys, and teacher logs for measuring the quality of teaching. Teacher assignments can provide insight into teachers' intentions and expectations for students, as well as the types of opportunities to learn presented to students on a day-to-day basis. Since teacher assignments are created as part of the normal teaching practice, studies of teaching practice through the lens of teacher assignments are less likely to place undue burden on teachers or data collectors. Further, teacher assignments have the potential for providing summative information about instruction, as well as rich formative information and opportunities for teachers to reflect on their own work (Goe, Bell, & Little, 2008).

Existing studies on instructional quality using teacher assignments, although limited, have demonstrated the utility of teacher assignments for studying the quality of classroom instruction and how it affects student learning. Research on school reform conducted by the Consortium for Chicago School Research under the Chicago Annenberg Challenge, for example, indicates that when teachers organized instruction around assignments that demanded higher-order thinking, in-depth understanding, and elaborated communication, that made a connection to students' lives beyond school, students produced more intellectually complex work (Newmann, Lopez, & Bryk, 1998; Bryk, Nagaoka, & Newmann, 2000; Newmann, Bryk, & Nagaoka, 2001). The Chicago research further suggests that students who received assignments requiring more challenging intellectual work demonstrated better performance on standardized achievement tests in reading, writing, and mathematics (Newmann et al., 2001). Similar results were obtained in studies conducted by Matsumura and her colleagues (Matsumura, Garnier, Slater, & Boston, 2008; Matsumura, Garnier, & Pascal, 2002). Another study done by the American Institutes for Research and SRI International examined the differences in rigor and relevance of assignments between small and large schools for the Bill & Melinda Gates Foundation (Mitchell et. al., 2005; Evan et. al., 2006; Shkolnik et. al., 2007).

For the purpose of this RETA project, we built the measurement of the quality of teacher assignments upon the rubrics developed by researchers at the Consortium on Chicago School

Research (Newmann et al., 1998; Bryk et al., 2000; Newmann et al., 2001). For the work with GBMP, we adapted the existing rubrics based on our understanding of the GBMP project and their definition of effective teaching in STEM. Specifically, our teacher assignment scoring rubrics were designed to reflect two dimensions of effective teaching: rigor and relevance. The rigor of mathematics assignments was measured by the extent to which assignments asked for 1) deep understanding of important mathematical content, 2) mathematical problem solving and reasoning, and 3) effective communication about problems and solutions. The relevance of mathematics assignments was measured by a fourth criterion, the extent to which assignments had relevant contexts and real-world connections.

Table 1 shows the components of effective teaching that would be expected in the classrooms of the teachers who participated in the professional development provided by GBMP and compares them to the four components of rubrics for measuring the quality of assignments collected from teachers. As shown in the table, our teacher assignment scoring rubrics cover three of the four components of effective teaching expected from the GBMP participants and include the additional component of mathematics problem solving and reasoning.

Table 1. Components of Effective Teaching

Expected of GBMP PD Participants	**Measured by Teacher Assignment Scoring Rubrics**
Deepening knowledge of important mathematical ideas	Deep understanding of important math content
Communication	Effective communication about problems and solutions
Productive disposition	Relevance contexts and real-world connections
Inquiry and reflection	N/A
N/A	Mathematical problem solving and reasoning

This study uses the rigor and relevance measures separately as well as combined into a single overall quality measure. Effective teacher assignments are both rigorous and relevant. One might expect that teachers who had received the professional development provided by GBMP would be making more progress towards effective STEM teaching than those who had not, and would have turned in more rigorous and relevant assignments.

Section 3: Explanatory framework

For this project, teacher assignments were collected from 67 teachers in total: 51 teachers who had received professional development provided by the GBMP program (treatment teachers) and 16 teachers who had not (comparison teachers). Each teacher was asked for 8 assignments along with a face sheet and other relevant materials for each assignment. The face sheets described the assignments (i.e., title, date collected, date due, explanation of the assignment, mathematics concepts and/or skills demonstrated by students, etc.) In total, 486 assignments were collected and scored: 359 assignments from treatment teachers and 127 from comparison teachers.

To score the assignments, we trained six experienced middle school mathematics teachers to score assignments on each of the four criteria in sessions conducted by our mathematics scoring leader. To facilitate and manage the scoring of teacher assignments, we developed an Access-based online data entry system, the Teacher Assignment Scoring System (TASS). In TASS, scorers could click on the link to a particular assignment; view the assignment, face sheet, and supplemental materials; and enter scores for each criterion based on the scoring rubrics. Each assignment was scored by two scorers on two of the criteria, allowing us to measure rater severity and account for it in estimating rigor/relevance scores for each teacher assignment. The database allowed for immediate reporting of inter-rater reliability for each criterion.

Based on the criterion-specific raw scores, which were typically on a 1-4 scale, a rigor score, a relevance score, and an overall quality score were estimated for each assignment using Many-Facet Rasch measurement (MFRM), which is a measurement model that takes into account both rater severity and item difficulty and produces a measurement error for each estimated score (Linacre, 1989). The Rasch scores for assignment rigor/relevance were converted to a 0-10 scale for easier interpretation.

A comparison of the Rasch scores of assignment quality indicates no significant difference in assignment quality between the treatment and comparison teacher. We found that the assignments collected from both treatment and comparison teachers were concentrated primarily at the lower end of the scales for all four individual criteria. Almost three quarters (73%) of the assignments relate to an important mathematics concept but require very little or no conceptual understanding of the concept. Over three quarters (78%) of the assignments require little or no problem solving or reasoning, and almost as many (74%) require little communication or explanation beyond writing the answer. The majority (61%) of the assignments were given the lowest rating on Criterion 4, as they make no attempt to address mathematics issues or problems that have real-world connections.

In addition to descriptive analyses of assignment quality ratings on the original three- or four-point scales, we also analyzed the Rasch scores of three assignment quality measures: rigor, relevance, and overall quality. The Rasch scores take into account both the difficulty of the criteria and the severity of different scorers. Given the measurement errors embedded in the assignment quality scores and the clustered data structure (measures within assignments and assignments within teachers), we assessed the differences in assignment quality between treatment teachers and comparison teachers using a three-level HLM latent variable model, controlling for a variety of teacher background characteristics (e.g., teaching experience, grade level, mathematics major, and teaching certificate). No statistically significant differences were found in the rigor, relevance, or overall quality of teacher assignments.

Although there were no differences found between treatment and comparison groups in effective teaching as measured by the assignments teachers gave to their students, it is possible that the professional development provided by GBMP contributed to other areas of effective teaching not measured by the assignments, such as the level of inquiry-based teaching.

A key contribution of this study is methodological. It demonstrates the utility of classroom artifacts, teacher assignments in particular, as useful tools for measuring the quality of teaching. It also demonstrates how the Teacher Assignment Scoring System provides a useful platform for effectively managing and streamlining the scoring process, and how the assignment scores can be properly analyzed with an advanced analytic method—HLM latent variable modeling. It is our hope that these underutilized measurement tools and analytic methods will become part of an expanding repertoire of methodological tools that will contribute to the rigor of educational research.

Section 4: **Lessons learned**

There are two lessons learned in this study: one concerning professional development in effective teaching of STEM subjects, and the other concerning the type of information that we should collect from teachers as part of teacher assignments collection efforts

For professional development in effective teaching of STEM subjects, it may be helpful to show teachers how they can develop rigorous and relevant assignments, or change assignments in ways that will make them more rigorous and relevant. This study did not measure how "difficult" the assignment was in terms of content, as long as the assignment covered an important content area for the given grade level. Instead, it measured the extent to which the assignments ask students to form a conceptual understanding, exhibit problem solving and reasoning skills, and effectively communicate their solution path, while showing how that concept might relate to a real-world issue or problem. If teachers are drawing assignments from textbooks, and treatment and comparison teachers are using the same textbooks, and teachers do not learn how to alter the assignments where necessary, it is unlikely that professional development will change the assignments given by teachers.

The first lesson learned leads to the second. For next year's data collection, we plan to ask teachers for the source of their assignments (textbook, online source, or teacher-designed, for example). We will compare the sources of assignments for the high-quality assignments and low-quality assignments to see where the differences (or similarities) lie. We will explore whether teachers have existing sources of rigorous and relevant assignments, or whether high-quality assignments tend to be designed by individual teachers. We believe this will contribute greatly to effective professional development and teaching, particularly in STEM subjects, where teachers may be more likely to draw assignments from textbooks.

Abstract Title:
Feedback for Improving Teaching and Learning

MSP Project Name:
Mathematically Connected Communities-Leadership Institute For Teachers (MC^2-LIFT)

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Strand 2

Summary:
Mathematicians, mathematics educators, researchers, and K-12 teachers at New Mexico State University involved in the Leadership Institute for Teachers (LIFT) collaboratively design and improve mathematics lessons and coursework in the two year institute. Reflective feedback is a central strategy to think about what we do, how we communicate, and what we learn. Specific tools and strategies are strategically used throughout the semester to provide data /feedback to teacher leaders and instructors in the LIFT courses. The feedback is used over time in developing a learning system that values stakeholder voice and focuses on what and how we learn. The feedback strategies and tools provide evidence to take action for improving learning.

<u>Section 1: Questions for dialogue at the MSP LNC</u>

1. What is the role of feedback in effective STEM teaching?
2. How are LIFT participants' voices and ideas used for peer-to-peer support?
3. How is feedback used to redesign coursework and improve instruction?
4. In what ways do school based support teams provide feedback for learning?

<u>Section 2: Conceptual framework</u>

Our definition of effective STEM teaching is: creating an environment in which students actively engage in problem solving and mathematical dialogue. Effective STEM teaching facilitates learning for *all* students as they engage in cognitively demanding tasks. The teacher designs the classroom environment so that students have sufficient opportunities for reasoning and sense making which result in useful mathematical knowledge, skills, and dispositions. Effective STEM teaching requires the teacher's continual development of their professional content, pedagogical knowledge and skills, and relies on feedback through ongoing assessment of what students are understanding and not understanding.

Background

Mathematicians and math educators and K-12 classroom teachers work together to build the knowledge skills and dispositions needed for effective math teaching. Three features of the LIFT project are 1) the creation of a Teacher Leadership Institute in which mathematicians and educators team teach and blend mathematics and pedagogy; 2) the requirement for teacher leader candidates to apply their learning in their classrooms and schools with mentoring from the School Support Team; and, 3) the use of K-12 mathematics progressions that allow teacher leaders to understand what students need to learn deeply over time and which would allow the leaders to differentiate instruction in their own classrooms and support other teachers to meet the needs of diverse learners. We (the LIFT instructors) are working with a cohort of 31 K-12 public school teachers, to whom we refer to as the LIFT teachers.

The MC^2-LIFT project is organized into four teams. The Development Team develops and facilitates the institute courses. This team includes both mathematics educators and research mathematicians to accomplish a goal of collaboratively designing and teaching coursework for LIFT K-12 teachers. The Research Team gathers, analyzes, and shares data regarding the actual changes in LIFT cohort teacher's classroom practice and teaching knowledge that result from the coursework and school-based support. The Research Team includes an internal evaluator, external evaluators, and mathematics educators and researchers. The School Support Team works with LIFT teachers in their classrooms and during institute courses, helping them apply what they are learning in their Institute courses. The School Support Team also works with school leaders. Its members include mathematics educators and former public school teachers who also participate in Development Team meetings, helping to ensure that what they see in classrooms shapes the development of institute courses. Each of these teams has several common members for communication and knowledge sharing. The Management Team also includes members from the Development, Research and School Support Teams.

Effective mathematics teaching requires teachers to have a strong background in mathematics and understand how to teach mathematics content so students can make sense of the concepts. They also need to be strong in research-based pedagogical practices; in particular, they need to know how to facilitate a student-centered classroom with an emphasis on activities leading to deep understanding and synthesis of learning. LIFT institute courses are designed to give the teacher's content and pedagogical knowledge, and the institute facilitators also model good teaching practice. Notably, we make great efforts to model the launch/explore/share/summary lesson structure and facilitator questioning, rather than lecturing and answering questions. The study of mathematics is through vertical content trajectories and cognitively demanding tasks that are accessible for all K-12 teachers yet challenging enough to push teachers thinking and sense making of the mathematics. Institute work is designed to integrate mathematics and pedagogy, and to require application of institute learning to the teacher's classrooms and schools.

Feedback to Improve Teaching and Learning

If teachers are to develop their intellectual and leadership capacities and apply them to benefit students learning, they must have opportunities to analyze and reflect on their learning and to

provide feedback to improve instruction and contribute to course improvement. One of the LIFT program design practices is to provide ongoing opportunities for stakeholders (K-12 teachers in the program, the school administrators, mathematicians and math educators) to reflect, utilize evidence/ data to communicate, and provide feedback through a variety of venues regarding their learning experiences in LIFT. The feedback is purposefully requested, gathered and analyzed as a formative assessment process to inform and impact coursework, school support, math or education lessons, and inform the next steps for the LIFT program.
The research (Wiliam & Thompson and Cobb et al.) focuses on the uses of timely strategic feedback as a student, within a classroom, or a research project. Utilizing feedback provides explicit opportunities for adjustments to a process, event, or idea. An important consideration when making improvements in a course or program is obtaining timely relevant feedback through assessment and revision to support learning based on shared course goals. Additionally, students should play an active role in monitoring and improving their learning and serve as resources for each other.

LIFT teachers receive feedback from instructors in the courses in a variety of formats. Writing assignments require LIFT teachers to explain their mathematical thinking. Instructors provide feedback on the mathematics writing but there are also peer reviews.
The LIFT teachers engage in structured peer edits in groups by using reflection questions to make comments on a peer's paper. Peer feedback is incorporated in the education course performance tasks as well.

LIFT teachers are required to put their learning from the Leadership Institute into practice at their school site. In order to help them transition learning from institute into practice, the LIFT teachers are supported at their campus through partnerships with School Based Leadership Teams (SBLT) comprised of administrators and instructional leaders that also attend some of the Institutes. The LIFT teachers also collaborate with School Support Teams (SST) comprised of LIFT instructors that provide ongoing support for the teachers and administrators at the school site. The School Support Teams provide a critical support and feedback mechanism to connect the LIFT program expectations to the school cultures and practices. LIFT teachers and administrators provide feedback to their SST mentors for the sake of improving onsite support, coursework, or leadership support.

The tasks, assignments and instructional approaches in both the education and math courses are adjusted based on feedback from LIFT teachers on how well course instructors are doing in supporting learning of all cohort members. For example, LIFT teachers use daily reflective feedback or protocols to reflect on instruction. LIFT teacher feedback is essential in guiding the day-to-day learning opportunities and the coursework over time.

We have developed some useful strategies and protocols to make the feedback a part of teaching and learning for LIFT instructors and teacher leaders. The innovative processes and structures for feedback provide opportunities for collaboration, input, and continuous deliberation in order to study and learn through our teaching practices in mathematics classrooms at the university and in public schools. Effective STEM teaching includes evidence-based feedback to measure progress towards shared LIFT goals and to assess and improve teaching and student learning.

