School Improvement through Elementary Mathematics Coaches: Impact on Teacher Beliefs and Student Achievement

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Recent reports have suggested that school-based mathematics specialists or coaches may support the improvement of mathematics teaching and learning in elementary schools by targeting teachers' understanding and action (e.g., National Council of Teachers of Mathematics [NCTM], 2000; National Research Council, 2001; National Mathematics Advisory Panel, 2008). The intent is for a knowledgeable colleague with a deep understanding of mathematics and of how students learn, as well as pedagogical expertise, to serve as an on-site resource and leader for teachers. The mathematics coach is to break the culture of teacher isolation whereby teachers work in private, without observation or feedback, and to collaborate with other professional development efforts in order to increase a school's instructional capacity (Neufeld & Roper, 2003). In practice, many schools are using their Title 1 funds to finance mathematics coaches, many rural areas are turning to on-site teacher leaders as a means of offering leadership to small populations of teachers spread over large geographical areas, and a number of urban districts are positioning mathematics coaches within their schools in an effort to advance test scores (Glod, 2007; Keller, 2007). While there are descriptive reports regarding the intent or use of coaches (e.g., Campbell, 1996; Corcoran, 2008; Dempsey, 2007; Foster, 2007; West & Staub, 2003) and resources for teacher leadership (e.g., Miller, Moon & Elko, 2000), there is very little empirical research addressing the activity and impact of mathematics coaches.

Background and Purpose

There is no single model of coaching; both past studies and current implementation efforts embody a variety of approaches. Joyce and Showers (1980) coined the term "peer coaching" to describe pairs of teachers providing reciprocal feedback and support to each other in an effort to improve their knowledge and skills. Seven years later, Loucks-Horsley and colleagues (Loucks-Horsley, et al., 1987, p. 83) used the term "helping teachers" to describe those teachers who served to enhance the teaching of others through mentoring and professional dialogue. Whether termed a specialist, coach, support teacher, or teacher leader, in many school districts today the intent is to place in a school a highly knowledgeable teacher, who frequently does not have responsibility for the instruction of a classroom of students, in order to advance instructional and programmatic change. The intent is for the specialist or coach to catalyze and sustain the implementation of school-based efforts focused on curriculum, instruction, and assessment in order to support the emergence of collective professional habits that advance school-wide growth and change, as well as student learning and achievement (Campbell & White, 1997; Marzano, Walters & McNulty, 2005; York-Barr & Duke, 2004). This goal aligns with aspects of varying frameworks or perspectives characterizing effective professional development (Ball & Cohen, 1999; Borasi & Fonzi, 2002; Garet, Porter, Desimone, Birman & Yoon, 2001; Little, 1993; Lord,

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Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA, April 13-17, 2009.
Developed with the support of the National Science Foundation, Grant No. ESI-0353360. The statements and findings herein reflect the opinions of the authors and not necessarily those of the Foundation.

1994; Loucks-Horlsey, Love, Stiles, Mundry, & Hewson, 2003; Smith, 2001; Stein, Smith & Silver, 1999; Supovitz, 2001; Thompson & Zeuli, 1999; Wilson & Berne, 1999) and ideally represents collaborative, inquiry-based learning.

There is a small body of research addressing the work and influence of specialists or coaches who work with multiple teachers (not peer coaches), generally addressing intended practice and teachers' perceptions of impact or characteristics of changed instructional behavior, frequently within reading or writing instruction (e.g., Ai & Rivera, 2004; Becker, 2001; Dempsey, 2007; Driscoll, 2007; Foster, 2007; Rodgers & Rodgers, 2007; Valencia & Killion, 1988; West & Staub, 2003). There is an emerging cautionary body of work that characterizes the challenges that whole-school instructional coaches or specialists initially experience, such as understanding the curriculum across grades or courses, dealing with principals, transitioning from teaching students to coaching teachers, balancing multiple responsibilities, understanding and negotiating school culture, addressing expectations for assessment, and setting priorities within time constraints (Neufeld, Baldassari, Johnson, Parker, & Roper, 2002; Neufeld & Roper, 2003; Neufeld, Roper & Baldassari, 2003; Poglinco & Bach, 2004; Poglinco, et al., 2003; Russo, 2004; West & Staub, 2003). This literature review identified only one publication reporting a positive relationship between mathematics student learning and professional development that included this approach to coaching, but this post-test-only, intact-group design did not control for possible initial differences between groups of students (Foster & Noyce, 2004).

When whole-school mathematics coaches or specialists are placed in a school, the ultimate intent is to positively impact student learning. Yet, one could argue that an additional measure of coaching effect is the impact of a coach on teacher change. When elementary mathematics coaches work with teachers, they address the mathematical knowledge and instructional practices of teachers, but in so doing, they may also impact teachers' beliefs. Indeed, there is evidence that teachers' perceptions of mathematics teaching and learning change or persist in concert with their instructional practices (Ross, McDougall, Bruce, Jafaar & Lee, 2004; Ross, McDougall, Hogaboam-Gray & LeSage, 2003). As such, teachers' beliefs about mathematics teaching and learning, as well as student achievement, are appropriate outcomes for evaluating the effectiveness of elementary mathematics coaches as a vehicle for school improvement. However, due to space and time limitations, this paper will only interpret teachers' beliefs regarding mathematics teaching and learning as an independent variable in the analysis of impact on student achievement.

In 2004, the National Science Foundation funded a collaborative project involving four universities and five school districts that collected data within a 3-year randomized control-treatment design to investigate the work and impact of full-time mathematics coaches in elementary schools in Virginia. This study's 24 treatment and 12 control schools represent a range of demographic and economic settings in urban, suburban, and urban-edge schools. The coaches in this study were experienced classroom teachers who were selected by their school district and assigned to provide full-time support in a school, after completing coursework in mathematics content and in leadership-coaching as well as study of models, resources, and best practices for mathematics instruction. This paper reports on the effects of coaching on student achievement data in Grades 3-5 as measured by the high-stakes, standardized assessment administered in Virginia as required by *No Child Left Behind* federal regulations. As such, it characterizes the activity of mathematics coaches over time, addresses the impact of coaches on student achievement (controlling for the degree of involvement between coaches and classroom teachers as well as for teacher beliefs and experience), and provides insight regarding coaching as a vehicle for instructional reform in a school improvement model. The research questions being addressed in this paper are:

- What activities did elementary mathematics coaches engage in and what proportion of their total time did they spend completing those differing duties?
- What was the impact of coaches on student achievement, as influenced by coaches' degree of involvement with individual teachers and by teachers' beliefs and teaching experience?

Theoretical Perspective

The perspective underlying this work is that capacity for school-based improvement, as indicated by student achievement, teacher beliefs, and professional practice, emerges through the interaction of human capital, social capital, and financial resources (Spillane & Thompson, 1997). Human capital increases as mathematics coaches gain knowledge of mathematics content and of research addressing the learning and teaching of mathematics and as they develop leadership and coaching skills that will be critical in work that aims to foster a shared perspective of mathematics teaching and learning. Social capital increases as coaches and teachers work together to develop professional network(s) addressing mathematics teaching within an emerging school community. With increased social capital, human capital encompasses classroom teachers. Financial resources refers not only to funding to support the placement of the coaches, as well as materials for instruction, but also time to learn, implement, and revise the meaning of reform and growth within a local school and time to develop trust and collaboration.

Perspectives characterizing the meaning of mathematical knowledge, learning, and teaching also influenced this work. The intended mathematical knowledge and the vision of instruction promoted in the coach-preparation courses encouraged coaches to focus and support teachers' efforts not only to address students' skill with mathematical procedures and computation but also to address students' understanding of the concepts and principles underlying those procedures across the spectrum of rational number and operations, geometry, measurement, probability, data analysis and early algebra. The intention promoted in the coaches' preparation courses was for teachers and coaches to work together so that instruction would come to emphasize student thinking and "principled knowledge" (Spillane, 2000) as teachers and students questioned each other in order to "make sense," expecting explanation and justification for mathematical reasoning, problem-solving approach, and solutions.

Method

Coaches

Five school districts in Virginia, representing urban, urban-edge, and suburban communities, identified one or more triples of schools with comparable student demographics and comparable traditions of student performance on state mathematics assessments. One school was randomly selected from each of the 12 triples and assigned a mathematics coach during the 2005-06 school year. The first cohort of 12 coaches completed five mathematics content courses and one leadership-coaching course during 2004 and 2005 prior to placement, as well as a second leadership-coaching course during their first year of service as a coach. Of the 12 coaches in the first cohort, 11 remained in one of the original treatment schools for 3 school years (August 2005 through June 2008). One treatment school closed due to redistricting after the 2006-07 school year, and one coach in this cohort retired at that time, accepting a position as half-time supervisor of coaches across that school district. The coach displaced by the school closing was re-assigned to the school formerly supported by the newly retired coach, thus maintaining placement of a third-year coach across all of the remaining Cohort 1 schools during Year 3 of the study. A second cohort of 12 coaches completed a similar offering of these same content and leadership courses during 2006 and 2007. This second cohort of 12 coaches was randomly assigned to one of the two remaining schools in each triple in August 2007, after completing the same five mathematics content courses and one leadership-coaching course prior to placement. One year of treatment data has been collected from this cohort; two years of control data have been drawn from these same schools. The third school in each triple retained its control status throughout. Thus the design permitted a controlled, 3-year data collection addressing the impact of coaches. This design is not longitudinal. It is a point-in-time study conducted over a 3-year period, identifying the source of data for each year as being from a school representing either a first, second, or third year of treatment or control status.

