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Building and Sustaining a Professional Learning Community: Joining in with Teachers to Improve Mathematics Teaching and Learning

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The project focused on four strands of support for professional development: Technology, Algebraic Thinking, Reflecting on Practice, and Project-Based Learning (PBL). We studied the effect of implementing these support structures with the teachers as we examined how the professional development facilitated the transition for teachers to make both their classrooms and schools sites for inquiry, and form and sustain professional learning and inquiry communities. A number of quantitative and qualitative measures were used throughout the three years of the project to gather evidence about teachers' growth in each strand. Including measures of teachers' knowledge of content and pedagogy, indicators of the quality of the PBL units they developed, and indicators of the level of reflection in which teachers engaged. While findings revealed that teachers experienced growth in each of the strands targeted by the project, we paint a picture of potential challenges and successes associated with joining with schoolteachers to create and sustain a professional learning and inquiry community.

Key words: *secondary level teachers, professional development, professional learning communities, project based learning*

Public education in the United States is inadequately preparing today's students for tomorrow's workforce and professional careers (National Center on Education and the Economy, 2008; The National Academies, 2007). In this paper, we discuss how our professional work with five rural school districts attempts to meet the mandates of national educational boards and councils while engaging students in 21st Century skills. The study evaluates the effect of the support structures provided through the professional development, and how we can continue supporting the teachers. Thus, our research question is, how does the professional development facilitate the transition for teachers to

make both their classrooms and schools sites for inquiry, and form and sustain professional learning and inquiry communities?

Context

Limestone County Mathematics Advancement Partnership Project (Limestone MAPP, a fictitious name of the county) is a three-year professional development funded by a State Department of Education. The project was designed to improve students' mathematics understanding, achievement, and algebra readiness in grades 4-12 by enhancing teachers' mathematical knowledge for teaching and knowledge of inquiry-based teaching approaches. By establishing professional learning communities where student learning is a fundamental goal, teachers are engaged in dialogue about critical aspects of mathematics teaching –knowledge of students, learning, curriculum and pedagogy–while developing confidence in their ability to teach mathematics. Situating our approach in current research and best practices in teaching mathematics, our goal is to join with the teachers and work towards the practice of teaching and learning mathematics for understanding.

This partnership between a higher education institution and Limestone County schools specifically targeted four areas of mathematics teaching and learning, namely: (a) fostering algebraic thinking, (b) project based learning, (c) reflecting on practice, and (d) learning mathematics with technology. The scope of this paper will focus on the first three strands.

In the first strand, algebraic thinking, we supported teachers to transition from engaging in algebraic reasoning from a personal point of view to fostering algebraic thinking in their classrooms, and reflect on how instructional tasks are maintained at a high level of cognitive demand.

For the second strand, project based learning (PBL), we supported teachers to transition from learning the basics about PBL and its framework in year 1 to design, implement, revise, and share PBL units in the third year of the project. This included a transition stage developing and implementing simpler Problem Based Learning Tasks (PrBL) in years 1 and 2. We adopted the Buck's Institute for Education's definition of PBL (2014) as "students go[ing] through an extended process of inquiry in response to a complex question, problem, or challenge. While allowing for some degree of student 'voice and choice,' rigorous projects are carefully planned, managed, and assessed to help students learn key academic content, practice 21st Century Skills (such as collaboration, communication & critical thinking), and create high-quality, authentic products & presentations."

Lastly, in the third strand, reflecting on practice, the goal was for teachers to become critical and reflective about their own practice. By the end of the project we wanted teachers to be comfortable engaging in collaborative reflection with their peers, videotape their lessons, and share and reflect on

their practice with others. They were supported in their development by engaging in inquiry cycles that varied in levels of collaboration, ranging from individual written reflections to team planning a lesson, teaching it, revising it, re-teaching it, and videotaping themselves to share their practice with others.