Section 3: Explanatory framework

We are learning that evidence and feedback are an essential aspect of effective STEM teaching. We have developed structures for feedback that provide ongoing information about learning and effectiveness of the program. There are explicit pause points for reflecting on practice and LIFT teacher learning in the university courses. It also includes peer-to-peer feedback on performance tasks or specific assignments in the courses themselves.

Both the mathematics and education courses use a variety of strategies for obtaining feedback to improve courses through studying teaching and the resultant progress towards explicit learning goals. These include strategies such as journey analysis writings, pre/post tests, surveys/questionnaires, and course evaluations. The feedback also includes dialogue and purposeful informal conversations through the school support team, focus groups, and peer feedback. As LIFT instructors, we utilize practices like feedback to improve learning and to model STEM teaching that includes instructional and course improvement based ongoing assessment/feedback.

We incorporate feedback in the instructional and leadership conversations. The coursework, leadership planning, school support, all require collaborative professional relationships that include dialogue, listening, responding and revising, evidenced based suggestions, and other opportunities that build from the ideas and insights of the teacher leaders. The use of feedback provides a generative paradigm for maximizing learning in the LIFT cohort.

Section 4: Lessons learned

We have learned that it takes trust, time and opportunities to develop a learning culture. Teachers need to know their voice is valued. Effective teaching requires strategic assessment that provides evidence and a process for continued learning. Using feedback from assessments that occur minute-by-minute, day-by-day and course-by-course provide the evidence for improving teaching. As LIFT instructors we must engage in teaching as a professional activity that builds relational trust, knowledge, dispositions and understandings of mathematical ideas in ways that support curiosity and eagerness to continue learning over time. When LIFT teachers provide input and feedback they are more invested in the work and the quality of the learning experiences can be improved.

Here are some comments from LIFT instructors and LIFT teachers, which have helped us to learn about our program:

LIFT instructors:

- For years, students would say to us "I understand the material, I just can't explain." We realized this was code for "I don't really understand this; I can just follow some algorithm." We push the participants to explain the mathematics we study in the course so that the other members of the cohort can understand their explanation. That forces them to examine and provide support for many steps they would have otherwise used without justification. We believe that this reexamination of ideas they already know leads to a deeper individual learning.

- We push LIFT teachers to think more deeply about both reasoning and communication. They have a tendency to make assumptions that they should think about more than they do.
- Our use of unstructured peer-to-peer feedback activities didn't give much useful feedback. When we make the activity structured, with focus questions for them to address, then they started to give helpful information.
- One problem with mathematician feedback on a first draft of a written assignment is that participants tend to ignore any parts of their paper without feedback and edit to try to "please us", rather than thinking about their paper in its entirety. We haven't found a feedback mechanism that gets them to reread and redo an entire paper rather than tweak individual sentences.

LIFT teachers:

- We get feedback in class via peers and from the LIFT instructors (both formally and informally along the way- like with our action research projects). I do something similar in my class through homework, in class feedback and one on one interaction.
- I use feedback in my classroom in the same manner that the LIFT facilitators use with use. For example a self-reflection with rationale.
- Through peer editing I had the opportunity to see someone else's perspective. I also got ideas on what I needed to change. This happened through peer editing and the school support team.
- The questioning of my thinking and the questioning of my action research project really made me examine my own practices.
- In LIFT I use feedback to reflect on my own understanding and communication to improve my work. At work- As an educator I offer questions, comments to promote my students thinking and understanding. I try to be timely, the more immediate the feedback the more impact.
- When we give feedback to our instructors, it is very evident they read and reflect on it and make needed changes to instruction. I try to follow this in my practice because it provides evidence to students that their needs and thoughts are being considered.

These lessons learned have led us to adjust our LIFT program by making our assignments be more focused and getting the participants to give a polished and concise (but complete) explanation of a mathematical idea, and to have them conduct structured peer edits of their papers to develop their math content and communication skills. We also have learned that when we solicit feedback from LIFT teachers we need to take explicit action and respond to the evidence in ways that support effective teaching and learning in our LIFT program.

We include teacher leaders' voices in designing the learning experiences and building a collaborative culture focused on learning. Through this process, LIFT teacher leaders better understand that their voice and ideas matter and that their own students in their classrooms are empowered and invested in making meaningful changes to improve learning when they are part of the teaching equation.

Abstract Title:
Task Analysis: A Process of Documenting Task-Level PCK

MSP Project Name:
Mathematics Teacher Leadership Center

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Strand 2

Summary:
We describe a task analysis process developed to support our MSP's goal of increasing teachers' pedagogical content knowledge (PCK) and their teaching effectiveness. During a task analysis, teachers think systematically about and articulate PCK for teaching a rich math task. A task analysis results in:

- An appropriate range of strategic approaches and correct answer(s)
- Pedagogical moves and tools/technology that support student thinking
- Possible mathematical difficulties and misconceptions students might face
- Content and process standards the task addresses

We will share our thinking about task level PCK and examine teachers' task analysis work. Anecdotal evidence suggests the task analysis has potential to support the development of teachers' PCK and serve as a research tool for measuring or evaluating a teacher's PCK.

Section 1: Questions for dialogue at the MSP LNC

Are you familiar with any tool similar to the task analysis?

What ideas or suggestions do you have for improving the task analysis?

Section 2: Conceptual framework

We believe effective math teaching involves teachers

1. Establishing and maintaining a supportive classroom culture for all students to engage with and make sense of mathematics
2. Establishing appropriate and well-defined learning goals that capture the big ideas of mathematics and the ways of thinking about and doing mathematics
3. Monitoring via formative and summative assessments the progress students are making towards the learning goals
4. Designing and implementing instruction that supports the desired classroom culture, aligns with the learning goals, and is responsive to student thinking and learning

Effective math teaching results in appropriate growth of mathematical learning for all students. The goal of our MSP is to develop effective mathematics teachers and teacher leaders via two graduate programs: a Master's Program for in-service secondary mathematics teachers and a Teacher Leadership Program for 4^{th}-12^{th} grade experienced mathematics teachers or teacher leaders. Both programs involve deepening teachers' mathematical understanding, pedagogical content knowledge (PCK), and understanding of the interactions among culture, mathematics, teaching and learning. We believe that improving teachers' PCK is associated with improving their instruction and, ultimately, student learning.

Our intent was to develop teachers' PCK in the Master's Program through courses focused on teaching specific content, such as Algebra and Geometry. For the Teacher Leadership Program, we had two goals related to PCK: 1) We wanted the teacher leaders to understand what PCK is and why it is important and 2) We wanted to suggest ways in which teacher leaders could help other teachers develop PCK. The literature base informed our thinking about the first goal, but was not as helpful for the second one. Our discussions led to the idea that PCK can be viewed in different grain sizes. That is, PCK can be thought of with respect to multiple grade levels, a single grade level, a unit, a lesson, or, at its most basic, a task. Because it seemed the most accessible, we focused our thinking on task level PCK. We asked: What PCK is appropriate for a specific mathematics task? Drawing on the literature and our own experiences, we developed the task analysis, which is a template for documenting task level PCK. In particular, the task analysis is structured to capture:

- An appropriate range of strategic approaches and correct answer(s) for the task
- Pedagogical moves and tools/technology that support student thinking
- Possible mathematical difficulties and misconceptions students might face
- Content and process standards the task addresses

While the task analysis informs lesson planning by anticipating student thinking and considering how best to respond to and support that thinking, we view the task analysis as a separate process. Lesson plan elements that are not part of the task analysis include: how to launch a task, how to group students, what strategies to emphasize, what information to introduce or review with students, how students will document and share their work, and how student thinking will be assessed. It is therefore possible to develop any number of lessons from one task analysis. As such, a task analysis is not as explicitly tied to any particular teacher's style of teaching as a lesson plan is. Completed task analyses, then, could form a body of work that records the thinking behind effective lesson planning. Such a knowledge base could be shared within a department, a district, or over the internet.

Section 3: Explanatory framework

Before teachers engage in a task analysis of a rich mathematical task, they complete the math task and debrief the various solution strategies. Next teachers work in groups to complete the task analysis using the task analysis template. When appropriate, we discuss as a group how the teachers completed the task analysis and move on to lesson planning. We often conclude by having teachers reflect orally and in writing about the task analysis process. From these experiences, we have refined the clarity and usability of the task analysis template and compiled a FAQ document based on common questions teachers have had about the task analysis. From the reflections we have learned that teachers:

- Recognize the value of articulating task level PCK prior to teaching a lesson
- Prefer to complete a task analysis with other teachers because they feel the conversation deepens their thinking
- Feel that a complete written task analysis is not possible for every task they teach, but that knowing the task analysis process helps develop some habits of mind that improve planning a lesson

To date, we have collected enough anecdotal evidence to suggest that experienced teachers value the task analysis for their own practice as well as for supporting other teachers in developing PCK. Therefore, we plan to continue to use the task analysis in our graduate courses. In addition, we are in the process of designing a more formal research program to systematically i) study how the task analysis process supports teacher development of PCK and how this is reflected in their teaching practice and ii) explore how the task analysis might be used to measure and evaluate a teacher's PCK.

Section 4: Lessons learned

In pursuing our MSP's goal of improving teachers' PCK, we found that we lacked specific strategies for supporting teacher leaders in learning how to help other teachers develop PCK, which we did not know when we wrote the proposal. In the process of solving this problem, we developed the task analysis for making explicit the PCK associated with a particular math task. Implementing the task analysis in our graduate program for in-service teachers launched another learning process for us. We have worked to understand effective strategies for introducing the task analysis to teachers, how teachers prefer to engage in the task analysis process, and how to provide feedback about task analysis work. We still have much to learn about how teachers integrate the task analysis into their teaching and leadership practices and how the task analysis is tied to improving mathematics instruction.

Abstract Title:
Collaborative Development of Biology and Geology Content Courses for Future Elementary and Inservice Teachers

MSP Project Name: NCOSP

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Summary:
The North Cascades and Olympic Science Partnership (NCOSP), in partnership with California State University Chico (in biology) has developed and implemented semester-long courses in biology and geology based on the model provided by Physics and Everyday Thinking (Goldberg et.al. 2006) which incorporates the research base described in How People Learn (NRC 2000). The sequence of courses is offered for future teachers at Western Washington University and three community colleges. The biology materials have been adapted for use in high schools in two school districts. More than five years of evaluation data indicate that the courses are effective in helping future teachers learn important content through instruction that explicitly models effective teaching practices. A five-year longitudinal research study was recently funded.

Section 1: Questions for dialogue at the MSP LNC

How are the biology and geology course materials that have been developed used in an in-service context?

What impact have these courses had on K-12 teaching and student learning? How are they used in local high schools?

Who teaches the courses and how are faculty members prepared to teach them?

How can these materials be used in both a university and high school setting?

What impact have these courses had on the elementary teacher preparation program?

What assessments are used to measure student learning?

How is technology used in these courses?

Section 2: Conceptual framework

Our innovative ideas synthesize three research areas into a coherent picture of **Effective Science Instruction** in the classroom. We bring together the cognitive science foundation described in the NRC report *How People Learn: Brain, Mind, Experience, and School* (NRC 2000), the research-based instructional strategies of Formative Assessment Process/Assessment for Learning (see for example William, 2011), and the research on the impact of professional teacher collaboration, including the critical role of building leadership (see for example Garmston and Wellman 1999, City, Elmore, Fiarman, and Teitel, 2009) and www.edtrust.org). An effective science lesson is a learning cycle that engages the student not only in the content, but also in the pedagogy, making leaning strategies transparent to increase student's self-efficacy. Students work individually, in small groups, or with the whole class when appropriate. At each stage, when appropriate, there are opportunities for structured teacher-, self-, or peer-assessment to generate information necessary for providing useful feedback to guide students. There is also the tacit but critical assumption that adequate instructional materials are available. The lesson contains the following steps. It:

1. Begins with sharing important learning targets with students to make sure that each student understands the goal, how it will be assessed, and the criteria for success fully demonstrating achievement,
2. Draws out student's initial ideas about the learning target to make them visible to both the student and teacher,
3. Engages students in sufficient activities to gather evidence relevant to exploring the concepts in the learning target. These activities can be classical inquiries, observations of phenomena, exploration of text, technology-based simulations or demonstrations, or a lecture if that is appropriate,
4. Engages students in analyzing, thinking about, and reflecting on the evidence, initial ideas, and learning target and communicating their thinking to their peers and teacher,
5. Requires students to generate artifacts that demonstrate their evidence, analysis, and thinking. This can be a lab report, concept sketch, presentation, paper, solved problem etc. Assessment of the learning reflected in these artifacts informs the next cycle of steps 3-5 and the timing of when to continue on to step 6,
6. Brings the class together for a final sense making session to engage students in reflecting and communicating their new understandings,
7. Concludes with an assessment that gives the students the opportunity to demonstrate their learning. This assessment may be used for grading purposes or may be used formatively.

In our work, we add the additional expectation that teachers will continuously work to increase the effectiveness of their instruction through professional collaboration with their peers around student work, supported by their building and district leaders.

The biology and geology course materials developed are used in small classes (24 students) and are modeled after the *Physics and Everyday Thinking* materials developed by Fred Goldberg and his team at San Diego State University. Students work in groups of three and engage in simultaneous cycles of individual, small group, and whole class work while exploring their initial ideas around the desired learning target, gathering evidence, and reflecting on how the evidence relates to the learning target and their initial ideas. Scientists' ideas are introduced periodically to reinforce student thinking and provide academic language. Technology is used when appropriate in collecting evidence. Students periodically are encouraged to step back from the science content and explicitly consider and discuss the pedagogy used as examples for consideration as they prepare to become teachers or to go back into the classroom in the case of in-service teachers.

Instructor support materials have been developed to provide material and pedagogical support for faculty new to teaching with these materials. These include both nuts and bolts advice and explications of the underlying framework and rationale for the instructional model.

Section 3: Explanatory framework

We now have more than five years of experience using these materials with both preservice and in-service teachers. Results from carefully designed and validated pre and post testing show that students are achieving the targeted learning goals. Limited results comparing outcomes from our courses and traditional lecture courses addressing similar content indicate that our courses are more effective in helping students learn.

Experience with teaching these courses has profoundly impacted participating faculty's ideas about teaching and learning as measured by periodic surveys, interviews and classroom observations using the Horizon Research Protocol. New approaches to instruction are being incorporated into classes taught in the biology and geology departments of all the participating institutions.

Students are arriving in elementary science methods classes with significantly deeper content knowledge and new ideas about effective science instruction. This has enabled us to significantly revise the focus of the methods courses. A longitudinal study has just begun through a DRK-12 grant to explore the impact of the new content courses and the revised teacher preparation program on new teacher performance.

