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Mathematics Coaching Knowledge: Domains and Definitions

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A coach can be broadly defined as a person who works collaboratively with a teacher to improve that teacher's practice and content knowledge, with the ultimate goal of affecting student achievement. The National Mathematics Advisory Panel (2008) reports that school districts across the country are using mathematics specialists, including coaches, to improve instruction in elementary school systems. They also note that there is little research supporting the effectiveness of mathematics specialists.

Though limited, the evidence supporting the effectiveness of mathematics coaches is growing. There are a handful of studies showing indications of a connection between coaching and student mathematics achievement (Brosnan & Erchick, 2009; Campbell, 2010; Campbell & Malkus, 2009; Meyers & Harris, 2008; Wilkins, 1997), and if we broaden our focus to coaching in any content area, there is additional evidence that coaching is effective in supporting teacher change (Bowman & McCormick, 2000; Doughtery, 1993; Heberly, 1991; Kohler, Crilley, Shearer, & Good, 1997; Munro & Elliott, 1987; Showers & Joyce, 1996; Sparks & Bruder, 1987; Wineburg, 1995). A result of particular interest to professional developers is a finding by Knight (2004) that, within the first six weeks of the school year, instructional coaches reported that 85% of coached teachers had implemented at least one strategy learned in a summer workshop, compared to 10% of teachers who received no coaching support. Other studies have shown that coached teachers are more likely to engage in collaborative activities and that coached teachers believe their students learn more because their practice has been strengthened as a result of being coached (Sparks & Bruder, 1987; Smylie, 1989).

Not every study has found positive effects for coaching. Murray, Ma, and Mazur (2009) found no increases in student achievement due to peer coaching. Gutiérrez, Crosland, and Berlin (2001) found that coached teachers did not change their instruction in substantive ways. Olson and Barrett (2004) found that individual coaching sessions had limited success in supporting teachers' professional growth. These findings raise important questions about what it means to be an effective coach.

A closer look at one of the studies of mathematics coaching offers insights into a difficulty in studying its impact on instruction and student performance. While Campbell and Malkus (2009) found that the use of elementary school mathematics coaches had a significant positive impact on student achievement, the effect only emerged as a coach gained experience in the position. Moreover, the mathematics coaches in the study were highly trained, having completed five mathematics content courses and two leadership courses specifically designed to prepare them for their coaching assignments. According to Campbell and Malkus (p. 22), "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 staff in the assigned school learn and work together" [emphasis added].

Exactly what knowledge is required to create a "knowledgeable coach"? Clearly, mathematics coaches should possess mathematics content knowledge, but what additional knowledge and skills are held by effective instructional coaches? While the literature is rich in providing details about what constitutes mathematical content knowledge

(Hill, Rowan, & Ball, 2005; Ball, Bass, & Hill, 2003; Shulman, 1986), mathematics coaching knowledge has largely been without formal definition.

Identifying what constitutes the knowledge for coaching is a dilemma that affects school leaders as well as researchers. With many schools turning to coaching as a school-based effort to increase teacher effectiveness and student achievement, a challenge presented to these institutions is determining what knowledge is held by effective instructional coaches. Currently, school leaders must wade through an impressive amount of literature to try to identify knowledge domains for effective coaching. (See Deussen, Coskie, Robinson, & Autio [2007] for an in-depth but not complete review of coaching literature.)

This article will describe efforts by the research project Examining Mathematics Coaching (EMC)[1] to define mathematics coaching knowledge. EMC is a five-year research and development project examining the effects of a coach's knowledge for coaching on a diverse population of K-8 teachers. Project leaders believe that knowledge of coaching significantly affects a coach's effectiveness as measured by impact on teacher practice, attitudes, and beliefs, and ultimately student achievement. EMC recognizes that researchers, professional development providers, and school leaders could benefit from more clearly defined knowledge domains for mathematics coaching. From the research point of view, exploring the impact of mathematics coaches using well-defined knowledge domains will lead to closer examination of the impact of mathematics coaches who seem knowledgeable and well-prepared for their coaching roles.

