MEMO Two: Student Achievement Analysis
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Context of the project
Our LSC project was conducted in a mid-sized urban city in the Midwest. While some LSC projects have engaged multiple school districts, we focused within a single, urban district, Peoria District 150 of Peoria, Illinois. We worked with the teaching staff from all 16 elementary schools and the fifth-grade teachers from all 14 middle schools. The district serves approximately 15,000 students. The families and students served by this district represent an economically and socially diverse group, much like the population of other urban school districts in this country; approximately half the schools in the district served a majority of students having an SES profile that would be characterized as low income (overall, 62% of the students in the district are low income). In contrast to those schools having a majority of low SES students, there were also several schools serving students with relatively high SES characteristics.

We believe the historical context of this school district regarding professional development is also relevant to this analysis; the district had not engaged in any comprehensive teacher development for elementary-level mathematics teaching prior to this LSC. While the district had provided opportunities for sporadic, one-time seminars and allowed for some scattered work across the district involving follow-up to seminar attendance, there had not been any work to engage teachers in the work of tying together their curricular plans with assessment instruments in a cyclical manner, nor had their been any sustained work to build the mathematical content knowledge related to pedagogy. The curriculum in place was a text-reliant pattern of executing daily exercises from Addison-Wesley standard two-page teacher/student textbooks with assessments coming directly from the published sources. An over-arching pattern of teacher-student interaction based on the dominant role of the teacher in evaluating and directing discourse often prevented the expression of student questions or alternative, invented approaches to mathematical problems by students.

Two previous large-scale grant projects were relevant to the work of PRIME in addressing these deficiencies in professional development in this district: LINKS was a project that addressed the geometry knowledge and pedagogical practices of high school teachers of some Peoria teachers along with teachers from other local districts (finishing by 1995) and the PUMP project addressed the algebra preparation of middle school students by promoting improved teacher knowledge and pedagogy for algebra instruction across grades 6-10 among middle school and high school teachers in Peoria between 1995 and 1998. These efforts helped district officials understand the potential model of summer institutes, followed by classroom visits and academic -year half-day seminars. Still, nothing of this sort had been attempted with elementary-level teachers of mathematics.

What we hoped would improve student achievement
We believe student achievement depends directly on strong, careful, reflective classroom teaching. To enhance classroom teaching we established four objectives: (1) extend

teachers' pedagogical content knowledge; (2) promote teachers' reflective analysis of mathematics teaching and learning; (3) improve teachers' mathematical problem-solving and content knowledge; and (4) foster the development of teacher leaders and communities of learners within and across schools.

In keeping with these four objectives for improving instruction in the classroom, we designed an extensive program of interaction between university faculty members in mathematics and mathematics education, graduate students and, expert teachers from other school districts. Five essential aspects comprised the professional development process in our project: (1) mathematically-focused week-long summer sessions, (2) sequential classroom visits (at least four per year) by faculty or research assistants, (3) regular grade-level meetings (two meetings per semester) focused on teacher participation and sharing of sample student work, (4) the use of innovative curriculum material (*Investigations in Number, Data and Space*), and (5) a leadership development program for volunteer teachers.

What We Found

In retrospect, what we ended up accomplishing with the teachers in District 150 was different than we intended, yet close to the five design tenets. Our summer sessions were consistent in implementation across all three years of the project, covering measurement and geometry during the first summer, number and arithmetic operations in the second summer, and then probability, statistics and pre-algebraic reasoning during the third and final summer. But many teachers reported that they did not understand or appropriate the novel and ideal lessons from the first summer since the mathematical ideas (geometry and measurement topics) were less familiar to them than number and operations topics; thus, they did not feel adequate to the task of developing or adapting different lessons on measure or geometry but were more willing to do this after the second summer as it related to topics they found more familiar (i.e., number and operations).

During the second year, teachers were now more inclined to participate in classroom-based conversations when visited by project staff, probably due to their increased confidence regarding the number and operations theme. Throughout the entire span of our project, we found that teachers voiced struggles and occasional opposition concerning the use of the featured curriculum, the *Investigations in Number, Data and Space*. They often said they would continue to use their present text series from Addison Wesley (most likely since it did not require such intensive reading and preparation for each lesson).

While there was a persistent tendency by a majority of our project teachers to resist the complete implementation of the *Investigations* curriculum in their classroom work, there were some significant changes in teacher knowledge of mathematics and its pedagogy for elementary children that we attribute directly to the investment of sessions based on these instructional materials during summer institutes and academic year seminars. The teachers met a striking and challenging vision for teaching and learning mathematics with reflection, student participation, and activity-based exploration. By connecting academic year seminars to the summer institutes, we found that teachers gained an increasing

appreciation for the reform vision of mathematics instruction with their students; the requirement for the academic year seminars was that teachers bring in samples of student thinking and reasoning from two assigned Investigations topics addressed during the previous summer institute; in the process of sharing about their own efforts to implement these lessons and about their students' ways of thinking and working on the assigned elements of *Investigations* lessons, often expressed a pleasant element of surprise to find what their students had accomplished, or what other teachers at their grade level had been able to stimulate students in their classrooms to explore or discuss.