Section 4: Lessons learned

Careful preparation of the faculty is critical in effectively teaching the courses. We had the advantage of working as a team of 25 faculty from the university and community colleges with time and resources to collaborate. We also began by preparing and co-teaching the *Physics and Everyday Thinking* curriculum in an in-service setting led by one of our physics faculty who had been involved in piloting the materials. Over the course of three years the group met monthly to read the research, talk through options, and develop the plan for writing and piloting the materials. Faculty new to the courses were required to co-teach with an experience colleague prior to teaching the course independently. Common assessments and classroom observations using the Horizon Research protocol allowed us to exercise quality control.

As the materials are published we have attempted to make clear our intent and instructional expectations through the instructor support materials. Given the resources it would be ideal to provide explicit training to faculty planning to use the materials.
Participation of practicing teachers in the development process was invaluable. The insights and advice from the six NCOSP Noyce Master Teachers that worked with the faculty, especially in helping create the instructor support materials, brought an enhanced real-world perspective to the work.

In today's world, content appropriate for preservice elementary teachers is also appropriate for ninth and tenth grade high school students. The Bellevue School District and Bellingham High School have successfully implemented versions of the biology course as their Introductory biology course for all students along with explicit professional development for the teachers. The implication is that if courses like this could be successfully implemented in the high schools, many students, especially future teachers would arrive at the university better prepared to learn science at a deeper level.

Community college faculty are a huge untapped resource. Community colleges are potentially the ideal location for future teachers to earn their general education credits in science. Classes are small and taught be instructors that, in large part, are committed to teaching. Careful preparation of the community college faculty is critical. Like most scientists, they have deep content knowledge, but little or no experience with education or education research. Given the opportunity, it is our experience that community college faculty are eager to engage in improving their instruction, though the process takes significant time and effort.

Abstract Title:
Development and Implementation of Learning Progression-based Teaching Strategies (LPTSs) for Environmental Science

MSP Project Name:
Targeted Partnership: Culturally Relevant Ecology, Learning Progressions and Environmental Literacy

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Summary:
Our Targeted Partnership, Culturally Relevant Ecology, Learning Progressions and Environmental Literacy, is centered on four Long Term Ecological Research sites: Baltimore, Maryland (urban); Kellogg Biological Station, Michigan (agro-ecosystems); Ft. Collins, Colorado (short grass steppe); and Santa Barbara, California (land/marine ecosystems). Each site is working with middle and high school science teachers to enhance environmental science teaching. We describe the development and use of research-based learning progressions to explore how students and teachers learn environmental science in strands focusing on carbon cycling, evolution and biodiversity, and water systems. We then discuss the place-based, culturally-responsive models of professional development we have created and tested to support the use of learning progression-based teaching strategies in the diverse classrooms encompassed by our multi-site project.

Section 1: Questions for dialogue at the MSP LNC

Our proposal promotes learning progressions as a tool for guiding student assessment, teaching practices and professional development. They place an emphasis on students' understanding of big ideas and important principles as opposed to the specific content or narrow facts related to those concepts. This raises several questions about approach and application, particularly in the current *Race to the Top* environment. The adoption of the learning progression approach and its implementation through Learning Progression-based Teaching Strategies and the requisite approaches to professional development raises the following questions:

Questions related to the research approach

- How do the learning progression research approach and assessments align with the current content and process-based assessments?

Question related to implementation

- How can we best implement our proposed model for professional development within the current K-12 and higher education environments?
- How would this play out in different pre-service and in-service contexts?

Section 2: Conceptual framework

Learning Progressions-based Teaching Strategies (LPTSs) – are models of pedagogical approaches that are informed by research on learning progressions. The overarching goal of this work is to integrate useful insights from research into student and teacher learning into models of professional development and support. These models should be robust and share common vision and approaches, while being flexible so that place-based and culturally-responsive teaching and implementation can occur. Our project has identified the following practices as comprising what we call Learning Progression-Based Teaching Strategies in environmental science for middle and high school environmental science instruction. These, then, represent our definition of effective teaching in our field.

1. Focus instruction on important **big ideas** in the field of study. These are identified by experts in the field, consistent with the required curriculum at the local, state and national levels, and supported by research on student learning (ideally, learning progression research).
2. Plan instruction based on **anticipated level of student understanding**, informed by research on learning progressions for the subject.
3. Develop and use **formative assessments** to guide selection of instructional strategies and sequences. Ideally, these would be interpreted based on learning progression research.
4. Support student learning through careful **attention and response to student thinking** during classroom discourse and in comments on student work.
5. Engage students in guided or open **inquiry with authentic events and experiences**. For environmental science, this includes direct experiences with organisms and ecosystems outside.
6. **Link environmental science to real problems** in the local, nearby environment. This anchors students' learning in their culture and place.
7. Have students **engage in and reflect on science-based citizenship practices** – using knowledge to explain and predict; using science skills and understandings to investigate, evaluate and critique arguments; and being motivated and confident to use science in decision making.

In order for teachers to be effective at implementing these practices, they need:

1. **Strong content understanding** of the topics of instruction. This includes having accurate information about the content knowledge of the unit and their importance for environmental science literacy. It also means having an honest appraisal of her/his own level of understanding and setting goals for personal learning and growth.
2. **Pedagogical content knowledge** based on an appreciation of student learning trajectories and the kinds of scaffolded thinking and experiences student need to advance along the learning progressions.
3. **High quality instructional materials** that reflect the best of what we know about how students move along the learning progressions for that topic. These include clearly articulated goals for student learning, a clear instructional sequence to support inquiry and scaffold conceptual learning, and connections to place and important environmental challenges.
4. **Tools for building student reasoning** and practice in using these in a cognitive apprenticeship activity sequence: establishing the problem, modeling, coaching, fading, maintenance.
5. **Access to current research about student learning** in a format that is understandable and useful in their planning.
6. **Formative assessment tools** embedded in their instruction to help track students' progress in learning progression levels and recommend appropriate activities for students at different levels.
7. **Practice with and support for responsive teaching.** Both in professional development workshops and meetings, and in supported classroom teaching, teachers benefit from the chance to anticipate student responses to embedded prompts and activities, and then to practice both effective discourse strategies and instructional choices.
8. **Self efficacy and motivation** to adopt, adapt and implement the learning progression-based teaching strategies in their classrooms.

We have designed our project's professional development (PD) program to test and implement a blend of approaches to support teachers' use of Learning Progression-Based Teaching Strategies. The variety of geographic and institutional settings represented in our project provides a rich diversity of PD contexts and challenges, and is yielding a tapestry of approaches. The project's PD program includes:

1. Professional development experiences – summer institutes and schoolyear workshops, in most cases over 2 or more years for each participating teacher – that include
   a. Explicit instruction in the theory and procedures involved in developing, refining and applying learning progressions about the big ideas in environmental science.
   b. Examining student responses to our content assessments and to formative assessments embedded in the TEs, using a learning progression framework.
   c. Engaging the teachers in content learning while carrying out activities in the TEs.
   d. Reflecting with teachers about classroom implementation challenges of the TEs and related learning progression based teaching practices.
   e. Practice with responsive teaching, use of formative assessments, and instructional aides with staff and other teachers.
   f. In school support
2. Supporting resources, including
   a. Instructional materials (in our project, we refer to these as our Teaching Experiments

(TEs) in Carbon, Water and Biodiversity, and our Case Study Citizenship Activity). These include teachers' guides, and classroom materials for students.
   b. Instructional aides, including visualizations and other large-format graphical organizers (to be used with entire classes).
   c. Equipment and supplies for investigations in the classroom and the schoolyard.
3. A supportive learning community to foster and sustain innovation and implementation across the years, including
   a. On-line exchange of ideas, sharing of resources and feedback
   b. In-school support from other teachers (as Teachers in Residence or Lead Teachers), project scientists and educators, or Graduate 6-12 Fellows.
   c. Periodic meetings with project staff, other teachers, etc.
4. In-depth and extended professional development opportunities for select teachers, including
   a. Year-long Teachers in Residence opportunities for full-time emersion in the project's research and development work.
   b. Research Experiences for Teachers opportunities, usually for 6 weeks during the summer and continuing into the following school year. These involve mentored research either in environmental science or some aspect of teaching and learning.
   c. Lead Teachers are engaged in some sites to help lead project Summer Institutes and Schoolyear Workshops, and to provide in-school support to other teachers.
   d. Teacher exchanges between sites foster learning about the approaches and challenges found in different parts of the country.
   e. Enrichment field trips (e.g., a teacher trip to Costa Rica) and other PD workshops (e.g., a Soils Institute) provided interested teachers with an opportunity for additional growth.

Section 3: Explanatory framework

Each of the four sites in the project – SBC (Santa Barbara Coastal in California), SGS (Short Grass Steppe in Colorado), KBS (Kellogg Biological Station in Michigan) and the BES (Baltimore Ecosystem Study in Maryland) – have developed PD programs that reflect their local and regional ecological, educational, cultural and socio-economic contexts. The common elements are described in Section 2. In addition to these, each site has developed distinctive approaches to fostering the use of Learning Progression Based Teaching Strategies among our participating teachers. For example:

1. SBC has staff scientists and educators, graduate students and a Teacher in Residence that spend dedicated time with the faculty at each participating school. This can involve curriculum planning, examination of student pre-test results, TE implementation, documentation of teaching practices and student outcomes, and logistical support during instruction. The conversations that take place while implementing this approach give staff a chance to explore patterns of student thinking and learning with the participants.
2. The SGS team of scientists, educators, and Teachers in Residence has guided their teacher participants in developing Action Research plans to explore some aspect of student thinking and learning in their own classrooms. Each research project probes the impact of a specific teaching strategy based on the learning progression research of the project.
3. The KBS team is developing ways to support teachers in using student responses in the pre-assessments to shape their plans for implementing the TEs and other units.

4. In BES, staff scientists and educators, Teachers in Residence, Lead Teachers and Graduate Students all support and respond to teachers' journal entries where they are asked to reflect on student learning challenges and how they would respond for each workshop topic.

We have a well-articulated research agenda for exploring questions about the relationships between teachers' knowledge, skills, attitudes, their socio-cultural and environmental contexts, their professional development experiences (including our programs), their teaching and their students' learning and other responses. Our research and assessment tools include:

1. PD Documentation and Reflection. Site PD leaders complete several forms and surveys to document and reflect on their workshops and other PD activities.
2. Content Assessments. Most teachers complete at least one of the content assessments (carbon, water or biodiversity) at the beginning and the end of their participation (pre- and post-testing). The same assessments are used for students and teachers. The teacher versions include several pedagogical content knowledge items.
3. Teachers' Survey. Teachers complete a survey in late spring, serving as a pre-survey for first time new teachers and as a post-survey for continuing or ending teachers. This gathers information about: 1) the nature of their classroom implementation of the teaching experiments and other instructional innovations they carried out based on their experience in the project, 2) their perceptions of student responses to the new instruction, 3) their understanding of learning progressions and the utility of our research into student learning for their classrooms; and 4) the factors that support or constrain their environmental science teaching and the influence of their PD experiences on these factors.
4. Teaching Experiment Logs. Each teacher is expected to teach at least one of the TE units during the school year, and then to submit a completed Teaching Log that details their implementation and any changes they made. It also collects information on their use of several of the teaching strategies described in Section 2 above.
5. Portfolios. Teachers at the Baltimore site submit portfolios that documented key aspects of their teaching over the school year.
6. Journal Prompts. Teachers at the Baltimore site responded to journal prompts after each of the school year workshop. These ask them to reflect on what big ideas in environmental science were highlighted in the workshop, what would interest and what would challenge their students to learn about these ideas, and what approaches they might take to incorporate the ideas or pedagogies from the workshop into their instruction.
7. Interviews. All sites engage in various types of conversations (interviews) with teachers over the course of the school year. These are used to help complete a Teacher Information Dataset with information about each teacher's participation in PD activities and teaching activities.
8. Classroom observations. Staff currently is using a pilot form to record observations about each teacher they visit in the course of providing in-school support. This form will be used as a starting point for a Learning Progression Based Teaching Strategies Observation Protocol we are developing to pilot test in spring 2012.
9. Case Study. We plan on implementing a pilot case study of teachers identified as "high implementers" of our targeted teaching strategies in spring 2012, with hopes of implementing a more complete study in the summer 2012 and the following school year.

Preliminary analyses of the Teacher Survey showed the following results:

1. Teachers reported significant benefits from program participation in terms of their

understanding of the big ideas in environmental science, and their understanding and use of learning progressions in their teaching.

2. Most teachers reported that their students responded favorably in all 5 dimensions included in the survey, with student learning of content and skills receiving the most agreement.
3. Teachers most often indicated these factors as supporting their use of the targeted teaching practices: 1) their personal commitment to the environment, 2) practical wisdom from their teaching, 3) confidence that their students will learn and succeed, and 4) personal motivation to use the practices. These results support our emphasis on focusing our PD work on building self efficacy and motivation for innovative practices. The factors rated as limiting by the most teachers included time, availability of field trips, and standardized curricula and tests.

Section 4: Lessons learned

In this session we will discuss how we have organized the development of Learning Progression-based Teaching across four geographically and culturally disparate locations: Baltimore, Santa Barbara, rural Michigan, and rural Colorado. Two results have emerged from our work. First, the data from our assessments of teachers and their students indicated that in many instances the content knowledge of teachers and their placement along the learning progression framework was not at the advance level that we had anticipated, and in some instance was not much farther advanced than their students. Second, our learning progression research is supporting the development and testing of professional development models that are both site-specific while sharing a common core of practices and strategies. A common set of instructional materials is honed to local environmental and cultural resources and constraints through this flexible professional development model. Student and teacher research at each site supports the place- and culture-based approach. The diversity of our sites provides us with ample examples of how to adapt the key features of our professional development model for fostering the use of ;learning progression-based teaching strategies with different populations.

Abstract Title:
Supporting Inquiry-Rich Teaching Through Professional Development within a District-Higher Education Partnership

MSP Project Name:
RITES

Presenter:
Jay Fogleman, University of Rhode Island

Authors:
Joshua L. Caulkins, University of Rhode Island (Lead)
Jay Fogleman, University of Rhode Island

Strand 2

Summary:
There is a need for instructional materials to help teachers enact inquiry-rich science in their classrooms. Technology-enhanced investigations can provide students with opportunities to collect data using probeware and investigate natural systems through models and simulations. The RITES partnership is a statewide collaboration between grade 6-12 schools and higher education to develop inquiry-rich activities addressing state standards and to provide meaningful learning opportunities for Rhode Island students. A challenge faced within the partnership is how to design PD that helps teachers use RITES materials effectively. This study describes the design of 16 PD short courses attended approximately 100 teachers. We used course evaluations, pre/post assessments, short course observations and interviews to determine how teachers benefited from the PD.

Section 1: Questions for dialogue at the MSP LNC

How are you measuring student achievement and student outcomes?
How are you ensuring all members of your partnership feel included and that they have a role in shaping the nature of your MSP?
What are you doing to ensure the sustainability of your MSP?

Section 2: Conceptual framework

RITES Definition: Effective STEM teaching is creative, responsive instruction that is (a) attentive to learner knowledge base, initially and evolving through a course experience, (b) rich in the use of inquiry, (c) supported by appropriate and efficient technology, and (d) contextualized by synergistic decision-making and curricular design on the part of school programs, schools, districts, and states.

