The Lesson Study Process—An Effective Intervention to Reduce the Achievement Gap*

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A four-year grant studied the effects of the lesson study process on decreasing the achievement gap in middle school math and science classrooms. The grant delivered collaborative, sustained professional development over a four-year period to 44 6th-8th grade math and science teachers at two middle schools and served approximately 2,400 students. The professional development model combined the lesson study process with summer institutes in math and science, strategies for working with English learners, and site-based and grade specific activities. A professional learning community evolved as teachers integrated math, science, literacy, and the Common Core State Standards (CCSS) into their classrooms.

Keywords: achievement gap, lesson study process, science, technology, engineering and math, professional development, middle school science, middle school math

Introduction

The Teaching Excellence and Achievement in Mathematics and Science (TEAMS) project was a four-year study funded by the California Department of Education's Improving Teacher Quality State Grants Program (ITQ) State Agency for Higher Education. The purpose of the TEAMS project was to study the effects of the lesson study process on decreasing the achievement gap in middle school science and math classrooms. The project was designed to deliver collaborative, sustained professional development to 6th-8th grade math and science teachers at two middle schools in Southern California to be referred to as School A and School B.

The project goals were to deliver professional development to teachers in order to:

1. Increase the level of student achievement in math and science through the lesson study process;
2. Provide a sustained professional development for 6th-8th grade teachers to deepen both their subject matter and pedagogical content mastery in math and science;
3. Address how English learners, Black, Hispanic or Latino, White, socially economically disadvantaged (SED) students, and students with disabilities (SWD) can achieve success in math and science;
4. Provide mentoring, coaching, and leadership skills to participants;

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5. Develop teaching/learning collaborative environments within individual and between participating departments.

Method: The Lesson Study Process

The lesson study process was the primary intervention. The professional development model combined the following activities: content summer institutes in math and science that applied to credentials in math and science, strategies for working with English learners and the Common Core State Standards (CCSS), site-based and grade specific activities, and field trips and mandatory sessions every year. These sessions included strategies for integrating writing, comprehension, and vocabulary development into the math and science classrooms; classroom management strategies; incorporating technology into the classroom; differentiated instructional methods for math and science; multiple measures of assessment; and multiple intelligences.

The lesson study process involved small teams of 6th-8th grade math and science teachers from two middle schools who planned research lessons together. Each teacher taught a lesson which was video recorded. The video recordings were very powerful when teachers examined both their teaching performance and the students' reactions to their teaching. The team analyzed, reflected, refined, and retaught their lessons. The reflections included a focus on student learning in order to assist the teachers in understanding each student's specific academic needs (Lewis, Perry, & Murata, 2003; Stigler & Hiebert, 1999; Takahashi & Yoshida, 2004).

The lesson study process provided an "umbrella" for the intervention plan (see Figure 1). Project teachers worked collaboratively to analyze their lessons. Teams were able to assess their knowledge of content standards, determine how their students learn, examine evidenced-based practices in the lessons appropriate for all students, and implement a data-driven cycle of inquiry. Teachers utilized both formative and summative assessments. Through collaboration and coaching of one another, they focused on how to improve instruction for all their students and explored ways to integrate academic literacy and interdisciplinary methods into teaching math and science. The intervention plan enabled teachers to integrate the different components into the lesson study process and evaluate each component's effectiveness.

The essential elements of lesson study are for teachers to form teams based on identified goals of a particular lesson, plan lessons in alignment with both content and standards that reflect these goals, study and improve the lesson, and deepen subject matter knowledge. In the TEAMS project, one teacher taught a lesson while other team members observed and video recorded both the teacher and the students. Data were collected through the videos to study the students and teacher responses to the lesson. Through review of the videos, the teams were able to analyze in depth each teacher's patterns of questions as well as student responses to the questions.

