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Call for Manuscripts

The editors of the ***NCSM Journal of Mathematics Education Leadership*** are interested in manuscripts addressing issues of leadership in mathematics education and reflecting a broad spectrum of formal and informal leadership at all —levels. Categories for submittal include:

- **Key topics** in leadership and leadership development
- **Case studies** of mathematics education leadership work in schools and districts or at the state level and the lessons learned from this work
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- **Commentaries on critical issues** in mathematics education
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***Note:** Information for manuscript reviewers can be found on the inside back cover of this publication.

NATIONAL COUNCIL OF SUPERVISORS OF MATHEMATICS (NCSM)

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Purpose Statement

The ***NCSM Journal of Mathematics Education Leadership*** is published at least twice yearly, in the spring and fall. Its purpose is to advance the mission and vision of the National Council of Supervisors of Mathematics by:

- Strengthening mathematics education leadership through the dissemination of knowledge related to research, issues, trends, programs, policy, and practice in mathematics education
- Fostering inquiry into key challenges of mathematics education leadership
- Raising awareness about key challenges of mathematics education leadership, in order to influence research, programs, policy, and practice
- Engaging the attention and support of other education stakeholders, and business and government, in order to broaden as well as strengthen mathematics education leadership.

Comments from the Editors

Angela T. Barlow, *Middle Tennessee State University*
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> *An excellent mathematics program requires effective teaching that engages students in meaningful learning through individual and collaborative experiences that promote their ability to make sense of mathematical ideas and reason mathematically.* (National Council of Teachers of Mathematics [NCTM], 2014, p. 7)

As mathematics education leaders, we are key to achieving the excellent mathematics program described in the above quote from NCTM (2014). Although our duties may vary, our work provides us with the opportunity to influence the establishment of an instructional vision in our school settings as well as to support others in attaining this vision. In this issue, the different author teams address not only the notion of a shared vision but also the work of administrators, elementary mathematics specialists, and mathematics coaches in achieving the vision.

With regard to a shared vision, Munter, Stein, and Smith examine the professional practices outlined in *Principles to Actions* (NCTM, 2014) and *It's TIME* (National Council of Supervisors of Mathematics [NCSM], 2014). With attention given to delineations of knowing and doing mathematics, these authors describe the contrasting perspectives of dialogic instruction and direct instruction as they relate to the professional practices (NCSM, 2014; NCTM, 2014). In doing so, Munter and colleagues question whether all those aspiring to these practices have a shared vision of instruction. Further, they suggest that in order to develop a shared vision, referred to as a common pedagogical core, descriptions are needed of both observable practices and their underlying rationales regarding how the practices support learning goals.

Following the establishment of a vision, as mathematics education leaders we must give attention to ways for best supporting teachers in understanding and achieving the vision. To this end, Bennett, Amador, and Avila address the role that administrators play in this process. In their article, the authors detail a professional development designed to support administrators' skills in noticing students' mathematical thinking. Bennett and colleagues argue that such noticing skills are required in order for administrators to support the development of mathematics teachers' instructional practices, and they report on the support that their professional development provided for advancing administrators' noticing skills.

In addition to administrators, elementary mathematics specialists and mathematics coaches support teachers in understanding and achieving the vision. With regard to elementary mathematics specialists, de Araujo provides an overview of the literature related to elementary mathematics specialists. In doing so, she separates elementary mathematics specialists into two broad categories: mathematics coaches, who work directly with teachers, and specialized mathematics teachers, who work directly with students. Through her examination of the literature, de Araujo establishes the need for additional research regarding not only the impact of elementary mathematics specialists but also the effective preparation of these individuals. As to mathematics coaches, Whitenack and Ellington describe three common challenges that mathematics coaches faced when supporting teachers. For each challenge, the authors provide a vignette, as well as a discussion of the challenge and potential means for overcoming the challenge. By illuminating these challenges, the authors aim to enhance the reader's skillset for handling these and other closely related situations.

Although quite diverse, the articles in this issue address the various roles that mathematics education leaders play in establishing and achieving a shared vision of instruction. As the new school year is upon us, we hope that you will find the information provided by these authors helpful, as you consider the role you play in developing an excellent mathematics program! ✪

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Is there a Common Pedagogical Core? Examining Instructional Practices of Competing Models of Mathematics Teaching

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Abstract

Debates concerning which ideas should be included in the K-12 curriculum, how they are learned, and how they should be taught are longstanding. Although the adoption of the Common Core State Standards for Mathematics largely resolves content-*focused aspects of the debates,* pedagogical *decisions remain open to interpretation. The National Council of Teachers of Mathematics and the National Council of Supervisors of Mathematics have attempted to address this issue with recent calls to action, promoting particular instructional practices that represent a shared vision of the goal for every mathematics classroom. We examine these practices from the perspectives of two competing approaches to mathematics instruction—*dialogic *and* direct*—to ask whether a shared vision is sometimes inaccurately presumed, and to press for a common pedagogical core that includes not only specifications of observable practices, but also their underlying rationales in terms of equitably supporting all students in coming to know and do mathematics.*

Introduction

Since the publication of the *Curriculum and Evaluation Standards for School Mathematics* in 1989, the National Council of Teachers of Mathematics (NCTM) has worked to build and promote a consistent vision for learning and teaching mathematics that focuses on thinking, reasoning, and communicating rather than almost exclusively on memorization and procedural fluency. During that time, research, standards documents, policy statements, and curricular materials have provided further support for and refinement of this vision. For almost as long, though, this vision has been met with resistance. Criticism has been lodged on both mathematical and pedagogical grounds, leading to longstanding, divisive debates concerning which ideas should be included in the K-12 curriculum, how they are learned[1], and how they should be taught (Klein, 2003; Schoenfeld, 2004).

Recently, *content*-focused aspects of the debate have been largely resolved. The latest standards document, the Common Core State Standards for Mathematics (CCSSM; Common Core State Standards Initiative [CCSSI], 2010), represents an unprecedented agreement across previously divided parties regarding K-12 mathematics content[2]

[1] For more on this topic, we refer the reader to Donovan and Bransford (2005).

[2] The consensus to which we refer is primarily among mathematics educators and mathematicians. We acknowledge that in political and popular arenas, the CCSSM have recently come under increased scrutiny. But even there, only a handful of states have not adopted the Standards, and recent polling suggests that a majority of adults still support the Standards (Henderson, Peterson, & West, 2015), with any decline in support varying along political lines, which suggests that concerns are likely less about the Standards' content than implementation.

(Conference Board of the Mathematical Sciences, 2013; NCTM, 2013). *Pedagogical* decisions, however, remain open to interpretation: "[t]he standards themselves do not dictate curriculum, pedagogy, or delivery of content" (CCSSI, 2010, p. 84). This is to say that the CCSSM specify *what* but not *how* mathematics should be taught in schools.

Professional mathematics education organizations are trying to address this issue regarding how mathematics should be taught. Since the release of the standards, these organizations have argued that the CCSSM "will enable teachers and education leaders to focus on improving teaching and learning, which is critical to ensuring that all students have access to a high-quality mathematics program and the support that they need to be successful" (NCTM, 2010, p. 1). Moreover, the focus on improving teaching and learning and ideas about what counts as high-quality mathematics instruction have recently been reinforced in two publications: *Principles to Action: Ensuring Mathematical Success for All* (NCTM, 2014) and *It's TIME: Themes and Imperatives for Mathematics Education* (National Council of Supervisors of Mathematics [NCSM], 2014). Each includes a set of instructional practices that are meant to define the kind of high-quality instruction that represents the goal for every mathematics classroom, and of reform and professional development efforts (mapped onto each other in Figure 1). The ways that such documents and their respective lists are interpreted, however, will be influenced by individuals' current practices, perspectives, and institutional settings (EEPA, 1990). Consequently, these new documents run the risk of being interpreted as merely providing new labels (and perhaps clearer definitions) for what one presumes that s/he already does, which can present challenges for those charged with effecting and supporting instructional change and improvement (Cohen, 1990).

The purpose of this article is to make the case that specifications of professional practices, such as those offered by

FIGURE 1.

NCSM's (2014) "Research-affirmed instructional practices" mapped onto NCTM's (2014) "Mathematics teaching practices"

"Mathematics teaching practices" (NCTM, 2014)	"Research-affirmed instructional practices" (NCSM, 2014)
Establish mathematics goals to focus learning	
Implement tasks that promote reasoning and problem solving	Embed the mathematical content they are teaching in contexts to connect the mathematics to the real world
Use and connect mathematical representations	Provide multiple representations—for example, models, diagrams, number lines, tables and graphs, as well as symbols—of all mathematical work to support the visualization of skills and concepts
Facilitate meaningful mathematical discourse	Create language-rich classrooms that emphasize terminology, vocabulary, explanations and solutions
Pose purposeful questions	Respond to most student answers with "why?," "how do you know that?," or "can you explain your thinking?"
Build procedural fluency from conceptual understanding	
Support productive struggle in learning mathematics	Elicit, value, and celebrate alternative approaches to solving mathematics problems to that students are taught that mathematics is a sense-making process for understanding why and not memorizing the right procedure to get the one right answer
Elicit and use evidence of student thinking	Devote the last five minutes of every lesson to some form of formative assessments, for example, an exit slip, to assess the degree to which the lesson's objective was accomplished
	Conduct daily cumulative review of critical and prerequisite skills and concepts at the beginning of every lesson
	Take every opportunity to develop number sense by asking for, and justifying, estimates, mental calculations and equivalent forms of numbers
	Demonstrate through the coherence of their instruction that their lessons—the tasks, the activities, the questions and the assessments—were carefully planned

the NCTM (2014) and NCSM (2014), should be viewed not as collections of what are often referred to as instructional strategies or best practices, but rather as representing approaches to teaching mathematics that are coherent and consistent with respect to perspectives on what it means to know and do mathematics and how children learn it (Donovan & Bransford, 2005). In so doing, we raise the question of whether the achievement of a shared instructional vision is sometimes inaccurately presumed, and offer suggestions for avoiding that pitfall. It is our view that making the CCSSM a reality in our nation's classrooms will require establishing a genuine, common pedagogical core among all members of the educational system, which includes not only specifications of observable practices, but also their underlying rationales in terms of equitably supporting all students in coming to know and do mathematics.

Over the last few years we have sought to better understand and clarify the distinctions between two competing models of instruction: dialogic and direct. Both are coherent and consistent with respect to particular commitments to students' learning; but, in our view, of the two, only dialogic instruction aligns with the vision promoted by NCTM and NCSM. After describing our process for specifying distinct instructional models, we present and compare the resulting models. Then, we turn to the recent calls to action noted previously to consider them from the perspectives of these competing approaches to mathematics instruction, concluding with suggestions for mathematics education leaders and other stakeholders.

Methods

We sought to specify distinct models of mathematics instruction, beginning with different commitments to what it means to know and do mathematics, theories of learning, and perspectives on teaching. We did so with an eye toward an eventual comparative research study of the effectiveness of different instructional models, but first and foremost to understand—and draw clear distinctions between—viable alternatives to mathematics teaching.

To aid in this effort, we convened five meetings that brought together 26 mathematicians, educators, psychologists, and learning scientists, each time separated into two groups representing different perspectives on learning and instruction (see the appendix for a list of participants). Each meeting focused on some aspect of preparatory work for the eventual study. Two meetings were devoted to defining what it means to know and learn mathematics and specifying distinct instructional models—which, as a result, we came to refer to as dialogic and direct. By focusing the initial meetings on the articulation of the theories of learning and teaching on which the two instructional models are built, subsequent discussions of curriculum and assessment, professional development, and implementation could then be framed in terms of the models' underlying theories.

Each meeting consisted of a combination of simultaneous small group discussions among proponents of the same model and whole group discussions in which each group shared the essence of their discussion with members of the other group—not with the goal of reaching consensus, but of identifying exactly how their perspectives *differ*. All meetings were audio recorded and all artifacts created for and during the meetings were archived. Following each meeting, a summary was produced and vetted by the authors. The summary was then shared with participants, feedback was solicited, and a revised version of the summary was created.

Instructional Models

Based on the input of the experts at the meetings we convened, we specified two distinct mathematics instructional models. Below we provide abbreviated descriptions of what teaching entails in each, preceded by brief summaries of the perspectives on knowing and learning mathematics that underpin the respective pedagogies, and followed by a discussion of their similarities and differences. (Complete descriptions of the models are available upon request. A fuller description of this work is reported in Munter, Stein, and Smith, in press.)

Knowing and Learning

In general, advocates of both models viewed two prominent consensus documents—the National Research Council's five strands of mathematical proficiency (Kilpatrick, Swafford, & Findell, 2001) and the CCSSM (both content and practice standards)—as reasonable representations of *knowing and doing* mathematics, but emphasized different aspects of those strands and practices. For example, the direct instruction model does not emphasize the communication aspect of the third Standard for Mathematical Practice (SMP). Although a good student may have an internal dialogue concerning other aspects of that standard, communicating effectively with others is not a necessary capability. In the dialogic model, communicating effectively with others is fundamental to knowing (and learning). Similarly, in the direct instruction model, to "make conjectures and build a logical progression of statements to explore the truth of their conjectures" (CCSSI, 2010, p. 6) is limited to trying strategies for solving a problem posed to the students; student questions that drive instruction or lead to new mathematical investigations are not emphasized as they are in the dialogic model.

Although their goals are similar, the two models attempt to achieve them by offering different *learning opportunities* to students. In the direct instruction model, when students have the prerequisite conceptual and procedural knowledge, they will learn from (a) watching clear, complete demonstrations of how to solve problems, with accompanying explanations and accurate definitions; (b) practicing similar problems sequenced according to difficulty; and (c) receiving immediate, corrective feedback. Whereas in the dialogic model, students must (a) actively engage in new mathematics, persevering to solve novel problems; (b) participate in a discourse of conjecture, explanation, and argumentation; (c) engage in generalization and abstraction, developing efficient problem-solving strategies and relating their ideas to conventional procedures; and, to achieve fluency with these skills, (d) engage in some amount of practice. The *pedagogies* by which these opportunities are afforded are described separately in the next sub-section.