Though widely recognized as critical to science teachers as they attempt to integrate inquiry-rich instruction into their practice, researchers have struggled to understand how to design PD that fosters classroom inquiry, is salient for a wide range of teachers, and is sustainable within district-university collaborations (Fullan, 1991; Wei, Darling-Hammond, Andre, Richardson, & Orphanos, 2009). If teachers are going to adopt new materials and use them well, they must have access to effective PD experiences (Penual et al, 2007). In this study, we describe how several teams of secondary teachers and higher education faculty working within a statewide Math-Science Partnership (MSP) between district and higher education faculty designed and enacted PD to model inquiry instruction, address key science concepts, foster teachers' buy-in and use of a collection of computer-based investigations designed to foster inquiry in grade 6-12 classrooms. We will address the following research questions:

a. How do facilitators design and enact PD to foster teacher participation in inquiry during their respective short courses?
b. What role does inquiry play in the short courses, and to what degree do teachers find these short courses useful in deepening their knowledge of inquiry?
c. How do teachers' engagement in inquiry in the short courses contribute to their learning of science concepts?

Section 3: Explanatory framework

a. How did facilitators represent and support inquiry in their short courses?

Each of the resource teams developed at least one inquiry investigation for teachers to use in their classrooms. It was intended that teachers would have a chance to use these investigations in the short courses, and engage in activities that would deepen their background knowledge around the investigation topics. We observed at least one of these learning opportunities in each short course using our observation rubric. Our preliminary analysis of these observations suggest that the activities provided opportunities for teachers to experience procedures related to conducting investigations, but provided only limited opportunities for teachers to discuss their findings or how they would use the activities in their classroom. Interestingly, when teachers were provided with individual computers, observers noticed that teachers did not have as much need to discuss their investigation plans, results, and conclusions.

b. How did teachers value the inquiry experiences offered in the PD?

Though teachers consistently reported very high levels of satisfaction with the short course content and instruction on the PD evaluations, there were patterns regarding which types of PD activities were valued most highly by participants. As indicated in our previous finding, instructors were encouraged to include inquiry-rich activities as a theme in each of their short courses, and our preliminary observation data confirms that these opportunities occurred. Unsolicited anecdotes from a number of teacher participants indicated they were impressed and excited by the partnership between higher education and middle/high school science teachers as co-instructors for each course.

c. How did teachers' engagement in inquiry contribute to their learning?

Preliminary examination of the pre-post assessments administered in each course suggests that teachers showed clear content learning gains in all courses, a finding which was generally expected but important nonetheless. To address our third research question, these results will be compared with our overall evaluation of the degree that inquiry was supported within each short course. This analysis is ongoing.

Section 4: Lessons learned

Developing curriculum materials and PD that teachers find useful as they enhance the inquiry opportunities in their classrooms is a challenge. Within this statewide collaboration, district and higher education partners are committed to creating resources that have lasting value among teachers across the state, and effective PD is essential in that effort.   Little work has been done to determine what teachers actually learn from PD. This work contributes our understanding of how district-university partnerships can teachers' needs and concerns.

Abstract Title:
"Equity Practices" for Teaching and Student Learning: How to Go Below the Surface of the Words

MSP Project Name:
MOBILIZE: Mobilizing for Innovative Computer Science Teaching and Learning

Presenters:
LeeAnn Trusela, University of California-Los Angeles
Thomas Philip, University of California-Los Angeles

Authors:
LeeAnn Trusela, University of California-Los Angeles
Thomas Philip, University of California-Los Angeles (Lead)

Strand 2

Summary:
Our model of "effective teaching in STEM" addresses inquiry-based instruction, equity in teaching and learning, and computational thinking concepts. We will discuss what equity practices mean for teaching and learning, especially in the context of a classroom project based on technology/computational thinking.

We ask how to integrate our critical perspective about the purposes of technology, schooling, and STEM education into our work with teachers. We question how to turn our theory about schools reproducing inequitable and unjust processes, and the current myths about technology as the great equalizer, into alternative practices with teachers. Within the larger context of a "culture of power," we examine our own approaches to helping teachers develop effective methods for encouraging students to see themselves as capable "doers" of STEM.

Section 1: Questions for dialogue at the MSP LNC.

Beyond classroom instructional techniques directed at equity, such as graphical organizers, instructional conversations, cooperative learning groups, and use of academic language, what might "equity" practices in STEM look like in the context of a Mobilize project?

How do we create openings in schools for teachers and students to deeply engage with excluded and marginalized perspectives that have the potential to challenge the inequitable foundation of schooling?

What should be the "objectives" of "equity practices"?

Section 2: Conceptual framework.

Context:
Mobilize: Mobilizing for Innovative Computer Science Teaching and Learning is a targeted National Science Foundation Math Science Partnership. The core partners are: UCLA Graduate School of Education and Information Studies (Center X), the Los Angeles Unified School District (LAUSD), the UCLA Center for Embedded Networked Sensing (CENS), and the Computer Science Teachers

Association (CSTA).

Mobilize builds on teenagers' engagement, creativity and dexterity with mobile technology. At the heart of Mobilize is the CENS Participatory Sensing system - an innovative method of data collection and analysis in which students use mobile phones and web services to systematically collect and interpret data about issues relevant to them and collective causes with which they identify. These data and analyses are augmented with other data sets and analysis tools to both deepen and broaden students' investigations.

Now in its second year, Mobilize seeks to create hands-on, inquiry-based, curricular units that employ participatory sensing, and teacher professional development for computer science, mathematics, and science high school classes. Mobilize projects bring together STEM and computational thinking with students' sense of civic involvement in their own communities.

Mobilize is committed to assuring access for innovative instruction, especially in schools with high numbers of African Americans and Latino/a students. Mobilize was first introduced this past summer 2011 to core teams of math, science, and computer science teachers from 5 LAUSD schools that strongly represent these populations. Our aim is to have interdisciplinary teams of Exploring Computer Science (ECS), mathematics, life and physical science, as well as social science students and teachers working on Mobilize projects by 2015. As computer science is now an integral part of innovation across all fields, a goal of Mobilize is to strengthen computer science instruction throughout our educational system.

Mobilize sits at the crux of several critical issues: How can we foster innovation and inventiveness, improve STEM education for students and teachers, and increase access to quality and rigorous education for more students? The insights we gain from Mobilize about increasing opportunities for inquiry-based, rigorous learning of computer science and about innovative teacher professional development, especially in large urban school districts, will be critically important across multiple disciplines, communities, and institutions. Mobilize addresses the centrality of information technologies in our students' lives, for whom a critical view of computing will be increasingly important as they enter the work force and engage as members and leaders of multiple communities.

Defining Effective Teaching in STEM through Mobilize

With UCLA's Center X as one of the project's guiding partners, Mobilize is imbued with a philosophy of seeking to transform public schooling to create a more just, equitable, and humane society through inquiry and change as community of teachers, students, parents, community members, elected officials, researchers and others engaged in democratic life. Mobilize builds upon Center X research and practice in understanding that the complexity of teaching requires gathering multiple measures to evaluate the effectiveness of that teaching (e.g., through observations, an array of models for measuring student academic growth, surveys to gather information on student perspectives on quality of teaching, rubrics for classroom artifacts and reflections on practice, teacher portfolios, action research, and effective and impactful teacher professional development). However, this evaluative model is effective only within the larger context of a community of learning.

It is important to make clear that we are still at the very outset of the Mobilize project, so we are currently in the process of formulating a definition of what effective teaching will look like in Mobilize classrooms. Once we have a better understanding of how Mobilize will fit across content areas – particularly math and science – we will be able to provide a more detailed description of future professional development. However, we are able to state definitively now that we are strongly guided by the belief that the effective teacher fosters innovation and inventiveness in the classroom by:

- Creating opportunities for students to actively participate in learning

- Recognizing the wealth of knowledge that students bring with them and building on that knowledge
- Posing tasks that are relevant, inquiry-based and academically rigorous
- Scaffolding learning with equitable access to resources
- Encouraging “sense making,” not memorization

Given that we believe these are the features of the a truly powerful learning environment, we will work to develop professional learning communities of teachers to foster classrooms that are aligned with these tenets. Our Mobilize teacher professional development will be tested against at least three principles: it will (1) offer meaningful intellectual, social, and emotional engagement with ideas, materials, and colleagues; (2) take explicit account of the context of teaching and the experience of teachers - focused study groups, teacher collaboratives, and long-term partnerships afford teachers a means of locating new ideas in relation to their individual and institutional histories, practices, and circumstances; and (3) prepare teachers to employ the techniques and perspectives of inquiry. Further, it will provide the possibility for teachers and others to interrogate their individual beliefs and the institutional patterns of practice (Little, 1993).

Our Mobilize project believes that teachers must be actively involved in their own professional development. This does not mean participating in a “hands-on” activity as part of a scripted workshop; it means that teacher development “must actively listen to and sponsor the teacher’s voice; **establish opportunities for teachers to confront the assumptions and beliefs underlying their practices**; avoid faddism and blanket implementation of favored new instructional strategies; and **create a community of teachers who discuss and develop their purposes together, over time**” (Fullan & Hargreaves, 1992, p. 65).

Section 3: Explanatory framework

With these principals in mind, in July 2011 we organized a summer “think tank” of computer science, math and science teachers to pilot our Mobilize lesson plans, and to see what emerged. In July 2011, five interdisciplinary teams of teachers - each comprising one math, one science, and one computer science teacher – came to UCLA for seven days to learn about participatory sensing and collaborate on ways to integrate Mobilize into math and science courses and the varied contexts of LAUSD schools. Teachers experienced a data campaign, learned from experts at CENS, and brainstormed ideas for creating an interdisciplinary project to apply at their schools during the next school year.

Our interdisciplinary teams spent seven days, eight hours a day, immersed in the key concepts of Mobilize: data collection, analysis and representation – first without using smart phones as a tool, then incorporating the phones as they learn more about the processes of data collection through participatory sensing. Each teacher had his/her own smart phone loaded with the latest version of canonical applications (developed by the CENS technology team) to be used for data collection, upload, and analysis throughout the course of the program. The teams gained hands-on experience using the same apps that their students will be using during the spring 2012 implementation, and participated in daily brainstorming sessions focused on how this approach to data collection and analysis might be useful in their respective content areas.

Additionally, the Mobilize team shared information on new ways of thinking about statistical analysis and inference, and guided teacher teams in exploring possibilities for integrating Mobilize into interdisciplinary projects and in collaborating to develop lesson plans that were shared on the final day of the program. Teachers also attended three different workshops presented as part of the CENS High School Scholars Summer Program, and learned – alongside LAUSD students – about innovative applications of technology and data gathering, representation, and analysis. For the first time, teachers and students had the opportunity to spend time participating in a combined activity focused on participatory sensing, after which they debriefed and discussed their experiences. This "think tank" approach created an opportunity for the teachers and students to learn together and provide further feedback on how to best integrate Mobilize units into math and science classrooms. In our panel at the NSF-MSP conference in January, we will reflect on what we learned from this "think tank" (for good and bad) and the challenges we now face.

Moreover, our professional development model is set up to mirror the collaborative, inquiry-based, and "equitable practices" that we hope teachers will bring into the classroom. What we hope to learn is how to effectively manage the complexities and tensions that arise between competing concerns in the world of technology and education, and how to best engage with these issues in our teacher partnership. While we strongly believe that "a framework that attempts to highlight how the use of technology in the classrooms must be understood within our larger social, political, and economic contexts and within a vision of what it means to live in an equitable and democratic society," we want to learn how to best partner around this perspective and the array of expectations and priorities that teachers have when they attend professional development and other learning spaces.

Our focus here will again be on "equity" and what it means, and how it informs future professional development. Since our project can be regarded as part of the debate about technology in the schools, and to what use it should be put, we consider it important for us to reflect on how we weave together our theoretical stance on theories of learning, the purpose of technology, and the purpose of schooling - as they all relate to equity - into our practice with teachers.

Section 4: Lessons Learned

There are two major lessons we have learned so far about preparing and supporting effective teaching in STEM:

1. If equity in instruction is one of our goals, as a team we must unpack what "equity" really means. Is it based on "head counting" of learning opportunities (e.g., equal numbers of girls and boys, equal numbers of African-Americans and Latinos), or is there a more critical interpretation of what "equity" is, especially in the context of technology use and purposes of schooling? How do we encourage teachers to facilitate classroom norms and practices that afford opportunities for students to develop identities that embody proficiency in the "culture of power"? What role has technology and schooling played to further inequity, and how will we make this analysis a critical part of our Mobilize program with teachers?

2. In a technology-based project, there is a real challenge in developing different streams (tool development, curriculum development, equity focus) in parallel. We will discuss how we experienced the strong pull from the technology side to get it up and running first, with the equity mission - and all that it entails - following second. We have learned how this has certain consequences for the direction of a project, and also coincidentally mirrors the pressures that teachers confront as they design their lesson plans and classroom experiences. We must now examine the ways in which technology can act as a sort of "mediator" in STEM education and instruction, and how it comes with its own biases and weaknesses that can be transmitted to students in the classroom context.

In this panel we will reflect on these lessons and how our work will be impacted as we move into years 2-5 of Mobilize.

Abstract Title:
NebraskaMATH, Getting it Right from the Start:
Supporting Effective Instruction in the Primary Grades

MSP Project Name: NebraskaMATH

Presenters:
Michelle Homp, University of Nebraska-Lincoln
Susie Katt, Lincoln Public Schools

Authors
Michelle Homp, University of Nebraska-Lincoln (Lead)
Susie Katt, Lincoln Public Schools
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Strand 2

Summary:
We will share information about coursework and study groups for K-3 teachers becoming K-3 Mathematics Specialists in Nebraska. We discuss how we have refined our courses and study groups over time, and how we are focusing on helping teachers to become more intentional, planful, observant, and reflective mathematics teachers. We also share one presenter's perspective in the dual role of a K-3 district math coach and course instructor, and what she sees as necessary to support K-3 teachers to teach math more effectively. We also discuss the role of K-3 teacher leaders in a distributed leadership model to support more effective math teaching state-wide.

Section 1: Questions for dialogue at the MSP LNC
What role does content knowledge play in effective mathematics instruction?

What role does understanding student learning play in effective mathematics instruction?

What are characteristics of effective teacher leaders? Are there characteristics which are unique to leadership within the field of mathematics? Are there characteristics which are unique to leadership specifically among teachers of primary grades?

Section 2: **Conceptual framework**
Primarily Math is an initiative to strengthen the teaching and learning of mathematics in grades K-3. This part of the NebraskaMATH program was inspired by the belief that meeting high expectations with respect to teaching and learning math in K-12 schools must begin with greater achievement in the early grades. Just as there are wide gaps in children's readiness to learn to read, many children begin formal education well behind their peers with respect to their readiness to learn mathematics. Primarily Math is designed to respond to this need by encouraging expertise in the teaching of mathematics in the early grades. In short, with regard to

the mathematics education of school children, the goal of Primarily Math is to get it right … from the start.