School districts were paid an allotment of $25,000 per coach per year in order to offset the cost of replacement classroom teachers. Coaches were also paid an annual stipend of $2,500 for participating in the data collection phase of the study. All 24 coaches were female. Eight of the coaches are African American; one coach is Asian; the remaining coaches are Caucasian. A summary of the prior professional experience and background of the 24 coaches as of the time they began their first course is noted in Table 1. As indicated, Cohort 1 was a somewhat more seasoned group of teachers than were the individuals in Cohort 2.

Table 1: Coaches' Prior Professional Experience and Background

Source	Cohort 1			Cohort 2		
	Mean	**Standard Deviation**	**Range**	**Mean**	**Standard Deviation**	**Range**
Master's Degree Recipient (0/1)	0.5	0.52	0 to 1	0.42	0.51	0 to 1
Number of Graduate Credits (No Master's Degree)[a]	21.17	19.26	0 to 57	2.57	3.64	0 to 9
Number of Graduate Credits Beyond Master's Degree[b]	4.17	7.05	0 to 17	5.4	8.85	0 to 21
Number of Credits in Mathematics Content	10.42	7.44	3 to 24	6.0	3.38	3 to 12
Number of Credits in Mathematics Education	7.50	6.72	3 to 27	4.0	2.26	0 to 9
Years of Teaching Experience (Elementary School)	14.83	9.60	5 to 31	12.92	8.63	4 to 29
Years of Teaching Experience (Middle School)	4.67	4.73	0 to 10	0.42	2.24	0 to 5

[a] These statistics are calculated on the data submitted by the subset of coaches who did not have a master's degree at the beginning of their coursework for the coaching program. [b] These statistics are calculated on the data submitted by the subset of coaches who did have a master's degree at the beginning of their coursework for the coaching program.

Professional Development of Coaches

The 24 coaches completed five mathematics courses designed for them by a course development team consisting of college mathematics and mathematics education faculty, experienced district mathematics coordinators, and experienced classroom teachers. The *Numbers and Operations*, *Geometry and Measurement*, *Algebra and Functions*, and *Probability and Statistics* courses used relevant modules of the *Developing Mathematical Ideas* professional development series (e.g., Schifter, Bastable, & Russell, 1999), together with other materials created or culled by the development teams. The *Rational Numbers and Proportional Reasoning* course accessed differing case-based materials (Lamon, 1999; Fosnot & Dolk, 2002). Coaches completed these courses at one of three locations, each with different instructors. All courses were team taught, with the team typically including both a mathematician and a mathematics educator. There was variation in the emphasis given to the goals of increasing teachers' content and pedagogical knowledge. For example, the *Numbers and Operations* course emphasized pedagogical issues, with numerous activities that required teachers to examine children's thinking. In contrast, much of the *Geometry and Measurement* course involved teachers grappling with mathematical concepts as students, focusing more on the mathematics content and less on the pedagogical implications. The first educational leadership course accessed NCTM's standards documents (NCTM, 1991, 2000) as well *Adding it up* (National Research Council, 2001). Coaches were placed in schools following completion of this first leadership course and the five mathematics courses. Subsequently, during their first year of placement, they completed the second educational leadership course focused on coaching, accessing a variety of published references (e.g., Wood, Nelson, & Warfield, 2001) as well as accompanying video segments and cases (Miller, Moon & Elko, 2000; West & Staub, 2003).

Longitudinal data have been collected addressing the change in coaches' beliefs about mathematics teaching and learning and coaches' mathematical content knowledge as well as their knowledge of mathematics for teaching in a pretest-repeated posttest design. Due to time and space limitations, those data are not being addressed in this report.

Teachers

Over the course of the 3 years, there were 1,593 teachers of Kindergarten-Grade 5 mathematics in the 36 cooperating schools who agreed to participate in the study. As indicated in Table 2, the teachers in the three cohorts of schools did not differ substantively in terms of their professional experience or demographics. In Table 2, the schools randomly assigned to treatment status for 3 years are Cohort 1 schools; the schools randomly assigned to control status for 2 years (2005-07) and then treatment status for 1 year (2007-08) are Control 1/Cohort 2 schools; the remaining schools randomly assigned to control status for 3 years are labeled as Control 1/Control 2 schools.

Data Sources

Student Achievement. All students in Grades 3 through 8 in Virginia are expected to complete a state-wide, standardized achievement test in mathematics termed the Standards of Learning Assessment (SOL) annually. Through this high-stakes measure, Virginia meets the expectations for assessment as required under the *No Child Left Behind* federal regulation. SOL data include a total scale score for mathematics (possible scores ranging from 200 to 600), as well as five subscale scores (possible scores ranging from 0 to 50) addressing: number and number sense; computation and estimation; measurement and geometry; probability and statistics; and patterns,

Table 2: Teachers' Professional Demographics (2005-08)

	Cohort 1			Control 1/Cohort 2			Control 1/Control 2		
Year	**05-06**	**06-07**	**07-08**	**05-06**	**06-07**	**07-08**	**05-06**	**06-07**	**07-08**
Master's Degree	36.4%	38.2%	35.0%	40.5%	46.7%	45.9%	35.1%	40.6%	41.8%
Years of Teaching Experience									
1 or 2 years	16.3%	18.7%	17.9%	24.8%	15.6%	14.8%	14.5%	11.3%	13.1%
3 or 4 years	10.1%	9.8%	6.8%	11.8%	18.0%	17.2%	8.4%	14.3%	14.8%
5 through 9 years	34.9%	32.5%	33.3%	27.5%	28.7%	29.5%	19.8%	21.1%	16.4%
10 or more years	38.8%	39.0%	41.9%	35.9%	37.7%	38.5%	57.3%	53.4%	55.7%
Certified Teachers	98.4%	95.9%	96.6%	94.1%	94.3%	95.9%	93.9%	94.0%	96.7%
Female	93.8%	93.5%	92.3%	83.7%	86.1%	83.6%	87.8%	86.5%	88.5%
Race/Ethnicity									
American Indian/ Alaskan Native	0.0%	0.0%	0.0%	0.7%	0.8%	0.8%	0.0%	0.0%	0.8%
Black/African American	25.6%	22.0%	20.5%	30.7%	30.3%	27.0%	23.7%	27.1%	27.9%
White	72.1%	74.0%	76.1%	65.4%	68.0%	70.5%	73.3%	68.4%	64.8%
Asian/Asian American	0.0%	0.0%	0.0%	1.3%	0.0%	0.0%	1.5%	2.3%	1.6%
Hispanic/Latino	1.6%	2.4%	1.7%	0.7%	0.8%	0.8%	0.0%	0.0%	0.0%
More than one race	0.8%	1.6%	1.7%	0.7%	0.0%	0.0%	0.8%	1.5%	3.3%
***n* of Teachers**	333	316	309	393	333	332	356	323	319
School Attrition		29.4%	23.7%		36.4%	30.0%		32.6%	22.9%

functions and algebra. For purposes of labeling performance, total scale scores at or above 500 are deemed Advanced Passing, total scale scores from 400 to 499 are deemed Passing Proficient, and total scale scores below 400 are deeming Failing. The SOL's are administered annually, typically during the last half of May. While the SOL's in Grades 3 and 5 have been administered since the 2001-02 school year, the Grade 4 SOL's were administered for the first time within the 2005-06 school year, the first year of placement of coaches in this study. Further, while the Grade 4 and Grade 5 SOL's only assess content associated within the grade-level standards of that single grade, the Grade 3 SOL assessment measures content from Kindergarten through Grade 3. Thus, the analysis that follows separately considers the third-, fourth-, and fifth-grade students' scores across 3 years (2005-08) with data from 2004-05 serving as a baseline.

Teacher Beliefs. The teachers of mathematics in the control and treatment schools completed a beliefs survey in Fall 2005, and again in Spring 2006, 2007, and 2008. This assessment was constructed using a 20-item instrument developed by Ross and colleagues (Ross, McDougall, Hogaboam-Gray & LeSage, 2003) with the addition of 10 additional items addressing equity and directed instruction. Using a Likert Scale, respondents rated each of 30 statements on a scale of 1 (strongly disagree) to 5 (strongly agree). The statements in the survey reflected perspectives about mathematics curriculum and instruction and perspectives regarding the needs of students and student understanding. These data were then translated so that a value of 1 consistently reflected a perspective of strongly agreeing with traditional statements emphasizing directed teaching and mathematical structure as a basis for curriculum and strongly disagreeing with statements that viewed teaching as supporting students' efforts to build understanding within their emerging conceptual frameworks. A value of 5 consistently indicated a perspective that strongly disagreed with traditional statements and strongly agreed with statements emphasizing student needs and understanding. The reliability of the total 30-item scale as indicated by Cronbach's alpha is .797.

Coaches' Activity and Engagement with Teachers. To account for their changing actions in school within and across each school year, coaches detailed the nature and duration of their daily activities using a data collection-transmittal program (see Figure 1) operating on a Personal Digital Assistant (Dell Axim X50™; PDA). Instructional Specialist Activity Manger (ISAM) is a menu-oriented, entry interface that allows coaches to log the duration and category of their daily activity and to log a weekly reflection describing their level of engagement with particular teachers in a given week, with teacher identification cycling over the course of the school year.

Within the Daily Activity Log option of ISAM, coaches chronologically indicate the duration of an activity (see Figure 2) and then to "click" the primary identification of that activity (see Figure 3). Based on a branching network, activities of interest trigger the presentation of more detailed sub-choices, which coaches again select by "clicking" on the button of interest (see Figure 4). After entering the activity for a time period, the coaches may review and, if necessary, modify their entry. They may also select a "note" option that triggers a word processing window for the creation of narrative notes (see Figure 5). After the activities of a complete day are entered, coaches may review the day's entries, review and enter additional notes, and, if necessary, modify the listing prior to confirmation (see Figure 6).