Following the teacher's reflection, the lesson was taught again by another teacher in the team and the process was repeated. Each teacher in the team wrote pre-observation questions, reflections, and self-assessments of their observations and responses of both students and the teacher. This process was repeated with at least three to four lessons evaluated per year. Through the process, the teams asked the following questions:

1. What did we learn that can be applied directly to our classroom?
2. What aspects of students' learning needs are clarified?
3. What curricular adjustments have we made that improved instructional delivery?

Figure 1. Lesson study umbrella.

The lesson study process provided project teachers with scientific opportunities to learn from their peers, collect evidence, test lessons, revise their lessons, and teach the lessons again using those revisions (Lewis et al., 2003). This process demonstrated to the teachers that teaching is a cultural activity where they could improve their teaching through analysis, inquiry, and a collective focus in instruction and learning outcomes (Stepanek, Appel, Leong, Mangan, & Mitchell, 2007). Discussion in grade level teams focused on ways to present their lessons so they were culturally relevant and responsive to all their students and positively affected underachieving students (Ladson-Billings, 1995).

Background Information

Table 1 summarizes the two schools' demographics in 2007-2008 and again in 2011-2012 disaggregated into subgroups.

Table 1

Demographics of the Two Schools

Enrollment by group	2007-2008		2011-2012	
	School A	School B	School A	School B
Black	15.80%	19.40%	17.90%	14.40%
American Indian	0.70%	0.40%	0.50%	0.90%
Asian	1.00%	2.40%	2.60%	1.30%
Filipino	0.30%	2.10%	3.90%	0.40%
Hispanic or Latino	70.60%	65.40%	63.10%	71.90%
Pacific Islander	0.20%	0.40%	0.60%	0.20%
White	9.60%	9.50%	9.70%	8.10%
Multiple or no response	1.70%	0.40%	0.80%	0.60%
SED	82.00%	70.00%	72.50%	93.20%
English learners	34.00%	21.00%	41.40%	42.40%
SWD	15.00%	13.00%	13.30%	12.30%

Results

An analysis of the project's goals and outcomes indicated that all five goals were met.

To Increase the Level of Student Achievement in Math and Science

The first goal of the project was to increase the level of student achievement in math and science. Test scores and interviews indicated that significant progress was made over the four years of the grant.

A variety of measurable outcomes were collected and evaluated for this study. The Academic Performance Index (API) is a measure of academic performance and progress of schools in California and provides an overall view of a school's academic performance. API scores range from a low of 200 to a high of 1,000. Table 2 shows School A and School B's API scores over the four years.

Table 2

API Scores for School A and School B

Year	2008-2009	2009-2010	2010-2011	2011-2012	Delta
School A	721	729	762	789	68
School B	629	686	691	708	79

California Standards Tests (CSTs) are criterion-referenced tests taken at each grade level for middle school math and the 5th and 8th grades for science. There are five performance levels for reporting results of CST's: "Advanced", "Proficient", "Basic", "Below basic", and "Far below basic". Math and science scores for School A are discussed below.

As shown in Figure 2, School A 6th grade scores on the CST math test indicated that student scores progressed in the "Advanced" level (16% to 30%) over the four years, while "Basic" scores decreased from 25% to 23%, "Below basic" from 18% to 15%, and "Far below basic" scores from 18% to 10%.

Figure 2. School A 6th grade math CST scores.

The 7th grade math scores (see Figure 3) on the CST math test at School A indicated a significant growth of the students who scored "Advanced" in 2008-2009, from 10% to 25% in 2011-2012, and 31% who scored "Proficient" in 2008-2009 to 42% in 2011-2012. "Basic" decreased from 37% to 22%, "Below basic"

decreased from 17% to 9%, and “Far below basic” from 6% to 2%.

Figure 3. School A 7th grade math CST scores.

CST math scores for 8th grade Algebra at School A slightly progressed from 6% of the students who scored “Advanced” in 2008-2009 to 7% who scored “Advanced” in 2011-2012. The largest increase in “Advanced”, 13%, was in the third year of the project. “Proficient” in 2008-2009 was 18% and increased to 29%; “Basic” was 23% in 2008-2009 and increased to 25% in 2011-2012; “Below basic” was 36% and decreased to 30%; and “Far below basic” was 16% and decreased to 9% (see Figure 4).