To establish coaching knowledge domains and develop an operational definition of coaching knowledge that capitalizes on the existing knowledge of experts in the field of mathematics coaching, EMC researchers convened a panel of experts. This work resulted in a set of domains of mathematics coaching knowledge and a definition for each domain.

Methodology for Creating Domains and Definitions

The project chose to use a modified Delphi method as its means to convene the expert panel. This method allowed us to bring experts in mathematics coaching to consensus around a particular topic and enhance decision-making. (For more information on the Delphi method and the variations it can take, consult Clayton, 1997; Garavalia & Gredler, 2004; and Chamberlin, 2008, and the references contained therein.) Through a series of online, text-based surveys, EMC engaged 12 panel members in three phases over 18 days. Of the 12 panelists, six are authors or co-authors of coaching or mathematics coaching books; four are directors of grant-funded professional development projects on mathematics coaching; one is a mathematics coaching practitioner; and one has studied coaching as a researcher in mathematics education. The panelists did not interact directly with each other, and EMC researchers did not know the specific authorship of panelist contributions.

The EMC Project provided expert panel members with this definition of mathematics coaching: "*A mathematics coach is an on-site professional developer who enhances teacher quality through collaboration focusing on research-based, reform-based, and standards-based instructional strategies and mathematics content that includes the why, what, and how of teaching mathematics.*" Throughout the process, panelists were asked to reflect on models of coaching and report areas of coaching knowledge, unique from teaching knowledge, that contribute to effective mathematics coaching. The EMC researchers then identified domains of knowledge using qualitative analysis techniques.

At the conclusion of the panel's contributions, EMC researchers examined the panelists' responses to determine whether or not there was consensus among respondents regarding the definition of coaching knowledge provided. Based on the responses provided by panel participants, eight domains of coaching knowledge were initially identified by EMC researchers. (See Table 1 below.)

Table 1

DOMAINS OF MATHEMATICS COACHING KNOWLEDGE	
Assessment	Student Learning
Communication	Teacher Development
Leadership	Teacher Learning
Relationships	Teacher Practice

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The domains and draft definitions of each were then given back to the panel for critique and elaboration, although because the EMC researchers concluded that the domain and definition of communication were consistently and sufficiently identified and defined by panelists from the outset, "communication" was not included in the subsequent analysis by the panel. Once the collective thinking regarding these domains of mathematics coaching knowledge and definitions for each of the remaining seven domains were established, the expert panel provided individual levels of agreement and responded to open-ended questions on aspects of each of these definitions.

Using a five-point scale (1=strongly disagree, 2=disagree, 3=neither agree nor disagree, 4=agree, and 5=strongly agree), panelists rated their levels of agreement to definitions for each domain of mathematics coaching knowledge using two prompts: 1. This definition captures my thinking related to coaching knowledge of [each knowledge domain], and 2. This definition informs my work related to coaching knowledge of [each knowledge domain]. Based on analysis by EMC researchers, there was a high level of agreement and high level of consensus among panelists for the definitions of each of the seven domains.

Respondents were also asked to provide additional comments on definitions based on four open-ended questions that addressed words, phrases, or key features that respondents may have considered missing, unclear, or superfluous in each definition of each domain. The open-ended questions are presented in Table 2.

Based on responses from the expert panel, EMC revised the definitions of the seven domain areas, and these along with the initial definition of the domain of communication are reported in Table 3 (see pages 17-19). This generation of EMC Project-specific definitions, which reflected the EMC researchers' knowledge while considering the panelists' comments, allowed the definitions to be modified in ways that eliminated laundry lists, addressed any ambiguity in the articulation of skills, practices, and beliefs, and also framed the definitions in terms of knowledge. Some ideas were also moved from one domain to another by EMC researchers who applied a project-based filter that considered what a coach needed to know beyond what a teacher needed to know.

