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COACHING, IMPROVED MATHEMATICAL TEACHING PRACTICES, AND STUDENT LEARNING

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This longitudinal study examines an intensive coaching program and found that such coaching improves both teachers' practices and students' mathematics performance in the United States. Teachers are better equipped for understanding what students know and how to shape and reshape their instruction based on student needs. In addition, the longer students were involved with teachers who had intensive coaching professional development, the higher their mathematics performance, which was consistent across grades 3-10 and in all 35 districts participating in the study. The results are significant not only for the districts in this particular study but also potentially for districts nationwide, as most states are transitioning to the Common Core State Standards, and teachers will need the types of intensive support and resources described in this paper to make the transition successful.
Coaching, Performance Assessments, Teaching Practices

INTRODUCTION

Historically in the United States, each individual state has independently developed its own academic mathematics standards and assessments. Since 2001, the state standards and assessments have had to be compliant with the federal No Child Left Behind Act, which required all states to assess all students in grades 3-8 and once in high school in both mathematics and English Language Arts. However, since each state developed their own standards and assessments, it was impossible to compare how students across states were mastering content. For instance, a concept in one state's sixth-grade mathematics standards might be taught and tested in another state's fourth-grade mathematics classrooms. The Obama administration wanted all students to be expected to meet the same rigorous mathematics content at the same grade level and depth of complexity, across any state, district, and school. Thus, the Common Core State Standards (CCSS) for mathematics and English Language Arts were developed in 2010.

The CCSS in mathematics is a set of mathematics standards that have been adopted by 45 of the 50 states, the District of Columbia, and one of the five territories in the United States.

The 47 entities that have signed on have committed to teaching and assessing the same knowledge, skills, and abilities, and for the first time, the U.S. will have a very nearly national set of standards. The CCSS call for a substantial increase in the breadth and depth of mathematical knowledge students must acquire to be college and career ready. Most states that have compared their own state mathematics standards to the CCSS have found that they need to move what is taught to earlier grades and teach the material with more depth. More modeling and mathematical practices are being included and are expected to be tested on large-scale assessments, and two assessment consortia, each consisting of a large number of states, have been formed to create common assessments to be used across states.

Given the upcoming transition to the CCSS, it is important to identify effective resources that provide guidance to teachers on next steps in their teaching practices. The use of complex performance tasks is touted as critical in the two assessment consortia, and as a result, there is high need to find ways to transition teachers' use of these new assessment types as well as ways to build their capacity to use that information to truly improve their teaching and thus student learning. This work cannot happen without effective and strong professional development and support for teachers.

THEORETICAL FRAMEWORK

The Common Core State Standards (CCSS) call for a substantial increase in the breadth and depth of mathematical knowledge students must acquire to be college and career ready. Unfortunately, few school districts in the nation have the capacity to help their students meet rigorous mathematics requirements. National and state-level reports document critical shortages and high attrition in the overall supply of appropriately trained and certified mathematics teachers, especially in urban areas (National Science Board, 2006). The majority of secondary mathematics teachers lack deep knowledge of the mathematics content they are expected to teach (Barth & Haycock, 2004; Massell, 1998). In fact, Ingersoll (1999) found that a third of all secondary school teachers of mathematics nationwide have neither a major nor a minor in mathematics. Moreover, research shows inconsistencies in instruction across classrooms within the same district and even within the same school. Teachers interpret the same instructional ideas in various ways (Marzano, 2003; Stigler & Hiebert, 1998, 1999), and accordingly make independent decisions about whether and/or how to ignore, adapt, or adopt policymakers' recommendations for instruction (Spillane, Reiser, & Reimer, 2002). If the most significant variable for improving student learning is the teacher (Boaler, 1998; Sanders, Horn, 1994; Schmidt, McKnight, Valverde, Houang & Wiley, 1997; Wright, Horn & Sanders, 1997), finding and investing in effective professional development efforts are necessity.

In urban districts faced with these and other difficult issues—including heavy turnover among administrators, administrators who do not understand what is needed to support a high level of mathematics learning, and low expectations from both teachers and administrators for the performance of their students—mathematics instruction has proven very difficult to improve (Bamburg, 1994; Beck-Winchatz & Barge, 2003; Tauber, 1997). As a result, all too often, students in urban school districts are not given adequate opportunity to enroll—and succeed—in challenging mathematics (National Science Board, 2006).