Figure 4. School A 8th grade Algebra CST scores.

CST science scores for School A 8th grade progressed from 16% of the students who scored “Advanced” in 2008-2009 to 30% in 2011-2012. There was a decrease from 25% of students who scored “Proficient” to 23%; “Basic” decreased from 25% to 23%; “Below basic” decreased from 18% to 15%; and “Far below basic” decreased from 18% to 10% (see Figure 5).

Figure 5. School A 8th grade science CST scores.

The increase in scores at School A can be attributed in part to the changes grade level teachers made as a result of the TEAMS project. When the project began, most teachers operated in more of a “silo” effect and although they met together, they did not collaborate much as a team. After four years of working together to plan, teach, and reflect on their lessons, the teams of teachers have grown much more comfortable asking their colleagues for help.

The teachers reported that they shifted from isolation to working together to improve their instruction.

We shifted from isolation to seeing real great activities. Seeing videos from other teachers was great. The project became real when we had a visual point of reference on what and how we taught. It brought the project to what we do every day, teaching and learning. (6th grade science/math teacher)

After the first year, all teachers were required to video record their lessons at least three to four times a year and share them with the other members of the team. Substitutes were provided to enable the team to observe each other teaching and to assist in the video recording.

Watching yourself on video, there is no better critic than yourself. You see your verbal ticks. I took note of what others did in their videos and incorporated what worked for them. That increased my knowledge as I saw more effective ways to work with students. (6th grade science/math teacher)

The teams of teachers moved from a teacher-centered focus to the one that was more student-centered. They saw how understanding and integrating the theory of multiple intelligences and multiple measures of assessments helped them better analyze how their students learned.

Informally, I am using the multiple intelligences more. I ask myself questions all the time, “Am I teaching to all my students?”. I remind myself that not every student learns from lecture. (7th grade science teacher)

I am more observant of my students’ interest in the lesson. If they are not engaged, I make an adjustment and teach the lesson in a different way. (8th grade science teacher)

The teachers moved to more purposeful and connected instruction, relying not only on direct instruction, but on guided and independent work. They integrated technology into their classrooms and became more creative.

Students felt they could accomplish the work and their confidence improved. I asked more of students, “How did you get the answer?”. Before it was acceptable to just give the answer. But now, I want them to show their work. I am moving more from direct instruction to independent work. (7th grade math teacher)

The teachers actively participated in the planning, video recording, leading, and reflection processes for lesson study.

Lesson study helped me see that I need to shorten my lectures and spend more time allowing for more guided practice. We are checking for understanding much more every day. (7th grade science teacher)

Debriefing and reflecting are very important. Every time we do the feedback together, we make changes in our lessons and analyze the different stages for presenting a lesson. (7th grade math teacher)

Going to each other’s classroom was great. It was very helpful to observe each other’s classroom management strategies. (7th grade science teacher)

During the third year, all grade level teams taught interdisciplinary math and science lessons. They planned the lesson together and taught it collaboratively.

When we did science and math lessons, my students said at first “Why do we do science in math?”. Then, it opened their eyes to the integration of math and science in real life. (8th grade math teacher)

Having the goal to integrate science and math into our lessons made us become more creative. That was necessary to create the blended lessons. (8th grade science teacher)

We are integrating science and math into the concepts, and students are able to recall information better. (8th grade science teacher)

The teachers expressed to the leadership team that the project had made them better teachers and helped their students become better students.

Our lessons were really well planned and well done. There was also spill over from teacher to teacher and those ideas were applied to individual lesson planning. (7th grade science teacher)

The 7th and 8th grade science teachers at School A made extraordinary progress over the four years of the project. They video recorded each other teaching, debriefed and reflected on how to improve their lessons.