Pedagogy

Direct instruction. In the direct instruction model, typical lessons include (a) the teacher's descriptions of an objective, motivating reasons for achieving the objective, and connections to previous topics; (b) presentation of requisite concepts; (c) demonstration of how to complete the target problem type; and (d) scaffolded phases of guided and independent practice, accompanied by corrective feedback.

During guided practice, the teacher invites the class to solve similar problems (perhaps with some students working them at the board), answering students' questions, and correcting errors. In order to transition into independent practice, the teacher might begin by priming students' work through minimally prompted presentation (e.g., completing the first two steps in solving a problem), and gradually withdraw that support. During independent practice, the teacher's feedback should focus on how strategies need to be corrected (rather than emphasizing that mistakes have been made), and should not interrupt students' thinking. For example, after a student has solved a problem, the teacher might tell the student what s/he did accurately, and what needs to be modified in order to achieve a complete, accurate solution.

Across these phases, lessons should be captivating, which can be accomplished through keeping a brisk instructional pace, inviting group unison responses to questions, and providing focused praise. Lessons should also be interactive. For example, after students have solved a number of fraction multiplication problems using number lines and area models, the teacher could draw attention to the rule, $\frac{a}{c} \cdot \frac{b}{d} = \frac{ab}{cd}$. To do so, teachers might invite students to state whether they have noticed a pattern, since it is likely that in solving the progressively difficult problems one or more students will have developed an efficient algorithm. Interacting with students in such a way is good for classroom relationships, keeping students on task, and making the environment more interesting. However, who articulates such a pattern is not important, only *that it gets articulated* (by someone).

Dialogic instruction. In the dialogic instruction model, although instruction will not fit a particular pattern within every lesson, it should, over time, provide coherent sequences of opportunities for students to engage in tasks that have been carefully designed to surface particular mathematical ideas and to build new understandings from previous knowledge. This requires teachers to:

a) have access to and be able to make use of learning progressions—sensible (preferably research-based) paths by which students are likely to reach a set of explicit learning goals given a particular instructional sequence;

b) engage students in two main types of tasks: 1) tasks that initiate students to new ideas and deepen their understanding of concepts, and 2) tasks that help them become more competent with what they already know (with type 2 tasks generally not preceding type 1 tasks);

c) orchestrate productive discussions that make mathematical ideas available to all students and steer collective understandings toward the mathematical goal of the lesson;

d) introduce tools and representations that have longevity (i.e., can be used repeatedly over time for different purposes, as students' understanding grows); and

e) sequence the necessarily varied types of classroom activities in a way that consistently positions students as autonomous learners and users of mathematics, each an agent who has and is developing mathematical authority in the classroom.

A key aspect of this model is the flexible use of multiple representations, which should be used by students to *think with* rather than being limited to illustrate concepts. Equally important to the effective use of multiple representations is encouraging discussion that translates between representations, making explicit the relations between them, including those that are considered standard. Along these lines, with regard to coordinating the use of representations with instructional goals, there are times when it is beneficial for students to be able to choose which representation to use and other times when constraining students to the use of a particular representation will better accomplish the learning goals (with the former more often the case early in the development of a new topic).

An inherent challenge of this model is affording learning opportunities that are emergent through instruction that is *systematic* (see the description in Figure 2 about creativity). This seeming contradiction is reconciled by ensuring that the paths that any given group of students' learning take eventually lead to (at least) the mathematical goals of a particular instructional sequence or grade level. By flexibly following students' reasoning, the teacher can build on their initial thinking to move toward ideas important to both students and the discipline.

Similarities

Specifying and comparing these two models has revealed both differences and similarities. Regarding the latter, we found that in both models, both conceptual understanding and procedural fluency are not only valued as important forms of knowledge, but are viewed as being developed together. Additionally, we found that both models emphasize using carefully designed, purposefully sequenced, mathematically rigorous tasks; closely monitoring students' reasoning; and providing regular opportunities for practice—although the purpose and nature of those tasks, those student diagnoses, and that practice may differ between the models.

Differences

Previously, we alluded to differences between the two models with respect to classroom talk, group work, learning progressions, mathematical tasks, representations, and the role and timing of feedback. In Figure 2, we summarize these differences as well as three additional areas of distinction: students' classroom roles and mathematical creativity; the introduction and role of definitions; and the purpose of diagnosing student thinking. Although abbreviated, we present the differences in table form to allow for more direct comparisons conceptually, and to provide a tool for teachers' and teacher leaders' reflection and conversation.

(Re)Considering "High-Quality" from Competing Perspectives

As alluded to previously, NCTM and NCSM, two prominent professional organizations in mathematics education, have each recently published calls to action (NCSM, 2014; NCTM, 2014), including lists of research-based instructional practices that represent the goal for how mathematics should be taught in classrooms (see Figure 1). Not surprisingly, there is considerable overlap in the lists, which symbolizes the consensus that has developed by these organizations over time. However, advocates of different approaches to instruction would, at least in name, likely embrace a majority of these practices. In some cases, it may be that an instructional practice transcends pedagogy. For example, "establish[ing] mathematics goals to focus learning" (NCTM, 2014, p. 12) and enacting "carefully planned" lessons (NCSM, 2014, p. 30) are important in both dialogic and direct approaches to instruction, and for similar reasons.

In other cases, however, the summaries presented in Figure 2 suggest that very different instructional models may employ similar practices, but in different ways and for different purposes. For example, related to the NCTM's practice of "implement[ing] tasks that promote reasoning and problem solving" (2014, p. 17), the NCSM (2014) authors suggested, specifically, that teachers should "embed the mathematical content they are teaching in contexts to connect the mathematics to the real world" (p. 30). From a dialogic perspective, one key purpose of this practice is to provide opportunities to mathematize familiar contexts (Putnam, Lampert, & Peterson, 1990), quantifying relations in order to solve problems by distilling the mathematical essence of a situation and deciding

FIGURE 2.
Major distinctions between dialogic and direct mathematics instruction

Dialogic Instruction	Distinction	Direct Instruction
Fundamental to both knowing and learning mathematics. Students need opportunities in both small-group and whole-class settings to talk about their thinking, questions, and arguments.	The importance and role of **talk**	Most important during the guided practice phase, when students are required to explain to the teacher how they have solved problems in order to ensure they are encoding new knowledge.
Provides a venue for more talking and listening than is available in a totally teacher-led lesson. Students should have regular opportunities to work on and talk about solving problems in collaboration with peers.	The importance of and role of **group work**	An optional component of a lesson; when employed, it should follow guided practice on problem solving, focus primarily on verifying that the procedures that have just been demonstrated work, and provide additional practice opportunities.
Dictated by both disciplinary and developmental (i.e., building new knowledge from prior knowledge) progressions.	The **sequencing of topics**	Dictated primarily by a disciplinary progression (i.e., prerequisites determined by the structure of mathematics).
Two main types of tasks are important: 1) tasks that initiate students to new ideas and deepen their understanding of concepts (and to which they do not have an immediate solution), and 2) tasks that help them become more competent with what they already know (with type 2 generally not preceding type 1 and both engaging students in reasoning).	The nature and ordering of **instructional tasks**	Students should be given opportunities to use and build on what they have just seen the teacher demonstrate by practicing similar problems, sequenced by difficulty. Tasks afford opportunities to develop the ability to adapt a procedure to fit a novel situation as well as to discriminate between classes of problems (the more varied practice students do, the more adaptability they will develop).
Students should be given time to wrestle with tasks that involve big ideas, without teachers interfering to correct their work. After this, feedback can come in small-group or whole-class settings; the purpose is not merely correcting misconceptions, but advancing students' growing intellectual authority about how to judge the correctness of one's own and others' reasoning.	The nature, timing, source, and purpose of **feedback**	Students should receive immediate feedback from the teacher regarding how their strategies need to be corrected (rather than emphasizing that mistakes have been made). In addition to one-to-one feedback, when multiple students have a particular misconception, teachers should bring the issue to the entire class's attention in order to correct the misconception for all.
Students' learning pathways are emergent. Students should make, refine, and explore conjectures on the basis of evidence and use a variety of reasoning and proof techniques to confirm or disprove those conjectures (CCSS-M-SMP 3), asking questions that drive instruction and lead to new investigations.	The emphasis on **creativity**	Students' learning pathways are predetermined and carefully designed for. To "make conjectures and build a logical progression of statements to explore the truth of their conjectures" (CCSS-M-SMP 3) is limited to trying solution strategies for solving a problem posed to them.
Students' thinking and activity are consistent sources of ideas of which to make deliberate use: by flexibly following students' reasoning, the teacher can build on their initial thinking to move toward important ideas of the discipline.	The purpose of **diagnosing student thinking**	Through efficient instructional design and close monitoring (or interviewing), the teacher should diagnose the cause of errors (often a missing prerequisite skill) and intervene on exactly the component of the strategy that likely caused the error.
Students participate in the defining process, with the teacher ensuring that definitions are mathematically sound and formalized at the appropriate time for students' current understanding.	The introduction and role of **definitions**	At the outset of learning a new topic, students should be provided an accurate definition of relevant concepts.
Representations are used not just for illustrating mathematical ideas, but also for thinking with. Representations are created in the moment to support/afford shared attention to specific pieces of the problem space and how they interconnect.	The nature and role of **representations**	Representations are used to illustrate mathematical ideas (e.g., introducing an area model for multi-digit multiplication after teaching the algorithm), not to think with or to anchor problem-solving conversations.

when mathematical modeling is appropriate. In a direct instructional approach, however, this instructional practice is likely employed to give students opportunities to develop the ability to adapt a procedure to fit a novel situation as well as to get better at discriminating between types of problems. The goals that underlie the use of real world problems have implications for how a lesson is structured. What may be used in dialogic instruction to *initiate* an idea through mathematizing may be used in direct instruction to solidify an idea and support the development of adaptability.

Similarly, both direct and dialogic instruction advocates would likely agree that teachers should "elicit and use evidence of student thinking . . . to assess progress toward mathematical understanding and to adjust instruction continually in ways that support and extend learning" (NCTM, 2014, p. 53), perhaps even with an exit slip during "the last five minutes of every lesson" (NCSM, 2014, p. 30). However, as the descriptions in Figure 2 suggest, the reasons for employing such practices differ across competing instructional models. In direct instruction, the teacher should consistently work to diagnose the cause of students' errors (e.g., a missing prerequisite skill) and intervene on exactly the component of the strategy that likely caused the error, which is typically achieved through efficient instructional design and close monitoring or interviewing. Alternatively, teachers taking a dialogic approach treat students' thinking and activity as sources of ideas on which they, the classroom community, can build to move toward important mathematical ideas. In this case, the emphasis is on not only whether but also how students understand an idea.

Both of these recent calls to action refer to a "shared vision" of high-quality mathematics instruction, which they represent with lists of "practices." The two examples above, however, illustrate how particular instructional practices can be interpreted differently and enacted for different purposes, depending on the instructional approach in which they are being used. This fact calls into question what it is that is "shared" when we refer to a shared vision. More importantly, though, it points to the importance of talking about, attempting, and reflecting on such practices in terms of the underlying goals we have for mathematical activity in the classroom and children's learning, a point to which we return in the discussion section.

Discussion

In this article, we have presented abbreviated versions of two instructional models, identified differences in the models' goals for students' learning and the ways by which the models are intended to achieve their goals, and examined currently promoted instructional practices from the perspectives of those competing models. To be clear, we do not claim that the two models we have described are *the* two, only that they are different. But their differences are not evidenced simply by the instructional practices that they employ: teachers in dialogic classrooms may very well demonstrate some procedures, just as students in a direct instruction classroom may very well engage in project-based activities. Our conjecture is that it is not a matter of the particular instructional practices, necessarily, but rather when the practice is used, the purpose for employing a particular practice, and how the practices within each model fit together into a cohesive whole that is important. For example, a teacher in a dialogic classroom may demonstrate a procedure, but only *after* students have developed an understanding of the concept and are able to connect the procedure to its underlying mathematical meaning. Hence the practice, while on the surface may be similar to what you might find in a direct instruction classroom, potentially leads to a very different learning outcome.

Identifying high-quality instructional practices helps to clarify and solidify what we are working to achieve in every mathematics classroom; but identifying distinctions between competing instructional models—even idealized versions—helps to clarify *why* teachers might employ those practices. Thus, we argue that specifications of high-quality instruction must include the identification of both instructional practices and the underlying rationales for employing those practices.

Our call for a more complete specification of high-quality instruction has implications for multiple stakeholders. For example, although it is as yet unclear whether it is possible or necessary to pursue a shared instructional vision across an entire school district, recent research suggests that, for those who choose to initiate district-wide improvement efforts, a coherent, well-articulated instructional vision is foundational (Cobb & Jackson, 2011). Without well-communicated and agreed-upon goals for students' learning, along with the specification of and rationale for particular instructional practices for achieving those goals, the basis for leaders' decisions will be tenuous. For example, leaders may select instructional materials, district- and school-based professional development, formative assessments, or interventions for struggling students that match the superficial features of dialogic instruction but that are aligned to a different underlying theory of how students learn. To maximize the coherence of the system, each of the above decisions must align with and support the enactment of a clear instructional vision. If we begin with a specification such as those provided in this article, the adequacy of decisions regarding all other aspects of an instructional system can be measured against that vision.

Considering the distinctions we have drawn can also be helpful to teachers and those directly supporting teachers. Articulating the rationales underlying our instructional choices can help get beyond the promotion of particular, so-called teaching strategies or best practices to careful reflection on how and why particular strategies or practices are used. We offer two suggestions for doing so. First, we echo numerous other educators and researchers in recommending an emphasis on the CCSSM SMP as the kind of mathematical activity in which we want to support students in participating. But within that emphasis, we recommend that teachers and leaders approach the SMP as both an end and a means—not just the goal for what students will eventually do, but the kind of activity in which they need to engage now so that they can learn mathematics. In addition, paralleling the holistic interpretation of NCTM's (2014) and NCSM's (2014) instructional practices that we have promoted, we recommend that teachers and leaders avoid the temptation to emphasize some SMP to the exclusion of others, and instead treat the practices as interrelated parts of a whole—all necessary to define authentic disciplinary engagement.