To address this problem, school districts are pouring enormous quantities of resources to improve their mathematics programs' capacity to deliver a consistent and rigorous curriculum, aligned with state (and now national) standards and assessments, that prepares students for success in college and entry into high-quality workplaces. Yet despite these substantial investments, evidence of the effectiveness of district and school reform efforts varies greatly in quality and usefulness by district.

It is critical that we find a way to develop and support a high-capacity cadre of teachers to ensure students are being taught the depth of the mathematics expected in the CCSS. This requires investment in professional development, and the field needs to find programs that have shown success in improving both mathematics teaching and learning.

Questions

This study looks at an intensive coaching program, as described in the next section. The purpose of this study was to analyze the potential impact of coaching on both teachers' pedagogy and students' mathematics performance. The two main research questions include:

1. What is the relationship with students' mathematics performance within a single year for coached and non-coached teachers?
2. What is the relationship in performance of students who work with well-coached teachers across several years?

DESCRIPTION OF THE INTERVENTION

The Silicon Valley Mathematics Assessment Collaborative (MAC) has a project focused on mathematics content coaches, developed on the idea that improvements in students' mathematical achievement are based on improved teacher mathematical and pedagogical content knowledge. MAC has developed a set of tools for training mathematics coaches to model the behaviors they hope their teachers will employ in their classrooms throughout 35 school districts in the San Francisco Bay Area, which encompasses a demographically diverse set of at-risk youth.

Coaches are experienced teachers working individually with less-seasoned teachers on improving their mathematical teaching and learning. Coaches provide hands-on and individually tailored professional development for the teachers at least 20 times per year, while also engaging at least monthly with other coaches to improve their own teaching and coaching methods. The main job of the coach is to get teachers to focus on student thinking and mathematical pedagogy. The coach works with teachers in and out of the classroom on analyzing student work, reviewing and exploring mathematical concepts, reviewing and revising lesson plans, and reflecting on a lesson after the coach's observation.

Building teacher capacity is key in MAC's vision of coaching. MAC wants the coaches to encourage teachers to adopt new frameworks for thinking about their students' mathematics learning; this, they hope, will help teachers learn to assess their own instructional practices and make changes where needed. To accomplish this, coaches encourage teachers to reflect on their practices and ask the teachers open-ended questions to keep them focused on specific goals. This type of questioning models for teachers how to assess their own practices. If a teacher has a misconception about aspects of the content, the coach can help the teacher reflect upon this in their meetings by having the teacher use logical arguments to derive correct mathematical understanding of different ideas. Teachers can then use this same technique with their students who are struggling with competing rationales for understanding math concepts.

An additional level of coaching around formative assessment was also provided to a subgroup of the MAC participating teachers. The First in Mathematics Collaborative (FiMC) was established in 2006 using nine of the 28 MAC districts to test out new formative assessment efforts. Note: that the students in the FiMC districts were comparable in terms of students classified as economically disadvantaged, English Language Learners, ethnic minorities, with parents that had no college experience (Foster & Poppers, 2009).

As part of the MAC development work, it was clear that effective formative assessment is more complicated than implementation of a system. Substantial support was needed for both teacher and student learning. Fosters & Poppers (2009) describe the aims and process of the FiMC:

> The FiMC process aimed to engage teachers in an integrated effort to deepen their understanding of the mathematics involved in a given concept and their students' thinking relative to this concept - including both accurate knowledge and misconceptions, and to use that information to design new instructional approaches that target students' current needs. In FiMC we intended to use tools and procedures to provide a structured approach in order to scaffold the learning for teachers.
>
> This is not a quick intervention. In order to be successful and motivated to sustain their efforts, teachers need informed and skillful guidance until they attain some level of proficiency; however, as teachers begin to experience results in the form of deeper understanding for themselves and that of their students, they find the process to be highly engaging and generative. FiMC has gathered evidence that the process produces significant results. We believe that investments in rigorous teacher learning - structured to support application in the context of one's own classroom – can promote significant student learning. (p. 3-4)

DATA SOURCES AND METHODS

Quantitative data includes thirteen years of data, matching both teachers and students across the years since 2004. This data includes the number of years teachers have been coached, those that have received additional coaching via FiMC, and the performance of their students on the Mathematics Assessment Resources Service (MARS) exam and statewide assessment results, including demographic information on for both teachers (years teaching, gender, ethnicity, type of school) and students (gender, ethnicity). The MARS exam is a performance assessment at each grade level, made up of five tasks. These five tasks assess concepts and skills at each grade level in addition to problem solving, reasoning, and communication skills. Teachers are involved in scoring these performance assessments and talking about the depth of student learning as part of their professional development. MARS is a project funded by the National Science Foundation, with roots in three universities: the University of California, Berkeley; Michigan State University; and the Shell Centre, Nottingham, England (http://www.nottingham.ac.uk/~ttzedweb/MARS/).