Scheduled classroom visits by project staff were productive in general, but not always without difficulty. These visits were not always carried out in uniform ways; the graduate assistants were only assigned to work on our project for one year, and sometimes less. Thus, many teachers did not have a consistent, ongoing conversation with a mentor, but a scattered set of visits by different graduate students across the three-year lifespan of PRIME. Our case study work indicates that some teachers were ambivalent or non-cooperative with the visiting teacher mentors, and the fifth-grade teachers at the middle schools did not receive classroom visits as often as planned, but sometimes only once a year.. In spite of shortcomings in the systematic classroom visitations, there were usually 4 to 6 visits per teacher per year; we believe this was an important means of accountability and also an encouragement for most project teachers.

Finally, we hoped to enhance classroom teaching beyond the duration of PRIME by developing structures that supported on-going teacher collaboration and fostered coordination and articulation within and across grade levels. One group of 16 teachers responded voluntarily to an invitation for leadership development involving reflection, and action research work involving their own students, resulting in unusual levels of collegial interaction and support. This teacher leader group continued to meet and served as leaders during the academic year following the grant, including taking lead roles as presenting teachers at district-developed institutes for promoting greater pedagogical content knowledge. But without incentives for participating in leadership activities beyond the grant, these leaders have not maintained the scope of leadership they once exhibited. The district has enlisted these teacher leaders in the writing of school-based assessment instruments to design and write grade-level exit tests in mathematics. But this has not helped them carry on the intended work of promoting shifts in pedagogy among their fellow teachers, nor has it enabled them to promote professional discourse about the substantive mathematics in their curriculum. Much could be gained by supporting these teachers as mentors in their buildings.

Evidence for improved student achievement

Overall, the percentage of grade 3 students in Peoria School District scoring at or above standards on the Illinois State Achievement Test (ISAT) for Grade 3 increased from 55% in 2000 to 78% in 2003 while the average performance statewide increased from 69% to 75% during that same time period. Our analysis of student achievement addressed potential effects on the teaching and learning of mathematics; first we examined variations between schools by SES, and then we looked for individual level differences among students according to the professional development experiences of that students'

teachers for the three years leading up to the students' evaluation on the ISAT for Grade 5. Our analysis of the school-level achievement data revealed a significantly higher percentage of students in low-SES schools with lower teacher participation in project activities scoring at the lowest level, termed "academic warning" compared with students at low-SES schools having higher participation by teachers. But further comparisons between schools with varying levels of teacher participation did not indicate significant differences in student achievement.

Next, we looked closely at the individual experiences of students, attending to differences between students who might have had some teachers that did not participate in project activities. We examined the relationship between teacher engagement in PRIME activities during the years 2000-01, 2001-02 and 2002-03 and the mathematics achievement of corresponding students on the 2003 Grade 5 state-level standardized mathematics test for Illinois. The Peoria School District had 1085 Grade 5 students in the 2002-2003 school year. For this study, students were excluded if they were not in the district all three years, or if they did not fit the grade-level profile of students who reached Grade 5 in the fall of 2002 along with this cohort. The resulting number of students in the study was 826. For each student, the following data were gathered and used: Socioeconomic status (SES), Grades 3, 4 and 5 teacher names, and 2003 Grade 5 ISAT score.

We examined the entire cohort of District 150 students who completed the fifth grade in the Spring of 2003. We examined their ISAT achievement scores, attending to their varying experiences with particular teachers during the period from 2000 through the Spring, 2003. Some students had teachers for all three relevant years (Grades 3, 4 and 5) that did not participate in PRIME (n = 35), though this was unusual. Most students had some PRIME-participating teachers for 1 or 2 years and teachers who were not participating in PRIME for the other year(s) (n = 498). Finally, the remaining students (n = 293) had three consecutive years of instruction from PRIME-participating teachers (See Appendix: Table 1). Thus, we posited that students who were instructed by teachers who had been and were continuing to participate in the professional development activities of PRIME would post higher achievements on mathematics tests than those instructed by a group of teachers less engaged with PRIME.

Of the 826 students, 621 or 77.1% were considered to be of low-socioeconomic status and were given a score of "1" for SES. The Pearson correlation between low SES and Grade 5 ISAT scores was -.554 and significant at the 0.01 level (See Appendix: Table 2). Due to this significant correlation, SES was factored out in order to compare Grade 5 test results. The Grades 3, 4 and 5 teacher names were compared against a master list of PRIME teachers to indicate the number of years and at which grade level, each student had been taught by a teacher who was a PRIME participant. Next, we collapsed these data (See Appendix, Table 4) to focus on total number of years each student was taught by a PRIME participating teacher. An analysis of variance showed that for low-SES students, PRIME had a significant effect at the 0.01 level (See Appendix: Table 3).