Figure 1: ISAM Data Menu

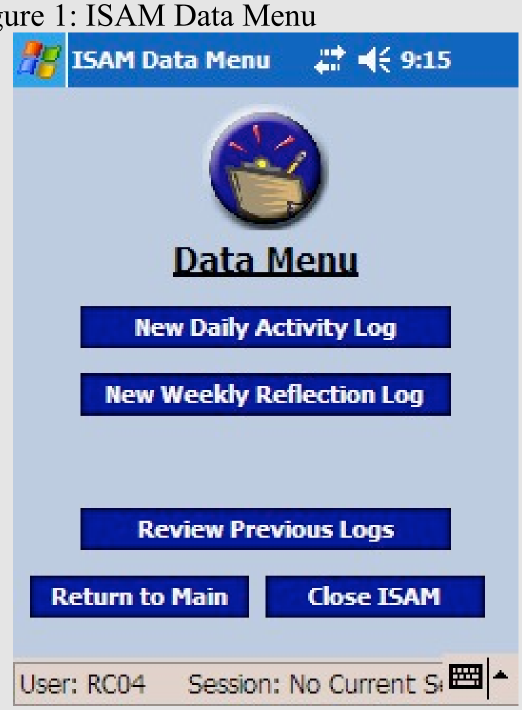


Figure 2: ISAM Time Entry

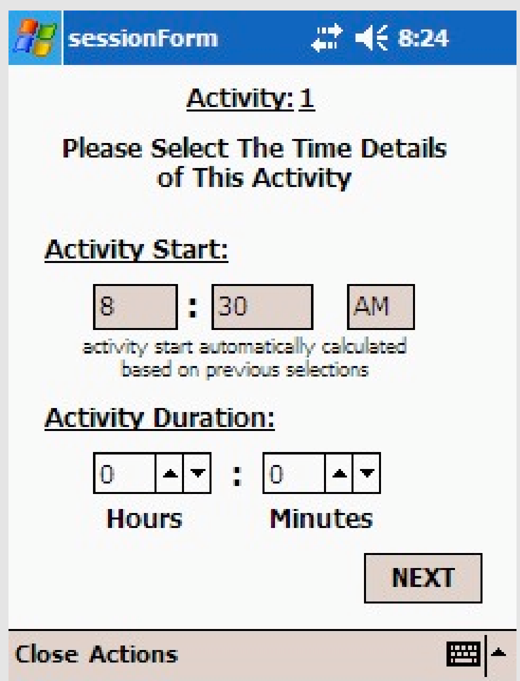


Figure 3: ISAM Activity Menu

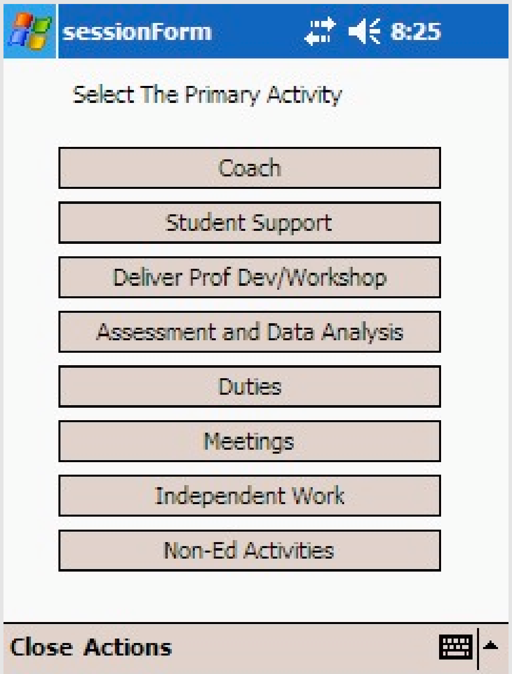


Figure 4: Branch to Detailed Choices

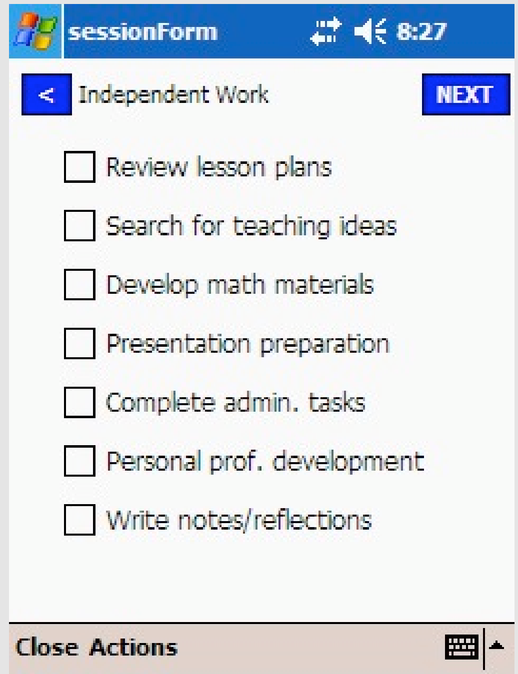


Figure 5: Review Activity

Figure 6: Day in Review

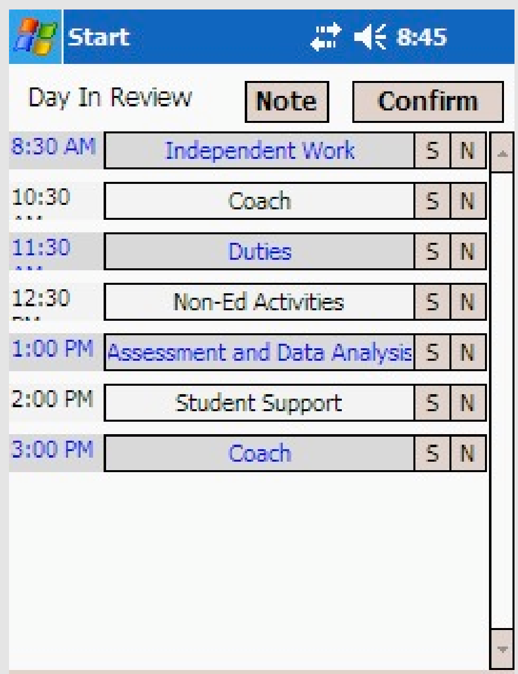


Figure 7: Grade-level Planning Engagement

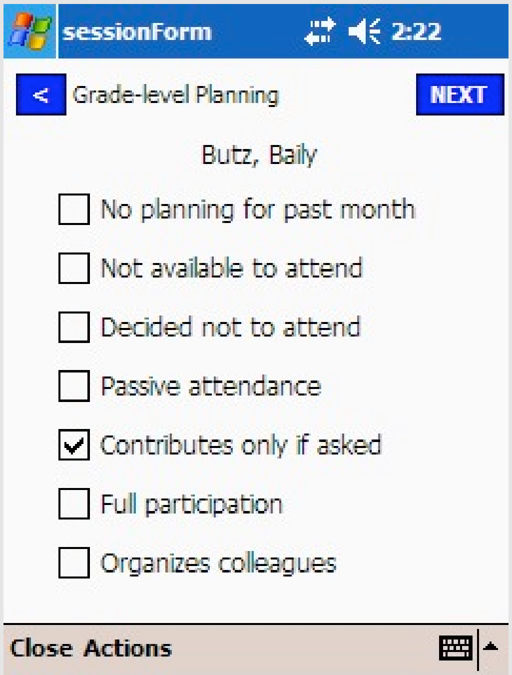
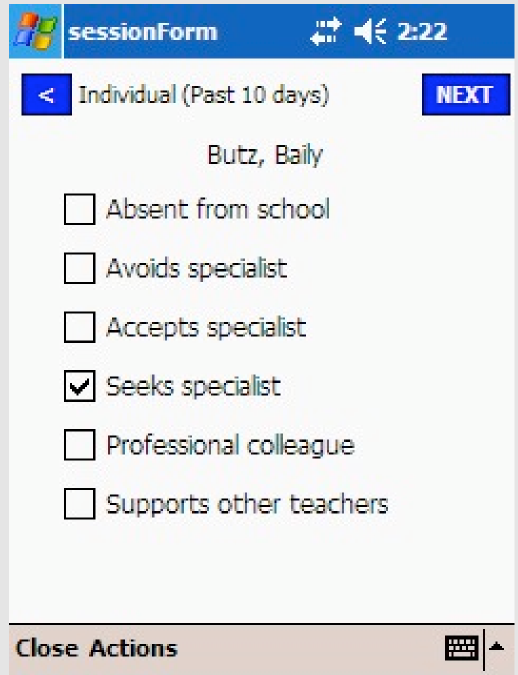


Figure 8: Individual Engagement



The Weekly Reflection Log lists the names of 1/6 of the teachers in a school each week, with the names cycling over a 6-week period so that each teacher's name appears once in that period and six times over the course of a school year. This log asks the coaches to reflect on their interaction with a named teacher and indicate the teacher's level of engagement with the coach during group-directed, grade-level planning sessions over the past month (see Figure 7) and during individual interaction over the past 10 days (see Figure 8). As with the Daily Activity Log, coaches may review their entries and modify the listing prior to confirmation.

Daily and Weekly confirmed data are subsequently transmitted over the Internet onto a comprehensive data management platform housed on a server at the University of Maryland.