The overall design of the Primarily Math program includes three components:

i) an investment in the education of outstanding K-3 teachers through an 18-hour graduate certificate program designed to support effective instruction by strengthening mathematical and pedagogical knowledge;
ii) participation in study groups supported by project staff to transfer knowledge gained in the graduate program into teaching practice, and to support those teachers considering or entering into leadership roles;
iii) a research study designed to inform Nebraska and the nation regarding the impact of Primarily Math on student achievement.

This discussion will focus on the first two components of the Primarily Math program--the courses which comprise the graduate program, the ongoing support for collaboration and leadership--and the ways in which these support effective instruction in mathematics.

By *effective* instruction in mathematics we mean instruction which incorporates

- task design that is informed by both the mathematical content and practice standards (from the Common Core State Standards), that engages children in high level thinking, and that supports children's learning by accessing prior knowledge; and
- intentional planning that is grounded in an understanding of children's mathematical development (or learning trajectories), yet is responsive to children's needs, using formative assessment to adjust the instruction as appropriate; in other words, instruction that is intentional, planful, observant and reflective.

Furthermore, effective teaching in mathematics is grounded in the belief that all children, given the right opportunities and support, are capable of developing a strong, conceptual understanding of (age appropriate) mathematical concepts.

The Primarily Math K-3 Math Specialist Certificate Program consists of the following courses:

Course	Term	Length	Title
Year 1			
Math 800P	Summer	1 week	Number and Operation for K-3 Math Specialists
Math 801P	Summer	1 week	Geometry, Measurement & Algebraic Thinking for K-3 Math Specialists
TEAC 808A	Fall	semester	Teaching Math K-3: Planning Lessons for Diverse Classrooms
TEAC 808J	Spring	semester	Helping Young Children Become Mathematical Thinkers
Year 2			
Math 802P	Summer	2 weeks	Number, Geometry and Algebraic Thinking II for K-3 Math Specialists
TEAC 907	Summer	2 weeks	Communities of Practice and Mathematics
TEAC 836B*	Summer & Fall	semester	Leadership and Mathematics Instruction

*TEAC 836B is offered as an optional course for teachers assuming a leadership position.

Courses in the Primarily Math program seek to strengthen teachers' content and pedagogical knowledge in order to better equip them to intentionally plan and design tasks which lay the groundwork for effective mathematics instruction in the classroom. Ongoing collaboration with study groups then provides teachers with the support of peers to help facilitate the transfer of knowledge gained from the graduate program into teaching practice.

After completion of the 18-credit hour graduate program, teachers move into one of three roles based on their own strengths, their districts' needs and the needs of the Primarily Math research study: math coach, math-intensive teacher (teaching at least two K-3 math classes) or K-3 generalist. The study groups into which the teachers are placed are organized by UNL faculty in collaboration with districts personnel and focus on a study of mathematical ideas prompted by the descriptive review of student work and the planning and debriefing of common formal math lessons and activities outside of math class.

The (optional) leadership course is designed to explore the many facets of leadership in math education to equip participants to serve as leaders in their schools and districts in order to promote effective mathematics instruction among their colleagues.

We see the Study Groups as a vehicle for supporting teachers to make continuing changes to their practices as they focus intensely on lesson planning, including task design, framing good questions to pose, worked examples, and drawing connections among teachers' and students' use of multiple representations. By engaging teachers in professional conversations about mathematics teaching and learning that extend beyond graduate coursework, we hope to better support teachers on their journey to becoming more effective mathematics teachers at the K-3 level.

Section 3: **Explanatory framework**

Consistent with a recommendation found in the 2008 National Math Panel Report, *Foundations for Success*, the Primarily Math research team is studying the relative benefits derived from utilizing graduates of the program as either K-3 math coaches, math intensive teachers who teach math to more than one class at the K-3 level, or teachers (especially at the kindergarten level) who remain as generalists in the classroom. Entering the third year of NebraskaMATH, (and the second year with K-3 Mathematics Specialists in buildings), it is too soon to expect to see big improvements in student achievement. We plan for the research results to feed back into our project design, and to be made public for other projects to use in the near future.

In the mean time, Primarily Math instructional teams use other feedback to continually revise and improve program courses. Feedback from end of course evaluations, informal interactions with teacher participants and reflective practices on the part of the instructors (including informal analyses of student work) serve as the primary means through which courses thus far have been revised.

The first two mathematics courses are designed to strengthen teachers' conceptual understanding of the mathematics addressed in grades K-3 curricula in order to better equip them to be intentional and planful teachers of mathematics. One of the more demanding aspects of the course is the high level of written explanation and justification that is expected from each participant. Now in its third iteration, feedback from participants has led to revisions in the course which address (among other things) means of assessing homework, preparation for the writing component, and preparation for the course expectations in general (along with slight modifications in the mathematical content).

Pedagogy courses focus on designing and implementing math lessons aimed at helping children become mathematical thinkers. The first course focuses on becoming more observant and reflective based on children's learning, with a special emphasis on children's learning trajectories; the second emphasizes meeting the needs of diverse learners, including the intentional selection and use of particular teaching strategies coupled with systematic reflection on learning outcomes. It includes a focus on the nature of planning and teaching when both are based on an understanding of and willingness to be responsive to children's mathematical understandings. The third course is designed to help students in Primarily Math become increasingly more intentional, planful, observant and reflective while situated in their own contexts, giving particular attention to creating coherence and connections to the learning trajectories of children. Revisions of these courses include (1) the addition of a "Family Project" (which was strongly encouraged and coordinated by an early childhood specialist who is a PI on the project); (2) a switch from designing individual lessons to build up to a unit, to instead focusing on planning units comprised of a series of mathematical tasks; (3) an added emphasis on developing questioning skills and the facilitation of mathematical discussions.

The goal of the leadership course is to help teachers become intentional, effective and reflective instructional leaders. Originally the content was focused on exploring aspects of coaching supplemented with other leadership roles a teacher might assume after completion of the Primarily Math program. However, because a significant number of participants are classroom teachers without an opportunity for becoming a coach (as this is often not feasible in small, rural schools and districts), the course has been modified instead to emphasize broader aspects of leadership, with the goal of grooming "informal coaches" in schools and districts where a formal coach is not feasible.

Among those participating in the first cohort of teachers in the Primarily Math program was a teacher already serving as a full-time teacher-leader in one of our larger school district partners. Susie Katt, the K-2 Math Coordinator for Lincoln Public Schools (LPS), completed the program as a participant, and has now joined the instructional staff for subsequent iterations of a variety of courses. In particular, she is the now the lead instructor for the program's course in leadership. Katt's perspective on the various components of the course has greatly contributed to efforts to strengthen the project.

Section 4: **Lessons learned**

Each of the Primarily Math graduate courses has undergone revision and refinement for each cohort. Instructional teams reflect on each course during and after instruction, in order to make the course even better the next time. At this point, we are preparing course materials to post publically on our website for other instructors to use. We've learned that sometimes, one has to try a specific learning activity before being able to see how (in)effective it is at supporting teacher learning.

We have learned that primary teachers need to be well supported in their efforts to become more effective teachers of mathematics. Informing teacher participants of the challenges and high expectations that await them prior to the onset of coursework is essential. In the mathematics content courses, participants need forewarning of the focus on written explanation and justification, and carefully planned activities which provide guidance on how to write about mathematics need to be incorporated into the course.

In the pedagogy courses, later iterations have focused on the development of mathematical tasks and the incorporation of mathematical conversations in primary classrooms. Chapin, O'Conner and Canavan (2009) *Classroom Discussions: Using math talk to help students learn* was added as a required text.

We have also learned to equip teachers early in the program with images of what different teaching strategies might look like (such as by using video cases) in order to encourage them to take risks and implement change as they complete the coursework rather than waiting and emphasizing this near the end of the program.

In terms of leadership, we found it necessary to help teachers realize their potential for influencing mathematics instruction outside of their own classrooms as many participants didn't view themselves as leaders in their buildings or districts. This included a sharper focus on the different types of leadership roles a classroom teacher could assume and revisions of course assignments designed to communicate the expectation of leadership on the part of each participant; a leadership action plan was incorporated into course requirements as well as a reflection paper to "gently nudge" Primarily Math graduates to take on more formal leadership roles.

We also learned the importance of addressing the impact of *change*. Participants discovered that colleagues who have not been part of the Primarily Math program found the shift toward teaching more conceptually to be quite daunting. As a result, the leadership course incorporated an emphasis on the processes teachers experience as they implement changes into their practice, and as well as the type of support participants as leaders can provide their colleagues as they work to improve their instruction. Participants in the leadership course also found that they needed their own "support group"; consequently part of class time was spent debriefing with one another about the challenges of assuming leadership roles.

Having a teacher leader involved in the program both as a participant and as an instructor has strengthened the integrity of the Primarily Math program. As an instructor, the fact that Katt had also completed all of the coursework allowed her to better identify with later participants. It also enabled her to find specific correlations between course content and classroom practice, helping the courses maintain relevancy to the day-to-day work of the teachers. Katt's role as a district leader has assisted with the continuation of a strong network of teachers within Lincoln Public Schools; a network that has continued to grow stronger through Katt's efforts to provide continued community and learning experiences, even though the Primarily Math coursework has been completed. In addition, utilizing Katt as an instructor, has opened the door for other past participants to serve in leadership roles for later cohorts; thus continuing their opportunities to grow as leaders.

Our focus on helping K-3 teachers become more intentional, planful, observant, and reflective, seems to have good face validity; as we get deeper into the research project associated with Primarily Math, we will also use those results to refine this focus to better support teachers on their journey to more effective K-3 mathematics teaching.

Abstract Title:
A Decade-Long Effort to Improve the Teaching of K-12 Mathematics in Rapid City, South Dakota

MSP Project Name: PRIME

Presenters:
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June Apaza, Black Hills State University
Becky Carroll, Inverness Research
Maggie Austin, Technology & Innovation in Education
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Strand 3

Summary:
Now in its 10th year, Project PRIME has assembled a wide array of evidence, both direct and indirect, about improved teaching of mathematics within Rapid City Area Schools. Direct evidence exists in the form of classroom observations conducted over the life of the project by PRIME's external evaluation team, Inverness Research. Indirect evidence exists in the form of student outcomes: Achievement on state test; achievement on a more performance-oriented test; and student attitudes. A powerful story is emerging, attributable largely to a robust infrastructure that has been established to support teacher growth. The session will share how far the district has come, factors contributing to success, obstacles along the way, persistent challenges, and the path ahead.

Section 1: Questions for dialogue at the MSP LNC

How are classroom observations used by the project?

How do classroom observations relate to system and capacity measures?

What connections can be drawn between student outcomes and effective teaching?

What political capital do classroom measures and system/capacity measures have in an era of almost total focus on student achievement scores?

How do teacher supports need to differ at different grade levels?

How have lessons about effective teaching at the K-12 level and about the support of K-12 teachers been transferred to pre-service and to university environments? How about the other way around, from university setting to K-12?

To what degree are lessons learned within this project transferable to other projects and settings?

Section 2: Conceptual framework

Definition of Effective Teaching:

Our project claims no originality in its definition of effective teaching of math. Rather, it has drawn from the math education literature and from the math education community the rich descriptions, research syntheses, video cases, and the like. Early sources that we used to develop common vision among project leaders, K-12 teacher leaders, building administrators, and university faculty included *Adding It Up* (2001, Kilpatrick, Swafford, Findell, eds.) and *Making Sense: Teaching and Learning Mathematics with Understanding* (1997, T. Carpenter and colleagues). We've since come to know and appreciate definitions offered by many others including Ruth Parker, Glenda Anthony, and Margaret Walshaw, to name a few.

Key elements of effective teaching that our project emphasizes:

Providing students with rich, meaningful, challenging mathematical tasks
Focusing on big mathematical ideas and on connections between them
Creating a safe and productive classroom community of learners
Paying attention to conceptual understanding, procedural fluency, student discourse, mathematical representation, and student dispositions
Drawing from a depth of pedagogical content knowledge to recognize patterns of student thinking, to anticipate and diagnose misconceptions, and to guide the learner in productive directions

Project Design:

At its core, Project PRIME is a professional development project for K-12 teachers of math within Rapid City Area Schools, a district of approximately 13,000 students in western South Dakota. Learning opportunities for in-service teachers have included graduate-level classes designed to deepen content knowledge, to build pedagogical content knowledge, to explore and discuss implementation of specific instructional materials, and to build leadership capacity. Some classes are offered district-wide while others are offered within buildings. Complementing these classes, teachers have access to building-based and district-wide teacher leaders and classroom coaching.

The project has established other supports as well, including adoption of new instructional materials and coursework for principals. In the area of student assessment, the project has been administering a more performance-based assessment to complement state-mandated testing and has introduced measures of student attitudes and disposition. PRIME's external evaluation team, Inverness Research, has been conducting periodic classroom observations over the life of the grant and has also been studying the degree to which the district and the project are working systemically and building capacity. Also, throughout its 10-year duration, the project has made abundant and strategic use of student, classroom, and system data to motivate and to sustain change.

Section 3: Explanatory framework

Direct formal evidence about the teaching of mathematics within the project comes primarily from classroom observations conducted by Inverness. Indirect evidence comes from student outcome data such as achievement on standardized tests and measures of student attitudes.

Classroom observations indicate improved teaching across all grades over the course of the project -- with a last round of observations yet to be conducted in this current Year 10. Increases in student achievement tell a generally consistent story.

The highest lesson ratings overall and the greatest gains in classroom observation ratings early on were at the elementary grades. Student achievement data, on both the state-mandated test and the more performance-oriented one, show a consistent picture of strong and rising student achievement at the elementary grades.

The quality of middle school teaching was notably lackluster through the first seven years of the project, as demonstrated by external evaluation findings. Leveraging these findings, the project has placed special emphasis at the middle school level over the past two years, and great strides have resulted. The value of the project's extra efforts at middle school were affirmed in the spring of Year 9 by a much improved collection of middle-school-only classroom observations.

On the more performance-oriented assessment, administered at both 4th and 8th grades, the project has seen strong growth (with Cohen's Effect Sizes > 0.4 at both grades) between Years 3 and 9. Attitude measures tell an interesting and consistent story as well.

Student outcome data have shown less compelling and dramatic progress at the high school level. Again, classroom observations have helped to provide insights into why and are helping to prompt more intensive teacher supports and bolder changes there as well.

With a strong focus on effective instruction across the entire district and on reaching <u>all</u> learners, the achievement gap between American Indian students (the largest historically underrepresented group with respect to mathematics within the district) and non-American Indian students has been steadily shrinking. More than twice the number of American Indian students scored proficient or above in Year 9 of the project compared to Year 1.

Section 4: Lessons learned

We believe that we're amassing a compelling collection of student outcome data to support our initial beliefs about what constitutes effective mathematics instruction. Having classroom observation data to complement the student outcome data has been invaluable -- both to help interpret student-level data and to guide the project's path forward.