Second, as stated previously, a majority of the practices identified in the NCTM (2014) and NCSM (2014) reports would likely be embraced by advocates of different instructional approaches—but not all. For example, as indicated by the distinctions in Figure 2, at least two of the eight practices identified in the NCTM report would not be emphasized by advocates of direct instruction: "support productive struggle in learning mathematics" and "facilitate meaningful mathematical discourse" (p. 10). In direct instruction, corrective feedback is provided as soon as possible so that students are not left to struggle; and, although interaction is encouraged, participating in mathematical discourse is not emphasized as a goal or valued as a strong learning support as it is in dialogic instruction. Because these two practices are incompatible with a direct instruction approach, they stand apart from the others in their potential as anchors for developing and promoting a particular instructional vision. For example, professional development efforts could focus specifically on affording opportunities for productive struggle in solving complex tasks (Stein, Grover, & Henningsen, 1996; Smith & Stein, 1998) or on orchestrating productive mathematical discussions (Smith & Stein, 2011; Stein, Engle, Smith, & Hughes, 2008), and make explicit how the other practices are in service of, or at least related to, those two key practices.

Conclusion

The authors of the CCSSM (CCSSI, 2010) were intentionally silent on the topic of pedagogy. Since that time, researchers and practitioners have been converging on a definition of high-quality mathematics instruction, as comprised of particular instructional practices. These efforts have recently been amplified by calls to action by the NCTM (2014) and the NCSM (2014). The models described in this article represent two distinct perspectives on how instructional practices characterized as high quality might be interpreted and enacted. Examining and reflecting on our goals, teaching, and professional development efforts through these lenses can help us move past the presumption of a shared vision to the work of establishing a genuine, common pedagogical core. ✪

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Appendix

Participants in the Meetings Hosted at the University of Pittsburgh*

Participant	Area	Institution
Sybilla Beckmann	Mathematics	University of Georgia
Jo Boaler	Mathematics education	Stanford University
Diane Briars	Mathematics education	Past President, National Council of Supervisors of Mathematics (NCSM)
Richard Clark	Educational psychology	University of Southern California
David Cordray	Psychology	Vanderbilt University
Mark Driscoll	Mathematics education	EDC
Janet Fender	Professional development	My Direct Instruction Consultant LLC
Anne Garrison	Mathematics education	Vanderbilt University
James Greeno	Learning sciences	University of Pittsburgh
James Hiebert	Mathematics education	University of Delaware
John Hollingsworth	Classroom instruction	President, DataWORKS Educational Research
Mary Ann Huntley	Mathematics education	Cornell University
Ken Koedinger	Cognitive psychology	Carnegie Mellon University
William McCallum	Mathematics	University of Arizona
John Opfer	Psychology	The Ohio State University
Randolph Philipp	Mathematics education	San Diego State University
Frank Quinn	Mathematics	Virginia Tech
Anna Sfard	Mathematics education	University of Haifa, Israel
Alan Siegel	Computer science	New York University
Edward Silver	Mathematics education	University of Michigan
Jon Star	Educational psychology / Mathematics education	Harvard University
Marcy Stein	Education	University of Washington Tacoma
W. Stephen Wilson	Mathematics	Johns Hopkins University
Michael Winders	Mathematics	Worcester State University
Hung-Hsi Wu	Mathematics	University of California at Berkeley
Judith Zawojewski	Mathematics education	Illinois Institute of Technology

Facilitators: Charles Munter, Mary Kay Stein, and Margaret Smith, University of Pittsburgh

*Although all participants reviewed the full descriptions of the instructional models, inclusion of an individual's name on the above list is not to imply that the individual necessarily agrees with the additional assertions made in this paper. Information listed was current at the time of the meetings.

Framing Professional Conversations with Teachers: Developing Administrators' Professional Noticing of Students' Mathematical Thinking

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Julie M. Amador, *University of Idaho*
Christine Avila, *Idaho State Department of Education*

Abstract

In this paper we share the first phase of an on-going professional development project for administrators aimed at helping them facilitate non-evaluative professional conversations with mathematics teachers. School administrators have the ability to support teachers' instructional practice, however, administrators' ability to notice pivotal moments in students' mathematical thinking greatly influences the quality of support they can provide. Findings indicated that administrators were initially not specific about noticing students' mathematical thinking when observing lessons, but their ability to notice and plan for conversations about students' mathematical thinking developed over time.

Introduction

The Conference Board of the Mathematical Sciences' release of the *Mathematical Education of Teachers II* (CBMS, 2012) highlighted the complex interdisciplinary enterprise of mathematics teaching, demanding teachers have knowledge of instructional practices as well as mathematics content. The National Council of Teachers of Mathematics' (2014) *Principles to Actions: Ensuring Mathematical Success for All* further emphasized key teaching practices necessary to effectively support students' learning of mathematics as well as a call to action for administrators to help teachers create and sustain meaningful opportunities to learn mathematics. In essence, a primary focus of administrators and other school and district leaders is to create opportunities for teachers to understand and reflect on student-centered teaching and develop the pedagogical content knowledge necessary for effective instruction (Fernandez & Zilliox, 2011; Hill, Ball, & Schilling, 2008).

One way to support teachers' development in both content and pedagogy is by helping them focus on student-centered and evidence-based learning environments. This means closely examining the practices of teachers. From a teaching perspective, to engage in instruction that foregrounds student thinking, teachers need to be able to first *professionally notice* the thinking of students. Professional noticing, hereafter referred to as noticing, involves attending to, interpreting, and responding to students based on their thinking (Jacobs, Lamb, & Philipp, 2010). Two prominent researchers in the field of noticing, van Es and Sherin (2008), have used this construct to refer to the identification of what is important about a classroom situation, the ability to make connections between classroom interactions and principles of teaching and learning, and the ability to use what is known about the context to reason about classroom events. Such practices allow for more responsive teaching, teaching that deliberately connects pedagogical moves to specifics of students' understanding (Thomas et al., 2014). For the purposes of this paper, noticing will be understood to be the interconnected process of attending, interpreting, and responding to students based on specific evidence of their thinking and reasoning. Although previous research has focused on various aspects of teachers' noticing (e.g., Jacobs et al., 2010; Sherin, Jacobs, & Philipp, 2011; Star & Strickland, 2008; van Es & Sherin, 2002), very little has focused on the administrators' noticing of students' mathematical thinking as a means of supporting mathematics teachers' instructional practices.

In transforming learning across a school, the role, importance, and impact of the administrator as an instructional leader cannot be emphasized enough (Zepeda, 2013). However, in order for long-lasting and systematic change to occur in instructional practices across classrooms and schools, school administrators need to reorganize the setting and nature of instructional support provided (Cobb & Jackson, 2011). Clarke and Hollingsworth (2002) stated that professional growth, which includes improvements in instructional practices, occurs in a dynamic and interrelated process situated within a multi-faceted environment dealing with the teacher's personal beliefs, experimentation in their practice, and feedback or information from external sources. This means that administrators, acting as an external source, can situate feedback and initiate non-evaluative professional conversations to support teachers' instructional practices (Feiman-Nemser, 1996). Based on the construct of noticing, the nature of these conversations should be grounded in specific evidence of students' mathematical thinking and reasoning. Thus, the capacity and level of understanding needed to effectively notice is a critical component in providing focused instructional support.

Administrators often set school-wide priorities and provide support based on what they understand (Price, Ball, & Luks, 1995). Yet, many administrators do not fully understand the type of mathematical learning that should occur in classrooms (Buschman, 2004) or they may believe that, because they do not understand mathematics content well enough, they are less able to provide the focused instructional support required to ensure rigorous content standards are met. As a result, administrators often shift their focus to other content areas instead of providing content-based support or are not specific about the mathematics they observe (Nelson & Sassi, 2000). Such beliefs are further amplified in secondary schools wherein the mathematics courses offered include more advanced mathematics not well understood by administrators. Burch and Spillane (2003) found that administrators need to account for the role of mathematics content knowledge and teachers' epistemological beliefs about learning mathematics as they continue to lead school reform in mathematics. This further highlights the need to notice students' mathematical thinking as administrators work with their mathematics teachers to improve learning.

Although supporting teachers of mathematics from an instructional standpoint may seem challenging because administrators may lack content knowledge, the nature and focus of the support can begin by focusing on students' mathematical thinking. A tremendous body of research (e.g., Ball, 1995, 1998; Boaler & Staples, 2008; CBMS, 2012; Grossman, Schoenfeld, & Lee, 2005; Ma, 2010; National Research Council, 2001; Schifter, 2001) has indicated that teachers need to shift their understanding of teaching as an independent pursuit to an interactional social endeavor that helps students make sense of the mathematics under study. As such, the role of the administrator as an instructional leader also needs to shift to help teachers recognize their classrooms as sense-making environments (Burch & Spillane, 2003). This requires attending to, and appropriately interpreting, key mathematical moments during the class, which are fundamental elements of noticing.

As such, specific attention to help administrators understand the essence and nature of effective instruction is imperative to them providing the instructional guidance they are often expected to provide regardless of their school context (Hallinger & Murphy, 1985). That is, without focused support on understanding effective mathematics instruction, specifically designed for school administrators, school-wide efforts to improve the teaching and learning of mathematics will be left to the interpretation of individual or small groups of teachers and may lack a cohesive and concerted effort. Although it is unreasonable for instructional leaders to be experts in all content areas, it is reasonable to expect them to have professional conversations with teachers centered on specific evidence of student learning within the classroom. The effectiveness of these non-evaluative professional conversations is greatly dependent upon the specific evidence gained from noticing students' thinking, as evident in their conversations or work. In doing so, the professional practice of administrators can be further developed and strengthened to provide specific and focused support to their teachers to improve instruction (van Es & Sherin, 2008). Therefore, the researchers initiated a project to answer the following questions: How do administrators notice students' mathematical thinking when observing mathematics teaching and how does their noticing shift as a result of focused professional development on noticing?

Project Overview

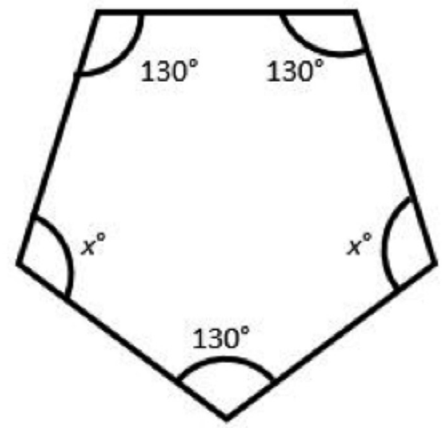
The purpose of this project was to understand and increase administrators' abilities to notice key mathematical moments of students' thinking and reasoning so they would be better able to support teachers (van Es, 2011). This qualitative study focused on K-12 administrators' attending, interpreting, and responding during a two-day professional development session. This context allowed researchers to better understand, and describe, nuances in participants' ability to notice.

Participants included 23 principals, assistant principals, and other district leaders such as superintendents and curriculum specialists, from elementary, middle, and high schools from one small, semi-rural school district. During this two-day professional development session, participants focused on learning the structures of noticing by studying and analyzing four videos of K-12 mathematics teaching from their own school district (Kisa & Stein, 2015). This paper focuses on one portion of the professional development session: a two-part project that was generated around one of those four videos that will be referred to as the *Case of Ms. Hemingway*.

Case of Ms. Hemingway

One module in the professional development session, the Case of Ms. Hemingway, was divided into two parts. Part One of the module was completed during the professional development session and Part Two of the module was completed independently after the conclusion of the workshop. Each part of the module featured video that was situated in Ms. Hemingway's ninth grade integrated mathematics classroom wherein students were to determine the missing angle measures shown in Figure 1. In this classroom, students were placed in heterogeneously mixed groups with three to five students per group. The videos for Part One and Part Two of the Case of Ms. Hemingway were based on this same geometry problem within the same class period but showcased different students presenting their conjectures, justifying their thinking, and responding to questions and comments posed by other students and the teacher.

FIGURE 1.
Missing angle problem.



Part One. For the first part of the module, all participants watched Part One of the video of Ms. Hemingway's lesson and then collaborated within a small group to identify three pieces of evidence of students' mathematical thinking. Participants then recorded this evidence on a poster along with interpretive comments and possible follow-up questions. This occurred prior to learning about the noticing framework (van Es, 2011). Essentially, Part One of the Case of Ms. Hemingway served as a pre-assessment of the participants' noticing.

Introducing the noticing framework. After the participants wrote about and discussed their initial noticing comments, the facilitator asked them to look at their notes and identify specific students and the mathematics in their notes. Some participants were able to recall some of the students' names, but none of the participants had written down, or could identify, the specific mathematics in the video, just general concepts such as, "they were working with triangles and a pentagon" or "students were trying to find a missing angle." They expressed difficulty with more advanced noticing as they were used to paying attention to other contextual classroom features.

The workshop facilitator then provided the participants with the van Es (2011) noticing framework, stressing that this framework was non-evaluative by design and should not be used for teacher evaluations. Participants were reminded again that the importance of their noticing was to be better able to facilitate a professional conversation, focused on the learning of the students, to support and help improve teachers' instructional practices. Next, using the framework, participants were asked to discuss and describe the notable differences between the various levels on the framework. Quickly, the participants recognized that their noticing had been focused more on Level 1 type actions. When framed within the context of using their notes to guide a professional conversation with teachers, participants recognized that the lack of specificity in what they noticed not only impacted how they interpreted the students' learning, but also failed to provide them with any concrete evidence of student learning. In essence, there would have been nothing of significance for the participant and the teacher to discuss that could have influenced future pedagogical moves for mathematics teaching beyond general environmental and behavioral issues.

Part Two. In the second part of the module, participants watched Part Two of the video of Ms. Hemingway's lesson independently. Then, participants answered questions about their noticing of student thinking, Ms. Hemingway's noticing of student thinking, and possible ideas for supporting Ms. Hemingway with her mathematics teaching. Part Two served as the post-assessment to understand the extent to which the professional development session influenced their ability to notice as a means of facilitating professional conversations with teachers around teaching.

Analyzing Responses

Data were collected from Part One and Part Two of the module. For Part One, all written records of what participants had noticed were collected, including individual records and group posters of what was noticed. For Part Two, responses analyzed included participants' individual typed responses based on their viewing of Ms. Hemingway's lesson. This included responses to six prompting questions (see Appendix A).