Analysis and Results

Activity of the Coaches (ISAM data)

The ISAM data from the PDA's provide two types of data: the distribution and duration of coaches' activities and coaches' self-reports of the level of engagement between individual teachers and the coach assigned to that teacher's school. The level of engagement data drawn from the Weekly Reflection Logs are being used in the next section of this paper as a measure of the nature of interaction between coaches and teachers in the analysis addressing the effect of coaches on student achievement. In contrast, the Daily Activity Logs simply characterize the duration and nature of coaches' activity across up to 3 years of placement in a school. Although coaches were not expected to complete tasks related to their work responsibilities outside of their contract day, many coaches did so. Therefore, this presentation of the activity data distinguishes between those two contexts for activity.

Contracted Workday. Table 3 presents a frequency distribution of the Cohort 1 coaches' activities as a proportion of mean time spent in each activity on a contract day, identifying only activities for which the majority of the time spent occurred within the contracted work day. If a coach was absent from work on a contracted day, that time is not reflected in Table 3. Therefore, Table 3 characterizes how coaches spent their time when they were at work during a contracted workday. The mean length of a contract day for a coach was 7 hours, 22 minutes; the median length of a contract day for coaches was 7.5 hours (contract times ranged from 7 hours to 8 hours over the 24 schools). Thus, on average, the coaches were paid to spend 36 hours, 50 minutes at school each week with a 40-week school calendar. In terms of hours per day, the values in Table 3 may be interpolated according to the formula that 13.6% is equivalent to 5 hours per week (comparable to 1 hour per day) and 2.7% is equivalent to 1 hour per week.

The data in Table 3 indicate that, for the most part, the Cohort 1 coaches interpreted coaching as working with an individual teacher rather than group coaching of grade-level teams or other groups of teachers within their schools, as 80-83% of their coaching time was spent with individual teachers. The amount of contract-day time that Cohort 1 coaches spent working with individual teachers decreased by 40 to 45% over the 3 years. Over that same period, the amount of time that they spent addressing assessment increased by 27 to 39% and the amount of time that they devoted to school-based duties increased by 42 to 69%. The increase in activity related to assessment was evident in each of the five school districts, with frequency of time devoted to assessment responsibilities being a consistently modal feature in the urban districts. Because mathematics coaches were not assigned across all schools in a district, shifting of coaches' time to assessment responsibilities is probably a local school response to concerns associated with assessment demands, a response that is evident within and between districts. In contrast, the increase in time that Cohort 1 coaches spent teaching or supporting students without an observing teacher present (thus not coaching through demonstration teaching, modeling, or co-teaching) varied by individual coaches, not districts. Thus, this was most likely a reflection of a principal's request and not a consistent response to district policy or pressure.

Time allocated to attending meetings that did not have a mathematics focus varied by individual school placement and declined over time, with no patterns beyond a minimal base level evident within school districts. In contrast, the time Cohort 1 coaches spent in meetings that did have a mathematics focus was quite consistent within districts, while being unique across districts. This indicates that a coach's attendance at a meeting was likely not an individual decision, but reflected an expectation of either a principal or a district office. Further, as these Cohort 1 coaches gained expertise over time, all local administrators were less likely to expect their attendance at a meeting when the agenda was not related to mathematics.

The dominant school-based duty assumed by the Cohort 1 coaches occurred concurrent with the opening and closing of the school day for children. The coaches were assuming daily bus duty. Many coaches indicated that this was a conscious decision on their part as not only did it endear them to the teachers in their building to take on the responsibility of bus duty every day, it also was at a time when few, if any, teachers would be available to meet individually with a coach.

For the most part, time allocated to Non-educational Activities was at mid-day and reflected a break for lunch. (10.2% reflects 45 minutes per day.)

The Cohort 2 coaches also were responsible for daily PDA entries during 2007-08, their first year of placement. Table 4 presents the proportional distribution of their mean time over activity

Table 3: Proportion of Cohort 1 Mean Contract-day Time Over Main Coaching Activities

Activity	2005-06	2006-07	2007-08
Coaching Teachers	21.9%	13.1%	12.2%
Coaching an individual teacher	18.2%	11.0%	9.7%
Coaching a grade-level team	3.2%	1.8%	1.9%
Delivering other on-site professional development	0.5%	0.3%	0.6%
Preparing for Teaching/Coaching	11.8%	12.4%	11.9%
Supporting Assessment	10.6%	13.5%	14.7%
Developing assessments	2.6%	2.2%	2.7%
Supporting administration of assessments	4.4%	7.0%	7.4%
Grading tests; entering data	1.1%	1.8%	2.4%
Summarizing and interpreting data	2.4%	2.5%	2.3%
Teaching or Supporting Students (not demonstration or modeling)	3.0%	4.4%	4.5%
Supporting the School Mathematics Program	5.0%	4.2%	4.8%
Aligning curricula; referencing materials	0.3%	0.8%	0.5%
Developing materials/delivering presentations for program support	4.7%	3.4%	4.2%
Performing School-based Duties	6.5%	9.2%	11.0%
Monitoring students	5.1%	8.0%	8.6%
Emergency coverage /Non-math school coordination	1.3%	1.1%	2.4%
Materials Management/ Communication Tasks	9.7%	11.0%	11.6%
Materials management	3.3%	3.3%	4.0%
Photocopying	1.0%	1.0%	0.9%
Communication (telephone; email; flyers)	4.4%	5.0%	5.3%
PDA data entry	1.0%	1.8%	1.3%
Attending Meetings	9.2%	6.8%	7.0%
Attending math-related meetings	5.9%	3.5%	3.7%
Attending non-math-related meetings	3.3%	3.3%	3.3%
Engaging in Personal Professional Activity	13.2%	14.7%	11.0%
Preparing for or delivering off-site professional development	2.4%	2.1%	1.9%
Attending local/project professional development	3.4%	4.4%	4.3%
Writing notes and reflections	2.3%	1.9%	1.3%
Reading professional resources/graduate coursework	3.2%	3.4%	1.3%
Attending state or national professional development	2.1%	2.9%	2.3%
Non-educational Activities (lunch, break, travel, all-school event)	9%	10.8%	11.3%

within the contracted workday, along with a re-listing of the Year 1 and Year 3 proportional times for Cohort 1 coaches. Thus Table 4 allows comparison of the distribution of activity during the first year of placement for two differing cohorts (Cohort 1 during 2005-06 and Cohort 2 during 2007-08), as well as a comparison of the distribution of activity of novice and experienced coaches during the same academic year (both cohorts during 2007-08).

A number of patterns may be discerned from the data in Table 4. First, similar to the pattern observed in the Cohort 1 data, Cohort 2 coaches were more likely to coach an individual teacher rather than to work with a grade-level team or another group of teachers within their schools, as about 75% of their coaching time was spent with individual teachers. This is probably a reflection of the model of coaching presented to both cohorts by the project-supported courses and workshops and their local districts. The amount of time that each of the two cohorts spent coaching teachers was more consistent when the year of work was constant (both cohorts in 2007-08) than when the extent of experience was constant (Cohort 2 in 2007-08 and Cohort 1 in 2005-06). This may mean that during 2007-08 there were common outside influences impacting coaches' decisions as to how much available time they had to spend working with individual teachers.

The Cohort 2 coaches spent somewhat less time than the more experienced Cohort 1 coaches addressing assessment during 2007-08, primarily because Cohort 2 coaches had less time devoted to developing assessments (typically quarterly benchmark assessments) and to assessment management, such as organizing, scheduling, training for, and monitoring administration of assessments. This may reflect the increased managerial expertise presumed of Cohort 1 coaches during their third-year of placement. As apparent within the Cohort 1 data, the frequency of time devoted to assessment responsibilities was a consistently modal feature in the entries of the Cohort 2 coaches who were placed in urban districts.

For a number of tasks, the frequency of occurrence over Cohort 1 and 2 was more comparable when the year of experience was held constant. These tasks included working with students without an observing teacher (e.g., tutoring groups of children or substitute teaching), supporting a school's mathematics program, attending meetings, writing notes and reflections, and personal professional development (reading professional resources and attending/completing work related to graduate courses). The increased prevalence of activity associated with writing notes and reflections as well as personal professional development probably reflects the fact that all coaches completed the second leadership-coaching course during their first year of placement. Further, many of the coaches in each cohort completed an additional graduate course or two during their first year of placement as they completed requirements for a masters degree within the following summer or fall semester.

The amount of time that coaches spent addressing communication, such as email correspondence, was more comparable by academic year than by year of expertise. All of the participating school districts provide email addresses and access to their instructional and administrative staffs. The increase in time evidenced between 2005-06 and 2007-08 is most likely a reflection of changes in school culture and not the project. In contrast, the assumption of school bus duty responsibilities is most likely a project-related artifact. Cohort 1 coaches met with their Cohort 2 counterparts, offering advice about how to build trust and entrée into their school placements. "Volunteer for bus duty" was a common message shared by the more experienced coaches.