We've come to appreciate the importance of well-designed instructional materials that are consistent with the project's vision of effective teaching and that are implemented consistently from classroom to classroom.

We've also learned something about the power of assessments that align well with the project's vision of effective teaching.

We have learned what facets of the project have been most helpful to teachers at different places on the path to becoming stronger teachers of mathematics -- when coaching is perceived to be most helpful, when classes are, and when it matters most to have the right instructional materials.

We've learned that K-12 systemic reform takes a long time. Ten years in, we've still got a long way to go, especially at the secondary level, not to mention all of the work left to do to transfer lessons the project has been learning to university settings -- for teacher preparation and for regular university math classes.

We have increased appreciation for the power of data to prompt and sustain a system-wide change initiative. Communication of results, highlighting accomplishments as well as challenges, has helped to create buy-in and commitment.

Abstract Title:
Learning Together: A User-Friendly Tool to Support Research on STEM Education Interventions

MSP Project Name:
Knowledge Management and Dissemination

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Strand 3

Summary:
The MSP KMD project is charged with situating what MSPs are learning in the broader knowledge base. MSP KMD has developed a "User-Friendly Tool" to provide a common language for project teams with varying research backgrounds to discuss their STEM education research. The tool describes key considerations in designing and reporting research on STEM education interventions, includes reflection questions for research teams to use when considering their research designs, and illustrates the use of the tool with sample research designs. The LNC session will engage participants in using this tool with a hypothetical research design for studying the impact of an MSP intervention on STEM teaching. Participants will also consider implications of this tool for their own MSP research.

<u>Section 1: Questions for dialogue at the MSP LNC</u>

- What is involved in measuring effective STEM teaching? How might this answer differ for in-depth studies of a handful of teachers versus larger-scale, project-wide studies?
- What common challenges do MSPs face in investigating the extent to which their work is promoting effective STEM teaching?
- What venues can MSPs use to share the knowledge they are generating with other STEM faculty who are interested in improving STEM teaching?

<u>Section 2: Conceptual framework</u>

Strand 3 addresses the question, "How do we know we are making progress toward more effective STEM teaching?" Each MSP project is designed to contribute to the field's understanding of STEM teaching and learning through research on its work, and it is through this research that progress toward more effective STEM teaching can be made, documented, and disseminated.

The Math and Science Partnership Knowledge Management and Dissemination (MSP KMD) project was funded as a Research, Evaluation, and Technical Assistance project to support knowledge management within the Math and Science Partnership program and to disseminate information to the broader mathematics and science education community. The overall goal of MSP KMD is to synthesize findings in the K–12 arena in a small number of important areas, articulating the contribution of the MSP program to the knowledge base and identifying both promising practices/strategies and gaps for further investigation. MSP research can provide evidence about what progress is being made toward effective STEM teaching and how MSP interventions contribute to that progress. Results of such research add to the field's understanding of how to promote and support effective STEM teaching.

MSP KMD's synthesis of research findings does not rely on a single definition of "effective teaching in STEM." Rather, it involves understanding what evidence there is that progress is being made toward any particular study's definition of effective teaching. MSP KMD developed the Standards of Evidence for Empirical Research (Heck & Minner, 2010) to facilitate synthesis of research findings. The Standards of Evidence draw from numerous writings about research rigor, quality, and reporting including efforts focused on quantitative, qualitative, and mixed methodologies. Application of the Standards of Evidence tool requires considerable expertise and training. "Learning Together: A User-Friendly Tool to Support Research on STEM Education Interventions" was developed to translate some of the key ideas in the Standards of Evidence in ways that are applicable to a broader audience. For example, the tool points out the importance of teams defining constructs, such as effective STEM teaching, involved in their research and ensuring that measures reflect the team's definitions.

Using findings from earlier MSP KMD work, the User-Friendly Tool provides key considerations in designing and reporting research on STEM education interventions, reflection questions for project teams, and sample research designs. The considerations and reflection questions are organized into four sections: (1) identifying research questions, (2) selecting instruments, (3) designing studies, and (4) sharing what has been learned. Two sample research study designs illustrate the use of the tool to make decisions and evaluate trade-offs in design decisions.

Section 3: Explanatory framework

Using the Standards of Evidence as a tool, MSP KMD conducted extensive reviews of empirical literature on deepening the content knowledge of mathematics and science teachers, developing and supporting teacher leaders, and involving STEM disciplinary faculty in K–12 STEM education. Applying the Standards of Evidence to a range of empirical education research studies allowed MSP KMD researchers to confirm some common challenges and limitations in documentation, design, and instrumentation that others have observed in educational research (e.g., Hill & Shih, 2009; Sztajn, 2011). Examples of such limitations include descriptions of treatments that do not provide information about who facilitated the treatment, designs in which the reason a treatment would lead to an outcome is unclear, and the use of assessments that do not target knowledge addressed by the treatments.

Research on effective STEM teaching, and mathematics and science education more broadly, has greater potential to contribute to the knowledge base when it is designed, implemented, and reported using high standards of evidence and documentation. MSP KMD's findings about challenges and limitations in the existing literature led to the creation of the User-Friendly Tool to support MSP teams in their research endeavors, including investigating STEM teaching. Although KMD developed the tool with the intent to help research teams strengthen their study design, the tool is not a step-by-step guide for designing research, nor is it intended to substitute for involving experts in social science research when designing studies.

Section 4: Lessons learned

Research is at the heart of MSP project activities. At the same time, the diversity of research backgrounds among MSP team members creates unique challenges, as well as many benefits. The User-Friendly Tool is intended to create a common language among MSP team members, including education researchers, STEM faculty, and K–12 educators and administrators. It includes a particular emphasis on bridging the differences between research in STEM fields and research in STEM education.

In the areas of education research studied by KMD, empirical findings in current research tend to have limitations stemming from research design and/or reporting and do not provide very much guidance for practitioners on designing interventions to promote more effective STEM teaching.

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Abstract Title:
Data Connections: Methodology for Developing Student Achievement Trajectories to Estimate Teaching Effectiveness

MSP Project Name: Data Connections

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Strand 3

Summary:
While effective teaching is conceptualized broadly, statistical modeling is one approach to identify teaching which induces growth in student achievement that exceeds expectations. In particular, one tool for measuring the impact of MSP programs on teaching effectiveness is student achievement data. Detecting the impact of a MSP project on student achievement requires more than a single snapshot of student performance. Instead, a coherent picture of student progress is needed before, during and after a project's initiation. However, the data available to projects often do not meet the technical requirements of current statistical methods. This project is investigating the use of new methods to analyze less-than-ideal data. These methods and their applicability to MSP projects will be discussed in this session.

Section 1: Questions for dialogue at the MSP LNC

- How can value-added models be effectively used to estimate teacher effects when student achievement data are from a variety of measures at different times, and what (if anything) can these models reveal about effective teaching in STEM?

- How can MSP impact on teacher effects be estimated? Are these effects short-term or can they be sustained?

- What issues arise when attempting to develop student trajectories from multiple measures of student achievement?

Section 2: Conceptual framework

While our conception of effective teaching is quite broad, encompassing quantitative and qualitative features and measures, for the purposes of statistical modeling, we define effective teaching in STEM as teaching which induces growth in student achievement that exceeds expectations. Our RETA is in its first few months; as our modeling is refined, we hope to include other student and teacher measures, and thus broaden our definition of effective teaching to include an impact on students' attitudes toward and self-efficacy related to mathematics. While we are not satisfied saying that teaching is effective when students grow more than expected on state achievement tests, the fact is that such tests are currently used in this way and will continue to be for the foreseeable future. When determining the quality of MSP projects, comparative evaluations will inevitably use student achievement tests. In order to understand how these data characterize MSP projects and teaching effectiveness, we need to better understand the statistical modeling of such data.

NSF’s MSP programs provide substantial content-based professional development to teachers. Through the MSP program, NSF is making a significant investment in the education of our nation’s mathematics teachers. Increasingly, there is considerable interest in finding out which MSP projects appear to be effectively improving the quality and impact of mathematics teaching and thus are candidates for scaling up.

Statistical modeling is one approach to help measure teaching effectiveness. Newly developed methodologies can help programs evaluate and interpret student and teacher data in productive and meaningful ways. In particular, one tool for measuring the impact of MSP programs on teaching effectiveness is student achievement data. Value-added modeling techniques aim to estimate teacher and school effects and the changes to such effects that can be associated with specific interventions (such as MSP professional development). Value-added modeling methods provide opportunities to estimate the proportion of variability in achievement or student growth attributable to teachers, as well as estimate an individual teacher’s effect on student learning. Of urgent concern is to develop and explore the opportunities and limitations of value-added modeling techniques for use with less-than-ideal (e.g., real) school district data on student achievement.

Professional development programs focus on improving teachers’ abilities to provide quality instruction, but rigorous evaluations are needed to determine whether these programs are actually effective. Value-added modeling techniques provide opportunities to estimate the relationship between teacher development and student learning, but most require student achievement data to be on a single developmental scale over time (McCaffrey, Lockwood, Koretz, & Hamilton, 2003). Typically, available assessment data do not meet such requirements, limiting analyses that can be conducted.

The purpose of *Data Connections* is to develop statistical models to create a coherent picture of teaching and learning. Our initial focus is on using value-added models to estimate teacher effects, and how those models can be adapted for use with less-than-ideal (e.g., real) school district data on student achievement. Specifically, we are using a simulation study to investigate the use of z-scores, parallel processing, and binning by quantile to estimate teacher effects and student achievement trajectories across different assessments given at different points in time. Eventually, we will connect student achievement trajectories to measures of teaching quality, and connect measures of student and teacher attitudes to each other and to measures of student achievement and teaching quality. *Our overall goal is to develop, refine, and disseminate* *statistical models that develop a coherent picture of mathematics teaching and learning, particularly in regard to MSP programs.*

Our MSP is using data gathered by other MSP projects to develop models of student achievement data in order to attempt to detect effective teaching. While the newness of our RETA precludes substantial results at this point in time, should we find differential teaching effects for those teachers who have participated in various MSPs, this would inform the community about the effectiveness of such projects.

Section 3: Explanatory framework

Our MSP is directly studying the intersection between K-12 student success and effective STEM teaching by using student achievement data to estimate teacher effects. Analysis of student achievement data is challenging when high-quality longitudinal data on a single developmental scale are not readily available. Student achievement data from Middleview Public Schools[1] (MPS) exhibit such complexities. Since the 2003-2004 academic year, a variety of criterion- and norm-referenced tests have been administered to 5th-8th grade students within MPS.
In order to investigate how value-added models can be effectively used when student achievement data are from a variety of measures at different times, the z-score, parallel processing, and binning by quantile methods were explored for use with less-than-ideal student achievement data. With the Educational Value-Added Assessment System (EVAAS) model (Sanders, Saxton, & Horn, 1997), changes in raw scores are not meaningful when test scores in successive years are not on a single developmental scale. To compensate for this problem, standard z-scores can be used. In a given academic year, a student's Z-score indicates how many standard deviations the original score is away from the average score for a grade. Changes in Z-scores reflect changes in relative position across years for a group of students, but not necessarily changes in academic achievement, when measures are on different developmental scales (McCaffrey et al., 2003). The standardized scores allow for within-group comparisons across academic years.

Z-scores can be vulnerable to outliers and wide swings in standard deviations; the small population of Nebraska's rural districts exacerbates this problem. Non-parametric methods, in theory, are less vulnerable and more robust. Non-parametric alternatives to z-scores based on binning, code scores into ranks based on their quantile rank. The basic idea of binning is to rank student achievement test scores for each year and then divide them into quantiles. A student making "expected" progress would tend to stay at approximately the same rank, relative to other students in the study population, from year to year. Steady movement up in rank over a period of years would indicate the student is making "above expected" progress.

Whereas z-scores and binning procedures model student achievement scores within a subject, such as mathematics, for a given year as univariate random variables, parallel processing allows us to simultaneously model multiple scores for a student within a given year and subject. That is, growth curve, or parallel processing, models allow characterization of changes on repeated measurements over time. One type of multivariate growth curve model is the curve-of-factors model (Little et al., 2006). The curve-of-factors model establishes a latent growth curve to describe changes in a latent construct, such as mathematics ability, measured by multiple indicators over time.

We conducted a simulation study to compare the use of these three models (i.e., a z-score model, a binning by quantile model, and a curve-of-factors model) when data are simulated assuming a curve-of-factors model. Model parameters specified for the simulation were based on summary statistics obtained from the MPS student achievement data. Comparisons across models were made for both a complete and a missing tests case to investigate the impact of having only one, instead of two, indicators of a construct in one or more years. For each simulation and model combination, the teacher effect estimates were ranked within each year. This allowed us to compare how well each model predicted teaching effectiveness, as defined by student achievement.

Section 4: Lessons learned

Because our project was only funded in 2011, we do not yet have results that have been able to feed back into our project design as lessons learned. However, we anticipate developing and refining statistical methodology for estimating teacher effects. As we test our model with simulated and then actual MSP data, the results will feed back into our design. Once we are able to use the model with MSP data, we plan to then help the MSPs interpret the results and consider how the MSP project could be refined based on the estimated impact of the MSP on teaching effectiveness.

While we acknowledge z-score, binning, and parallel processing approaches have limitations, each is an appropriate alternative to using raw data when analyzing less-than-ideal student achievement data across a mixture of norm- and criterion-referenced tests over time. Methodology developed and explored via simulation provides promise for measuring one facet of teaching effectiveness. However, it is important to carefully consider what data are needed and how much baseline data should be obtained when estimating the impact of a professional development program. Ideally, these methods can be extended to other value-added modeling approaches, as well as other professional development programs, and could eventually be used to establish potential relationships between changes in a teacher's mathematical knowledge for teaching mathematics and changes in student achievement. By developing viable models to estimate teacher effects from complex, heterogeneous rural environments and creating models that connect measures of student achievement and attitude to measures of teaching quality, teacher attitude, and teacher networks, we hope to address what most MSP programs are attempting to do. Many MSP programs offer professional development to teachers, in the hopes they will influence teaching quality, teacher attitude, and teacher networks, which in turn will increase student achievement and improve student attitudes. Our work to develop useful statistical models will serve the entire MSP community and those who work to effectively evaluate the work of MSP programs, as well as potentially impact other federally-funded and non federally-funded education programs that are trying to achieve similar outcomes.

Abstract Title:
Conceptually-Rich Mathematics Coaching: Will Mathematics Specialists Put Into Practice What They Have Learned?

MSP Project Name:
Preparing Virginia's Mathematics Specialist

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Strand 3

Summary:
With respect to the education of Mathematics Specialists, effective STEM teaching involves presenting K-8 mathematics ideas in ways that help our MSP Institute participants develop a rich conceptual understanding of the content and develop a deep understanding of how children learn mathematics. In this session, we will describe how our definition of effective STEM teaching is implemented in the courses participants take in our program. We will present data from our initial visits to our participants' school buildings that address the questions: Are teachers preparing to be middle school Mathematics Specialists able to implement similar teaching strategies in their classrooms? And how will what they are learning and how they are teaching impact them when they assume roles as mathematics coaches?