To analyze the data, the two researchers independently began with a preliminary exploratory analysis (Creswell, 2012) using the van Es (2011) *Framework for Learning to Notice Student Mathematical Thinking* (see Appendix B) to code responses. Examples of these codes included environment, focus on teacher, pedagogy, and interpretive, which are all descriptors within the framework. Next, the different levels of noticing (i.e., Leve1- Baseline, Level 2- Mixed, Level 3- Focused, and Level 4- Extended) were used as predetermined categories (McMillan & Schumacher, 2006) and participants were then assigned to one level of noticing based on the extent to which the codes from their documents aligned with the noticing categories. In instances when the researchers did not agree, they discussed all data points for a given participant and came to a consensus as to which category they belonged.

Findings

The following describes the participants' noticing of students' mathematical thinking. The findings from Part One of the Case of Ms. Hemingway are organized according to Jacobs et al. (2010) processes of attending, interpreting, and responding, though responding was not explicitly addressed. That is, only the initial stages of noticing were analyzed and thus reported. Following this, results from Part Two of the Case of Ms. Hemingway are presented as a contrast with the initial noticing.

Part One: Initial Group Noticing

Attending. The participants primarily focused on the teacher's actions or comments with little to no specific evidence of students' mathematical thinking (see Appendix C). That is, participants tended to notice what the teacher said and whom she called on. In addition, they referenced statements made by the teacher about the general learning context.

Although most small groups of participants indicated that students made an erroneous assumption, this statement came directly from a statement that the teacher made and not from their *own* noticing of student thinking. Other pieces of evidence identified by the participants included such comments as "Mike shows his work" and "students had different responses," but these were merely observations. Again, the nature of their noticing seemed to be on classroom moments that did not pertain to specific mathematical ideas. Other identified moments included statements such as, "[The teacher] paired both groups' strategies close together to 'drill down' to the misconception." In this comment, the participant did not attend to visible or audible evidence of students' mathematical thinking, but made inferences without citing specific student words or actions. Statements of this nature were interpretive, that is, participants imposed meaning on the teachers' actions, but the only real evidence would be that two strategies were presented one after the other. The purpose or intended outcome of sequencing these two strategies may have been to highlight the group's misconception but without more specific evidence from the video, or a conversation with the teacher, such a statement was marginally supported, at best.

Only one statement out of all statements submitted by the participants included any reference to mathematics: "Students knew the properties of triangles." Even so, this statement was ambiguous about the specific properties students used or how those properties were being applied to solve the problem. Despite being asked to identify and record three pieces of evidence of students' mathematical thinking, all participants' noticing aligned with Level 1 in the noticing framework (van Es, 2011). Specifically, the participants attended to the teachers' pedagogy and impressions of whole-class learning; they focused on — general impressions within the classroom and included evaluative comments with few details or specific evidence.

Interpreting. As with the participants' attention to evidence, their interpretive comments also lacked in-depth noticing (see Appendix C). This was due, in large part, to the fact that the evidence provided was unspecific and vague. For example, when discussing evidence of students' mathematical thinking, Group 1 stated, "[The teacher] acknowledged that there were four possible approaches" and then interpreted this to mean that students utilized "multiple strategies." However, simply acknowledging the fact that the teacher identified four different approaches in the students' work did not imply that the students understood the meaning or structure of the strategies used. Furthermore, both of these statements could be understood to mean the same thing, making both more general observations of student learning and not an internalization of the evidence and interpretation of what this specific incident might have implied about students' understanding of the mathematics.

Another small group, Group 4, also had an indistinct interpretation of students' thinking as they recorded the fact that the teacher "invited a group to show one solution" as evidence and then wrote that the "teacher knew what the students were thinking" as the interpretation of this evidence. Again, and partly due to the fact that the evidence was ill-defined, participants' interpretations lacked substance, especially if one were to use these notes as a means to facilitate a professional conversation with the teacher about student learning. In fact, all of the listed interpretive comments failed to adequately synthesize or illuminate the possible implications nuanced in students' thinking. As such, the noticing of these participants provided little to no foundation upon which they could provide any meaningful instructional support, guidance, or leadership for this teacher. The statements were lacking specificity with respect to attending to the relationship between particular students' mathematical thinking and between teaching strategies and student mathematical thinking because they were not articulating the students' mathematical thinking. This reduced their ability to then make connections between how the students were thinking and effective pedagogical strategies and thus appropriately frame a focused professional conversation around the teaching and learning of mathematics.

Reflective statements. Throughout much of the workshop, the participants expressed that the process of noticing was rather difficult for them. Many indicated that they had been trained to look for environmental evidence such as *I can* statements on the board and student work on the walls. They also looked for students' behaviors as quantified by the amount of non-academic talking occurring or raising of hands to speak, and other safety issues, such as ease of access between desks or the use of extension cords for multiple electrical items. All of these items matter and are worthy of attention but they are of little to no assistance in helping teachers improve their instruction or the mathematical learning experiences of students. The participants' struggles seemed to be in simultaneously paying attention to things that might be part of an evaluative teacher observation as well as noticing specific evidence of student thinking. One participant commented, "We know we are supposed to be the instructional leaders in our schools, but [we] have just not been trained to think this way."

Part Two: Individual Noticing

Attending and interpreting. Each participant had a final project to complete wherein they were asked to independently watch Part Two of the Case of Ms. Hemingway, record their noticing, and then develop questions they would ask the teacher to better understand the mathematical thinking of the students in the video. This was done outside of the time allocated for the professional development workshop. Baseline categories for each individual were based on their group codes from the Initial Group Noticing phase. Based on analysis using the van Es (2011) framework, of the 23 participants, 16 moved from a *Baseline* (Level 1) level to either a *Mixed* (Level 2) or a *Focused* (Level 3) level of noticing (eight moved to a *Mixed* and eight moved to a *Focused* level) with some comments extending into the *Extended* (Level 4) level of noticing. Seven participants remained at a *Baseline* level of noticing.

For those who moved from a *Baseline* to a *Mixed* or *Focused* level of noticing, the attending, or what they noticed, aspect of their noticing was much more detailed but often lacked sufficient specificity or centered primarily on evaluative an interpretive comments with few details. In the first *Mixed* example, the participant paid specific attention to angle measures but also made an evaluative comment about the student's (Emily) understanding that was not supported in specific evidence. Robert wrote,

> I noticed Emily split the trapezoid into two Isosceles triangles. Emily knew total angles equaled 540 and that the triangles needed to equal 360. That allowed her to determine the unknown angles. I think it suggests that [she] understood the process but I think she may still have confusion about the other team's process.

Another example of a response coded as Mixed, similarly noticed the student's mathematical thinking. This participant, Sue, wrote,

> They knew to break the trapezoid into parts (isosceles triangle and trapezoid, then trapezoid into triangles) to find angles that were usable. They seemed willing to take steps to problem solve, but [were] unaware of the impact one step had on the outcome of solving the problem. They seemed to understand that angles divided helped them solve, but weren't quite able to accomplish the larger task.

Again, the attention and reference to specific and noteworthy events about students' thinking, along with focused interpretive comments, provided a basis from which the participant could facilitate a professional conversation with this teacher. In this case, Sue grouped the students together and referred to them collectively, which was not as specific as the aforementioned example about Emily provided by Robert. However, Sue noticed key mathematical components of the thinking, such as the outcome of breaking a trapezoid into triangular regions but because it was unspecific to one student's thinking, it was coded as *Mixed*.

An example of a *Focused* noticing comment included specific details about a particular student along with more evaluative aspects. This participant, Mr. Kay, wrote,

> Emily split the figure into two trapezoids, it appears, but she didn't need to draw the extra line to create the triangle. In her mathematical thinking, she appears to have a misunderstanding of the theorem about isosceles trapezoids, and that she could use it (with the congruent angles) to determine the missing angles.

This example provided details about Emily's thinking that would be specific enough for the participant to generate a conversation with Ms. Hemingway about Emily's possible misconceptions. However, the evaluative nature of the comment still contains an evaluative aspect.

The greatest difference between the *Mixed* and *Focused* comments was in the nature of the interpretive comments. Those in the *Mixed* level were evaluative in nature, not based on specific evidence in *what* they noticed, or were still focused on the teachers' pedagogy. Whereas *Focused* comments were interpretive in nature, participants were making meaning about student learning based on the evidence and centered on specific and important mathematical comments or written work. For example, several interpretive comments included statements such as, "Nick used an unusual method but was able to explain his thinking," or "Nick has a unique outlook on this problem" wherein the choice of the word "unusual" and "unique" were evaluative in nature. Another participant commented that "[Emily] does not have a clear understanding that she could use the congruent angles of the isosceles trapezoids to solve, and not add the additional step of drawing the triangle." Although this statement might be an appropriate interpretive comment, there was no specific evidence in the participants' attending from which to make such a claim. It is as though he recognized there was evidence to make the statement, but without being able to refer back to this evidence, this interpretive statement would not be useful in facilitating a professional conversation; it lacked the substance necessary to initiate such a conversation.

There were also seven participants whose final project showed no growth in their ability to notice students' mathematical thinking. These participants' comments focused on broad and vaguely supported *Baseline* statements such as "all three [students] thought well mathematically," "the class demonstrated an understanding of an isosceles trapezoid," and "I noticed the students also had the critical thinking skills needed." Furthermore, their interpretive comments were inconsistent, general, and typically evaluative, which suggested they were still struggling with noticing specific evidence of students' mathematical thinking. Statements such as, "Emily's group struggled with applying specific concepts to this problem" and "the students have a fair understanding of geometric principles and can apply those principles to the material" again, provided little evidence or interpretation of students' mathematical thinking for the participants to facilitate a meaningful and focused professional conversation with the teacher. Some of the comments implied observed evidence, such as "I notice that they all have an understanding of the sum of interior angles," but it would be difficult to use such a comment as a reference when talking with the teacher about the students' understanding of the mathematics.

Implications and Next Steps

Although the majority of the participants improved in their ability to notice students' mathematical thinking and reasoning, there are two primary areas to highlight based on the findings from this project: 1) recognizing the nature of evidence needed in order to meaningfully facilitate a professional conversation with their teachers, and 2) the continued support needed for administrators to develop their noticing.

Necessary Evidence

The purpose of the professional development session was to understand and increase administrators' abilities to notice key mathematical moments of students' thinking and reasoning, so they would be better able to support teachers' instructional practices. In the Case of Ms. Hemingway, the intent was that an administrator could observe such a lesson, notice specific elements of students' mathematical thinking, and then meet with Ms. Hemingway and facilitate a conversation about students' thinking. Essentially, for the administrator to be able to develop noticing in teachers, he or she must have the necessary noticing skills and be able to interpret the complex interdisciplinary enterprise of mathematics teaching (CBMS, 2012). Since administrators often make instructional decisions based on their understandings, supporting them in noticing key elements in a mathematics classroom is essential for them to make decisions or encourage classroom-based and school-wide actions that reflect students' thinking (Price et al., 1995).

Findings from this study highlighted the importance of administrators recognizing the nature of evidence that is necessary for meaningfully supporting teachers and for engaging in professional conversations with teachers to transform schools (Zepeda, 2013). As seen in Part One of this project, the participants were not specific with their evidence and the noticing did not generate talking points that included student evidence. In contrast, as the participants engaged in Part Two of the project, they were able to begin to notice at more advanced levels. This suggested that the professional development session on noticing may have afforded opportunities for the development of noticing among the participants wherein they could reconsider the nature of their instructional support (Cobb & Jackson, 2011). These findings are promising because they indicate that noticing may be developed among administrators when they engage in activities that encourage and scaffold their development. In addition, these findings represented a shift from only evaluating teachers to also facilitating professional conversations about students' learning of mathematics.

The structure of the professional development session, based on a group setting and collaborative opportunities to discuss noticing, provided the participants with opportunities to work with others as their noticing was scaffolded (Clarke & Hollingsworth, 2002). In Part One, the participants were in groups and had the opportunity to share their ideas and observations with peers. In contrast, in Part Two the participants worked individually to notice students' mathematical thinking. There are possible explanations for their shift in noticing from Part One to Part Two.

One possible explanation for the shift in noticing is that the group structure of the setting for Part One provided the participants with opportunities to engage with others and hear varying perspectives. As the professional development progressed, the participants expressed their ideas with others and they were scaffolded with prompts and protocols to encourage their noticing. A second explanation about the shift in noticing relates to the timing of the introduction of the Learning to Notice Framework (van Es, 2011). During Part One, the participants were not aware of the framework and only gained awareness about the role of noticing and the framework after they had engaged in the initial activity. It is plausible that orientation with the framework, viewing classroom videos, and maintaining cognizance about the framework may have encouraged the participants to improve their level of specificity with regard to students' thinking in their noticing.

Another possible reason for the shift could be the scaffolding supports that continued during Part Two. Specifically, the participants all had their own individual copies of the Case of Ms. Hemingway and had specific prompting questions to answer after watching the video. Having a week to view, reflect on, and process Part Two of the video permitted them the opportunity to view the video repeatedly, which could have created an opportunity for continued recurring focus on students' thinking. If the participant did not fully understand how a student was thinking in the video initially, he or she could re-watch the video. With that said, researchers did not collect information on the number of times participants viewed the video in Part Two.

Although the video structure removed the authentic context of observing a teacher, these findings show further promise for the role of video in developing noticing (Star, Lynch, & Perova, 2011). By watching the video repeatedly during the workshop, the participants began to realize where they needed to focus their attention and they gained understanding about the mathematics content and what was important to notice (Price et al., 1995). Likewise, the questions the participants were required to answer in Part Two further encouraged noticing of students' mathematical thinking because the questions specifically prompted participants about exact students and their thinking. For example, question one stated, "What do you notice about Emily, Nathan, and Karrie's mathematical thinking?" To answer this question, the participants had to rely on specific notes and write explicitly about how Emily was thinking, how Nathan was thinking, and how Karrie was thinking. The questioning on this form forced the participants to be intentional about individual students, which further scaffolded their noticing and their specificity about mathematical content. The important concept from these findings is that with support, administrators can develop their ability to notice students' mathematical thinking and improve their competence with understanding the type of mathematical learning that occurs in classrooms (Buschman, 2004).