Table 4: Proportion of Cohorts 1 and 2 Mean Contract-day Time Over Main Coaching Activities

Activity	Cohort 2 2007-08 (Year 1)	Cohort 1 2005-06 (Year 1)	Cohort 1 2007-08 (Year 3)
Coaching Teachers	10.2%	21.9%	12.2%
Coaching an individual teacher	7.6%	18.2%	9.7%
Coaching a grade-level team	2.1%	3.2%	1.9%
Delivering other on-site professional development	0.5%	0.5%	0.6%
Preparing for Teaching/Coaching	11.8%	11.8%	11.9%
Supporting Assessment	12.5%	10.6%	14.7%
Developing assessments	1.2%	2.6%	2.7%
Supporting administration of assessments	5.1%	4.4%	7.4%
Grading tests; entering data	2.5%	1.1%	2.4%
Summarizing and interpreting data	3.7%	2.4%	2.3%
Teaching or Supporting Students (not demonstration or modeling)	3.6%	3.0%	4.5%
Supporting the School Mathematics Program	5.1%	5.0%	4.8%
Aligning curricula; referencing materials	0.5%	0.3%	0.5%
Developing materials/delivering presentations for program support	4.6%	4.7%	4.2%
Performing School-based Duties	9.8%	6.5%	11.0%
Monitoring students	8.2%	5.1%	8.6%
Emergency coverage /Non-math school coordination	1.6%	1.3%	2.4%
Materials Management/ Communication Tasks	11.4%	9.7%	11.6%
Materials management	3.3%	3.3%	4.0%
Photocopying	1.2%	1.0%	0.9%
Communication (telephone; email; flyers)	5.4%	4.4%	5.3%
PDA data entry	1.5%	1.0%	1.3%
Attending Meetings	9.5%	9.2%	7.0%
Attending math-related meetings	5.4%	5.9%	3.7%
Attending non-math-related meetings	4.1%	3.3%	3.3%
Engaging in Personal Professional Activity	14.4%	13.2%	11.0%
Preparing for or delivering off-site professional development	1.1%	2.4%	1.9%
Attending local/project professional development	5.0%	3.4%	4.3%
Writing notes and reflections	2.5%	2.3%	1.3%
Reading professional resources/graduate coursework	3.4%	3.2%	1.3%
Attending state or national professional development	2.4%	2.1%	2.3%
Non-educational Activities (lunch, break, travel, all-school event)	11.8%	9%	11.3%

Table 5: Time Spent by Cohort on Coaching Responsibilities Outside of the Contracted Workday: Descriptive Statistics

	Mean Hours per Week	Standard Deviation	Range
Cohort 1 2005-06	6.2	3.79	2.3 to 13.3 hours per week
Cohort 1 2006-07	4.6	2.79	2.2 to 9.8 hours per week
Cohort 1 2007-08	3.4	2.35	0.74 to 6.0 hours per week
Cohort 2 2007-08	3.8	2.73	1.8 to 9.8 hours per week

Out-of-School Time. The coaches varied in terms of how much out-of-school time they devoted to responsibilities associated with their work. As noted in Table 5, on average, the coaches spent 4.5 hours a week completing work-related activity for which they were not paid. This is equivalent to approximately180 hours or 24 extra days per year. While it is acknowledged that the amount of time that Cohort 1 coaches spent working outside of their contract day diminished over time and that the amount of work completed outside of the contract day was similar for Cohort 1 and 2 coaches in 2007-08, no rationale for this pattern is known.

Table 6 presents the coaches' mean out-of-school time in hours per category of activity by school year. A substantial portion of this out-of-school time was allotted to personal professional activities such as attending professional development sessions, reading professional resources, completing work related to or attending graduate courses, and writing notes and reflections. It may be that much of this time was related to the graduate coursework that a number of coaches

Table 6: Coaches' Mean Out-of-School Time in Hours per Activity Category by Year

Activity	Cohort 1 2005-06 (Year 1)	Cohort 1 2006-07 (Year 2)	Cohort 1 2007-08 (Year 3)	Cohort 2 2007-08 (Year 1)
Coaching Teachers	9.69	8.24	15.8	22.1
Preparing for Teaching/Coaching	31.4	26.5	18.68	11.13
Supporting Assessment	13.53	12.72	10.77	6.97
Teaching or Supporting Students (not demonstration or modeling)	4.68	4.02	3.17	1.97
Supporting the School Mathematics Program	17.05	11.28	8.17	5.97
Performing School-based Duties	26.04	25.24	13.57	13.88
Materials Management/Communication Tasks	36.84	21.14	22.51	29.60
Attending Meetings	25.83	14.86	14.3	14.28
Engaging in Personal Professional Activity	55.53	43.98	19.4	30.02
Non-educational Activities within Out-of-School Work Time (lunch, break, travel)	27.86	16.84	10.5	17.35
Mean Total Hours per Year	248.45	184.82	136.87	153.27

were completing during their first 2 years of placement as this pattern diminished markedly in the third year of Cohort 1 data entries, after the degree-seeking coaches in that cohort had completed their degrees. Materials management and communication also demanded much of the coaches' time outside of the contracted workday. Over half of this time was spent attending to communication tasks involving email, telephone calls or the production of flyers while the remaining time was split between PDA data entry and activity associated with supporting the purchasing, distribution, and management of educational materials.

The Cohort 1 coaches were more likely to spend their out-of-school work time preparing for coaching or teaching (demonstration teaching, modeling or co-teaching) rather than coaching teachers, but the Cohort 2 coaches evidenced the reverse pattern. For both cohorts, coaching time outside of the contract day was typically spent working with individual teachers, rather than with groups of teachers or grade-level teams. The out-of-school time devoted to the performance of duties almost exclusively involved monitoring students, while work associated with the school mathematics program involved activities such as a school's annual Family Math Night.

Student Mathematics Achievement

To determine whether coaches impact student mathematics achievement scores as measured by standardized assessments, this analysis accessed data on 25,048 student test scores drawn from Grades 3, 4, and 5 of 36 treatment and control schools over 3 years. Because of the nested nature of the data (students nested within classrooms, nested within schools) Hierarchical Linear Modeling (HLM) was applied. Across these 3 years, this sample included 1,149 teachers of the students in Grades 3, 4, and 5, of which 356 were in Cohort 1 schools, 419 were in Control 1/Cohort 2 schools, and 374 were in Control 1/Control 2 schools,

For each grade level, the primary dependent variable was the overall SOL Mathematics scale score, with complimentary analysis of subscale scores across five domains: Numbers and Number Sense, Computation and Estimation, Measurement and Geometry, Probability and Statistics, and Patterns, Functions and Algebra. Table 7 presents selected descriptive statistics for these variables.

Some variance in student scores can be attributed to the school that a student attends rather than to individual or treatment differences. By completing HLM before entering student-level demographic data, it is possible to determine the interclass correlation coefficient (ICC), a measure of the variance of students' scores associated with the schools attended by students. The ICC indicated that 10.4% of the variance in third-grade scores was due to schools, 9.8% in fourth grade, and 7.2% in fifth grade. Thus, on average, 9.1% of the difference in student scores in this sample is associated with school grouping and is not due to individual student differences.

The primary independent variable (Coach in School) in this analysis is a school-level variable that indicated whether a school had the services of an elementary mathematics coach. Because the point-in-time design provided student achievement data over 3 years of treatment, the impact of a coach could vary with time as the coaches gained experience. For this reason, a second school-level variable in the model identified whether a coach was in her first, second or third year of coaching (Coach Experience).

While coaches were responsible for working with an entire school, in practice their level of engagement with teachers varied. The Weekly Reflection Logs on the PDA's provided a categorical estimation of the quantity of both individual and group-level interaction between

Table 7: Selected Descriptive Statistics for SOL Scales by Grade

Source	*n*	Mean	Standard Deviation
Grade 3			
Overall Scale Score	8440	491.4	74.94
Number & Number Sense	8440	39.53	8.66
Computation & Estimation	8440	39.05	8.66
Measurement & Geometry	8440	40.3	8.99
Probability & Statistics	8440	40.86	10.67
Patterns, Functions & Algebra	8440	41.59	10.21
Grade 4			
Overall Scale Score	8257	467.1	76.79
Number & Number Sense	8257	37.5	9.39
Computation & Estimation	8257	36.57	8.62
Measurement & Geometry	8257	35.83	7.73
Probability & Statistics	8257	35.47	9.04
Patterns, Functions & Algebra	8257	37.18	9.2
Grade 5			
Overall Scale Score	8351	494.3	80.99
Number & Number Sense	8351	40.41	10
Computation & Estimation	8351	38.82	9.11
Measurement & Geometry	8351	37.89	8.14
Probability & Statistics	8351	39.27	9.77
Patterns, Functions & Algebra	8351	38.84	8.74

teachers and coaches. These reflections were entered approximately six times per year. In order to yield an annual measure of high engagement between a coach and a teacher, these entries were coded according to a 0/1 score (see Table 8) and summed. The proportion of these summed values to possible points (1 point per entry) yielded an Engagement rating. This proportion was then translated to a 0/1 binary measure (High Engagement) to indicate if there was or was not a high level of engagement between a teacher and a coach. Teachers who had an Engagement rating of 0.75 or higher were coded as 1 on the binary indicator of High Engagement. Based on this metric, approximately 22% of the Treatment teachers in Grades 3, 4 and/or 5 were deemed as having a high level of engagement with a coach. (See Table 9.)

Differential performance in standardized mathematics achievement scores has been associated with race/ethnicity and free and/or reduced lunch status at the school, classroom, and student level, therefore these variables were entered in a preliminary analysis. While poverty and proportion of minority enrollment were significant factors at the school and classroom levels, including both variables in the model introduced multicolinearity problems. Because proportion of minority enrollment explained more of the variance than did poverty, the resulting model includes a variable addressing minority enrollment and not poverty. As a result, both school- and classroom-level variables identifying whether a school's (classroom's) enrollment was 90% or more minority was entered into the model. Similarly, 0/1 indicators of minority status and free or

Table 8: 0/1 Engagement Values for ISAM Weekly Reflection Logs

	Engagement Value
Individual Engagement	
Seeks specialist/coach	1
Professional colleague	1
Supports other teachers	1
Accepts specialist/coach	0
Avoids specialist	0
Absent from school	0
Engagement During Group Planning/Team Meetings	
Full participation	1
Organizes colleagues	1
Contributes only when asked	0
Decided not to attend a meeting	0
Passive attendance at a meeting	0
No planning or group meeting scheduled	0
Not available to attend	0

reduced meal status were also entered at the student level.