Section 1: Questions for dialogue at the MSP LNC
Based on our previous work, elementary school teachers are eager to adopt non-traditional approaches to mathematics instruction. Initial data from our MSP Institute project reveals that middle school teachers are not buying into different instructional methods as quickly as their elementary school counterparts. We are finding that middle school teachers are less apt to use non-traditional methods of instruction. While our data is still preliminary, we are not seeing middle school teachers apply different methods of instruction involving the use of manipulatives, diagrams, and alternative computational strategies. On the other hand, elementary school teachers who have completed a similar Mathematics Specialist program do employ conceptually rich instructional strategies in their mathematics classrooms.

- How are the differences in mathematical content between elementary and middle school having an impact on our methods of instruction? In particular, how does the focus on algebra and geometry at the middle school level have an impact on the methods we use to engage participants in conceptually rich activities.

- What changes could be made to the instructional strategies we use in our MSP Institutes?

- What should change with regards to our expectations for happens in middle school classrooms when compared to elementary school classrooms? In particular, are middle school Mathematics Specialists able to implement similar teaching strategies when compared to their elementary school counterparts?

- How will what our participants are learning in the MSP Institutes and the methods they use in their classrooms have an impact on their roles as mathematics coaches in middle school buildings?

- How do the beliefs about mathematics learning and instruction of middle school teachers compare with the beliefs of elementary school teachers?

Section 2: Conceptual framework

For our MSP project, we are training a group of teachers to be Mathematics Specialists. Our focus is on being effective instructors of the mathematics courses the middle school teachers in our program are taking. Through this lens, effective STEM teaching is presenting K-8 mathematics ideas in ways that help our MSP Institute participants to develop a rich conceptual understanding of the content and to develop a deep understanding of how children best learn mathematics. The focus in our courses is on conceptual instead of procedural knowledge. Participants are encouraged to make connections between diagrams, tables, and algebraic or arithmetic calculations. They solve problems with a variety of non-standard methods and employ extensive use of manipulatives. In turn, we hope they will employ similar methods when they assume their roles as mathematics coaches. These teachers will become Mathematics Specialists in Fall 2012.

In terms of working with children, through mathematical instruction want them to develop a deep understanding of mathematical concepts and gain an understanding of why concepts and ideas are true. We don't want them to simply follow procedures. This can be accomplished by presenting information in multiple formats (i.e. diagrams, tables, graphs, etc.) and using manipulatives. The same is true for Mathematics Specialists. Our program integrates the same instructional approaches that are used with children. Our goal is to help our MSP Institute participants develop a deep understanding of mathematical concepts and also that they will use similar strategies in work as mathematical coaches in school buildings.

Teachers selected to participate in our MSP Institute project are working towards a Masters degree which will provide them with the credentials to be a Mathematics Specialist in middle schools. At this point in our project, participants have completed two summers and one school year of the degree program. In each summer Institute, they complete two mathematics courses and one-half of an Educational Leadership course. They complete the other half of the leadership course during the school year.

The mathematics courses are Numbers and Operations, Rational Numbers and Proportional

Reasoning, Functions and Algebra I, Functions and Algebra II, Geometry, Probability and Statistics. The primary textbooks used are the Developing Mathematical Ideas materials. The case studies and mathematics activities in these materials encourage participants to study mathematics in conceptually rich ways and develop a deep understanding of how to help children develop a conceptual understanding of mathematics. The Education Leadership courses have all been designed with a mathematics focus. Participants study effective teaching practices, methods for coaching teachers in their school buildings, the importance of assessment, and other aspects of being a mathematics leader in their school buildings.

Each course is taught by a team of instructors made up of Mathematicians, Mathematics Educators, Mathematics Supervisors from school districts who employ Mathematics Specialists, and middle school teachers already serving as Mathematics Specialists. Each member of the team strives to implement our definition of effective STEM teaching.

Section 3: Explanatory framework

With respect to effective STEM teaching, we are addressing the following research questions:

- Is the Mathematics Specialist preparation program effective in supporting the participants in their development of the skills necessary to be a Mathematics Specialist in a middle school?

- What is the nature of the coaching relationship between teachers and Mathematics Specialists? What is the focus of those coaching practices and their impact on instruction?

- When compared with elementary Mathematics Specialists, how effective are middle school Mathematics Specialists at making positive changes to the mathematics program in their school building.

We have constructed a mixed methods research design:

- Using a pretest/posttest design, we will evaluate the change in mathematical content knowledge, knowledge for mathematics teaching, pedagogical content knowledge, and beliefs about teaching and learning mathematics.

- From the twelve participants in treatment schools, three Specialists will be chosen to build case studies about their experiences in the school buildings.

We are collecting the following quantitative data:

- Pretest and posttest instruments for each of our mathematics courses.

- Beliefs survey about teaching and learning mathematics.

- The Specialists will record their activities daily through a website survey instrument. This data will provide a record of the nature and proportion of their daily professional activity of the Specialists over time. The instrument will allow them to document the amount of time spent on each activity.

We are collecting the following qualitative data:

- Digital recordings of select class sessions, and audio recordings of small group activities.

- Observations of the case study participants' professional activities in their respective school buildings. Interviews with the principal and other key personnel who work collaboratively with the case study participants.

We will use the pretest/posttest information to determine whether or not the participants have improved their understanding of mathematics content. We will evaluate the data we collect through classroom observations to determine whether or not our Mathematics Specialists are helping teachers and students in their school buildings develop a rich conceptual understanding of mathematics. By coordinating the quantitative data with the case studies, we will be able to document the exact nature of the Specialists' daily work and how particular course activities contributed in part to their effectiveness. We will compare the data we are collecting in this project with similar data that was collected in a previous MSP project that trained and followed a group of elementary Mathematics Specialists.

Section 4: Lessons learned

The courses for our current MSP Institute project were designed based on our experiences from designing and offering similar courses for elementary school teachers. We knew that the content would need to change. Middle school teachers need to spend time on different aspects of the mathematical curriculum when compared to elementary school teachers. We are learning that other aspects of our courses may need to change as well to get our participants to embrace non-traditional teaching strategies in their own classrooms and in their roles as coaches in the school buildings.

Abstract Title:
Effective Teaching in Middle School Mathematics

MSP Project Name:
Greater Birmingham Mathematics Partnership

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Strand 3

Summary:
The Greater Birmingham Mathematics Partnership (GBMP), through Phase I and II MSP awards, has focused its support and study on effective teaching of middle school mathematics (grades 5-8). Our approach to effective teaching in mathematics can be fit to an MSP logic model. Conditions involve partner commitments to summer courses, school-based PLCs, Community Math Nights, Administrator sessions emphasizing what inquiry-based instruction looks like, and Math Support Teams (MSTs) in the schools. Activities involve summer courses modeling inquiry-based pedagogy, support for inquiry-based teaching in the classroom, PLCs, coaching MSTs, and guidance in facilitating good PLC meetings. Outcomes include classroom observations showing increased implementation of inquiry-based instruction, and relating this to improved student achievement as measured by both aligned and unaligned instruments.

Section 1: Questions for dialogue at the MSP LNC

1. There is a dramatic discrepancy between teachers' self-report of utilization of inquiry-based teaching, as reported on a survey of professional development and instructional practice (PDIP) administered to GBMP teachers in collaboration with the American Institutes for Research, and the level of such implementation as measured by observation of the classroom using the Reformed Teaching Observation Protocol (RTOP) instrument. What might account for this discrepancy?
2. A linear regression analysis for n=175 observations (Year 1 and Year 2 combined) shows a statistically significant relationship between the number of GBMP summer courses taken by teachers (predictor variable) and their total RTOP score (dependent variable). Interestingly, the greatest variance in RTOP scores occurs at 3 and 4+ courses. Some teachers who have been very active in summer courses are high implementers in their

own classrooms, while many others remain low implementers even after taking multiple GBMP courses modeling inquiry-based pedagogy. What might explain this discrepancy?

Section 2: Conceptual framework

The Greater Birmingham Mathematics Partnership (GBMP) through Phase I and Phase II awards from NSF has focused its support and study of effective STEM teaching on two areas: (1) effective teaching of middle school mathematics (grades 5-8) and (2) effective teaching of pre-service middle school mathematics teachers. This report will focus primarily upon the former area, and largely as it relates to our Phase II work. Our approach to effective teaching in mathematics can be fit to the logic model described in the call for abstracts: *conditions, activities,* and *outcomes*. We will describe (Strand 3) *How we know we are making progress toward more effective STEM teaching.*

In Phase I we clarified our definition of Challenging Courses and Curriculum (CCC); we focused one four key aspects:

1. Deepening knowledge of important mathematical ideas.
2. Productive disposition.
3. Inquiry and reflection.
4. Communication.
5.

These continue to be the hallmarks for us of effective teaching in mathematics. Toward clarifying our definition of effective teaching further, we note that Laursen (et al., 2011) identifies several features of inquiry-based learning in the classroom. Our version of these features correlates well with the dimensions of the RTOP instrument for classroom observation (RTOP 2010, Sawada 2002), and are supported by the literature:

1. The main work of the class meeting is problem-solving (e.g., Savin-Baden and Major 2004; Prince and Felder 2007).
2. Class goals emphasize development of skills such as problem-solving, communication, and mathematical habits of mind (e.g., Duch, et al. 2001; Perkins and Tishman 2001).
3. Most of the class time is spent on student-centered instructional activities, such as collaborative group work (e.g., Gillies 2007; Johnson, et al. 1998).
4. The instructor’s main role is not lecturing, but guiding, asking questions, and giving feedback; student voices predominate in the classroom (Alrø and Skovsmose 2002).
5. Students and instructor share responsibility for learning, respectful listening, and constructive critique (e.g., Goodsell, et al. 1992; Lerman 2000; Prince 2004).

The *conditions* that GBMP supports to make it possible for teachers to be effective include the commitments by partner schools for teachers (at least 75%) to take at least two GBMP summer courses over 3 years of Phase II in order to continue to build mathematical content knowledge; for teachers to participate in 8-12 Professional Learning Community (PLC) meetings a year at their schools to become a group of teachers who purposely foster a culture of learning, mutual respect and reflection leading to high implementation of inquiry-based instruction; for schools to host Community Mathematics Nights, to build community support and involvement in inquiry-based learning; for school-level administrators to attend administrator sessions and learn to recognize and value inquiry-based learning; for teachers and schools to allow data to be gathered through classroom observations, performance-based assessments of students, observation of PLCs, and state testing data; and for schools to make available and implement inquiry-based curricular materials.

Continuing from Phase I, the *activities* upon which GBMP's support of effective teaching in mathematics include the aforementioned summer content courses for teachers, ongoing training and support for Mathematics Support Team teachers (MSTs) in each school who are the facilitators for PLCs in their schools and provide leadership in modeling inquiry-based teaching for their colleagues, PLC meetings which GBMP's MST training sessions during the school year help structure, coaching support provided by project personnel for MSTs, and education about and support of inquiry-based learning in the classroom. The MST sessions focus on helping the MSTs learn to facilitate PLC meetings that will support and encourage the above features of inquiry-based learning in their schools' classrooms.

The *outcomes* which GBMP continues to observe include increased teacher content knowledge in mathematics, improved success in student learning of mathematics, greater implementation of inquiry-based pedagogy in the classroom, and a more productive professional reflection on the role of inquiry-based learning in mathematic by teachers. How we are measuring such outcomes is discussed in the next section.

Section 3: Explanatory framework

We found in Phase I that a high level of implementation of inquiry-based pedagogy in the classroom was accompanied by statistically significant higher student achievement in mathematics. We measured in Phase I, and continue to measure in Phase II, the level of implementation of inquiry-based pedagogy mainly through classroom observations using the RTOP instrument (RTOP 2010, Sawada 2002). We measured in Phase I student achievement in mathematics using the state-administered SAT10 (Mathematics portion) and Alabama Reading and Mathematics Test (ARMT). Our Phase I data indicated that only about 12% of classrooms were high implementing. We were not able to observe all teachers' classrooms, but only a moderate sample.

In Phase II, we are working with a smaller number of schools, more intensively. The target level of faculty participation at all schools is 75%, and we are observing the classrooms of all participating teachers, again using RTOP. The research team also looks for specific activities in its observations such as use of inquiry-based materials and number talks. PLCs are observed at least twice a year using a scale incorporating PLC planning and preparation, management, and engagement factors. Drawing on a survey of professional development and instructional practice (PDIP) administered to GBMP teachers in collaboration with the American Institutes for Research, we have observed that self-reporting of inquiry-based instruction is at a dramatically higher level than the level supported by RTOP observations. During the second project year and continuing into the third, the project made significant changes in its approach to working with both MSTs and the PLCs to address discrepancies such as this, and the slow progress in meeting implementation goals. This year we prescribed the structure and content of PLC meetings, provided opportunities for MSTs to rehearse facilitating the meetings, and provided coaching for

MSTs in implementing inquiry-based pedagogy. This has had a positive impact on teacher engagement and on the effectiveness of the PLCs.
We are measuring student achievement with the ARMT (and SAT10 where available, though it is being phased out by the state) and with periodic administrations of Balanced Assessment (BA) items by teachers to their students as part of the project. 2009-2010 SAT10 growth is consistent with Phase I findings: students in high implementing classrooms had significantly higher achievement. 2009-2010 BA growth was generally not significant. The data for 2010-2011 has not yet been fully analyzed.

<u>Section 4: Lessons learned</u>

When we wrote our Phase I proposal, we did not realize how difficult and (on average) slow the transition of a teacher to being high implementing was. We believed then, and still believe, that improved mathematics content knowledge is a necessary condition. It is not sufficient, even when inquiry-based pedagogy is modeled in the content courses. When we wrote our Phase II proposal, we knew the transition was a lengthy and gradual process, but we were then building on the base of Phase I, with a well-established group of MSTs at most Phase II schools, many of whom were exemplars of moderate or high implementation. We now know that high implementing teachers are a fungible resource. By the beginning of Phase II, we had lost a significant number of our high implementing MSTs to schools not in the targeted group for the Phase II project. Our own success with individual teachers was a double-edge sword. Moreover, the high rate of teacher turnover in the Birmingham area had left us with a large group of low implementing teachers in the targeted schools who had not had any GBMP summer courses. When we wrote our Phase II proposal, we believed the literature supported the idea that engagement of teachers in PLCs was promoted by the degree to which teachers felt they had ownership, and we theorized that the latter was supported by the teachers being able to choose the PLC format and goals (within a set of structures supported by the literature. See Little (2000), Loucks-Horsley et al. (1987, 1998), DuFour (2004), Halmos et al. (2009).) In practice, having multiple models, implemented with varying degrees of success by MSTs, was unmanageable. As noted above, we made changes this year in MST training and PLC structure which have had a positive impact on teacher engagement and effectiveness of PLCs.