The EMC Project's primary purpose for conducting the study was to inform and guide instrument development to measure mathematics coaching knowledge. To help the reader understand how the panel definitions provided distinct ways of thinking about mathematics coaching knowledge, and how that allowed the project to enhance the definitions for the specific purpose of instrument development, both definitions are contained in Table 3, organized by domains.

Table 2

OPEN-ENDED QUESTIONS PERTAINING TO COACHING KNOWLEDGE DEFINITIONS
For each of seven coaching knowledge areas (100 words or less):
1. What words, phrases, or key features for the definition (if any) do you feel are missing and need to be considered for inclusion in the final definition?
2. What words, phrases, or key features (if any) do you feel are particularly unclear and need to be restated to minimize confusion or misunderstanding?
3. What (if anything) do you feel could or should be removed from the definition?
4. What other comments or suggestions do you have to enhance the overall quality and utility of the definition?

Use of Domains and Definitions

These domains and definitions present a starting point for further analysis of mathematics coaching knowledge. Until this effort by the EMC Project, identification of domains of knowledge and definitions for that knowledge were not compiled in a single resource. We believe that the present work has moved the field of coaching forward by identifying mathematics coaching knowledge domains and definitions with a high level of agreement and consensus among experts. We invite other projects and institutions to use these domains and definitions as a starting point for their own work on mathematics coaching.

For example, districts that employ mathematics coaches could use these coaching knowledge domains and definitions to identify teacher leaders who might be well-prepared to take on mathematics coaching roles. In addition, districts could use these domains to identify professional development courses that would be helpful for mathematics

coaches. The EMC Project, in fact, has designed its own week-long professional development course for project coaches (to be given in 2011 and 2012) that addresses each of the mathematics coaching knowledge domains.

Other potential users of these domains and definitions are supervisors of mathematics coaches, who could use these domains and definitions to inform their support of mathematics coaches in the field. In our own project, we are able to identify which coaches appear to demonstrate the mathematics coaching knowledge domains and definitions identified in this study, and we are working to understand how these mathematics coaches make an impact on teacher practice and student achievement. This could lead to a better understanding of the degree to which specific knowledge domains contribute to desired impacts. To that end, the EMC Project has developed an instrument containing items based on the mathematics coaching knowledge definitions formed by the panel and is using this instrument to measure changes in coaching knowledge. (This EMC instrument is available for use by other educators and researchers; please contact the authors for more information.)

Of course, definitions also have value in providing a structure around which a community can reach a common understanding. We have presented these definitions at a number of national conferences and engaged participants in examining these definitions, and over time it has become clear that participants regard the definitions as very comprehensive. Some observers have expressed a concern about how realistic it is to expect a mathematics coach to know everything in every domain. It is our position that the definitions represent a starting point, so that as the community of mathematics coaches evolves, these definitions will be open to modification and discussion.

Indeed, as studies like the EMC Project continue to yield results, researchers may find that mathematics coaches who seem to have this coaching knowledge may still not have the impact one would expect because of constraints that emerge during the actual practice of mathematics coaching. This is why strong productive collaborations between mathematics coaches and the instructional and administrative staff in schools are also essential.

It may also be the case that even with the support of knowledgeable mathematics coaches, teachers may also need the support of ongoing school-based or district-based professional development that allows for in-depth explorations of mathematics content knowledge and pedagogical content knowledge as well as other aspects of mathematics teaching and learning.

Finally, even knowledgeable mathematics coaches are likely to continue to need their own professional development as they continue to work to reflect on and strengthen their mathematics coaching practice in a wide range of contexts that include a wide range of challenges.