Continued Support

For administrators to fully realize their role as instructional leaders within schools, continued work on their ability to notice needs to occur. While many participants learned to more precisely notice students' mathematical thinking, one third did not shift in this ability. One reason for this, which the participants discussed during the workshop, was the reported lack of formal training they received in their administrative credentialing programs related to noticing. Participants frequently stated, "We have not been trained to do this, to notice." For these participants, creating a non-evaluative instructional support schema relating to their observations within classrooms seemed difficult to create as their noticing focused on environment, pedagogy, and evaluating the teaching. Realizing administrators' role of an instructional leader seems increasingly difficult to achieve if non-evaluative professional conversations cannot be meaningfully created. Again, the need for focused and on-going support in instructional leadership for administrators should be considered.

As evidenced with these findings, the professional development session resulted in an increased ability to notice for nearly two-thirds of the participants. However, as noted by a lack of research literature on administrators and noticing, little work is being done to specifically address the noticing needs of administrators. Therefore, we call for an increased emphasis on professional development support for administrators to learn and develop their abilities to notice. As evidenced by these data, Part One and Part Two provided necessary scaffolds to administrators to orient them to the process of noticing and the importance of noticing students' mathematical thinking. On-going professional development supports with included scaffolds, such as those used in this project, are necessary for growing and developing administrators' capacities to notice.

It should be noted that it is unclear how the change in participants' noticing skills might have been influenced by the pointed questions in the Part Two module. That is, the increase in noticing might have been a result of the lack of similar questions in part one or the lack of the option of reviewing the video in Part One. Furthermore, for this part of the project, the researchers did not follow the participants into an actual setting so it is unclear whether these skills would transfer into an authentic observational setting. A follow-up project is currently in its second year examining this aspect in further detail. Regardless, as — supported by Hallinger and Murphy (1985), administrators must be able to notice how students are reasoning mathematically if they are going to effectively facilitate professional conversations and support teachers in creating rich mathematical learning environments. ✪

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APPENDIX A.

Part Two — Prompting Questions

ANALYSIS QUESTIONS

Your noticing of student thinking

1. What do you notice about Emily, Nathan, and Karrie's mathematical thinking?
RESPONSE:

2. What might this suggest about Emily, Nathan, and Karrie's understanding?
RESPONSE:

Teacher's noticing of student thinking

3. Describe the teacher's responsiveness to Emily, Nathan, and Karrie's mathematical thinking.
RESPONSE:

4. Describe the extent to which you feel the teacher has the same understandings of Emily, Nathan, and Karrie's mathematical thinking as you.
RESPONSE:

Your plan of support for the teacher

5. What questions would you ask this teacher to better understand their understanding of Emily, Nathan, and Karrie's mathematical thinking? What do you intend to learn from these questions?
RESPONSE:

6. How would you support this teacher in the future to make pedagogical decisions that support the development of all students' mathematical thinking?
RESPONSE:

APPENDIX B.

van Es (2011) Framework for Learning to Notice Student Mathematical Thinking

	Level 1 Baseline	Level 2 Mixed	Level 3 Focused	Level 4 Extended
What Teachers Notice	Attend to whole class environment, behavior, and learning and to teacher pedagogy	Primarily attend to teacher Pedagogy Begin to attend to particular students' mathematical thinking and behaviors	Attend to particular students' mathematical thinking	Attend to the relationship between particular students' mathematical thinking and between teaching strategies and student mathematical thinking
How Teachers Notice	Form general impressions of what occurred Provide descriptive and evaluative comments Provide little or no evidence to support analysis	Form general impressions and highlight noteworthy events Provide primarily evaluative with some interpretive comments Begin to refer to specific events and interactions as evidence	Highlight noteworthy events Provide interpretive comments Refer to specific events and interactions as evidence Elaborate on events and interactions	Highlight noteworthy events Provide interpretive comments Refer to specific events and interactions as evidence Elaborate on events and interactions Make connect ions between events and principles of teaching and learning On the basis of interpretations propose alternative pedagogical solutions

APPENDIX C.

Administrator Noticing of Part One Video

	Evidence	Interpretative Comments	Follow-up Questions
Group 1	Acknowledge that there were 4 possible approaches	Students utilize multiple strategies	
	"Mike's group figured it out in a way that a lot of students have figured out that we determined doesn't quite work"	Teacher allowed productive struggle	How did the students resolve the inaccuracies/misconceptions pre-sented by Mike's group?
	Mike's group did it this way but made a bit of an assumption	Students possess foundational knowledge that helps them problem solve and analyze	How did you know that all the students understood the learning goal?
Group 2	Multiple strategies for solv-ing-shared 1 with whole class	Value in showing exemplars	How do you know if students under-stand the difference between the methods and their usage?
	Noticed the assumption Mike's group made	Aware of math thinking of students	
	Mike shows his work	Value of process after product	Does Mike know why it didn't work?
Group 3	Noticed an erroneous assumption		
	Teacher pointed out/evaluated error	Teacher stated these things rather than allowing them to discover mis-takes on their time	How could you have facilitated the lesson rather than directing?
	Teacher corrected [students'] subtraction		
Group 4	Invited a group to show one solu-tion	Teacher knew what the students were thinking	How did the erroneous assumption impact the course of the lesson?
	All students worked together to develop a shared understanding	Allowed for informal assessment and higher engagement	
	Students knew the properties of triangles	Students could apply their knowl-edge	
Group 5	[Teacher] highlighted one groups logic of "assumptions"		How did involving Mike's group's solution build a deeper conceptual understanding?
	Paired both groups strategies close together to "drill down" to the misconception	Helps keep track of what you are doing	
Group 6	Students had different responses	Mike's group made some assump-tions	How will you help Mike's group learn the correct method?
	Both strategies were displayed with an explanation by students	Elaborate 4 ways to solve	

The Need for Research into Elementary Mathematics Specialist Preparation

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Abstract

The continued concern for the mathematical preparation of elementary teachers has kept discussions of elementary mathematics specialists (EMS) a vital part of many mathematical reforms. With over half the states providing or in the process of developing EMS certifications, a closer examination of the ways in which EMS are prepared is needed. In this paper, I explore several types of EMS, the current state of EMS preparation, and literature related to EMS. I then discuss the potential constraints associated with preparing EMS. I close with a discussion of future avenues of research related to EMS preparation and a call for more research in this area.

Introduction

In a recent national survey, 57% of elementary teachers indicated they completed one or two college mathematics courses in the areas of number and operations, algebra, geometry, probability, and/or statistics. Thirty two percent reported taking three or four of these courses and only 10% completed courses in each of these five areas (Banilower et al., 2013). These data suggest elementary teachers are not likely to have received the 12 hours of specialized mathematics coursework recommended in the 2012 report by the Conference Board of the Mathematical Sciences (CBMS), *The Mathematical Education of Teachers II*. The limited mathematical preparation of elementary teachers in teacher education programs has contributed to calls for the development and use of elementary mathematics specialists (EMS) in American schools. EMS can be defined as "teachers with particular knowledge, interest, and expertise in mathematics content and pedagogy" (Reys & Fennell, 2003, p. 278) and can serve in a number of roles, from coaches to content specialists, at the school or district level.

Over two decades ago, the authors of the National Research Council's (NRC, 1989) document on the state of mathematics education, *Everybody Counts*, suggested that the U.S. continues to adhere to a generalist model of elementary teachers despite evidence that this is not the most effective model for student learning. The report discussed the need for specialized mathematics teachers in the elementary grades. More recently, Fennell (2011), former president of the National Council of Teachers of Mathematics (NCTM) and project investigator of the Elementary Mathematics Specialists and Teacher Leaders Project, wrote about the history of EMS.

> Elementary mathematics specialists are becoming the school or district level 'transition agents' for the Common Core State Standards for Mathematics. Mathematics specialists at the elementary school level are becoming increasingly important as we acknowledge the complexities of elementary mathematics teaching and learning. (p. 52)

Despite the growing support for EMS, the movement to formalized programs of study for such professionals is a recent phenomenon. Currently, 21 states have certification programs for EMS or are in the final stages of approving such a program. An additional eight states are in the process of creating such certifications (EMS & Teacher Leader Project, 2015).

This relatively recent trend toward the use of EMS is in response to a confluence of changes in the educational landscape in the United States. The emergence of EMS has created a need to understand and research the role, impact, and preparation of EMS in the United States. In this paper, I explore two types of EMS along with the current state of EMS preparation in the United States. I then discuss the potential constraints associated with preparing EMS. I close with a discussion of future avenues of research related to the preparation of EMS.

Why EMS?

Certainly, many of the concerns that framed early calls for EMS still exist today. For example, in 1989 the authors of *Everybody Counts* wrote, "Too often, elementary teachers take only one course in mathematics, approaching it with trepidation and leaving it with relief. Such experiences leave many elementary teachers totally unprepared to inspire children with confidence in their own mathematical abilities" (NRC, p. 64). Though this statement was made over twenty years ago, the data aligns with the aforementioned study by Banilower and colleagues (2013) who found that more than half of elementary teachers surveyed completed only one or two mathematics classes in college. The continued concern for the mathematical preparation of elementary teachers has kept discussions of EMS a vital part of many mathematical reforms.

Past NCTM president Linda Gojak (2013) discussed reasons that the mathematics education community should continue to advocate for the use of EMS in schools. Three of her reasons centered on issues involving the amount of time and knowledge, both pedagogical and mathematical, necessary to help children develop deep understandings of mathematics. She specified that EMS are needed to help meet the needs of diverse learners and noted that the heterogeneous nature of elementary classrooms necessitates great content area expertise. Gojak also countered the common arguments of EMS being too costly and concern over elementary children taught by multiple teachers: "The reality is that most children are under the care of multiple adults" (para. 5) and "schools that have adopted a modified departmentalization structure have done so with little or no additional cost" (para. 8). Finally, she indicated that EMS could help to increase the impact of professional learning communities by supporting teachers in professional development focused on the teachers' interests and roles.

In addition to Gojak's (2013) arguments, two points central to the current climate of mathematics education highlight the need to carefully examine the responsibilities and training of EMS in schools. First, mathematics teaching must improve if students are to increase their learning outcomes in mathematics. Ball and colleagues (2005) emphasized this point stating, "Little improvement (in student mathematics achievement) is possible without direct attention to the practice of teaching" (p. 14). In terms of the mathematics described in the Common Core State Standards for Mathematics (CCSSM) (Common Core State Standards Initiative [CCSSI], 2010), successful implementation requires that elementary teachers acquire additional mathematics knowledge, skills, and practices, as well as increase their capacity to more effectively use what they know and can do (CBMS, 2012).

Second, efforts to improve mathematics teaching at the elementary level will require a consideration of changes to the mathematical preparation of teachers (Reys & Fennell, 2003). There is evidence that many practicing elementary teachers are not adequately prepared to meet the demands for increasing student achievement in mathematics (Ball, 1990; CBMS, 2012). Publications from the NCTM (2000), the Association of Mathematics Teacher Educators (AMTE, 2013), the National Mathematics Advisory Panel (2008), and the NRC (1989) emphasized that most elementary teachers are generalists and, as such, are expected to teach all core subjects. Thus, many teachers never develop the in-depth knowledge and skills required to effectively teach elementary mathematics. In fact, the *2012 National Survey of Science and Mathematics Education* (Banilower et al., 2013) documented that although 77% of elementary teachers surveyed felt very well prepared to teach number and operations, only 56%, 54%, and 46% thought the same in regard to measurement, geometry, and early algebra, respectively. In addressing this dilemma, Wu (2009) specified a problem of scale and suggested a different approach.

> Given that there are over two million elementary teachers, the problem of raising the mathematical proficiency of all elementary teachers is so enormous as to be beyond comprehension. A viable alternative is to produce a much smaller corps of mathematics teachers with strong content knowledge who would be solely in

> charge of teaching mathematics at least beginning in grade 4. (p. 14)

The idea of preparing a cadre of EMS to help improve the mathematics education of elementary students is one that has been embraced by a number of states; however the preparation of these specialists and the role they fill in schools varies greatly.

How are EMS utilized?

Though the *Standards for Elementary Mathematics Specialists* (AMTE, 2013) detailed the training EMS should receive, these standards also discussed the wide range of roles to which such training may lead dependent upon the specific needs of the locations at which specialists are employed. Similarly, the mathematics education literature provides accounts of a number of different EMS models including mathematics coaches, teacher leaders, specialized content teachers (as referenced by Wu (2009)), and mathematics intervention specialists, or pull-out instructors, for special needs students (National Mathematics Advisory Panel, 2008). Though the names and responsibilities of these positions may vary from state to state or even district to district, in the following section I discuss characteristics of these broader categories found in the mathematics education literature.

In a 2009 research brief for NCTM, McGatha wrote of two categories of what I refer to as EMS—mathematics coaches and mathematics specialists. She defined the two groups according to the population with which they primarily worked. Mathematics coaches are the most common type of EMS and work primarily with teachers, whereas mathematics specialists typically work directly with students (National Mathematics Advisory Panel, 2008). For clarity, I have defined mathematics coaches as EMS who work directly with teachers. I refer to EMS who work with students as specialized mathematics teachers. It is important to note that in each case, mathematics coaches and specialized mathematics teachers, I am referring to EMS as teachers who have specialization in elementary mathematics. Therefore, it is possible that a teacher might serve in a role with duties similar to that of a mathematics coach or a specialized mathematics teacher but might do so without having "particular knowledge, interest, and expertise" (Reys & Fennell, 2003, p. 278). Under the definitions used in this paper, these teachers are not included in these categories.

Even with these distinctions between mathematics coaches and specialized mathematics teachers, there remains ambiguity in the role of EMS because many research studies and school districts have used the term to refer to positions that carry with them a number of different responsibilities (Campbell & Malkus, 2011; Olson & Barrett, 2004). In discussing the differences among EMS, the National Mathematics Advisory Panel wrote, "There is considerable blurring across types and roles" (2008, p. 43). In the following sections I discuss the distinction between these two roles.

Mathematics Coaches

Mathematics coaches are typically school-based specialists who are chiefly tasked with supporting teachers in improving their mathematics instruction. Mathematics coaches may be employed in elementary, middle, high schools, or at the district level to support multiple grades. Though mathematics coaches may retain some or all of their teaching responsibilities, it is more common for their full-time responsibility to be that of supporting teachers (National Mathematics Advisory Panel, 2008).