To summarize our analysis of individual student achievement, PRIME showed moderate success during the period 2000-2003. Our findings (available online at http://www.math.ilstu.edu/grants/prime/)
indicate that students in the lower-socio-economic category who had at least one teacher during grades 3, 4 or 5 participating in PRIME achieved significantly higher scores on the Illinois State Achievement Test (ISAT) for Grade 5 mathematics than students in the same socio-economic category with teachers who had not participated in PRIME. The combination of significantly higher gains on ISAT mathematics scores by Grade 3 students from District 150 during the years of PRIME (2000 through 2003) and these data connecting the involvement of project teachers to the performance of their students on the Grade 5 ISAT (for low SES students) supports the claim that PRIME professional development activities and programs led to improved teaching insofar as teacher participation in the project was associated with increased success on measures of students' mathematical knowledge and understanding.

Implications?

We attribute the improvements among student scores to four primary aspects of PRIME: (1) increased accountability structures (4-6 classroom visits per year with each project teacher) that promoted reflection on lesson design and implementation within the curricular guidelines; (2) consistent emphasis on the importance of attending to student thinking as a basis for lesson development or implementation (through the example of workshop leaders during the summer institute and in seminars and by interactions with classroom coaches in teachers' own classrooms); (3) modeling classroom instruction engaging students directly with illustrative objects, actions, drawings or narratives as representations of particular mathematical ideas (as illustrated and discussed in summer institute sessions and by practice and sharing at academic year seminars); and (4) affordances for teachers to collaborate on planning/assessment cycles to integrate state and national curricular guidelines into their school-wide and grade-level planning (during academic-year planning and sharing meetings in their schools).

Guiding teachers to examine and use richer mathematical tasks with their students by a consistent schedule of classroom visits and grade-level meetings integrated with summer institute coursework apparently shifted the established pedagogy among teachers, especially teachers of low-income students, leading to a richer learning environment for students. Given the demands of national testing mandates (i.e., No Child Left Behind Legislation), it seems clear that this project offered a means of promoting gains in student achievement, and particularly among low SES students, yet the project activities were not a simplistic effort to teach directly to the State Achievement tests even when teachers seemed to be asking for that. Rather, the project directed consistent session time during Summer Institutes and academic-year seminars and classroom visits to the promotion of *Investigations* lessons as models of good tasks, of ways of engaging students in mathematical exploration and discussion of critical mathematical ideas as ways of assessing and addressing students' exhibited strategies and struggles for the specific topics. This can be taken as a model for carrying out the work of professional development with the reasonable expectation of promoting student achievement in balance with a hope of promoting substantive mathematical thinking in elementary classrooms.

Appendix: Tables

Number of Years with a PRIME Teacher	Socio-economic Status (SES)	Number of students in category	Mean Score on ISAT/ St. Dev.
Never received instruction from a PRIME participating Teacher	Low High	30 5	145.8 (9.90) 184.6 (18.27)
Received instruction from PRIME teacher only in Grade 3	Low High	19 12	155.47 (10.43) 181.67 (9.94)
Received instruction from PRIME teacher only in Grade 4	Low High	47 26	162.60 (16.38) 188.65 (10.04)
Received 2 years instruction from PRIME teachers (Grades 3 and 4)	Low High	99 61	160.03 (15.32) 186.02 (14.33)
PRIME teacher only in Grade 5	Low High	47 5	156.34 (12.86) 157.60 (8.68)
2 years of PRIME teachers (Grades 3 and 5)	Low High	60 9	157.07 (12.59) 177.22 (7.71)
2 years of PRIME teachers (Grades 4 and 5)	Low High	97 16	162.97 (14.53) 174.06 (17.21)
PRIME teachers in all three years: Grades 3, 4 and 5	Low High	222 71	160.59 (12.40) 178.17 (15.34)

Table 1. Grade 5 ISAT scores based on SES status and PRIME descriptor.

ISAT Score by Number of Years with PRIME Teachers	Sum of Squares	df	Mean square	F	Significant
Between Groups	19649.047	7	2807.007	10.429	0.000 *
Within Groups	220167.5	818	269.153		
All	239816.5	825			

* $p < .01$

Table 2. Measures of association between ISAT Score and Number of Years with PRIME Teachers.

Relating ISAT score by Low SES students to the number of years with a PRIME teacher	Sum of Squares	Df	Mean Squares	F	Significance
Between Groups	6181.045	3	2060.348	11.166	0.000
Within Groups	113846.2	617	184.516		
Total	120027.2	620			

Table 3. ANOVA comparing Grade 5 ISAT scores for low-SES students grouped according to the number of years of instruction from a PRIME participating teacher.

Number of Years Students Received Instruction from a PRIME teacher: / SES Category	0 Years of instruction from PRIME teachers	1 year of instruction from a PRIME teacher	2 years of Instruction with PRIME teachers	3 years of instruction with PRIME teachers
Low SES	145.8 (9.90) n=30	158.8 (14.35) n=113	160.4 (14.55) n=256	160.1 (12.40) n=222
High SES	184.6 (18.27) n=5	183.09 (13.79) n=43	182.87 (15.10) n=86	178.17 (15.34) n=71
Combined SES (without respect to SES)	151.34 (17.68) n=35	165.49 (17.86) n=156	166.09 (17.61) n=342	164.85 (15.16) n=293

Table 4. Grade 5 mean ISAT scores, grouped by SES and by number of years of instruction from a PRIME-participating teacher.