Table 3

PROJECT DEFINITIONS OF KNOWLEDGE DOMAINS AND MODIFIED DEFINITIONS DERIVED FROM PANEL DEFINITIONS AND PHASE THREE PANELIST COMMENTS

	Panel Definitions	Project-Modified Definitions for Instrument Development
Assessment	A coach knows how to diagnose teachers' needs —personal, instructional, content, and management—and how data and assessment of student thinking inform instruction and work with teachers. The coach knows how to assess and use teacher content knowledge and pedagogical content knowledge to inform, grow, and support teachers. A coach deeply understands formative and summative classroom assessment and knows how to set goals for assessing effectiveness of lessons. A coach also knows how to select, adapt, and align curricula with assessments; knows how to use common learning trajectories; and knows when looking at student work is better than looking at numerical assessment results. The coach knows how to help teachers use assessment data to make informed decisions about instruction and student learning, and knows what teachers know about assessment, including different types, their uses, and limits.	A coach knows how to assess teachers' needs—personal, instructional, content, and management—and how to assess and use teacher content knowledge and pedagogical content knowledge to inform and support teachers. A coach knows how to determine what teachers know about assessment, including different types, their uses, and limits. A coach knows how to use data and assessment of student thinking to inform her or his work with teachers. A coach knows how to help the teacher learn how to set goals and assess lesson effectiveness. A coach also knows how to help the teacher learn when looking at student work is better than looking at numerical assessment results. The coach knows how to help teachers interpret and use assessment data to make informed decisions about instruction and student learning.
Communication	A coach knows how to communicate professionally with others about students, curriculum, and classroom practice. A coach knows how to mediate a conversation, by pausing, paraphrasing, probing, and inquiring. A coach knows how to ask reflective questions. A coach knows how to use nonverbal communication and knows how to listen actively in conversation. A coach knows how to communicate in problem-resolving conversations.	
Leadership	A coach knows leadership models and possesses the ability to identify, define, and communicate specific goals and objectives that relate to student success and align with the institution's vision for mathematics. The coach uses this vision and knowledge to inform work with other school leaders, to highlight the gap between teachers' espoused beliefs and actions, to develop trust with teachers and administrators, and to develop a deep understanding of the professional development process and impacts. A coach knows various ways to address challenges and how to communicate in ways that advocate for, negotiate with, and influence others.	A coach knows how to strategically identify, define, and communicate specific goals and objectives that relate to student success and teachers' professional growth, and align with the institution's vision for mathematics. The coach uses this vision and knowledge to inform her or his work with other school leaders, to bridge the gap that may exist between teachers' beliefs and their ability to implement instruction that reflects those beliefs, to earn trust with teachers and administrators, and to enhance teachers' content knowledge. The coach knows whether educational structures and policies impede or promote students' equitable access to quality instruction. The coach knows how to hold teachers, administrators, and schools accountable. The coach knows the coaching process and how to implement it. The coach knows how to address challenges and how to extend teacher cognitive processes regarding instruction – planning, doing, reflecting – and how to advocate for, negotiate with, and influence others.

Table 3 (continued)

	Panel Definitions	Project-Modified Definitions for Instrument Development
Relationships	A coach knows how to communicate professionally with a variety of audiences, and knows how to establish and maintain rapport and credibility with teachers based on trust, empathy, mutual understanding, and confidentiality. A coach knows about environments where positive relationships take place, including challenging and safe learning environments for teachers and students, collaborative working environments, and environments where people share common beliefs and goals with honest reflection. The coach knows how autonomy, issues of authority, and socio-cultural aspects of class, race, and gender for students and teachers influence relationships. A coach knows a range of concepts, theories, and frameworks (e.g., adult development, educational belief systems, cognitive styles, etc.) and how those relate to teachers, teachers' views of teaching and learning, and students.	The coach knows that the coaching relationship is grounded in content and how to use the relationship to support self-directedness in teachers. A coach knows how to communicate professionally with a variety of audiences, and knows how to establish and maintain rapport and credibility with teachers and other stakeholders based on trust, empathy, mutual understanding, and confidentiality. A coach knows about environments where positive relationships take place, including challenging and safe learning environments for teachers and students, collaborative working environments, and environments where people share common beliefs and goals with honest reflection. The coach knows how to work within the specific culture of the district and school. The coach knows how autonomy, issues of authority, and socio-cultural aspects of class, race, and gender for students and teachers influence relationships and influence perceptions and models of help and authority.
Student Learning	A coach knows how to create and manage mathematical learning environments that mediate factors in the K-8 spectrum including students' prior learning, age, race, gender, economic status, special needs, socio-cultural events, and school/district dynamics. A coach knows how to analyze student thinking and conduct mathematical error analysis, and has facility with a variety of instructional formats and strategies (mathematical discourse, mathematical exploration, meta-cognition, etc.) that help students engage in challenging and meaningful mathematics problems and tasks. A coach knows how to develop and how to provide teachers with learning opportunities aimed at improving student learning by analyzing student work.	A coach knows how to support teachers in analyzing student thinking and conducting mathematical error analysis, and knows how to support teachers in acquiring facility with mathematical processes (mathematical discourse, mathematical exploration, meta-cognition, etc.) that help students engage in challenging and meaningful mathematics problems and tasks. A coach knows how to develop and how to provide teachers with learning opportunities aimed at improving student learning by analyzing student work and student ideas as they are presented in the classroom. A coach knows how to help teachers recognize evidence of learning potential and deficits in student work. A coach knows how to help teachers become proficient at creating and managing mathematical learning environments in the K-8 spectrum. A coach knows how to support teachers in acquiring the ideas and the continuum of ideas in the K-8 mathematics classroom. A coach knows the research about student learning in mathematics.