Because prior research has indicated that students in classrooms with novice teachers frequently have significantly lower achievement on standardized mathematics assessments and because urban schools have higher teacher mobility with teachers who have less than 5 years of teaching experience, this analysis controlled for years of teaching experience at the teacher or classroom level. This analysis established this control by comparing the classroom SOL achievement scores of students whose teachers had 5 to 9 years teaching experience to the classroom scores of students whose teachers had 2 or fewer years, 3 or 4 years, or 10 or more years of teaching experience.

All teachers of mathematics in the treatment and control schools completed annual Likert-scale belief surveys addressing their perspectives of mathematics teaching and learning. Factor analysis identified two orthogonal factors, with seven items that distinguished beliefs associated with a traditional perspective emphasizing directed teaching and mathematical structure as a basis for curriculum (Traditional) and five items reflecting a perspective emphasizing student needs and understanding (Making Sense). While all 30 items within the beliefs instrument were entered in the factor analysis, only these items had sufficient variance as individual items and covariance as a set to make clear factors. This subset of items was included in a single factor

Table 9: Frequency of High Levels of Engagement between a Teacher and a Coach by Grade

Grade	**Percent of Treatment Teachers Coaches Rated as Highly Engaged with the Coach**	***n***
3	21.6%	407
4	23.6%	381
5	20.8%	351

analysis using Varimax rotation,[1] yielding the two factors with no cross-loadings, which were defined as the standardized factor scores mentioned above.

Findings for Grades 3, 4, and 5 student data are presented in Tables 10, 11, and 12, with the statistics for differing dependent variables presented in each column. The primary variable of interest (Coach in School) was not statistically significant at any grade for either overall or subscale scores. However, the coefficient associated with the coaches' increasing levels of experience was significant at Grade 3 ($p = 0.046$) and at Grade 5 ($p = 0.019$). That is, simply placing a mathematics coach in a school did not significantly impact students' overall mathematics achievement as measured by the SOL's. However, the positive impact of coaches became evident in the second year of placement (increase of 8.83 points [12% of a standard deviation] and 11.99 points [15% of a standard deviation] at Grade 3 and 5 respectively;) and continued to increase in their third year of placement (a 2-year gain of 17.66 points in Grade 3 [24% of a standard deviation] and 23.98 points in Grade 5 [30% of a standard deviation]).

The significant effect of Coach Experience at the school level was not evident in Grade 4. However, the variable High Engagement was statistically significant at Grade 4, the only grade evidencing this effect. That is, at Grade 4, the statistically significant positive impact of coaches on overall student achievement was limited to those classrooms where the coach had had a high level of engagement with a teacher, in which case the increase averaged 11.12 points ($p = 0.036$, 15% of a standard deviation). In addition, in Grade 4 and only in Grade 4, students who had teachers whose perspectives on mathematics teaching and learning emphasized student needs and understanding (a perspective potentially supported by coaches) also had significantly higher total SOL scores, averaging 5.53 additional SOL points ($p = 0.001$) for each standard deviation increase in the Making Sense factor.

The only other statistically significant effect on overall mathematics achievement scale scores at the school level was in Grade 4, where mean scores in High Minority Schools averaged 23.40 points higher than in other schools, controlling for High Minority Classrooms ($p = 0.007$). This variable was not significant at either Grade 3 or 5.

Years of teaching experience was not associated with differential performance in overall SOL mathematics scores at Grade 3, but it did significantly influence student achievement in Grades 4 and 5. In Grade 4, students in classrooms with 10 or more years of teaching experience averaged 7.86 more points on their total SOL mathematics score ($p = 0.045$, 10% of a standard deviation) as compared to students in classrooms with teachers having 5 to 9 years of experience. In Grade 5, this increase was even more pronounced, with an average increase of 14.32 points ($p = 0.001$, 18% of a standard deviation). In contrast, Grade 5 students in classrooms with teachers in their first 2 years of teaching averaged 27.03 points lower scores on the SOL's, as compared to students in classrooms with teachers having 5 to 9 years of experience ($p < 0.001$, 33% of a standard deviation).

Across all three grades, the individual effects of poverty, race/ethnicity, and special education status had consistently significant negative effects on total SOL mathematics scores as well as on most subscale scores ($p < 0.001$). In Grade 5, the impact of individual student race/ethnicity on overall SOL mathematics scores was moderated by the experience of a student's teacher. In this

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[1] In another factor analysis using oblique rotation, these two factors proved stable with a correlation of less than 0.15, so orthogonal rotation was used when creating the factor scores.

Table 10: Regression Coefficients (and p-values) by Grade 3 SOL Mathematics Overall Scale Score and Subscale Scores

	Scale Score		Number & Number Sense		Computation & Estimation		Geometry & Measurement		Probability & Statistics		Patterns, Functions & Algebra	
Intercept	**492.827**	**0.000*** **	**39.647**	**0.000*** **	**39.232**	**0.000*** **	**40.519**	**0.000*** **	**40.943**	**0.000*** **	**41.648**	**0.000*** **
School Variables												
Coach in School	1.242	0.840	0.077	0.906	0.356	0.595	0.072	0.905	-0.388	0.575	0.141	0.842
Coach Experience	**8.832**	**0.046***	**1.068**	**0.022***	0.773	0.107	0.691	0.108	0.604	0.214	**1.296**	**0.012***
High Minority School	5.103	0.515	0.302	0.718	0.722	0.404	0.839	0.292	-0.398	0.665	-0.303	0.736
Teacher Variables												
1 or 2 years experience	-4.446	0.349	-0.409	0.432	-0.241	0.650	-0.796	0.118	-0.395	0.519	**-1.023**	**0.048***
3 or 4 years experience	-4.706	0.287	-0.763	0.115	-0.533	0.283	-0.323	0.496	-0.470	0.411	0.486	0.313
≥ 10 years experience	-0.508	0.880	-0.117	0.749	-0.129	0.730	0.001	0.998	-0.104	0.809	0.452	0.212
High Engagement	-4.169	0.364	-0.169	0.734	-0.755	0.140	-0.169	0.728	0.029	0.961	-0.423	0.397
Traditional	-1.065	0.535	-0.011	0.953	-0.170	0.379	-0.046	0.802	-0.232	0.293	0.027	0.884
Making Sense	0.445	0.741	0.140	0.343	-0.061	0.687	0.044	0.760	-0.013	0.938	-0.097	0.509
High Minority Class	6.391	0.344	0.854	0.242	0.917	0.222	-0.064	0.928	1.388	0.090	-0.170	0.825
Student Variables												
Older Age at Testing	**-9.245**	**0.000*** **	**-0.628**	**0.001** **	**-1.019**	**0.000*** **	**-0.728**	**0.000*** **	**-1.403**	**0.000*** **	**-1.028**	**0.000*** **
Female	-2.170	0.128	**-1.119**	**0.000*** **	**0.417**	**0.017***	**-0.549**	**0.003** **	**0.693**	**0.002** **	-0.148	0.477
Special Ed (Disability)	**-43.583**	**0.000*** **	**-4.420**	**0.000*** **	**-3.603**	**0.000*** **	**-5.120**	**0.000*** **	**-4.800**	**0.000*** **	**-4.791**	**0.000*** **
Low SES (FARMS)	**-18.138**	**0.000*** **	**-1.634**	**0.000*** **	**-1.780**	**0.000*** **	**-1.671**	**0.000*** **	**-1.916**	**0.000*** **	**-1.491**	**0.000*** **
Minority Student	**-35.936**	**0.000*** **	**-3.692**	**0.000*** **	**-3.065**	**0.000*** **	**-3.569**	**0.000*** **	**-3.538**	**0.000*** **	**-2.903**	**0.000*** **

* $p < 0.05$ **$p < 0.01$ ***$p < 0.001$

Table 11: Regression Coefficients (and p-values) by Grade 4 SOL Mathematics Overall Scale Score and Subscale Scores

	Scale Score		Number & Number Sense		Computation & Estimation		Geometry & Measurement		Probability & Statistics		Patterns, Functions & Algebra	
Intercept	**470.188**	**0.000*** **	**37.876**	**0.000*** **	**36.934**	**0.000*** **	**36.146**	**0.000*** **	**35.733**	**0.000*** **	**37.305**	**0.000*** **
School Variables												
Coach in School	2.117	0.752	-0.226	0.751	0.507	0.508	-0.026	0.968	0.007	0.992	0.656	0.299
Coach Experience	4.250	0.363	0.294	0.552	0.833	0.119	0.115	0.799	0.529	0.230	0.483	0.264
High Minority School	**23.399**	**0.007** **	**2.697**	**0.004** **	**2.917**	**0.003** **	**1.982**	**0.017***	1.553	0.058	1.085	0.177
Teacher Variables												
1 or 2 years experience	-1.970	0.757	0.069	0.919	-0.610	0.390	0.108	0.862	-0.525	0.424	-0.257	0.686
3 or 4 years experience	-10.930	0.069	**-1.257**	**0.049***	-1.226	0.067	-0.643	0.272	-0.349	0.572	**-1.277**	**0.033***
≥ 10 years experience	**7.856**	**0.045***	0.403	0.330	**0.873**	**0.045***	**0.836**	**0.028***	**1.072**	**0.008** **	0.249	0.519
High Engagement	**11.123**	**0.036***	**1.117**	**0.046***	1.098	0.064	**1.284**	**0.013***	0.379	0.479	0.376	0.469
Traditional	1.151	0.538	0.086	0.663	0.245	0.240	-0.130	0.475	0.285	0.137	0.214	0.249
Making Sense	**5.527**	**0.001** **	**0.552**	**0.002** **	**0.400**	**0.031***	**0.499**	**0.003** **	**0.446**	**0.010***	**0.479**	**0.004** **
High Minority Class	-1.480	0.854	-0.880	0.309	-0.434	0.634	0.692	0.377	0.796	0.314	-0.587	0.449
Student Variables												
Older Age at Testing	**-14.591**	**0.000*** **	**-1.449**	**0.000*** **	**-1.121**	**0.000*** **	**-1.338**	**0.000*** **	**-1.484**	**0.000*** **	**-1.489**	**0.000*** **
Female	**-7.087**	**0.000*** **	**-1.519**	**0.000*** **	0.225	0.186	**-0.934**	**0.000*** **	**-1.025**	**0.002** **	-0.223	0.228
Special Ed (Disability)	**-38.904**	**0.000*** **	**-4.318**	**0.000*** **	**-2.646**	**0.000*** **	**-3.759**	**0.000*** **	**-3.876**	**0.000*** **	**-4.094**	**0.000*** **
Low SES (FARMS)	**-17.859**	**0.000*** **	**-1.932**	**0.000*** **	**-1.292**	**0.000*** **	**-1.444**	**0.000*** **	**-1.969**	**0.000*** **	**-1.686**	**0.000*** **
Minority Student	**-35.859**	**0.000*** **	**-3.640**	**0.000*** **	**-2.767**	**0.000*** **	**-3.258**	**0.000*** **	**-3.818**	**0.000*** **	**-2.938**	**0.000*** **