We are now automatically reflecting on our lessons. I did not realize how much I was changing my lessons. Now, I am looking at my lesson development and asking other teachers on my team to see how I could teach in a different way. We spend more time on engagement, collaboration, rigor, and accountability. (8th grade math teacher)

Working with special education teachers to see what works for special needs students and being able to integrate those strategies with mainstreamed students was very valuable. (6th grade science/math teacher)

To Provide Sustained Professional Development for the Teachers

The second goal of the TEAMS project was to provide sustained professional development for the teachers to deepen both their subject matter and pedagogical content mastery in math and science. Over the four years of the grant, 71 teachers participated in the grant, although the actual number ranged from 39 to 44 teachers each year. The number of years of participation varied due to staffing changes within both schools. There were 19 teachers and one math coach that participated in all four years of the grant. The teachers and students of those 19 teachers were matched and comparisons were made as to how much training they had with the project.

Two types of professional development were provided during the study: mandatory and non-mandatory. Mandatory professional development was offered during the academic year and provided the opportunity for

teachers to share the outcomes of their lessons and receive focused training required in the project. Non-mandatory professional development included content institutes offered throughout the year. During the four years of the grant, teachers completed 542 quarter units of professional development through content institutes.

Most of the coursework was completed by the teachers who participated in all four years. Overall, these teachers took the majority of the non-mandatory professional development (67% or 303 units), and several of these teachers were able to complete math credentials. In this study, there is a correlation between teaching staff stability, the amount of professional development teachers elected to participate in, and students' performance on CST tests.

To Address How English Learners, Black, Hispanic or Latino, White, SED Students, and SWD Can Achieve Success in Math and Science

The third goal was to address how English learners, Black, Hispanic or Latino, White, SED students, and SWD can achieve success in math and science. During the mandatory professional development, teachers received methods for working with English learners. They were able to participate in a summer institute on Sheltered Instruction on Observation Protocol (SIOP) training which provided many strategies for teaching English learners in math and science classrooms.

The federal No Child Left Behind Act (NCLB) requires states to develop annual measurable objectives (AMOs) that determine if a school, district, or the state as a whole is making adequate yearly progress toward the goal of having all students proficient in language arts and math by 2014. For California, the AMOs are the percent of students that must score "Proficient" or "Advanced" on science and math tests aligned with state content standards.

Table 3, together with Figures 6 and 7, demonstrates the growth of five subgroups at School A from 2008-2012. In 6th grade math, Black students at School A improved 10% from 2008 to 2012 (31% to 41%), "Proficient" and "Advanced" combined, and 7th grade from 36% to 63%, a 27% growth. Eighth grade Algebra students gained 14% from 13% to 27% and 8th grade science from 31% to 53%, a growth of 22%.

Hispanic or Latino students at School A who scored "Proficient" and "Advanced" in 6th grade math went from 29% in 2008 to 52% in 2012, a 23% improvement; 7th grade math students progressed from 40% to 66%, a 26% increase; 8th grade Algebra students increased their scores from 19% to 34%, a growth of 15%; and 8th grade science Hispanic or Latino students progressed from 39% to 46%, a 7% increase.

White students who scored "Proficient" or "Advanced" in 6th grade math went from 33% to 62%, a 29% increase; 7th grade math increased 21% from 52% to 73%; 8th grade Algebra increased 12% from 31% to 43%; and 8th grade science from 54% to 75%, a 21% increase.

SED 6th grade math students at School A progressed from 28% to 52%, a 24% increase; 7th grade math students went from 39% to 65%, a 26% increase; 8th grade Algebra students progressed from 17% to 35%, a 18% growth; and 8th grade science from 37% to 47%, a 10% increase.

CST scores for English learners from School A in 6th grade progressed from 8% "Proficient" and above in 2008 to 20% in 2012, a 12% increase; and 7th grade math from 11% to 34%, a 23% increase. Algebra I indicated 7% progress from 1% to 8%. Eighth grade science scores for English learners went from 17% to 19%, a 2% increase.