Table 3 (continued)

	Panel Definitions	Project-Modified Definitions for Instrument Development
Teacher Development	A coach knows various models of teacher stages of development, adult change, and the continuum of learning that teachers often experience (e.g., from beginning to experienced to expert teacher). A coach knows how to diagnose where a teacher is, recognize potential learning trajectories, and differentiate strategies to support an individual teacher's growth. A coach knows the motivations for growth and barriers to growth and recognizes the role of reflection and feedback.	A coach knows various models of teacher stages of development, adult change, and the continuum of learning (e.g., from beginning to experienced to expert teacher; or from an unsophisticated view of teaching to a sophisticated one) that teachers often experience in exploring content knowledge, pedagogy, beliefs, and management. A coach knows how to ascertain a teacher's understanding of mathematics, teaching, and learning and is able to differentiate experiences to support an individual teacher's learning. A coach knows teachers' motivations for learning and barriers to learning and supports the development and use of reflection and feedback to enhance teaching and learning.
Teacher Learning	A coach knows about teacher motivations; the myriad ways that teachers know and understand mathematics content; and the teacher's pedagogical and pedagogical content needs, which may or may not be recognized by the teacher. A coach knows developmental continuums, potential learning trajectories, and teacher beliefs about learning. A coach knows how to develop tasks that support teacher learning through reflective practice and self-directed goal-setting, and knows when to consult and when to collaborate. A coach knows there can be a gap between a teacher's knowing a strategy and effectively using a strategy.	A coach knows about internal and external teacher motivations and about effectively engaging teachers in the coaching process. A coach knows the myriad ways teachers know and understand mathematics content and the teacher's pedagogical and pedagogical content needs, which may or may not be recognized by the teacher. A coach knows about how an individual teacher best learns, incorporating knowledge about developmental continuums and teacher beliefs about learning. A coach knows how to support teacher learning through reflective practice and self-directed goal-setting. A coach knows how to help teachers recognize that there may be a discrepancy between vision and practice and how to help the teacher address that discrepancy.
Teacher Practice	A coach knows teacher beliefs about teaching practice, along with a depth and breadth of knowledge of all types of practice for effective management and learning (e.g., lesson planning, school support structures, learning environments, models of instruction, mathematical tasks, assessment, and strategies that support students based on factors such as age, gender, culture and ELLs, etc.). A coach knows when to use these and how they translate into teacher actions in classrooms for effective teaching and learning. Additionally, a coach knows research on effective teaching and learning, instructional strategies, and cognitive development on how children and adolescents learn.	A coach knows how to discern teacher beliefs about mathematics teaching practice and holds a depth and breadth of knowledge of all types of practice and instructional resources for effective management and mathematics learning. A coach knows how these practices and resources translate into teacher actions in mathematics classrooms for effective teaching and learning.

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