* $p < 0.05$ **$p < 0.01$ ***$p < 0.001$

Table 12: Regression Coefficients (and p-values) by Grade 5 SOL Mathematics Overall Scale Score and Subscale Scores

	Scale Score		Number & Number Sense		Computation & Estimation		Geometry & Measurement		Probability & Statistics		Patterns, Functions & Algebra	
Intercept	**494.891**	**0.000*** **	**40.356**	**0.000*** **	**38.861**	**0.000*** **	**38.000**	**0.000*** **	**39.232**	**0.000*** **	**38.993**	**0.000*** **
School Variables												
Coach in School	-5.760	0.426	-1.062	0.170	-0.468	0.527	-0.046	0.941	-0.667	0.836	-0.866	0.209
Coach Experience	**11.988**	**0.019***	0.981	0.069	**1.099**	**0.034***	0.663	0.116	**1.436**	**0.003****	**1.024**	**0.033***
High Minority School	7.407	0.423	0.058	0.953	0.239	0.801	1.107	0.157	-0.334	0.701	1.474	0.095
Teacher Variables												
1 or 2 years experience	**-27.026**	**0.000*** **	**-2.758**	**0.000*** **	**-1.806**	**0.013***	**-2.812**	**0.000*** **	**-2.158**	**0.005****	**-2.366**	**0.001****
3 or 4 years experience	9.435	0.121	1.020	0.100	0.465	0.452	0.694	0.220	0.415	0.525	0.980	0.090
≥ 10 years experience	**14.323**	**0.001****	**1.493**	**0.001****	**0.938**	**0.035***	**0.995**	**0.014***	**1.417**	**0.003****	**1.127**	**0.007****
High Engagement	6.992	0.234	**1.407**	**0.019***	-0.039	0.949	0.255	0.637	0.625	0.314	**1.112**	**0.046***
Traditional	-2.780	0.200	**-0.513**	**0.021***	-0.021	0.925	-0.229	0.257	-0.383	0.101	-0.031	0.883
Making Sense	-1.373	0.485	-0.040	0.843	-0.260	0.196	-0.092	0.613	-0.207	0.325	-0.015	0.935
High Minority Class	6.205	0.483	**2.162**	**0.024**	0.828	0.363	0.229	0.761	1.604	0.056	-1.373	0.104
Student Variables												
Older Age at Testing	**-14.751**	**0.000*** **	**-1.358**	**0.000*** **	**-1.225**	**0.000*** **	**-1.093**	**0.000*** **	**-1.553**	**0.000*** **	**-1.323**	**0.000*** **
Female	-0.870	0.565	**-0.906**	**0.000*** **	0.341	0.064	**-0.744**	**0.000*** **	**0.881**	**0.000*** **	0.077	0.655
Special Ed (Disability)	**-50.715**	**0.000*** **	**-5.128**	**0.000*** **	**-3.424**	**0.000*** **	**-4.431**	**0.000*** **	**-5.642**	**0.000*** **	**-4.797**	**0.000*** **
Low SES (FARMS)	**-17.643**	**0.000*** **	**-1.391**	**0.000*** **	**-1.431**	**0.000*** **	**-1.336**	**0.000*** **	**-1.506**	**0.000*** **	**-1.642**	**0.000*** **
Minority Student	**-27.775**	**0.000*** **	**-2.431**	**0.000*** **	**-1.845**	**0.000*** **	**-2.732**	**0.000*** **	**-2.043**	**0.000*** **	**-2.487**	**0.000*** **
With teacher having 1 or 2 years experience	**-17.713**	**0.049***	-2.394	0.056	**-2.276**	**0.036***	-1.927	0.057	-0.378	0.739	-1.410	0.173
With teacher having 3 or 4 years experience	**18.542**	**0.017***	**2.123**	**0.048***	**2.345**	**0.012***	1.525	0.080	0.669	0.493	1.367	0.124
With teacher having ≥ 10 years experience	-6.037	0.217	0.426	0.549	-1.100	0.072	-0.479	0.407	-0.743	0.247	-0.532	0.365

* $p < 0.05$ **$p < 0.01$ ***$p < 0.001$

grade, teachers in their first or second year of teaching had an additional negative effect averaging a loss of 17.7 points on their minority students' total SOL scores for mathematics, as compared to the scores of minority students in the classrooms of teachers with 5 to 9 years of teaching experience ($p = .049$). This was in addition to the negative effect associated with novice teachers found at the classroom level for all Grade 5 students. In contrast, minority students in the classrooms of teachers with 3 or 4 years of experience had, on average, higher overall SOL scores in mathematics as compared to the minority students of teachers with 5 to 9 years of experience (average increase of 18.54 points; $p =0.017$). That is, in Grade 5, the mathematics achievement of minority students was negatively impacted by novice teachers, an additive effect coupled to the negative impact that novice teachers had on all Grade 5 students, but this additional differential impact on minority students' mathematics achievement not only dissipated, it reversed once teachers had reached their third year of teaching.

Tables 10, 11, and 12 also present HLM results for all SOL subscales for Grades 3-5. Generally these results explain the findings for the total overall SOL scores for mathematics. For example, in Grade 5, the significant positive effect of experienced coaches on the total SOL scores was most evident in the three subscales of Computation and Estimation, Probability and Data Analysis, and Algebra, Patterns and Functions.

Discussion

Mathematics coaches are placed in elementary schools to construct leadership roles and to provide professional development addressing mathematical content, pedagogy, and curriculum. Theoretically, these leaders support collective collaborative professional development, providing knowledgeable "critical collegiality" (Lord, 1994). But, substantive change is neither rapid nor consistent. Coaches are called upon to navigate not only the complexity of teaching and student learning as it emerges in the classrooms of multiple teachers, but to do so while provoking the development of those teachers by advocating for their change, nurturing their performance, advancing their thinking, increasing their mathematical understanding, and saluting their attempts (Campbell & White, 1997). This is a demanding role, and a role that the profession does not understand and is only beginning to examine.

This study found that elementary mathematics coaches had a significant positive impact on student achievement over time, particularly in Grades 3 and 5, but this effect only emerged as a coach gained experience in the position. Simply allocating funds and then filling the position of elementary mathematics coach in a school will not yield increased student achievement. A coach's positive effect on student achievement develops as a knowledgeable coach and the instructional and administrative staffs in the assigned school learn and work together. This study's results indicate that in Grade 4 the positive relationship between coaches and student mathematics achievement was restricted to those students whose teachers had a high level of engagement with a coach. Further analysis of the PDA data may allow further interpretation of this grade-related result. For example, further examination of the Weekly Reflection Logs may reveal patterns of engagement in Grade 4 that are unique from those in Grades 3 and 5.

The coaches in this study worked with individual teachers, and the teaching experience of the teachers mattered. Across the treatment and control schools, the degree of prior teaching experience of teachers had a significant impact on student mathematics achievement, particularly for students in Grade 5. The mathematics achievement of students in the fifth-grade classrooms of novice teachers (teachers in their first 2 years of teaching) was substantially lower than that of fifth graders who benefited from more experienced teachers. Further, the SOL scores of minority students in Grade 5 who were assigned to novice teachers were, on average, approximately 45 points lower than the SOL scores of minority students assigned to teachers with 5 or more years of teaching experience. This result has implications for school staffing policies, particularly for consideration of the placement of teachers from programs such as Teach for America who may only be in a school for1 or 2 years. There is no evidence that the coaches in this study impacted the negative differential effects on student achievement frequently associated with student poverty and race/ethnicity.

As inferred from the PDA data, the coaches in this study were more likely to focus their coaching efforts on individual teachers, rather than on leading grade-level planning teams. The time that they had to coach individual teachers seemed to diminish over the 3 years of data collection, while the time that they devoted to supporting student assessment demands increased. While this pattern was evident across schools in each of the five cooperating school districts, it was particularly evident in the schools within the urban districts where a frequent pattern was time allocated to managerial aspects of assessment accompanied by time spent working with students without an observing teacher. It is recognized that if a teacher is absent on a given day, many administrators request that the school's mathematics coach, rather than the assigned substitute teacher, teach the mathematics lesson to that teacher's class on that day. However, this practice is not unique to urban districts. Each year, the PDA data revealed one or two schools where the percent of time that a coach spent providing mathematics instruction to students without an observing teacher ranged from 8 to 17%, making these locations virtual outliers in comparison to all the other schools. The identity of these schools varied somewhat from year to year, but they were always in the urban districts. The long-term impact of this practice may have diminishing returns because while the attention that a coach devotes to working with groups of students may positively impact the performance of those students on an annual standardized assessment such as the SOL's, the instructional knowledge and approaches of their teachers are not being addressed. Over time, those teachers may influence many more students.

