Journal of Teacher Education
2017, Vol. 68(4) 411–425

DOI: 10.1177/0022487117702579
journals.sagepub.com/home/jte
SAGE

Focusing on Teacher Learning Opportunities to Identify Potentially Productive Coaching Activities

Lynsey K. Gibbons[1] and Paul Cobb[2]

Abstract

Instructional improvement initiatives in many districts include instructional coaching as a primary form of job-embedded support for teachers. However, the coaching literature provides little guidance about what activities coaches should engage in with teachers to improve instruction. When researchers do propose activities, they rarely justify why those activities might support teacher learning. Drawing on the preservice and inservice teacher education literatures, we present a conceptual analysis of learning activities that have the potential to support mathematics and science teachers to improve practice. We argue that our analysis can inform research on mathematics and science coaching, coaching policies, and the design of professional learning for coaches.

Keywords

professional development, teacher learning, content-focused coaching, teacher leadership

Instructional coaching is an important component of teachers' professional development. Coaching involves teachers working with a more accomplished colleague as a primary form of job-embedded support to improve instructional practices (Campbell & Malkus, 2011; Coburn & Russell, 2008). This form of professional development is one of the fastest growing across the United States (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009). In fact, state-level officials have responded to this growth by developing endorsements in instructional coaching (e.g., currently 18 states have approved mathematics specialists certification, with an additional eight states in process; see mathspecialists.org). These states have charged university educators with designing curricula for supporting future coaches. Similarly, district content specialists in these states and beyond are charged with specifying coaching responsibilities and designing learning opportunities to support coaching practices. Both groups are required to address the following question: What do coaches need to know and be able to do to support teacher learning?

There is a growing body of research on various aspects of the role of instructional coaches. Studies have examined coaches' identity development (Rainville & Jones, 2008), the politics of coaching (Coburn & Woulfin, 2012), and the conditions that support coaching, such as the role that principals and districts play in coaching (Coburn & Russell, 2008; Gibbons, Garrison, & Cobb, 2011; Mangin, 2007; Matsumura, Garnier, & Resnick, 2010). Large-scale studies have shown that the implementation of instructional coaching in literacy and in mathematics is correlated with an increase in teacher efficacy (Cantrell & Hughes, 2008), improvements in teaching (Neuman & Cunningham, 2009), and increased student achievement outcomes as measured by standardized tests (Campbell & Malkus, 2011). While research on instructional coaching increasingly provides evidence of the impact of high-quality coaching, little is known about how accomplished coaches actually work with teachers. The goal of this article is to address this gap in the coaching research literature by reporting on a conceptual analysis that aimed to identify *potentially productive coaching activities*.

The central questions that framed the analysis are as follows: What does high-quality instructional coaching look like? What activities and practices reliably result in improvements in teachers' actual practice and thus in student learning? The current research base on effective coaching activities is relatively thin. The extant literature suggests that coaching appears to be highly personal and idiosyncratic, with coaches' practices varying significantly from school to school and district to district (Coburn & Russell, 2008). A few empirical studies have been conducted that use survey data to understand the activities typically performed by coaches (Bean,

[1]Boston University, MA, USA
[2]Vanderbilt University, Nashville, TN, USA

Corresponding Author:
Lynsey K. Gibbons, School of Education, Boston University, Two Silber Way, Boston, MA 02215, USA.
Email: lgibbons@bu.edu

Draper, Hall, Vandermolen, & Zigmond, 2010; Deussen et al., 2007). Coaches can refer to a small collection of books written by practitioners (e.g., Aguilar, 2013; West & Cameron, 2013), but in general, these books are not the result of empirical studies of effective coaching but, rather, the products of talented and experienced practitioners. In general, neither the studies nor the books describe whether and how the activities supported teachers' learning. Thus, these resources do not answer the needs of state and teacher education institutions that seek to provide training in effective coaching.

Furthermore, the activities in these studies and books typically focus on coaches working with individual teachers; however, several researchers have suggested that one-on-one coaching alone may not build collective capacity, an important aspect of school improvement (Lord, Cress, & Miller, 2003, 2008; Mangin & Dunsmore, 2015). Furthermore, state and district policies increasingly expect coaches to work regularly with groups of teachers. Thus, an important aspect of coaches' work, which is largely missing from the current coaching literature, is to lead groups of teachers as they investigate and improve instructional practices together.

Although there is a shared belief that instructional coaches can be a key lever for improvement (Bryk et al., 2013), there is no agreement on the technical core of instructional coaching. This is problematic as coaching endorsements and initiatives require significant resources. The goal of this article is to address this gap in the coaching research literature by conducting a conceptual analysis that aimed to identify *potentially productive coaching activities*. Given the limitations of the coaching literature, we examined numerous empirical studies in the *teacher education literature* in order to identify teacher learning activities and understand what preservice or inservice teachers had opportunities to learn.

We acknowledge that instructional coaching contexts differ in some ways from teacher education preservice and inservice settings. For example, in the studies from which we drew our findings, facilitators of inservice professional development frequently came from outside the district or school and were thus less familiar with the contexts in which teachers worked. In addition, both they and facilitators of preservice courses were often not familiar with teachers' current instructional practices and may not have provided follow-up support for teachers in classrooms.

In contrast, coaches who are typically familiar with other school and district improvement initiatives (e.g., adopted curriculum and pacing guides, principals' instructional expectations for teachers, and other supports for teachers' learning) can observe teachers' instruction and work one-on-one with teachers as well as with groups of teachers. It could be argued that instructors of preservice courses might have additional leverage because of their status (e.g., preservice teachers have to comply to receive a grade). In contrast, coaches need to develop trusting relationships with the inservice teachers they are charged with supporting (Neufeld & Roper, 2003).