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Abstract Title:
Qualitative Analysis of Changes in Teachers' Knowledge, Beliefs and Classroom Practices Based on Three Years of Professional Development

MSP Project Name:
Focus on Mathematics

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Strand 2

Summary:
This session presents methods researchers developed to collect and analyze data about how/ extent which FoM's 3-year masters' degree program deepens secondary mathematics teachers' MKT, beliefs about teaching and learning mathematics, and transfer of learning to their students. Methods include observations of PD sessions, review of teacher artifacts, interviews with teachers and faculty, classroom observations. The study focused on 4 secondary teachers; data was collected over 2-3 years; data analysis is currently being completed. Early analysis reveals the significant impact of contextual factors (school/district circumstances; teacher background/prior experiences) that bear on teacher learning and their influence on their work with students. This pilot study allowed researchers to develop and test research methodologies and to recognize the need for policy changes.

Section 1: Questions for dialogue at the MSP LNC

There is much debate about what is effective teaching, how to support it at both the pre-service and in-service levels, as well as how to 'measure' or 'assess' it as practiced.

- What does 'effective teaching' look like in secondary mathematics classrooms and what are the ways to measure it?
- What methods are MSPs exploring or effectively using to understand and document how/whether MSP professional development programs result in participants' using more 'effective teaching' practices?
- How do these methods account for the contextual factors that, at times, are not aligned with or do not support effective teaching practice?
- What changes are necessary at the school/district level to support such changes in teachers' classroom practices?

Section 2: Conceptual framework

FoM's view of 'effective teaching in STEM' is most readily captured by the Common Core practices. 'Effective teaching' depends on teachers' deep knowledge of mathematics for teaching, their ability to develop meaningful tasks/problem sets that build student understanding of the topic under study and make connections with what they already know and with other topics/strands of mathematics, their ability to uncover where/why students are struggling and provide critical on-the-spot support, as well as revisions of classroom plans, to help students progress.

The design of Focus on Mathematics' professional development programs includes the following components. Mathematicians facilitate sessions, they provide problems/problem sets that 'have a low threshold but no ceiling,' allowing teachers with different backgrounds and prior experiences to participate meaningfully, stretch their understanding, and build knowledge. Teachers work together during the session to explore the problems and try a range of approaches to solving them. In the process develop new insights, make connections with what they already understand, and build a more coherent view of the discipline. Teachers report that, as they work 'like mathematicians' during the sessions, they gain a new perspective on and empathy for students that struggle in their classrooms. Mathematicians facilitating sessions observe teachers' approaches and consult with small groups as they work through the problem sets. They use targeted questions rather than provide answers to struggling groups. The small groups share their work with the larger group, discussing the effectiveness and efficiency of their strategies, how their understanding shifted as a result of their collective experiences, and implications the session had for their ongoing work with students.

For this vision of teaching to be realized teachers need to understand several things and develop particular skills. Teachers need a broad and deep understanding of mathematics as a discipline and the ways in which different areas of mathematics are interconnected. To be able to help all students, teachers need a depth of experience as learners of mathematics in order to understand each student's thinking about an approach to each math problem and the connections s/he is or is not making. They should also have the ability to find/recognize/create problems of value that have a low threshold and no ceiling appropriate for the diverse students in their classes.

In addition, other conditions are needed for teachers to teach effectively. Within their schools they require sufficient time and resources to support their practice, and the autonomy to make decisions about pacing, and to recognize and allot more time to those elements of the curriculum that are particularly important to address. It is very difficult for teachers to teach in this way alone, and need a community of teachers, administrators, and others working together.

FoM's professional development programs and work with teachers is not focused on a particular set of classroom materials or curriculum resources, nor explicit pedagogical coursework. Understanding what teachers gain from their experiences in the program, how and what they bring back to their classrooms, and what either supports or inhibits their use of what they have learned from the program as they continue to work with students has not been easy to document. This study was designed to identify the connections between teachers' intensive involvement with FoM, how the program influenced their knowledge of mathematics for teaching, what they set out to do in their classrooms based on their learning, and how and whether they were able to accomplish the change they sought.

Several components of the research design, discussed in more detail in the following section, allowed the researchers to identify these connections. A definition of an 'effective' mathematics classroom was based on interviews with teachers in the masters degree program, the PIs, and was supplemented by the research literature.

Teachers were interviewed in depth over 1.5-2.5 years, enabling researchers to identify shifts in teachers' thinking, understanding and beliefs over time. FOM mathematicians and the researchers observed the teachers together and debriefed at a later date, completing the observation protocol.

Section 3: Explanatory framework

Findings from the research include: (1) teachers involved in the 3-year MMT program deepen their knowledge of mathematics, (2) teachers reflect on how their past learning experiences in mathematics frequently varied considerably from FoM's approach and this dissonance frames their thinking about the design of their own work with students, (3) some teachers do shift their practices in ways that resemble their experiences in FoM, (4) shifts in classroom practices are constrained by district/school curriculum resources, pacing guides, assessment and accountability practices, the lack of support/time to redesign courses and/or classroom tasks in collaboration with colleagues, and, in some instances, sufficient classroom time scheduled for students' mathematics courses.

To develop this understanding researchers asked 6 MTFs to participate in the case study. Their selection was based on the following criteria: (a) different levels of experience/years teaching, (b) different school districts, (c) both genders, (d) middle and high school levels, and (e) representation from both MTF cohorts (one beginning in Summer 2004 and the other beginning in Summer 2005). Each of the six teachers agreed to be subjects of our case studies. One teacher dropped out due to heavy teaching responsibilities; another teacher was not in a classroom teaching role at the time of the study leaving 4 public school teachers from 4 districts including two men and two women teaching at middle or high school levels.

Researchers developed a methodology that allowed them to understand change over time in a highly systematic and structured approach. For each case study participant, data were collected over a period of either two or three years, depending on when a teacher entered the MMT program.

Data included (a) interviews with the teachers and their principals, (b) classroom observations, (c) observations of program components, MTF professional development presentations, seminars), and (d) documentation of program activities that reflected teachers' learning processes. Researchers developed initial codes for data analysis based on the data and the FoM logic model. Then each researcher independently coded the same teacher interview, followed by discussions to establish inter-rater reliability. Researchers coded the data in chronological order using Hyper Research. Each researcher coded data relevant to teachers she had interviewed, plus other data pertinent to that teacher.

The team began with a visualization of the codes with one code per circle, and professional development in the center. Searching for a more systematic way to work with the coded data researchers decided to add arrows to link the circles/codes for one teacher, describing the interconnections between the codes, as represented by arrows from one circle to another. The arrows identified strings of codes with the first code in the string determined by the starting point for the direction of change. For example, a specific data point with arrows from TL [teacher learning] to CL [classroom teaching] to SL [student learning] indicates that what the teacher learned had an impact on her/his classroom teaching and, subsequently, student learning.

Researchers developed a matrix for each teacher, listing each data source along one dimension and the code strings along the other. Researchers recorded the number of data points for each string as it appeared in the analysis as an indicator of the central themes relevant to each teacher. Finally one researcher wrote the first draft of each study based on the analysis to date. At a later point researchers added observation data.

In the first step of writing the studies each researcher wrote the case concerning the teachers she had not interviewed, observed, or coded in order to assure validity. The researcher who had made classroom observations, however, completed the observation protocols. Initially observations were analyzed and written as separate reports that included all data related to the observations, including interviews. Information from observation reports and completed protocols was incorporated into the final case report as appropriate.

Section 4: Lessons learned

As external evaluators for FoM, we did not have a direct role in developing the proposal. However, in our work with the Principal Investigators over the years, they continue to consider how best to support teachers' work within the classroom.

Key learning about what is required to support effective mathematics teaching includes:

[1] Teachers need ongoing PD, continued and more explicit support to translate what they learned into more effective classroom practices.

Despite the considerable role the professional development program has played in teacher learning, translating those experiences for students in the classroom takes additional support from the partnership – the universities, the school, the district, and peer support. It is not a period of time where teachers, working alone, are either rewarded or supported for exercising autonomy.

FoM PIs recognize the need to provide additional support to help teachers translate their knowledge and skills into more effective classroom practices. Two PD efforts are designed to provide this support: [A] a set of 5 all day seminars focused on continuing to deepen teachers' knowledge of mathematics, exploring and presenting classroom applications, and connecting teachers to a broad, national network of mathematicians and mathematics educators focused on effective teaching, professional development programs, and policy initiatives, and [B] a team of teacher leaders working to develop and publish classroom tasks connected to the Common Core that encourage student use of the mathematical practices.

[2] District leader change: maintaining a shared vision of effective PD and classroom teaching over time. FoM is a partnership with 2 universities, the mathematics division of an educational research and development organization, and 5 different school districts. While mathematicians have remained constant, considerable leadership changes have occurred at the district and school levels. In addition, over the grant period, pressure to improve student test scores has grown considerably, as a growing number of schools is identified as 'failing.' District concerns about increasing test scores has, at times, led leaders to question the effectiveness of PD programs that focus on deepening teachers' knowledge of mathematics for teaching. Other PD strategies such as focusing only on areas where students struggle have competed for teacher participation. FoM has been less successful at convincing district and school leaders that their PD approach, and the type of classroom instruction they support, will lead to student understanding of mathematics, preparedness to take advance courses, and improved test scores.

[3] Learning mathematics and developing more effective classroom practices is a social/collaborative activity.

FoM's design was predicated on the development of a mathematical community. Cross schools and district, this has become an important outcome of the program. However, the changes in leadership and teaching staff at the school and district levels, and changes in administrative support for FoM PD practices, has made it more difficult to maintain and grow that community.

Abstract Title:
Evidence of Enhanced Teaching in Student Content Knowledge Gains: Missouri's A TIME for Physics First MSP

MSP Project Name:
A TIME for Physics First in Missouri

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Strand 3

Summary:
A TIME for Physics First, researching intervention effects on two cohorts of ninth-grade Missouri physics teachers, includes leadership building, content, pedagogy, research and evaluation components in its professional development model. Inquiry and modeling-based physics content in the classroom is emphasized. With a random-assignment, delayed-entry design, analysis of student pre/post physics content tests in the first treatment year permitted an early opportunity to confirm project assumptions that intervention would improve teaching and yield enhanced student achievement. Students of intervention teachers within one year after participation began showed statistically significant higher mean gains ($p < .000$, e.s. .53) compared to students of comparison teachers not yet participating, based on scores from the Test of Understanding Graphs-Kinematics. Teachers themselves experienced similar test results.

<u>Section 1: Questions for dialogue at the MSP LNC</u>

What characteristics are present in the learning environments (specifically schools) of students who attain higher levels of content?

Is student content knowledge the gold standard for MSP success?

How do those MSPs that work with student pre/post testing as a measure of student content knowledge gains meet the challenge of instrumentation?

Does classroom observation data offer sufficient evidence of effective STEM teaching, in lieu of student outcome results?

What value does data based on teacher self-reporting have in evaluating teaching effectiveness and the results of MSP participation?

Section 2: Conceptual framework

The *A TIME for Physics First* project defines effective teaching in STEM – concentrating on ninth grade physics, the focus subject of the project, allied with associated math content – as the sustained application of proficiency in pedagogical content knowledge through a curriculum that meets the needs of students in the school context. In the classroom and to the students, this definition means that inquiry-based activities, with instructional strategies that focus on modeling and a sequenced physics content basis with appropriate integration of associated mathematics content, support the schools' curricula. The project believes that such teaching engages and supports student learning in ways that effectively yield better outcomes in student achievement in terms of content knowledge gains and related skills.

The project, a five-year institute math science partnership, is investigating the effects of differential intervention on two cohorts of ninth-grade Missouri physics teachers. Intervention for both cohorts includes intensive leadership building, content, pedagogy, research and evaluation components; its professional development model strongly emphasizes inquiry and modeling-based physics content throughout. The professional development model therefore is closely matched to the project's definition of effective STEM teaching. Intervention diverges between the cohorts in one cohort receiving in-person coaching and the other receiving on-line mentoring, as the project researches their relative effectiveness in supporting teachers in making a positive impact on student learning. For the purposes of the period of this presentation, however, the first cohort represents the only intervention group, as the second cohort had not yet entered participation at the times pre/post tests were delivered and therefore were in a position to serve as a non-intervention (or pre-intervention) comparison group for the analyses.

A nonrandom-assignment, delayed-entry control group design of two cohorts of teachers of this type (N=64) permits comparison of selected outcomes with relative confidence. This set of teachers does not represent all participating teachers, but those recruited in time for the cut-off date for the random assignment. The design permitted an early opportunity for confirmation of the project's assumptions on the directness of the link between enhanced teacher pedagogical content knowledge as a result of its professional development and more effective teaching, and between more effective teaching and student achievement as measured by student content knowledge gains.

Section 3: Explanatory framework

In the first intervention year of the project, cohort 1 teachers attended a summer academy and follow-up workshops during the school years, and received classroom visits from coaches. Cohort 2 teachers had no intervention. Pre/post testing was done with both cohorts of teachers (intervention and comparison/pre-intervention) (N=53) and with students of both cohorts of teachers (N=1,433) using the Test of Understanding Graphs-Kinematics (TUG-K) and Misconception Oriented Standards-based Assessment Resource for Teachers (MOSART). Cross-cohort comparison showed that cohort 1 intervention teachers experienced a significantly higher mean gain of 5.15 ($p \leq .000$, Effect Size 1.46) on the TUG-K over cohort 2 comparison teachers who had not yet entered intervention, although no such significance in comparative gains was seen in MOSART results. Similarly, students of cohort 1 intervention teachers showed a statistically significant greater mean gain of 2.11 ($p \leq .000$, Effect Size .53) on the TUG-K compared to students of cohort 2 comparison teachers. The TUG-K content closely following the project's emphases on modeling and graphing, a direct connection between the project's activities, their effects on the teachers teaching, and subsequent student outcomes in specific focal domains can be seen.

Section 4: Lessons learned

This early confirmation of intervention efficacy offers strong validation of some of the premises of the project. At the same time, the challenges of instrumentation and sampling in the real-world context of a state's education system, with some teachers in cohort 2 having undergone a prior iteration of the project's intervention, could have conflated MOSART results. Student content test results alone concern only a portion of the project's intended student outcomes, and in themselves do not inform specifically how elements of intervention interrelated to affect teaching. Teachers attempting to implement the project's lessons and associated activities in their schools inevitably must face the challenges of their schools' curriculum, academic priorities and time constraints. While the current Physics First lessons reflect refinement based on previous implementations, teachers inevitably must adapt and choose what they can, such as to fit the broad variations in lesson lengths. Meeting the widely divergent needs of teacher participants also has continued to offer lessons to the team. Individual mixes of content and pedagogical knowledge and experience exist among any group of teachers; the additional supports offered by coaches/mentors, year-round refreshers, and sustained on-line contact offer the means to extend the intensive summers' interventions. More particularly on the analysis side, the project also is in the process of examining domain-specific MOSART results to investigate if information can be gleaned to enhance intervention activities and yield a finer understanding of the test results. Such early, useful results of the professional development model's impact on teachers' content knowledge and a corresponding impact on students' content knowledge offers support of the adoption of such cohort designs.