The AMO scores for Black, Hispanic, and White students at School A increased for all subgroups. Black

students increased from 24.9% in 2008-2009 to 46.9% in 2011-2012, Hispanic students went from 35.5% to 50.3%, and Whites from 51.9% to 57.1% (see Figure 6).

Table 3

Black, Hispanic or Latino, White, SED, and English Learners at School A

	6th grade math			7th grade math			Algebra I			8th grade science		
	2008	2012	Growth	2008	2012	Growth	2008	2012	Growth	2008	2012	Growth
Black	31%	41%	10%	36%	63%	27%	13%	27%	14%	31%	53%	22%
Hispanic	29%	52%	23%	40%	66%	26%	19%	34%	15%	39%	46%	7%
White	33%	62%	29%	52%	73%	21%	31%	43%	12%	54%	75%	21%
SED	28%	52%	24%	39%	65%	26%	17%	35%	18%	37%	47%	10%
English learners	8%	20%	12%	11%	34%	23%	1%	8%	7%	17%	19%	2%

Figure 6. AMO scores for Black, Hispanic or Latino, and White students at School A.

The AMO scores for SED students, English learners, and SWD at School A indicated that SED students' scores progressed from 33.8% to 50.8%, English learners went from 36.8% to 47.7%, and SWD from 26.6% to 44% (see Figure 7).

Figure 7. AMO scores for SED students, English learners, and SWD at School A.

To Provide Mentoring, Coaching, and Leadership Skills to Participants

The fourth goal was to provide mentoring, coaching, and leadership skills to participants as the teams began to build trust, collaboration, and respect for one another. Diverse leaders among teams began to evolve. Teacher leadership was demonstrated through technological expertise, content knowledge, presentation skills, and organizational ability. In each team, one or two teachers assumed the leadership role of organizing time to meet and plan the lessons. Other teachers who had technological expertise assumed leadership roles when the videotaping occurred and the teachers had to present their videos to other project teachers. Members of the team who were comfortable speaking in front of other teachers took the lead in speaking to the entire group. Each year, the leadership team observed more mentoring and coaching of one another. The responsibilities were distributed among team members. Some teachers had content expertise and others had creative pedagogical practices. The more the teachers learned to collaborate and trust each other, the different aspects of their leadership skills evolved. Several teams had not been able to work effectively before the project began. During the project, they worked together in small teams and respected what each of them could contribute to the lesson. Throughout the project, all teachers became much more collaborative with each other.

To Develop Teaching-Learning Collaborative Environments Within and Between Participating Departments

The fifth goal was to develop teaching-learning collaborative environments within and between participating departments. At the beginning of the project, the teachers were used to teaching primarily in isolation. Although they met regularly as departments, they had not observed in each other's classrooms. They had not planned collaborative lessons that required them to reflect both individually and as a team and then redesign and reteach their lessons.

In the first year, the teachers were allowed to volunteer to video record their lessons and review and reflect individually. At first, many of the teachers were intimidated by the lesson study process and were resistant to actively participate. Because the leadership team allowed the teachers to "ease" into the process, by the second year, resistance had disappeared. It was apparent after the first year that small teams of three to five teachers were more productive than whole department teams, as the teams provided a safe environment for teachers to share their lessons.

When the math and science teachers were all required to work collaboratively to develop an interdisciplinary lesson, there was uncertainty that they could actually develop an integrated lesson. They did not think the standards could be integrated. Once, they started working together, their creativity, engagement, and enthusiasm overcame their anxiety and they produced outstanding video presentations. The teachers realized that they were prepared for the CCSS which required teaching interdisciplinary lessons. They saw that they could work collaboratively to integrate math, science, and literacy into their lessons.

The teachers had established collaborative teams that built mutual student learning goals and outcomes, and provided opportunities to try new approaches and evaluate the results together. They enjoyed observing and video recording each other's classrooms and asked their colleagues for help in modifying their lessons. The teachers' reflections of their lessons created a more student-centered focus. They became more accountable for improving student learning.