> Whether termed a specialist, coach, support teacher, or teacher leader, in many school districts today the intent is to place a highly knowledgeable teacher, who frequently does not have responsibility for the instruction of a classroom of students, in a school in order to advance instructional and programmatic change across the whole school. (Campbell & Malkus, 2011, p. 432)

In many instances, mathematics coaches may serve as the main source of mathematical professional development to fellow teachers. Russo (2004) remarked on the close alignment of school-based coaching with the recommendations for effective professional development set forth by the National Staff Development Council. Further, teachers may give mathematics coaches a more favorable reception than outside professional developers (Russo, 2004). Despite the potential for the use of coaches to provide teacher development, there exist several potential barriers to the widespread adoption of mathematics coaching nationwide.

One such barrier is the availability of training for teachers to become mathematics coaches, although in recent years there has been an increase in programs that provide such training (EMS & Teacher Leader Project, 2015). Another potential obstacle is that the creation of such positions requires additional personnel and can therefore be expensive. Alternatively, using EMS-certified professionals as classroom teachers with the primary responsibility of providing mathematics instruction to multiple groups of students may be accomplished with current staffing levels (National Mathematics Advisory Panel, 2008).

Specialized Mathematics Teachers

A number of stakeholders in the mathematics education community have recommended the use of specialized mathematics teachers in elementary schools (AMTE, 2010, 2013; CBMS, 2012; NCTM, 2000; NRC, 1989, 2001). Specialized mathematics teachers have received particular preparation for their role teaching elementary mathematics. In some instances, teachers may be selected by administrators to departmentalize or volunteer to teach mathematics. These teachers may be referred to as elementary mathematics teachers or departmentalized teachers; however, in order to make a distinction among these teachers and teachers with specific preparation, I reserve the use of the term specialized mathematics teachers to those with particular training as EMS.

The use of specialized mathematics teachers as content specific teachers continues to gain support (e.g., Fennell, 2011; Gojak, 2013), perhaps in part because many schools have managed to identify a mathematics specialist without hiring additional professionals through departmentalization. By reorganizing the staffing assignments of current teachers at a particular grade level such that one teacher is responsible for mathematics while another is responsible for other content area(s), it is possible for such a model to be cost neutral (Reys & Fennell, 2003). Under this model, a teacher is responsible for delivering only mathematics (or commonly mathematics and science) content as opposed to the traditional generalist model. Despite calls for the use of specialized mathematics teachers, most elementary schools have yet to adopt a departmentalized structure (Fennell, 2011; Gojak, 2013; NRC, 1989).

In addition to content teachers, specialized mathematics teachers may also serve as mathematics intervention specialists, commonly referred to as pull-out instructors. Pull-out instructors are primarily concerned with addressing the needs of particular learners. These teachers may have a secondary area of specialty such as teaching English language learners or special education students. Pull-out instructors may work with students in a resource room setting or might visit different classes throughout the week as they support special needs students in the regular classroom setting. Although not as cost effective as the previously mentioned model, pull-out instructors may allow for more specialized expertise and personalized learning experiences for students.

Research on EMS

Despite the wide array of uses and the proliferation of credentialed EMS programs (Campbell & Malkus, 2011; EMS & Teacher Leader Project, 2015; Reys & Fennell, 2003), research regarding the impact of such positions on student achievement and teacher instruction is still sparse (Campbell & Malkus, 2011; Fennell, 2011). Further, little research exists on the effectiveness of particular EMS preparation programs. In this section, I discuss the extant literature related to EMS.

In reviewing literature related to EMS, the majority of studies located focused on mathematics coaching rather than specialized mathematics teachers, though the total number of articles was quite small. In 2009, McGatha noted just seven studies examining the impact of mathematics coaching. Although several other studies have been published in the ensuing years (e.g., Brosnan & Erchick, 2010; Campbell & Malkus, 2011), there is still a dearth of empirical evidence specifically detailing the impact of mathematics coaches.

Many existing studies examining the impact of mathematics coaches do so with regard to student achievement. Campbell and Malkus (2011) conducted the most comprehensive study to date focusing directly on the impact of mathematics coaches on student achievement. In their study, they utilized a randomized control methodology to examine mathematics coaches who had received extensive preparation in five school districts in Virginia. The authors found that although there were no significant gains in student achievement during the first year of a school wide coaching initiative, there were learning gains in the subsequent years. The authors suggested the reason for these findings. “A coach’s positive effect on student achievement develops over time as a knowledgeable coach and the instructional and administrative staffs in the assigned school learn and work together” (p. 451). The authors also cautioned against generalizing the study’s results to coaches with less expertise than those in the study.

Similarly, a study by Brosnan and Erchick (2010) also found a positive relationship between student achievement and their Mathematics Coaching Program. The

Mathematics Coaching Program was a school-based program in which teachers worked with a mathematics coach to plan and implement lessons. The authors claimed, "These results fully position us to challenge traditional views on teacher development approaches and argue that providing teachers with information is not sufficient to improve practice" (p. 1367). The results were consistent with those from Campbell and Malkus (2011) and also aligned with literature on effective professional development (Borko, 2004).

Some instances evidencing the impact of mathematics coaches more broadly are found within studies focused on large-scale reform efforts in which mathematics coaches play only one part of a larger professional development project. In a study by Ferrini-Mundy and Johnson (1997), the researchers found that a key aspect of the successful reform efforts of a large-scale professional development program was the presence of mathematics coaches at the schools. These coaches "helped spread ideas, facilitate communications among teachers, plan and initiate staff development, and address political problems with administrators and community members" (p. 119). The authors indicated that this was not evidence for the employment of mathematics coaches, but rather a critical piece in the particular context in which the study was conducted. Similar findings reporting the important role mathematics coaches play in larger professional development efforts were evidenced in other studies (e.g., Balfanz, Maclyer, & Byrnes, 2006; Campbell, 1996; Foster & Noyce, 2004).

Another area in which several recent studies have focused is on the particular skills and strategies mathematics coaches employ. Several articles investigating this aspect came from the Examining Mathematics Coaching Project (Barlow, Burroughs, Harmon, Sutton, & Yopp, 2014; Sutton, Burroughs, & Yopp, 2011; Yopp, Barlow, Sutton, Burroughs, 2014). These studies have provided greater insight into the ways in which mathematics coaches' views impact their practice (Barlow et al., 2014), uncovered a lack of consistency of coaches' assessments of coaching skills (Yopp et al., 2014), and attempted to define the domains of content knowledge needed for mathematics coaches (Sutton et al., 2011). Further study in this area is important in developing a knowledge base of coaching skills and knowledge upon which to develop and improve EMS preparation programs.

Despite the limited amount of empirical research dedicated to coaches, McGatha (2009) explained, "Substantial anecdotal evidence from programs throughout the United States indicates that coaching can be effective in teaching and learning" (para. 10). This anecdotal evidence may be part of the reason for the continued growth of interest in and preparation of mathematics coaches. Although the aforementioned studies provide some evidence regarding the positive impact of school or district-based mathematics coaches, little is known about the impact of mathematics coaches on important indicators such as teacher retention, teacher satisfaction, and teacher recruitment, a point I return to in a later section.

The research is also limited regarding the impact of assigning well-prepared elementary teachers to specialized teaching roles; that is, with greater responsibilities for teaching mathematics within their schools. Although little evidence of the impact of specialized mathematics teachers exists, some elementary schools have reorganized (departmentalized) to allow teachers to specialize in teaching a particular subject (Fennell, 2011; Gerretson, Bosnick, & Schofield, 2008). It is not generally the case, however, that elementary teachers are assigned (or choose) to teach mathematics because of their mathematical content knowledge and pedagogical expertise in teaching mathematics or because they have been credentialed as an EMS. Rather, teachers may take on or be selected for these roles for a number of reasons such as their interest in mathematics (Gerretson et al., 2008).

In 2009, McGatha noted, "Research on the effects of mathematics specialists (those who work directly with students) is virtually nonexistent" (para 2). In the same year, the report of the National Mathematics Advisory Panel (2008) found that of the 114 articles they examined, only one (McGrath & Rust, 2002) examined the impact of mathematics specialists on student achievement. This article found no difference in mathematics gain scores for those students in classes with mathematics specialists as opposed to those students in a traditional classroom structure. It is worth noting, however, that the study was limited to a single district and there was no description of the mathematics teachers' preparation, therefore it is unclear if the teachers received additional training as EMS. In light of the lack of research, the National Mathematics Advisory Panel (2008) called for research on this model.

> The Panel recommends that research be conducted on the use of full-time mathematics teachers in elementary schools. These would be teachers with strong knowledge of mathematics who would teach mathematics full-time to several classrooms of students, rather than teaching many subjects to one class, as is typical of most elementary classrooms. This recommendation for research is based on the Panel's findings about the importance of teachers' mathematical knowledge. The use of teachers who have specialized in elementary mathematics teaching could be a practical alternative to increasing all elementary teachers' content knowledge (a problem of huge scale) by focusing the need for expertise on fewer teachers. (p. 44)

Research is needed to investigate the impact of assigning well-prepared specialized mathematics teachers to mathematics teaching roles.

Research is also needed on effective ways to prepare EMS. In reviewing the literature on EMS, I found no empirical investigations into particular preparation programs for EMS. Instead, there exists anecdotal records highlighting particular professional development activities aimed at EMS (e.g., Bastable & Lester, 2005), studies examining teachers' personal transitions from teacher to mathematics coach (e.g., Chval et al., 2010), and papers that characterized the skills needed for coaching (e.g., Feger, Woleck, & Hickman, 2004; Sutton et al., 2011). It is crucial to examine particular programs for EMS preparation to ensure the programs are aligning with the needs and responsibilities of these individuals and to understand the types of experiences that adequately prepare EMS for their future roles. Many questions surrounding EMS preparation exist such as: Are formal classes designed to prepare EMS an effective means of EMS preparation? Is it sufficient to identify effective teachers and assign them to an EMS role? Answers to questions such as these are needed to understand best practices for EMS preparation. In the closing section, I further discuss needs for future research along this particular avenue. I next turn to the preparation of EMS.

Preparation of EMS Professionals

Commonly, administrators select EMS in light of their reputation as effective teachers. Chval and colleagues (2010) discussed this particular model stating, "Too often we assume that effective teachers will be effective coaches and these teachers need little support as they transition into their new roles as mathematics coaches" (p. 192). Though selecting accomplished teachers to serve in the role of EMS is still common, many states have set forth formalized approaches to preparing EMS. Some of these EMS certification programs are endorsements teacher candidates receive as a part of initial certification programs. More commonly, state-level EMS certification requires graduate level study and is delivered through either a graduate certificate or masters program (EMS & Teacher Leader Project, 2015).

The state guidelines/requirements for EMS certification vary; however, many states have recently created certifications that closely align with the AMTE EMS standards (2013) (EMS & Teacher Leader Project, 2015). Across states, EMS certification requirements vary according to the prerequisites for entering such programs (e.g., years of teaching experience and certification levels) as well as the number of credit hours required for program completion. For example, teachers seeking EMS certification in Missouri must have a teaching certificate and two years of teaching experience. In Michigan, however, the EMS program is offered as part of the initial licensure process wherein teachers are endorsed as EMS upon completing specified competencies through initial teacher certification coursework and passing an exam in elementary mathematics. Many of the state certification programs focus heavily on mathematics content but also include coursework in areas such as leadership, assessment, and pedagogy (EMS & Teacher Leader Project, 2015).

Regardless of whether a particular state grants EMS certification, some university-based teacher education programs have addressed the issue of elementary content competence by allowing elementary education majors to choose a content concentration or major area (e.g., Indiana University, 2015; Kansas State University, 2015; University of Michigan, 2015). These concentration areas may require additional content courses beyond those taken by all elementary education majors. However, the addition of classes may not adequately address the need for a deeper knowledge of knowledge for teaching. Battista (1994) noted that simply taking more mathematics courses may not enhance the knowledge and skills needed by elementary teachers.

> The additional mathematics that [elementary] teachers take must be taught properly. That is, it must be taught as sense making. Unfortunately, most university mathematics courses reinforce rather than debunk the view

> of mathematics as a set of procedures to be memorized. Because such courses simply perpetuate the mathematical mis-education that occurs in grades K-12, requiring teachers to take more of them will do little to solve the problems. (p. 468)

Instead, what is needed are courses that focus on the mathematics that elementary teachers will teach from an advanced perspective. As noted in the *Mathematics Education for Teachers II* report (CBMS, 2012):

> Like many undergraduates, future elementary teachers may enter college with only a superficial knowledge of K-12 mathematics, including the mathematics that they intend to teach. For example, they may not know rationales for computations with fractions or the role of place value in base-ten algorithms, and may not have the opportunity to learn them as undergraduates. (p. 4)

To address this issue, this report recommended that prospective teachers take a minimum of 12 hours of mathematics courses that foster a deep understanding of the mathematics they will teach. These courses should focus not only on the fundamental ideas of elementary mathematics, but also on the early childhood precursors and middle school successors so that teachers can better understand the vertical alignment of the elementary mathematics curriculum. Further, these courses, and any professional development experiences, should develop the habits of mind of a mathematical thinker and problem solver, including reasoning and explaining, modeling, seeing structure, and generalizing.

Although these goals are important for all teachers at the elementary level, additional competencies are needed for teachers who specialize in mathematics. The AMTE *Standards for Elementary Mathematics Specialists* (2013) provided guidelines for EMS credentialing, including a minimum of 24 hours of coursework, organized in three areas: content knowledge for teaching mathematics, pedagogical content knowledge for teaching mathematics, and leadership knowledge and skills. The content knowledge for teaching mathematics includes courses focused on a deep understanding of the K-8 mathematics curriculum as well as specialized content knowledge for teachers. The pedagogical knowledge includes attention to research and practice related to learners and learning, teaching, curriculum, and assessment. Finally, the leadership component focuses on skills needed for EMS to support their colleagues' development.

In addition to this coursework, the recommended program includes supervised mathematics teaching practicum experiences in which prospective EMS acquire experience working with a range of students and adult learners, including elementary students (e.g., primary, intermediate, struggling, gifted, English language learners) and elementary school teachers, both novice and experienced, in a variety of professional development settings. Though there continues to be growing interest and action toward the use of EMS professionals, there continues to be a need for research involving EMS.