Conceptual Framework

Our project draws from Cochran-Smith and Lytle's (1999) three conceptions of how teacher knowledge can be developed. Our goal was to help project participants grow into a pivotal role, generating *knowledge of practice*, and making both their classrooms and schools sites for inquiry, and form and sustain professional learning and inquiry communities. From this perspective, the major contexts for teacher learning are teacher networks, inquiry communities, and other school-based collectives in which teachers and others conjoin their efforts to construct knowledge. However, in this transition, we have relied on other ways to help teachers develop their knowledge, starting from *knowledge-for-practice*, in which we have used knowledge produced by previous research to inform teachers' practice. We have also used methods that align with a *knowledge-in-practice* perspective as we have engaged teachers in examining and reflecting on the knowledge that is implicit in good practice.

We believe that the products of our work can only be sustained when teachers create communities of practice. Many benefits result when teachers participate in true communities of practice; teachers share a sense of purpose and a sense that they are responsible to one another for achieving their goals, coordinating their efforts to assure student learning, and sharing responsibilities for decision making (Secada & Adajian, 1997).

Methodology

Participants

A total of 58 teachers in grades 4 to 12 participated in Limestone MAPP. Twenty-seven of these were secondary teachers teaching in grades 7 to 12. Teachers' participation in the project included 80 hours per year distributed among summer workshops (40 hours), four bi-monthly workshops with all five districts together, and four bi-monthly sessions in each of the districts. Year-round sessions alternated between sessions with all districts together, and sessions at each of the districts. A subgroup of five lead teachers, one from each district, assisted to ensure that project efforts are integrated into practice at the individual schools and will continue after the grant. The lead teachers worked closely with the Professional Development Team to plan workshops and provide support to the teachers between workshops.

Algebraic Thinking

We used measures developed by the Learning Mathematics for Teaching (LMT) project at the University of Michigan (Hill, Ball & Schilling, 2004). We chose two scales for our project: the Number and Operations Knowledge of Content and Students (NCOP-KCS) scale and the Middle School Patterns Functions and Algebra Knowledge of Content (PFA) scale. We used the scales at the beginning of the first year and then again at the end of each of the three years. We chose these two scales for the following reasons. We wanted to measure the way our program is impacting teachers' pedagogical knowledge. The NCOP-KCS scale not only measures knowledge of Number and Operations, but it also measures teachers' knowledge of students and how they learn number concepts and operations. Also, since one main focus of our professional development is on fostering algebraic thinking, we also wanted to have a measure of their knowledge of this topic.

Project-Based Learning

By the end of Limestone MAPP, the goal for this strand was for teachers to learn to develop and implement PBL units. We supported teachers in their development by first helping them learn to design and implement Problem Based Learning tasks. PrBL tasks are specific tasks or problems that allow multiple solution strategies in which students can work on and solve during class in 1 to 3 days. Students can work in small groups, or in pairs, and as in PBL, PrBL tasks are expected to address important standards and help students develop 21st Century skills. All secondary level teachers were expected to work in small groups to design at least one PrBL task each year during years 1 and 2. We analyzed the quality of the tasks they developed.

We utilized the rubric of the Six A's from the *Project Based Learning Handbook* (Markham, Larmer, & Ravitz, 2003) to guide our analysis of the PrBL math tasks. PrBL tasks were categorized using six themes: authenticity, academic rigor, applied learning, active exploration, adult connections, and assessment practices (see Table 1). These six themes are the Six A's that make a PBL unit relevant and rigorous. Table 1 includes the descriptors for the Exemplary criteria (the full rubric also includes descriptors for the Basic and Unsatisfactory criteria). Refer to pg. 34 of Markham et al. (2003) for the full Six A's rubric.

We replaced Markham et al.'s (2003) descriptors of Active Exploration because we felt it was important for PrBL tasks to be cognitively demanding rather than "students do[ing] field-based activities and gather[ing] information from a variety of primary sources" (pg. 34). Our lens of cognitive demanding tasks comes from Stein, Smith, Henningsen, and Silver's (2000) work. The Exemplary criteria for Active Exploration involve what Stein and colleagues call "Doing Mathematics." Refer to Table 1 to see what "Doing Mathematics" entails. A task was categorized in the Basic criteria if it was "Procedures without Connections," and in the Unsatisfactory criteria if it was

"Procedures Without Connections." Refer to Stein et al.'s (2000) work (pg. 16) to see a full explanation of these last two categories.