At the final mandatory session in May, 2013, the teachers were asked if they believed they could sustain the changes they had made during the grant. They responded that they had experienced a paradigm shift as a

result of the project and wanted to continue their student-centered focus and the ability to work collaboratively within their own department and across departments.

Quantitative and Qualitative Research

A total of 71 teachers participated in the TEAMS project over the four years. Only 14 teachers and one math coach from School A and five teachers from School B participated in the project all four years. The teachers and students of the original 19 teachers were matched and comparisons were made as to how much training they had with the project.

A number of longitudinal growth models were fit to the student data from each of the two schools that originally participated in the study. The growth models were fit using full information maximum likelihood (FIML) parameter estimation to handle the presence of missing observations.

Two different time-ordered waves of student data were analyzed: 1. Using data from four time-ordered waves of measurement; and 2. Using data from three time-ordered waves of measurement. It is important to note that the students within each of the time-ordered waves of measurement are distinct. The four-year measurements focused on data collected annually from the same students beginning with those obtained when they were originally in the 5th grade (which was used as their pre-program intervention baseline year scores) and ending in the 8th grade. The three-year time-ordered waves of measurement focused on data obtained annually from a different group of students beginning with measurements obtained when they were originally in the 6th grade (which was used as their pre-program intervention baseline year scores) and ending again in the 8th grade. The time-ordered measurements were used in the longitudinal analyses with only data from students exposed to teachers that had participated in all mandatory professional development workshops utilizing the lesson study process.

For purposes of this paper, only results analysis for School A is provided. Tables 4 and 5 present the obtained parameter estimates of the fitted models for School A student data for the 5th-8th grade levels and 6th-8th grade levels respectively. Both complete data (i.e., implying that data for each specific individual student was available at every time point) and missing data (i.e., implying that data during at least one time points was missing) were examined. The results are listed in two columns. The first column labeled Intercept corresponds values obtained at the beginning of the study (considered the initial levels of math CST achievement scores measured before the project began, i.e., representing the baseline year). The second column called Slope corresponds to the rate of change at the end of the obtained measurement (for example, in the case of 5th-8th grades, this would correspond to the average model change that occurred in math CST scores from the 5th grade to the 8th grade). The first value provided under the Intercept column is the mean value at the baseline grade level whereas the second value is the variance (taking the square root of this reported value would provide an estimate of the standard deviation). The first value provided under the Slope column is the amount of change in mean value of math CST scores (a positive value would indicate an increase and a negative value would represent a decrease in scores) and the second value provided is again the variance.

These displayed coefficients summarize important findings with respect to the program effect on student math CST scores at School A. For students observed within the 5th-8th grades, there is an average modeled increase in math CST scores across all ethnic groups when both complete and missing data are examined. For example, the mean value of the Slope factor was positive and significantly different from zero ($\mu_{\beta y} = 2.549$; $p < 0.05$), indicating that there has been over time a slight but steady increase in math CST scores from the initial

measured and also significantly different from zero mean value on the Intercept factor ($\mu_{\alpha y} = 341.081$; $p < 0.001$). We note that a non-significant covariance value between the Intercept and Slope factors was observed in every model examined and shows that initial levels of math CST scores are not related to the increasing levels of math scores over time, but that some other variable is responsible for this observed change. Based upon some additional evidence discussed further below, we infer that it is the activities within the mandatory professional development workshops utilizing the lesson study process that are responsible for these results.

Table 4

Fitted Growth Models for 5th-8th Grades at School A

	Complete data		With missing data	
	Intercept	Slope	Intercept	Slope
All students	341.081** 3436.515***	2.549* 17.011	341.082*** 3436.495***	2.459* 17.007
Hispanic students	334.157*** 2072.79***	3.872* 19.001	334.157*** 2072.846***	3.872* 20.005
African American students	311.361** 4816.842***	4.891* 45.116	311.360*** 4817.007***	4.891* 45.13
White students	396.620** 4712.067***	-9.123* 66.359	396.619*** 4712.233***	-9.122* 66.367
Other students	363.875** 4369.693***	3.125* 38.51	363.875** 4369.652***	3.125* 38.559