Avenues for Further Research

As previously discussed, there is a great need for research on EMS. The question of whether or not particular models of EMS positively impact teacher instruction and student learning in different ways or to differing degrees remains unanswered because, unfortunately, evidence related to this question is practically nonexistent. Though student achievement is certainly one component by which we might measure the impact of EMS, future examinations of EMS impact must move beyond student achievement to other important indicators or effectiveness such as teacher retention, teacher job satisfaction, and recruitment of high quality teachers. Understanding outcomes such as these may help to better inform policy. For example, teacher retention, particularly in high needs schools, is a difficult and costly problem (Luekens, Lyter, & Fox, 2004). If EMS are more likely to be satisfied and remain in these schools, policy makers may be more likely to make investments in hiring and preparing EMS.

Some insights on the impact of EMS might be gleaned from studies that identified characteristics of effective professional development or other studies more generally examining the characteristics of effective content coaching. It is important to better understand the impact of elementary mathematics specialists, including pull-out instructors and mathematics coaches. Further, the field must examine whether one model is more effective at improving student achievement or influencing other measures of teacher impact such as teacher retention. Mathematics educators must move beyond anecdotal evidence if they are to better inform practice and policy. Large scale, empirical studies could help make the case for the preparation and hiring of EMS, an issue that is of particular importance in light of the substantial changes that will result from the implementation of the CCSSM.

Similarly, research on effective programs focused on the preparation of EMS is needed. As the number of EMS preparation programs continues to rise, it is important that the mathematics education community study the variations among the programs' approaches to EMS preparation. What types of courses are needed to prepare EMS? Are different preparations required for specialized mathematics teachers and mathematics coaches? Are field-based experiences more effective for preparing EMS than traditional courses? Is being a master teacher sufficient or are specialized programs focusing on developing additional mathematics competency for teaching needed? This issue was raised in the National Mathematics Panel Report (2008).

> Given the paucity of evidence that general teacher certification has a positive effect on student achievement, it may seem counterintuitive to think that the use of elementary mathematics specialists would have positive effects. It is likely, however, that if the use of elementary math specialists is to have a positive effect, it will be because the training of specialists develops, in a more focused way, the specialized mathematical knowledge for teaching shown to have effects on student achievement. This suggests that policies and programs for elementary math specialist need to be developed in tandem with research that attempts to uncover those aspects of teacher knowledge and understanding most strongly related to student learning. (Ball et al., 2008, p. 5-56)

In other words, if specialized programs are beneficial, what are effective methods for delivering these programs and what content is of particular significance? Though districts and universities continue to invest in EMS preparation, it is done so without evidence as to what constitutes an effective program. Understanding the aspects of effective EMS preparation is crucial to the future success of such programs.

The community of mathematics educators is a vital component of the future success of EMS preparation and impact. Mathematics educators should critically examine EMS programs and the impact of EMS on student learning in order to continue to improve existing models and advocate for changes to state and local policy regarding EMS. Further, because many states already offer certification for EMS and many schools and districts employ EMS, it is necessary to begin to bridge current practice and research. As new mathematics educators take on research in this area, it is important that those already involved in the work of EMS use the research to inform practice. Thus, new studies regarding EMS must be accessible to not only institutions that prepare EMS, but also to school and district level personnel in order to align the use of EMS to evidenced best practices.

With the transition to CCSSM by a majority of U.S. schools, the utilization of EMS seems a promising component of successful implementation. This move also provides opportunities for rich avenues of research into EMS and their involvement in reform efforts and student learning. These opportunities will hopefully begin to span research and practice as the field comes to better understand best practices for EMS preparation and the impact EMS may have on student learning. ✪

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Lessons from the Field: Challenges We Face When Coaching Teachers

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Abstract

In this article, we highlight three of the common challenges that many coaches have experienced in one form or another: seeking administrative support for coaching teachers; working with teachers who are resistant or reluctant; and moving beyond demonstrating lessons. Each challenge has its unique set of circumstances that present possible opportunities for the coach to capitalize on and further support teachers' daily work. We use these particular examples to provide the reader with opportunities to examine and reflect on situations coaches might encounter.

Introduction

Many school districts have hired mathematics coaches to support teachers' ongoing professional learning (Grant & Davenport, 2009; Killion, 2008; York-Barr & Duke, 2004). Whether they work part-time or full-time (McGatha, 2010; Reys & Fennell, 2003), coaches engage teachers in professional development, monitor assessment practices, and more generally, help to implement the school improvement plan for mathematics instruction in the school building. Throughout their careers, they continue to develop a unique set of knowledge and skills that enable them to do this work (Campbell & Ellington, 2013; Campbell & Malkus, 2011). Their work with individual teachers is particularly important and necessary in order to support teachers' learning about teaching and students (Knight, 2011; Moreau & Whitenack, 2013).

In our state, we offer a graduate program for teachers that provides an in-depth study of mathematics and mathematics educational leadership to prepare them as mathematics coaches (also known by others as mathematics specialists, instructional coaches, mathematics assessment specialists, and so on). In this program, the teachers complete five mathematics classes, three educational leadership classes, and a field-based research project that focuses on their work as coaches. These courses provide teachers with opportunities to explore the range of roles and responsibilities they might have. For instance, one of the leadership courses focuses exclusively on coaching individual teachers. (For more information about this program and the different courses offered, please see: http://www.vamsc.org/index2.html.)

As teachers have moved through this program, we have followed them, and have noticed that they sometimes faced unique challenges as they transitioned into their new roles. In some instances, the challenges were anticipated, and in other instances, they were not (Donaldson et al., 2008; Knight, 2009). In this article, we explore in detail some of these unanticipated challenges that coaches faced as they were learning how to support teachers' daily work.

We will address three challenges: seeking administrative support for coaching teachers; working with teachers who are resistant or reluctant; and moving beyond demonstrating lessons. We provide vignettes of actual situations that highlight each of the three challenges. (Each individual that we feature in the vignettes was trained in the previously described program and is currently serving as a mathematics coach. Each is assigned full-time to one school building and has a primary focus of providing daily in-school professional development for teachers.) After presenting each vignette, we provide some possible ways that the mathematics coach might address the particular challenge.

Three Challenges

Each challenge that we present was identified through our observations and interviews with different mathematics coaches. Each of the coaches encountered all of these challenges in one form or another. However, the vignettes that we present here highlight particular key issues associated with each of these challenges as they were experienced by one of the mathematics coaches. These vignettes bring to the fore some of the unique ways that the mathematics coach addressed these challenges.

Challenge 1: Seeking Administrative Support for Coaching Teachers

Knight (2011) suggested that school buildings should be places that everyone is "actively engaged in professional growth, with the principal being the first learner" (p. 20). By working together, having regular planned meetings, the principal and the mathematics coach can develop a shared view about how to meet common goals for the school mathematics program (Knight, 2006).

There are many ways that the principal can assist the mathematics coach whether the mathematics coach is new to the position or the school or a long time member of the school's instructional team. For instance, the principal might spend part of one of the teachers' meetings at the beginning of the school year introducing the mathematics coach. During this meeting, the principal can share what the mathematics coach's responsibilities will be as well as provide opportunities for teachers to ask questions and become more familiar with the different ways they might collaborate with the mathematics coach (Inge, Arco, & Jones, 2013). As another example, when developing a professional development plan with individual teachers, the principal can suggest that teachers work one-on-one with the mathematics coach (Knight, 2011). As the principal, teachers, and the mathematics coach work together, they can develop a shared view of what the mathematics coach's responsibilities are in the school building (Knight, 2011). When there is not a clear understanding of the mathematics coach's responsibilities, however, the coach may have difficulty successfully engaging in her daily work with teachers. The vignette that follows illustrates one of the challenges a mathematics coach, Ms. Jenkins, encountered with the principal regarding her changing role during the school year as the school prepared for high-stakes testing.

Vignette 1. Ms. Jenkins' work changed during the second part of the school year. At the principal's request, instead of working with teachers in their classrooms, she worked with a range of students in a pull-out, intervention program to prepare them for the state-mandated tests. She needed to renegotiate her responsibilities with the principal so that she might more effectively work with teachers throughout the school year. Here is Ms. Jenkins' story.

> *Ms. Jenkins had been a teacher in this urban school district for several years, but this was her first year as a mathematics coach in a new school building. Over the past several years, this school received a passing score in mathematics from the state department, because its students met all of the expectations for the end-of-the-year state tests. As a result, Ms. Jenkins did not believe her role should focus heavily on assessment. Instead, she wanted to help teachers further learn about and develop their instructional practices. She worked with individual teachers, co-taught lessons, planned instruction, and conducted vertical and grade-level meetings. She used parts of these meetings not only to discuss logistical issues around testing and curricular frameworks, but also to engage teachers in advancing their own understanding of mathematics by exploring mathematical topics through problem solving.*
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> *Ms. Jenkins believed that she and her principal shared the same goals for the school's mathematics program and the same view of the role of the mathematics coach within the school. She worked hard at coaching individual teachers, developing activities, and meeting with teachers. Interestingly, the work that she had begun during the first half of the school year came to an abrupt halt after winter break.*
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> *When she returned from winter break, her school building principal asked her to begin preparing third, fourth, and fifth grade students for the state tests. Specifically, Ms. Jenkins was asked to develop weekly practice tests for each of the grade levels. These tests consisted of problems that matched the different skills and knowledge that students needed to pass the state tests.*

Ms. Jenkins scored these tests and identified students who did not give correct answers to test items. At the principal's request, students who did not receive a perfect score on these practice tests were pulled from their classrooms for remediation sessions conducted by Ms. Jenkins. Even students who typically scored exceptionally well on assignments and tests were pulled from regular class instruction to attend these remediation sessions. In some cases, Ms. Jenkins worked with several students at a time; in other cases, she worked with larger groups of students. How pervasive was this shift in the building? The principal requested that each teacher post the practice test results for their class by subject area beside each teacher's classroom door. These scores were in full view for all to see.

Discussion. When thinking about Ms. Jenkins' challenge, it is helpful to review the different responsibilities of mathematics coaches. We list a few here, as outlined by Inge, Arco, and Jones (2013, p. 241):

- work with administrators, teachers, students, parents, and the community to reach common mathematics goals;
- collaborate with individual teachers and teams of teachers through co-planning, co-teaching, and coaching;
- collect and analyze data in an effort to improve student achievement as well as mathematics curriculum and instruction;
- promote successful, research-based instructional strategies;
- assist in aligning curriculum and assessment resources to support and increase student achievement;
- conduct non-evaluative observations of teaching and learning to improve student achievement and mathematics instruction; and
- provide mathematics leadership that stimulates sustained systemic change and improvement in mathematics instruction.

As revealed by this list, the mathematics coach has many different responsibilities that support the school mathematics program and student learning of mathematics for understanding. Ms. Jenkins viewed her work as encompassing all of these responsibilities.

By mid-year, though, her views differed markedly from the views of the principal. Ms. Jenkins' challenge was to speak with the principal about her responsibilities as a coach. During the second half of the school year, she had few, if any, opportunities to work with individual teachers. How could she help the principal understand how important it was for her to coach individual teachers? Additionally, how could she convince the principal to let her return to her plan for the mathematics program for the building?

Let us begin with how Ms. Jenkins might have addressed her concerns. First, Ms. Jenkins needed to decide what information to prepare for the principal about the extent to which the principal's testing preparation plan, that is, the common assessments, were effective (Confer, 2006; Love, 2009; Walston & Overcash, 2013). Did these assessments help all students be more prepared for the test? If she determined that not all students benefitted, she would need to develop a plan for how to communicate her findings with the principal (e.g., Walston & Overcash, 2013).

In proceeding, Ms. Jenkins decided to look carefully at the student results from the practice tests. Because she had access to the different practice test scores for each of the grade levels, she analyzed this information to determine if this approach worked for all of the students. As she analyzed the test scores, to her surprise, Ms. Jenkins found some discrepancies. First, African Americans and other minority students were not scoring well. In other words, the trends across the practice test scores for different subgroups revealed that not all students were benefiting from this approach (cf. Darling-Hammond, 2007; Lewis, 2007; Suurtamm, 2012). Additionally, the analysis led Ms. Jenkins to ask new questions. Would gaps among different subgroups actually become more pronounced overtime? Could this school become one of the failing schools? By voicing these more general concerns when she met with the principal, she could perhaps make an even stronger case for why the test preparation procedures were not helping all students. She might suggest that they use these results to plan for her work with teachers, for example, using both high-stakes assessments and formative assessment practices (Walston & Overcash, 2013).

Once she gathered information about the practice tests (Confer, 2006; Inge, Walsh, & Duke, 2013; Knight, 2007), she was prepared for her meeting with the principal at the end of the school year. Prior to the meeting, she let the principal know that she would like to share results about the practice tests. She also planned to propose and further develop a plan with the principal that also included formative assessments for how to work with teachers and their students for the upcoming year (Inge, Walsh, & Duke, 2013).

As it turned out, Ms. Jenkins and the principal had the opportunity to discuss these issues during their meeting at the end of the school year. Unfortunately, they could not agree on the emphasis for Ms. Jenkins' role—coach of teachers versus high-stakes test preparation for students. Ms. Jenkins was at a crossroads. She could remain a coach in this building for the upcoming year and make plans to meet this challenge or she could request to be transferred to another school that might be a better fit for her. Perhaps there were other options that she had not yet considered?

One final point is worth noting here. Had Ms. Jenkins and the principal approached their differing views about the mathematics coach's responsibilities early on and developed a plan that worked for both of them, Ms. Jenkins may not have faced this challenge as the school year progressed. Of course, she may have needed to compromise with the principal in order to accomplish their common goals for the school mathematics program (Inge, Walsh, & Duke, 2013).

Challenge 2: Working with Teachers Who are Resistant or Reluctant

There are relevant points to consider on both sides that might explain why teachers are resistant or reluctant to working with mathematics coaches. On one side, teachers may appear resistant to suggested changes because they do not view the coach as an expert. For instance, they may have difficulty embracing a fellow teacher in a leadership role, particularly if the coach has less classroom experience (Donaldson et al., 2008). In response, a mathematics coach may adapt her role and responsibilities to such an extent that she is not able to effectively work with teachers—what Killion (2008) referred to as coaching light. On the other side, teachers may have justifiable reasons for resisting change. For instance, they may believe that the changes suggested by the mathematics coach are not reasonable or doable (Knight, 2009).