The coaches who are the subjects of this study engaged in substantive academic coursework that was designed to foster and support their transition to the position of whole-school elementary mathematics coach. As such, the results herein should not be generalized to other settings where an experienced teacher is simply named as the school-based mathematics coach with little or no prior professional development addressing the responsibilities and expertise presumed of coaches. Further, recently there have been recommendations that schools employ a specialized teacher model, particularly in the upper elementary grades, in which all students receive their mathematics instruction from a mathematically well-prepared teacher (National Mathematics Advisory Panel, 2008). While many of the cooperating districts in this study used the term "mathematics specialist" to describe their assigned coaches, the model of a specialized teacher for instruction was not implemented in this study. In the cooperating school districts where this study took place, a whole-school elementary mathematics coach was deemed more feasible financially and programmatically.

References

Ai, X., & Rivera, N. (2004). Linking ideas to practice: Effectiveness of coaching upon teacher practice. In Gangel, J., & Guyton, E. (Eds.), *Teacher education yearbook XIII: Research on alternative and non-traditional teacher education* (pp. 191-204). Lanham, MD: Rowman and Littlefield.

Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners: Toward a practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). San Francisco: Jossey-Bass.

Becker, J. R. (2001). Classroom coaching: An emerging method of professional development. In *Proceedings of the annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 751-760). Snowbird, UT.

Borasi, R., & Fonzi, J. (2002). Professional development that supports school mathematics reform. *Foundations, 3* [National Science Foundation Monograph 02-084]. Arlington, VA: National Science Foundation.

Campbell, P. F. (1996). Empowering children and teachers in the elementary mathematics classrooms of urban schools. *Urban Education*, *30*, 449-475.

Campbell, P. F., & White, D. Y. (1997). Project IMPACT: Influencing and supporting teacher change in predominantly minority schools. In E. Fennema and B. S. Nelson (Eds.), *Mathematics teachers in transition* (pp. 309-355). Mahwah, NJ: Erlbaum.

Corcoran, T. N. (2008, March). *The work of instructional coaches: Roles, relationships, tasks, and tools*. Presentation at the Annual Meeting of the American Educational Research Association, New York.

Dempsey, N. (2007). Five elements combine in a formula for coaching: South Carolina initiative carves out time for science and math coaches in schools. *Journal of Staff Development*, 28(2), 10-13.

Driscoll, M. (2007, April). *Managing complexity in mathematics coaching*. Paper presented at the Professional Continuum Conference (National Science Foundation-Educational Development Corporation) "Instructional Coaching in Mathematics: Researchers and Practitioners Learning Together." Boston, MA. Retrieved March 16, 2009, from https://secure.edc.org/mlt/conference07/Articles/M.Driscoll.doc

Foster, D. (2007, April). *Pedagogical content coaching*. Paper presented at the Professional Continuum Conference (National Science Foundation-Educational Development Corporation) "Instructional Coaching in Mathematics: Researchers and Practitioners Learning Together." Boston, MA. Retrieved March 16, 2009, from https://secure.edc.org/mlt/conference07/Articles/D.Foster.doc

Foster, D., & Noyce, P. (2004). The Mathematics Assessment Collaborative: Performance testing to improve instruction. *Phi Delta Kappan*, *85*(5), 367-374.

Fosnot, C. T., & Dolk, M. (2002). *Young mathematicians at work: Constructing fractions, decimals and percents*. Portsmouth, NH: Heinemann..

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*, 915-945.

Glod, M. (2007, December 26). Elementary math grows exponentially tougher. *Washington Post*, p. A01.

Joyce, B., & Showers, B. (1980). Improving inservice training: The messages from research. *Educational Leadership*, *51*(2), 57-61.

Keller, B. (2007, December 12). Coaching teachers to help students learn. *Education Week*, *27*(15), pp. 22-24.

Lamon, S. J. (1999). *Teaching fractions and ratios for understanding: Essential content knowledge and instructional strategies for teachers*. Mahwah, NJ: Erlbaum.

Little, J.W. (1993). Teachers' professional development in a climate of educational reform. *Educational Evaluation and Policy Analysis*, *15*, 129-151.

Lord, B. (1994). Teachers' professional development: Critical colleagueship and the role of professional communities. In N. Cobb (Ed.), *The future of education: Perspectives on national standards in education* (pp. 175-204). New York: College Entrance Examination Board.

Loucks-Horlsey, S., Harding, C. K., Arbuckle, M. A., Murray, L. B., Dubea, C., & Williams, M. K. (1987). *Continuing to learn: A guidebook for teacher development*. Andover, MA: The Regional Laboratory for Educational Improvement of the Northeast and Islands and The National Staff Development Council.

Loucks-Horsley, S., Love, N., Stiles, K., Mundry, S., & Hewson, P. (2003). *Designing professional development for teachers of science and mathematics*. Thousand Oaks, CA: Corwin Press.

Marzano, R., Walters, T., & McNulty, B. (2005). *School leadership that works: From research to results*. Alexandria, VA: Association for Supervision and Curriculum Development.

Miller, B., Moon, J., & Elko, S. (2000). *Teacher leadership in mathematics and science: Casebook and facilitator's guide*. Portsmouth, NH: Heinemann.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

National Mathematics Advisory Panel. (2008). *Foundations for success: Findings and recommendations from the National Mathematics Advisory Panel* (ED 00424P). Washington, DC: US Department of Education.

National Research Council. (2001). *Adding it up: Helping children learn mathematics*. Washington, D.C.: National Academy Press.

Neufeld, B., Baldassari, C., Johnson, C., Parker, R., & Roper, D. (2002, January). *Using what we know: Implications for scaling-up implementation of the CCL model*. Cambridge, MA: Education Matters. Retrieved January 23, 2008, from http://www.edmatters.org/reports.html#ccl1

Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity.* Cambridge, MA: Education Matters. Retrieved December 31, 2008, from http://www.edmatters.org/CoachingPaperfinal.pdf

Neufeld, B., Roper, D., & Baldassari, C. (2003, July). *Year 1 of Collaborative Coaching and Learning in the Boston Public Schools: Accounts from the schools.* Cambridge, MA: Education Matters. Retrieved January 23, 2008, from http://www.edmatters.org/reports.html#cc1

Poglinco, S. M., & Bach, A. J. (2004). The heart of the matter: Coaching as a vehicle for professional development. *Phi Delta Kappan*, *85*, 398-400.

Poglinco, S., Bach, A. J., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003, May). *The heart of the matter: The coaching model in America's Choice schools*. Philadelphia: University of Pennsylvania, Consortium for Policy Research in Education. Retrieved October 8, 2007, from http://www.cpre/org/images/stories/cpre_pdfs/AC-06.pdf

Rodgers, A., & Rodgers, E. M. (2007). *The effective literacy coach: Using inquiry to support teaching and learning*. New York: Teachers College Press.

Ross, J. A., McDougall, D., Bruce, C., Jafaar, S. B., & Lee, J. (2004). A multi-dimensional approach to mathematics in-service. In *Proceedings of the annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. Toronto, ON: University of Toronto, Ontario Institute for Studies in Education.

Ross, J. A., McDougall, D., Hogaboam-Gray, A., & LeSage, A. (2003). A survey measuring elementary teachers' implementation of standards-based mathematics teaching. *Journal for Research in Mathematics Education*, *34*, 344-363.

Russo, A. (2004). School-based coaching: A revolution in professional development – or just a fad? *Harvard Education Letter*, *20*(4), 1-4.

Schifter, D., Bastable, V., & Russell, S. J. (1999). *Number and operations, Part 1: Building a system of tens*. Parsippany, NJ: Dale Seymour.

Smith, M. (2001). *Practice-based professional development for teachers of mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Spillane, J. P. (2000). Cognition and policy implementation: District policymakers and the reform of mathematics education. *Cognition and Instruction*, *18*, 141-179.

Spillane, J. P., & Thompson, C. L. (1997). Reconstructing conceptions of local capacity: The local education agency's capacity for ambitious instructional reform. *Educational Evaluation and Policy Analysis*, *19*, 185-203.

Stein, M., Smith, M., & Silver, E. (1999). The development of professional developers: Learning to assist teachers in new settings in new ways. *Harvard Educational Review*, 69, 237-269.

Supovitz, J. A. (2001). Translating teaching practice into improved student achievement. In S. H. Fuhrman (Eds.), *From the capitol to the classroom: Standards-based reform in the states* (pp. 81-98). Chicago: University of Chicago Press.

Thompson, C. L., & Zeuli, J. S. (1999). The frame and the tapestry: Standards-based reform and professional development. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 341-375). San Francisco: Jossey-Bass.

Valencia, S., & Killion, J. (1988, Spring). Overcoming obstacles to teacher change: Direction from school-based efforts. *Journal of Staff Development*, *9*(2), 2-8.

West, L., & Staub, F. C. (2003). *Content-focused coaching*. Portsmouth, NH: Heinemann.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.) *Review of research in education* (Vol. 24, pp. 173-209). Washington, DC: American Educational Research Association.

Wood, T., Nelson, B. S., & Warfield, J. (2001). *Beyond classical pedagogy: Teaching elementary school mathematics*. Mahwah, NJ: Erlbaum.

York-Barr, J. & Duke, K. (2004). What do we know about teacher leadership? Findings from two decades of scholarship. *Review of Educational Research*, *74*, 255-317.