For one year, access to a comparable demographic of schools was used to compare teachers who received MAC coaching to those who were not involved in any MAC coaching. Since there was typically no natural control group of students against which to estimate the effects of coaching for the other years, we capitalized on the premise that instructional practice implementation is highly variable in quality across and within schools. Variability can stem from the effectiveness of the coach, in how well the teacher understands how to implement the practices, and in teacher skill sets. This variability can help us identify teachers with high levels of implementation (high, medium, and low) of their coached methods to compare with teachers who exhibit low levels of implementation. We created an ordinal leveling of teacher implementation levels that we used to measure various teachers' effects on student mathematics achievement. Additionally, we used a dichotomous coding for teachers participating in FiMC versus those who did not.

Qualitative data includes feedback and rating of teachers by the coaches across the years.

Given the size and scope of the data in this project, we began with exploratory analyses comparing whether the teachers participated in MAC, whether they participated in FiMC, and how their students' performance compared on the state's large-scale assessment in mathematics and the MARS performance tasks across grades and years. The results of those analyses across the years and the accompanying trends (e.g., performance of well-coached teachers with growth in student performance) were analyzed to show how well the two different assessment types reflected differences in teaching practices.

RESULTS

Use of the MARS data shows promise for improving teachers' pedagogy and students' mathematical learning. Qualitative results show that teachers are better equipped for understanding what their students know and how to shape and reshape their instruction accordingly. Teachers spend more time talking about student work and finding evidence of what students have learned rather than using anecdotal information to gauge students' understanding (Paek, 2008).

Not only do there appear to be changes in teachers' practices, but there also appear to be related improvements in student learning. For instance, Table 1 shows the pass rates on the state's large-scale mathematics assessment for the year where we had data for non-MAC teachers as a comparison group. Teachers who engaged in MAC coaching had a higher percentage of students passing the statewide assessment than those who did not. The differences in results are significant for all four grades.

Table 1. Percentage of Proficient Students on the Mathematics State-wide Assessment

Grade/ Course	Percentage of Proficient Students with Non-MAC Teachers	Percentage Proficient Students with MAC Teachers
6	42	64
7	29	59
8	15	25
Algebra I	52	70

In general, an increasing percentage of students taught by MAC-coached teachers are classified as proficient on the statewide mathematics assessment that has been in place since 2005 (note: only grades 3, 5, and 7 were assessed in 2005). Table 2 shows these increases from 2005 to 2011. However, in the middle school grades (grades 6-8) the percentage of proficient students vary across years without any clear pattern of improvement that is clearly seen in the elementary grade levels (grades 2-5) or in Algebra 1. The most drastic case is eighth grade, where the majority of students are not deemed proficient on the statewide assessment.

Table 2. Percentage of Students Above Proficient on the State-wide Assessment

	2005	2006	2007	2008	2009	2010	2011
Grade 2		71.9	72.8	72.0	75.5	76.4	79.8
Grade 3	70.0	69.9	70.3	71.0	74.4	76.6	79.0
Grade 4		66.8	67.8	75.9	77.0	75.9	78.7
Grade 5	56.0	59.8	62.1	63.2	65.4	70.1	76.8
Grade 6		60.0	58.7	53.6	55.3	62.8	61.3
Grade 7	51.0	52.6	54.3	53.7	52.7	62.1	61.6
Grade 8		37.9	31.6	40.8	36.9	41.5	42.0
Algebra 1		45.3	49.7	52.6	58.4	63.3	63.5

Since the MARS and state-wide assessments require different types of mathematics' understanding – MARS requires students to explain and justify their answers on performance-based tasks while the state-wide assessment is comprised of all multiple-choice items––we compared the percentage of proficient students on MARS to the percentage proficient on the state-wide assessment. Even though the assessments measure different mathematics skills, one would expect mathematics proficiency to show a higher match of students meeting standards on both of these assessments. For grades 2-5, the majority of students who were proficient on the statewide assessment were also deemed proficient on the MARS exam. This finding is opposite for grades 6-8 and Algebra 1, as the majority of students are not proficient on both assessments. This finding is most striking for grade 8 students, as the highest percentage of proficient eighth graders on both assessments is one-quarter of the population across the years. It is clear that even with the continued increases of proficient students across the years and grades on the state-wide exam, as students move through middle school, students are challenged in understanding both the basic concepts and higher-order thinking, especially with problem solving tasks.