In the vignette that follows, it is not clear which of these two positions best describes Ms. Brooks' challenge. Not knowing why she faced the degree of resistance that she did played a part in how she was able to work with some teachers, particularly those teachers who taught third grade.

Vignette 2. Ms. Brooks faced a difficult situation. Since the beginning of this, her second year as a mathematics coach at this school, her working relationship with the third-grade lead teacher prevented her from working with the other teachers at this grade level. As a result, two third-grade teachers had difficulties that neither they nor Ms. Brooks could have anticipated. Once Ms. Brooks became aware of the circumstances, she offered to help these teachers provide additional support for their students. Here is her story.

> *For reasons that she could not identify, the third-grade lead teacher would not collaborate with Ms. Brooks. She did not invite Ms. Brooks to attend grade-level planning meetings or to visit her classroom during mathematics instruction. In fact, Ms. Brooks had very few opportunities to work with the teachers in third grade.*
>
> *Of course, Ms. Brooks was concerned because third grade was a crucial year for mathematics instruction. Students needed to perform well on the state tests. Additionally, this particular school year, there were two teachers, Ms. Baker and Ms. Smith, both of whom had not taught third grade before. Also, they were first-year teachers who were new to this school building.*
>
> *One day, Ms. Brooks stopped by Ms. Baker's classroom and noticed that Ms. Baker was sitting in the dark alone, visibly upset. As she talked with Ms. Baker, she realized that Ms. Baker was upset because she had just attended a meeting with the principal and assistant principal about her poor job performance. As they continued to talk, Ms. Brooks told Ms. Baker that she would work with her as often as she would like to help her with her mathematics instruction. Ms. Brooks assured Ms. Baker that "she had her back." Later, she also mentioned to the principal that she and Ms. Baker had decided to work together. She wanted to assure the principal that Ms. Baker was agreeable to doing this and she even hinted that Ms. Baker had initiated the discussion about working together.*
>
> *Ms. Brooks and Ms. Baker began planning for the next week's lessons. During their first planning meeting, she realized that Ms. Baker did not know anything about the curriculum framework—a guide that all teachers in the school district were expected to follow as they planned for the content they would cover throughout the school year. The lead teacher had not shared this information with her new teachers—one of the lead teacher's responsibilities.*

It was now the middle of the school year. Essentially Ms. Baker (and Ms. Smith) had not adequately prepared her students for the upcoming state tests nor had she covered the material in the curriculum framework that was scheduled for the first half of the school year.

Ms. Brooks mentioned that the lead teacher should have provided the framework to Ms. Baker and Ms. Smith. Once Ms. Baker realized that the lead teacher had not provided the curriculum framework, she mentioned this fact to Ms. Smith. Ms. Smith immediately approached Ms. Brooks and asked if she could join the meetings with Ms. Baker to plan for mathematics instruction.

Ms. Brooks worked with Ms. Baker and Ms. Smith several times each week. As she planned with them, they collaboratively determined what content they had already covered and what content they still needed to cover before the upcoming state test. Ms. Brooks also made suggestions about how to implement different activities, co-taught and modeled lessons, and debriefed about the lessons.

The trio continued to plan throughout the rest of the school year. Although, they had a great deal of catching up to do, through their hard work, they were able to help their third-grade students learn some of the important ideas that they had not addressed previously. They also worked towards the common goal of preparing the students for the state test.

Discussion. Ms. Brooks' challenge was to determine where the breakdown in communication occurred and to make a plan to ensure that this type of situation did not arise again. How should she handle this situation? Should she communicate with the lead teacher? In addition, she had another dilemma. Should she break with tradition and approach the principal about this situation? And importantly, how could she use this opportunity to begin building a working relationship with the third-grade lead teacher?

If she decided to speak with the principal about this situation she would jeopardize her working relationship not only with the teachers involved but also with all of the teachers in the building (Inge, Arco, & Jones, 2013). She needed to address this issue and do so carefully.

Her first priority was to find a way to work with the third-grade lead teacher (cf. Moreau & Whitenack, 2013). What strategies might she employ? For one, she could invite the lead teacher to these planning sessions. If the lead teacher attended the planning meetings, Ms. Brooks could ask her to interject or offer additional suggestions from time to time. As another possibility, Ms. Brooks could have informal conversations with the lead teacher about some of the issues that they were addressing in the sessions. She might talk about what she was learning about effectively working with these new teachers. By doing so, Ms. Brooks would communicate that she respected the lead teacher's important role and at the same time provide opportunities for the lead teacher to consider new approaches when working with these novice teachers. By taking this tactic, Ms. Brooks could help the lead teacher to develop leadership skills (Zeller, 2006). Further, Ms. Brooks could explore other strategies if these attempts were unsuccessful. If need be, she could invite the principal and all of the third-grade teachers to the planning sessions to foster their collaborations and ultimately improve their working relationship.

When working with reluctant teachers such as the lead teacher in this vignette, it is important to understand why they might be resistant (Knight, 2009; Sheffield, 2006). As Knight argued, teachers may have very legitimate reasons for being resistant. The mathematics coach has the task of uncovering the teacher's concerns and reasons for apprehension. Sometimes simply offering to help, providing additional resources, finding ways to communicate (e.g., dropping by the classroom or sending an email), or even helping with bus duty can initiate a new collaborative, working relationship that is built on trust and mutual respect (Minervino, Robertson, & Whitenack, 2013; Sheffield, 2006).

As an aside, Ms. Brooks learned a lot as a consequence of her experiences with the third-grade teachers. She needed to monitor teachers' progress more closely even if she did not work with them regularly. When necessary, she needed to seek the principal's support when she faced resistance or reluctance from teachers. By making expectations explicit about working with the mathematics coach, for instance, the principal could eliminate these types of situations from occurring or at least prevent them from continuing for long (e.g., Inge, Walsh, & Duke, 2013).

Challenge 3: Moving Beyond Demonstrating Lessons

The third theme, moving beyond demonstrating lessons to support changes in teachers' practices, is another important challenge that a mathematics coach may face. To more effectively support teacher learning, the mathematics coach needs to provide opportunities for teachers to take on more and more of the teaching responsibility when they are working in the classroom together (Feiler, Heritage, & Gallimore, 2000; Killion, 2008).

When coaching individual teachers, some mathematics coaches model lessons for an extended period of time. This approach can be problematic and limit the extent to which teachers are able to explore new practices (Killion, 2008). This is not to say that demonstrating lessons should not be a part of the work. In fact, modeling lessons is a common coaching strategy that mathematics coaches use when working with both new and experienced teachers (Knight, 2007; Moreau & Whitenack, 2013; Silbey, 2006; West & Staub, 2003). It is important, however, that over time the coach takes less and less of a role during regular instruction when working with teachers. In fact, some suggest that the coach needs to move to co-teaching or observing the teacher after modeling two or three lessons (e.g., Knight, 2007; Silbey, 2006).

The coach and teacher's work during the lesson is only part of the story. In addition to co-planning and co-teaching the lesson, the coach and teacher need to spend time afterwards debriefing about the lesson. Each of these aspects of their work is important. In fact, planning, implementing, and debriefing about the lesson are all part of the coaching cycle—an important process in which coaches and teachers engage to support teachers and their students' learning. This cycle has been talked about extensively (e.g., Campbell, Ellington, Haver, & Inge, 2013; Felux & Snowdy, 2006; Knight, 2007; West & Staub, 2003). All three parts of the cycle are a critical part of the coach's work with teachers. In this third and final challenge, Ms. Johnson faced this challenge of moving beyond demonstrating lessons.

Vignette 3. It can be challenging to capitalize on opportunities to encourage the teacher to take a more active role in exploring new approaches. This was the case for Ms. Johnson. She found it difficult to help the mathematics teacher, Ms. Brady, try new instructional strategies when they worked together. Here is her story.

> *Ms. Johnson worked in a small school with only two teachers at each grade level. Third, fourth, and fifth grades were departmentalized, so one teacher, Ms. Brady, provided all mathematics instruction for each of these grades. By working with Ms. Brady, Ms. Johnson had the opportunity to affect mathematics instruction for all of the upper grades. Additionally, she was able to manage her time more easily so that she could work with Kindergarten, first-grade, and second-grade teachers who provided mathematics instruction for their own students. As such, Ms. Johnson was able to support mathematics instruction in the entire school building by working with only seven teachers.*[1]
>
> *During Ms. Johnson's first year as a mathematics coach, she worked with Ms. Brady on a regular basis. She and Ms. Brady worked well together and briefly planned before co-teaching lessons. However, because of time, Ms. Johnson was not able to employ the entire coaching cycle regularly. Usually, when Ms. Johnson visited, she taught parts or all of the lessons while Ms. Brady interjected or monitored students' independent or small group work. Sometimes they made spontaneous decisions about the lesson as the students worked independently. Other times they facilitated whole class discussions together as students presented their ideas.*
>
> *During her second year of working in this school building, Ms. Johnson had less opportunity to work regularly with Ms. Brady. When they did not work together, she noticed that Ms. Brady used worksheets more and more often.*

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[1] Ms. Johnson's arrangement is quite different from mathematics coaches in larger, suburban or urban school districts where the mathematics coach may be responsible for mathematics instruction for 20-40 teachers in the school building. Mathematics coaches in larger school settings have different sets of challenges when it comes to supporting the work of all teachers of mathematics. They may rarely have a block of time free. The tradeoff comes in the kinds of supports that Ms. Johnson has in comparison to her counterparts in suburban or urban settings. She does not have many opportunities for professional development and does not report to a mathematics coordinator or supervisor housed in the district office. The few chances that she has to work with others comes in the form of collaborating with mathematics coaches in other schools or districts that are close in proximity. So although she works with fewer teachers, she has few opportunities to participate in professional development activities that would allow her to develop or refine her coaching skills. To this end, it is quite remarkable that she continues to grow and deepen her understanding—which attests to the knowledge, skill, and motivation she brings to her work.

The lessons were sometimes procedural, with less focus on understanding the mathematics behind the different procedures students learned. Ms. Johnson was concerned because she was not sure that her work with Ms. Brady was as productive as it could be. Even when she and Ms. Brady co-taught lessons, Ms. Johnson continued to model the lessons and they were not able to plan or talk about their work together. Ms. Johnson was limited in the amount of time she and Ms. Brady had to plan and debrief. How could she move Ms. Brady to the next level? How could she effectively employ the coaching cycle as she worked with Ms. Brady? What could she do to support Ms. Brady's reflective practice?

Discussion. Ms. Johnson's challenge in this working relationship was a result of the little time she and Ms. Brady had to talk about and plan for instruction. When they were able to work together, Ms. Johnson continued to model the lessons and, in effect, was not able to provide opportunities for Ms. Brady to explore new forms of practice. As a consequence, Ms. Brady resorted to old practices, ones that are less effective in preparing students for the state tests. As a result, students were developing a view of mathematics that did not include problem solving, but instead, featured deriving right answers.

How could Ms. Johnson better support Ms. Brady's work? What were some strategies that she could use to help Ms. Brady take ownership of reform-based instruction? Since Ms. Brady was the only upper level teacher teaching mathematics, Ms. Johnson could not use grade-level meetings to address this issue. She could, however, hold vertical team meetings with all of the teachers (Domalik, Hodges, & Jaeger, 2013). During these meetings, she could plan problem-solving activities for the teachers and use them to engage teachers in discussions about their thinking and their solution strategies, as well as develop targeted goals across and within grade levels (Domalik et al., 2013; Doyle & Standley, 2013). She could also use these opportunities to model different strategies for conducting class discussions, highlighting children's ideas, and/or facilitating student learning.

Additionally, Ms. Johnson could develop a different action plan for her work with Ms. Brady. First, she and Ms. Brady needed to find a time to plan together—the first part of the coaching cycle (Knight, 2007; West & Staub, 2003). If they could not find time during the regular school day, they may have needed to meet before or after school. If Ms. Brady was not able to meet because of other school or personal responsibilities, the coach will need to be creative. In this particular school, for instance, because Ms. Brady taught all of the third, fourth, and fifth grade sections of mathematics, Ms. Johnson might capitalize on this arrangement to develop a modified version of the coaching cycle. They would still need to meet during lunch or some other free time during the day to plan for an upcoming lesson. During this meeting, they would plan the lesson by exploring the mathematics, developing or adapting activities, and crafting good questions for the whole class discussion. Ms. Johnson could offer to model parts of the lesson when teaching the lesson to the first group of students and then discuss how their roles might change as they teach the lesson for the second or third groups of students at other periods during the day. After co-teaching the lesson to the first group of students, the coach and teacher would also need to have a brief discussion between classes about what worked and what they need to change.

Ms. Johnson would need to take a lesser role in co-teaching the lesson to the second (and third) groups of students; she should encourage Ms. Brady to teach the main part of the lesson or to conduct the whole class discussion (Silbey, 2006; West & Staub, 2003). By the third time they co-teach the lesson, Ms. Johnson could take a minimal role during the lesson—and assure Ms. Brady that she is there to help if need be (Silbey, 2006; West & Staub, 2003).

Ms. Johnson and Ms. Brady will also need to find time to debrief about the lesson, perhaps during lunch or some other time during the next school day (Moreau & Whitenack, 2013; West & Staub, 2003). By making good use of Ms. Brady's teaching schedule, they can develop a modified version of the coaching cycle—an approach that should work well for both Ms. Johnson and Ms. Brady.

Conclusion

We have provided three different challenges that mathematics coaches may face in their work. We also provided several ways in which they could be addressed. Although we recognize that there may be other ways to address these challenges, we encourage the reader to consider the vignettes as starting points for devising other ways that they might be effective as they work with teachers. Considering real-life examples such as the ones that we have presented is important. Mathematics coaches can benefit from having opportunities to explore different options and anticipate possible outcomes as a way of helping them expand their knowledge and skills related to their work. Our intent is that the reader will use these vignettes for exploring in more detail how a mathematics coach might further develop the actions outlined in these scenarios. Additionally, we encourage the reader to identify and resolve other challenges that the mathematics coach might face using a similar exploratory process. As the reader does so, he or she can develop new insights into how the mathematics coach can meet a challenge and at the same time effectively support teachers and their students. ✪

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