Notes. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Table 5

Fitted Growth Models for 6th-8th Grades at School A

	Complete data		With missing data	
	Intercept	Slope	Intercept	Slope
All students	350.182*** 2890.837***	0.938 23.773	341.615*** 2998.051***	1.152 32.382
Hispanic students	347.147*** 2547.017***	1.479 54.71	336.678*** 2508.513***	1.301 28.525
African American students	3330.050*** 2232.460***	-1.234 142.568	324.956*** 2042.857***	-0.495 170.166
White students	394.826*** 2572.799**	-9.522* 65.651	375.524*** 3337.841**	-8.344 64.948
Other	376.151*** 3701.149**	9.099 461.387	381.283*** 4551.329***	12.876** 489.065

Notes. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Evidence of the impact of the professional development workshops in these math CST scores is provided by noting that a significant variance existed in the Intercepts across all ethnic groups at the beginning of the study. For example, the variance of the Intercept for the complete data ($s^2 = 3436.515$; $p < 0.001$) indicates that there is significant variability at time 1. This result reflects the fact that there is considerable individual variability in the average initial math CST scores of individuals at the beginning of the project (see Figure 2). In contrast, when examining the magnitude of the variance of the Slope factor, this variability is not evident at the conclusion of the study. For example, the variance of the Slope for the complete data ($s^2 = 17.011$; $p = 0.462$) indicates that there is

no significant variability. This suggests that on average the significant differences that were observed across at 5th grade students (which is before the lesson study intervention was introduced) are no longer as pronounced for those same students at the 8th grade. In a sense, a closing of the achievement gap has occurred.

Figure 8 presents an illustrative representation of this phenomenon using individual data for a random sample of 50 students at School A for a three-year time-ordered period. The thick line in the middle of the graph represents the mean value for the entire group of students. The significant variability at baseline time (before the lesson study intervention was introduced) can be seen by observing how scattered the individual lines are along the axis. The lack of significant variability at the last time point is evident by observing how clustered or closely grouped the lines are along the axis.

Figure 8. Graphical representation of growth trajectories for a sample of 50 students.

Examining the results presented for students within the 6th-8th grades indicates that they do not show a consistent average increase in math scores across all ethnic groups when both complete and missing data are examined. For example, the mean value of the Slope factor for all students, although positive, was not significantly different from zero ($\mu_{\beta_y} = 0.938$; $p > 0.01$), which indicates that there has been over time a minor increase in math CST scores from the initial measured but significantly different from zero mean value on the Intercept factor ($\mu_{\alpha_y} = 350.182$; $p < 0.001$). We note again that a non-significant covariance value between the Intercept and Slope factors was observed in every model examined and shows that initial levels of math CST scores are not related to the increasing levels of math scores over time.

For these students observed at 6th-8th grade levels, a significant variance existed in the Intercepts across all ethnic groups at the beginning of the study. For example, the variance of the Intercept for the complete data ($s^2 = 2890.837$; $p < 0.001$) indicates that there is significant variability at the initial measurement time point. This result reflects the fact that there is again considerable individual variability in the average initial math CST scores of individual students. In contrast, when examining the magnitude of the variance of the Slope factor, this variability is not evident at the end of the study. For example, the variance of the Slope for the complete data ($s^2 = 23.773$; $p = 0.809$) indicates that there is no significant variability among students. This suggests that on average, the differences that were observed across students at the 6th grade are no longer as evident at the 8th grade and implies that although there was no significant increase in math CST scores across students, the

program can again be credited with leading to a reduction in the variability of the scores among those students. This again may be conceptualized as a closing of the achievement gap. Perhaps the math CST scores for these students would have also shown statistically significant average increases if they had the opportunity to be exposed to teachers that had participated in the lesson study for more than just two years. The results presented in Tables 4 and 5 suggest that an ideal time to introduce teachers to the lesson study intervention strategy is when their students are first entering the 6th grade.