Table 1
Modified Six A's Rubric

Category	Descriptor for Exemplary Performance
Authenticity	Adults in the "real world" are likely to tackle the problem or questions addressed by the project. The problem or question has meaning to the students. There is an external audience for the student work
Academic Rigor	There is a well-defined and clear Driving Question that is derived from specific nation, state, district, or school content standards. The project demands breadth and depth of specific knowledge of central concepts. Students develop new habits of mind (e.g., questioning and posing problems; precision of language and thought; persistence).
Applied Learning	Students apply new knowledge to a realistic and complex problem. Students use multiple high-performance work organization skills (e.g., working in teams; using technology appropriately; communication ideas, collecting, organizing, and analyzing information). Students formally use self-management skills (e.g., developing a work plan, prioritizing pieces of work, meeting deadlines, identifying and allocating resources) to improve their teams' performance.
Active Exploration	Requires complex and non-algorithmic thinking—a predictable well-rehearsed approach or pathway is not explicitly suggested by the task, the instructions or worked-out example. Requires students to explore and understand the nature of mathematical concepts, processes or relationships. Demands self-monitoring of one's own cognitive processes. Requires students to access relevant knowledge and make appropriate use of it in working through the task. Requires students to analyze the task and examine task constraints that may limit possible solution strategies and solutions. Requires considerable cognitive effort and may involve some level of anxiety because of the unpredictable nature of the solution process.
Adult Connections	Students have multiple contacts with adults outside of school who have expertise and experience and who can ask questions, provide feedback, and offer advice. Students have the opportunity to observe and work alongside adults in a worksite relevant to the project. Adults outside of school provide students with a sense of the real-world standards for this type of work.
Assessment Practices	Students help in establishing assessment criteria. Students use a variety of structured self-assessments (journals, peer conferences, teacher or mentor conferences, and rubrics). Students receive frequent and timely feedback on their works-in-progress from teachers, mentors, and peers. The final product is a culminating exhibition or presentation in front of an informed audience. The project employs multiple products, and all products are aligned with outcomes.

We examined all PrBL tasks using the modified Six A's Rubric. With this coding scheme, the first two authors analyzed each PrBL task. Each rater's individual coding was later reconciled with the other rater to ensure inter-rater reliability.

Table 2
Reflecting on Practice Continuum Model

Level 1	Written Reflection: The teacher will type two (2) reflections about his/her class(es) using the Reflection Template and submit to the online reflection forum of our project.
Level 2	Personal Audio Reflection: The teacher will audiotape a class, then listen and reflect on the lesson. Post reflection to our online forum using Reflection Template.
Level 3	Observation and Pair Reflection: The teacher will invite a colleague to observe one of his/her classes. Then following the class (at a time convenient to both) he/she will meet with the colleague and reflect on the lesson. Then post reflection to our online forum using Reflection Template.
Level 4	Personal Reflection on Videotaped Lesson: The teacher will videotape a lesson of choice then privately reflect on the lesson. Post reflection to our online forum using Reflection Template.
Level 5	Pair Reflection on Videotaped Lesson: The teacher will videotape a lesson of choice. Then select a colleague to watch the video of him/her teaching. Then (at a time convenient to both) he/she will meet with the colleague and reflect on the videotaped lesson. Then post reflection to our online forum using Reflection Template.
Level 6	Pair/Team Reflection on Videotaped Lesson Followed by Teaching of Revised Lesson: The teacher will videotape a lesson of choice. Then a colleague or small team of peers will watch the video of him/her teaching. Then (at a time convenient to all) they will meet and reflect on the videotaped lesson and revise it. The colleague or a member of the team will teach the revised lesson to another class. Then post reflection to our online forum using Reflection Template.