Table 3. Percentage of Students Above Proficient on MARS and the Mathematics State-wide Assessment

	2005	2006	2007	2008	2009	2010	2011
Grade 2		65.6	67.7	63.6	64.8	72.1	72.5
Grade 3	57.0	63.6	62.8	57.3	66.1	61.3	66.3
Grade 4		57.9	56.0	58.4	67.4	57.6	65.8
Grade 5	49.0	51.6	52.1	51.1	53.6	47.9	64.4
Grade 6		52.5	49.0	47.6	46.7	36.3	39.6
Grade 7	42.0	32.6	42.7	43.9	33.7	48.6	23.5
Grade 8		25.5	18.1	12.1	6.0	25.5	17.0
Algebra 1		35.2	36.7	37.9	35.6	43.2	42.0

Using performance on the MARS tasks, we were able to track both teachers and students across several years. The longer students were involved in classrooms with MAC-experienced teachers, the more likely they were to meet the performance standards on MARS. An example of the performance of a cohort of students in grades 4–7 on MARS taught by MAC teachers shows that before teachers had MAC coaching, only 30% of students met the standards, compared with 58% after one year, 66% after two years, and almost 100% of students with MAC teachers after three years.

Within MAC, there is more intensive formative assessment coaching for a subset of teachers. Results on the large-scale assessment and the MARS show even higher percentages of proficiency. For all grades, students with FiMC coached teachers reached the proficiency cut-score for both MARS and the statewide multiple-choice assessment more than those who did not have this intensive training, but still utilized MARS data. Table 4 show that students are gaining conceptual understanding in more complex tasks where they need to justify and explain their reasoning (as on the MARS exams) and on the standardized assessment that span the content range of a given grade.

Table 4. Intensive Coaching (FiMC) and MAC-Only Coaching, 2009

Teachers	Grade 6 MARS	Grade 7 MARS	Grade 8 MARS	Grade 6 state-wide assessment	Grade 7 state-wide assessment	Grade 8 state-wide assessment
FiMC Coached	69	45	38	65	59	48
MAC Only Coached	45	28	20	50	48	35

These findings are examples of what can be found in the many years of MAC data. Given the limitations of the length of this paper, the findings reported here represent what has been consistently found across the years, even with an increasing number of students and teachers participating. For instance, in 1999, 21 school districts, 462 teachers, and 23,128 students were involved in the study. The project reached the largest number of students in 2004 with 81,075 students and 1622 teachers in 28 districts. When funding for the project needed to be supported solely by district funds, the number of participating districts, teachers, and schools decreased. In 2011, 28 districts participated with 38,538 students.

CONCLUSIONS

Teachers need intensive support and resources to help them successfully transition to the new standards of the CCSS. This transition includes a shift in instruction and types of assessments, as the CCSS stress a new set of problem solving and skills more explicitly than most state assessments to date. As a result, the field needs to understand what teacher support around studying complex performance tasks has proven successful for promoting positive changes in teaching and learning. Additionally, the MARS tasks are in line with the two assessment consortia's descriptions of must-needed performance tasks, so better understanding the data from these assessments and their relationship to improved teaching practices is paramount for informing the pragmatic decisions that will be made in the upcoming years around what types of mathematics tasks assess deeper student learning and reflect improved teaching practices.

This paper is the first in a series studying the usefulness of MARS resources for teachers and their students, and thus provides only a sneak peek at the many layers of data to be studied. This work was a preliminary look using simple exploratory analyses, and thus does not utilize the types of methodology for studying longitudinal nested data. The plan is to use hierarchical linear modeling and potentially other nested models to provide information to the MAC on how different sites may have varying results and to verify findings cross-sectionally across different grade spans. Qualitative case studies will be conducted to better understand practices, which will then be incorporated into improvements in the professional development resources for future use.

The Mathematics Assessment Collaborative has been able to demonstrate that intensive coaching significantly enhances student achievement, both on state standardized achievement multiple-choice tests and on more complex performance-based assessments. An even more focused intervention around formative assessment shows that students with such teachers have even further gains in both types of assessments. This finding is even true with the ever-increasing number of students and teachers involved every year, indicating that the process is scalable and sustainable, and not just privy to a privileged few. We need to find ways to capitalize on gains and findings like the MAC efforts to show what strong professional development looks like, and how such investments can truly improve mathematics teaching and learning.

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