The conditional model using “Years in TEAMS” as the predictor variable was examined. With respect to growth rates, an effect of approximately 1.50 CST points was obtained across all students (School A = 1.55). This coefficient can be interpreted just like a regression coefficient and corresponds to an average expected change of approximately 1.50 points in the student CST scores for every 1-unit change in the predictor variable. For every additional year a teacher spends in the project, his/her students would be expected on average to have growth rates that differ by about 1.50 CST points. This parameter indicates that the inclusion of the covariate improved the overall fit of the growth rates of students. Based upon these coefficients, it was determined that the covariate explained some of the variability in the student growth rates in both schools and these patterns were consistent across all student ethnic groups.

Discussion

There were many challenges in the first year of the TEAMS project. These included having the teachers learn how to properly utilize ways to video record, understand the needs and requirements of the lesson study process, move from a teacher-centered focus to a student-centered focus, and focus more on students’ attention to the lesson while recording a lesson. At first, the teachers were skeptical of the lesson study process which required them to participate in teams and be more open regarding their lesson planning.

During the second year of the project, data collection forms were reduced. There was new and easier video equipment. Teachers became more willing to share and collaborate. Project teachers began to switch from a teacher-centered focus to a more student-centered focus. Smaller teams were created to allow for much closer collaboration.

During the third year of the project, observations and video recording in each other’s classrooms became much easier. Teachers collaborated on interdisciplinary projects in math and science and discovered that they could work together in new and exciting ways. They taught in each other’s classrooms and realized the importance of integrating the two subjects.

In the fourth year of the project, teachers were innovative and excited about teaching their lessons. There was increased math/science collaboration with several integrated lessons and incorporation of the CCSS. Technological skills were enhanced. Challenge questions and collaborative lessons were developed to increase writing in science and math. Science notebooks were used in both math and science classrooms. Students became very enthusiastic as a result of the more innovative and engaging curriculum in both their math and science classrooms.

Lessons Learned

Lessons learned from this study are many. First, it takes time to build trust and respect when utilizing the lesson study process, a minimum of three to four years for sustainable change. Second, video recording was very powerful when teachers looked at both their teaching performance and the students’ reactions to their

teaching. Third, small teams of three to five teachers were more productive than whole department teams.

The lesson study process became a vehicle for teachers to share what they had learned and gain knowledge for refining their lessons in the future. Both the quantitative and qualitative results of the TEAMS grant have indicated improved instruction and understanding of subject matter, closer connections with matching long-term academic goals to individual student learning capacities and analysis of formative and summative assessments for each student. More varied daily classroom activities were designed by the teachers that appropriately matched how their students learned. There was a deeper focus on students' cultural and academic needs. English learners and special education strategies were incorporated into the lessons. All the teachers were able to more effectively understand how to match instruction to individual student learning.

One of the most significant outcomes of this project was that teachers increased their capacity to collaborate and learn together and gain greater trust and respect for each other (Byrum, Jarrell, & Muñoz, 2002). By the end of the four-year project, they had developed a deeper understanding of the content being taught, designed ways to collaboratively improve instruction, learned ways to integrate math, science, writing, and literacy into their lessons, discussed evidence of student learning, and developed a shared vision of effective teaching (Liptak, 2005).

A professional learning community evolved as a result of the lesson study process where teachers learned how to integrate math, science, and literacy into their classrooms, preparing them for the CCSS. Students were provided opportunities to think, discuss, and write about what they had learned. Leadership was demonstrated through technological expertise, content knowledge, presentation skills, and organizational ability.

In conclusion, the TEAMS project achieved all five goals. The lesson study process provided teachers with the tools for observing both their own teaching and their students' responses to their instruction. The overall results of the study were improved teachers' pedagogy, increased collaboration within and between departments, and greater trust and respect among the participants. Both the quantitative and qualitative data from the project indicate that the achievement gap was narrowed. These conclusions are supported by the increase in both math and science CST scores with all subgroups at both schools.

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