Reflecting on Practice

Throughout year 1 and year 2, secondary teachers completed two or three reflection cycles around a lesson they taught. Teachers chose from a menu of options that progress through six levels, from an individual written reflection of a lesson taught to a more collaborative reflection with a colleague or in a small group of colleagues Teachers' choices from the reflecting on practice continuum (see Table 2) were documented. We studied the progression of each teacher's choices through the reflection cycles, as well as calculated percentages of the group's choices for each reflection cycle. Table 2 depicts the various levels and reflection descriptions that teachers chose.
Insert Table 2 About Here

Results

Algebraic Thinking

A total of 51 participants completed the LMT scales both at the beginning and at the end of year 1. In year 2 we gave the scales again and 58 teachers completed them. A total of 42 teachers completed the LMT scales three times in the first two years of the project. As noted by the developers of

these scales, these measures are not designed to make highly accurate statements about individuals' mathematical knowledge. Instead, they can be used to compare groups of teachers' mathematical knowledge, or examine how a group of teachers' knowledge develops over time. To compute differences between each administration of the tests the raw score for each teacher was first calculated and then an average raw score was calculated for each test. Average raw scores were then converted to Item Response Theory (IRT) scale scores using conversion tables provided by the LMT project.

For the Number and Operations Knowledge of Content and Students scale, when considering all teachers who have taken all tests in the span of the first two years of the training (42 teachers), no significant difference was found between the end of year 1 and the end of year 2. However, significant change was found after the first two years in the scale score. This change was 0.499 or about one half of a standard deviation.

As far as Middle School Patterns Functions and Algebra Knowledge of Content, no significant change was found between the end of year 1 and the end of year 2. However, significant change was found after the first two years in the scale score. This change was 0.255643 or over one fourth of a standard deviation. Mean gains, or mean differences in standard deviation units, are referred to as effect sizes and are frequently reported in research. As a general rule, an effect size is considered noteworthy when it surpasses roughly a quarter (0.25) of a standard deviation.

Project Based Learning

The secondary teachers developed six PrBL units in year 1 and twelve PrBL units in year 2 and we analyzed them using the Six A's framework. All the units in year 1 and year 2 exhibited high levels of Authenticity and Applied Learning. The units were situated in the "real world" and could be found by adults tackling the same problem or questions the units addressed. In addition, there were appropriate Adult Connections to and/or audiences for the students' products. The units also engaged students in Active Exploration as well as multiple high-performance work organization skills, such as working in teams, communicating ideas, applying new knowledge to the problem, and organizing and analyzing information.

The units exhibited higher levels of Academic Rigor in year 2 than in year 1. We define academic rigor as being able to capture the depth of specific knowledge from central mathematical concepts. All the problems that students needed to solve were well defined and well grounded in the Common Core content standards (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010) and the Mathematical Practices of making sense of problems and persevering in solving them, constructing viable arguments, and critiquing the reasoning of others. We attribute the increase of Academic Rigor for year 2 PrBL units because year 2

teachers were required to predict and submit the mathematical work students might produce; we did not require this in year 1.

The units also exhibited higher levels of Assessment Practices in year 2 than in year 1. Units contained a variety of structured self-assessments and intermittent benchmarks to provide students with timely and formative feedback. Year 2 teachers expressed that this practice of providing students with formative feedback on their works-in-progress was an important factor in their assessment of students' learning as well as a support for students as they prepared to present their work to an authentic and informed audience.

Reflecting on Practice

During the first reflection cycle in year 1, secondary teachers were more comfortable with individual written reflections (Level 1) or co-planning with a colleague, observing each other, and reflecting together (Level 3). Forty-three per cent of year 1 teachers preferred to reflect on their practice individually, either with or without videotaping. Fifty-seven per cent of year 1 teachers reflected on their lessons in collaboration with at least one other teacher. While some teachers expressed a fear of videotaping because they were worried their administrators might use it for evaluative purposes, 19% of teachers videotaped their teaching to analyze and reflect upon their lessons during the first cycle (Level 4).

During year 2, there was an increase in the number of teachers who chose Level 4, that is, to videotape their lesson and then individually reflect upon it. Half of the teachers chose this option. The other half chose to either individually reflect without the use of video (Level 1), or to co-plan, observe and reflect with a partner, both with and without the use of video (Levels 3 and 5). The teachers became more comfortable with videotaping and, when given ample time during the school day, they were more comfortable co-planning a lesson, collaboratively analyzing its implementation through observations or video, and then co-reflecting. It is our hope that by the end of the project most teachers will be comfortable participating in Level 6, where teams of teachers engage in an iterative cycle of co-planning, teaching, co-reflecting, and co-revising the implemented lesson.

Discussion and Conclusions

This study reports on our professional development designed to help teachers (and administrators) transition from a view of teacher knowledge development as *knowledge-for-practice* to a view of *knowledge-of-practice.* While the progress may seem slow in transforming teachers to become vulnerable with each other and see their classrooms as sites for inquiry and professional learning communities, this study has begun to tease out some of the supports that in-service teachers need to feel more confident as emerging mathematics teacher leaders within their schools. Successes in the following

aspects of our project are early indicators of the potential success of this approach.

Algebraic Thinking

One major goal of our project was to target algebraic thinking. After the first year of the project we did not see a significant increase in teachers' knowledge for the Patterns Functions and Algebra Knowledge of Content. However, after two years of the training, the increase in the scale scores for this content area was statistically significant. As far as Number and Operations Knowledge of Content and Students, we saw a significant increase in teachers' knowledge of this topic after the first year; these gains have been maintained after the second year but no further increase has occurred. The fact that we are seeing significant change in the two scales after two years of the training is very encouraging. The changes we see suggest that we are impacting both teachers' pedagogical knowledge and their content knowledge.

Problem-Based Learning

For the second strand the goal of Limestone MAPP was to help teachers learn to develop and implement PBL units. Secondary teachers first designed and implemented Problem Based Learning tasks during the first two years of the project. The units they developed did a good job of addressing many of the features in the Six A's framework (Table 1). The units exhibited higher levels of Academic Rigor and higher levels of Assessment Practices in year 2 than in year 1. The fact that the quality of the units they are developing is improving suggests that they are developing the skills and knowledge needed to develop and implement PBL units.

Reflecting on Practice

In the beginning of the grant, teachers were somehow reluctant to collaborate with one another. Perhaps the willingness to collaborate (and learn new ideas) carried the risk of showing a weakness in one's teaching practices. Twenty-four per cent of teachers still prefer to reflect on their practice individually. In particular, they expressed fear of videotaping because they thought their administrators could use it for evaluative purposes. However, we have been successful in having 50% of the teachers reflect on their videotaping teaching segments. Changing the climate of what it means to reflect and collaborate was a gradual process, and is still a work in progress. We hope by the end of the project most teachers will be comfortable to participate in Level 6 of Reflecting on Practice, and perhaps reflect with other teachers from different school corporations.

References

Buck Institute for Education. (2014). *Project Based Learning*. http://www.bie.org/about/what_is_pbl.

Cochran-Smith, M., & Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. In A. Iran-Nejad & C. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 249-306). Washington, DC: American Educational Research Association.

Hill, H. C., Ball, D. L., & Schilling, S. G. (2004). Developing measures of teachers' mathematics knowledge for teaching. *Elementary School Journal*, *105*(1), 11-30.

Markham, T., Larmer, J., &Ravitz, J. (2003). Project based learning handbook: A guide to standards-focused project based learning (2nd Ed.). Novato, CA: Buck Institute for Education.

National Center on Education and the Economy. (2008). Tough choices or tough times: The report of the new commission on the skills of the American workforce. San Francisco, CA: Jossey-Bass.

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for Mathematics*. Washington, DC: Authors.

Secada, W. G., & Adajian, L. B. (1997). Mathematics teachers' change in the context of their professional communities. In E. Fennema & B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 193–219). Mahwah, NJ: Erlbaum.

Stein. M.K., Smith, M.S., Henningsen, M.A., & Silver, E.A. (2000). *Implementing standards-based mathematics instruction.* New York: Teachers College Press.

The National Academies. (2007). *Rising above the gathering storm: Energizing and employing America for a brighter economic future*. Washington, D.C.: The National Academies Press.

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