Despite these differences in the contexts of professional development and content-focused coaching, there is a deeper structural parallel that justifies drawing on the teacher education literature to identify potentially productive coaching activities. Professional development facilitators, teacher educators, and coaches are all more accomplished others whose goal is to support teachers in improving the quality of their instructional practices.

At present, practitioners and policy makers aiming to implement coaching programs cannot turn to a body of research on effective coaching activities and practices. Furthermore, researchers who investigate coaching initiatives cannot draw on prior work that specifies the types of coaching activities that have the potential to be effective. By drawing on the teacher education literature, we were able to identify a number of coaching activities that have the potential to support teachers' development. We view this as a first step in a program of research that will eventually investigate the identified activities empirically to understand whether and under what conditions they support teachers' development of high-quality instructional practices.

We situate this analysis in mathematics and science because the shift to high-quality teaching in these disciplines requires most teachers to significantly reorganize their current knowledge and practice (Next Generation Science Standards [NGSS], 2013; National Governors Association Center for Best Practices & Council of Chief State School Officers [NGACBP & CCSSO], 2010). While mathematics and science educators have made significant progress in articulating a vision of high-quality instruction, the literature on how content-focused mathematics and science coaches can support teachers' development of these instructional practices is not as advanced as the work in English language arts and literacy.

Supporting Teachers' Development of High-Quality Instructional Practices

High-Quality Instruction in Mathematics and Science

The mathematics and science education research communities have achieved a broad, empirically grounded consensus on the forms of classroom instruction that support students' attainment of ambitious learning goals (e.g., NCTM, 2000; NGSS, 2013; NGACBP & CCSSO, 2010). The goals for students' learning in mathematics emphasize the following: conceptual understanding and procedural fluency in a range of mathematical domains, mathematical argumentation to communicate and justify mathematical ideas effectively, and productive dispositions toward mathematics (NCTM, 2014). In science, student learning goals emphasize engaging students in meaningful scientific practices to make sense of the world (National Research Council [NRC], 2012). These goals require students to understand how to represent their claims to others, critique one another's ideas in ways that are civil and productive, and revise their ideas in response to evidence and argument (Windschitl, Thompson, Braaten, & Stroupe, 2012).

These goals for student learning are demanding and carry implications for instruction. Such instruction requires teachers to build on what students do as they attempt to solve challenging tasks, while holding students accountable to learning goals (Kazemi, Franke, & Lampert, 2009; Windschitl et al., 2012). Research in mathematics and science education has delineated a set of teaching practices that support students' achievement of these ambitious learning goals (NGACBP & CCSSO, 2010; NGSS, 2013; NRC, 2012), such as introducing challenging tasks without reducing the level of cognitive demand (Jackson, Garrison, Wilson, Gibbons, & Shahan, 2013; Kang, Windschitl, Stroupe, & Thompson, 2016). In mathematics, teachers are expected to monitor the range of solution strategies that students produce (Horn, 2012) and build on these strategies during whole-class discussions by pressing students to justify their reasoning and make connections between their own and others' solutions (Stein, Smith, Henningsen, & Silver, 2000). In science, teachers are expected to elicit and build upon students' ideas, support students to make progress in their thinking through material activities, and press students for evidence-based explanations (Windschitl et al., 2012).

These practices differ significantly from those used by current mathematics and science teachers, and their development involves a significant reorganization of current practices (Snow-Renner & Lauer, 2005). The required teacher learning encompasses mathematical or science content knowledge (Lo, Grant, & Flowers, 2008), pedagogical knowledge for teaching (Shulman, 1986; Suzuka et al., 2010), knowledge of student reasoning across disciplinary domains (Kazemi & Franke, 2004), and knowledge of curriculum (Ball, Thames, & Phelps, 2008), as well as learning to enact pedagogical routines that give rise to rich learning opportunities for students (Darling-Hammond et al., 2009). One key way to provide sustained support for teachers' learning and development of high-quality practices is through job-embedded professional development.

Instructional Coaching as a Form of Professional Development

Instructional coaches are typically highly accomplished teachers (Neufeld & Roper, 2003; Poglinco et al., 2003) who are based either in a single school or in the district central office and are charged with supporting instructional and programmatic improvements (Campbell & Malkus, 2011). In this analysis, we are concerned with *content*-focused coaching in which coaches aim to support teachers' development of high-quality instructional practices in a particular discipline. While content-focused coaches have instructional expertise, effective coaching is not a one-way process in which coaches impart technical skills to teachers. Instead, coaches support teachers in addressing problems of practice by engaging them in activities that focus on key disciplinary ideas, how students learn those ideas, and pedagogical principles to support students' learning (Coburn & Russell, 2008).

Methods for Identifying Potential Productive Coaching Activities

Characteristics of High-Quality Professional Learning

In the first phase of our analysis, we examined the teacher education literature to determine what is known about high-quality professional learning opportunities. Because we are interested in identifying a set of potentially productive coaching activities, we first needed to identify these characteristics to serve as criteria for identifying potentially productive coaching activities (see Figure 1 for a representation of the process of identifying activities). We found an emerging consensus in the teacher education literature regarding characteristics of professional learning (Desimone, 2009; Garet, Porter, Desimone, Birman, & Yoon, 2001; Putnam & Borko, 2000; Wilson & Berne, 1999). We examined seminal reviews of professional development, which had been published in peer-reviewed journals and have more than 700 citations (based on Google Scholar). Our synthesis of these reviews resulted in five characteristics that represent this emerging consensus.

The first characteristic of high-quality professional learning is that opportunities must be intensive and ongoing. The findings of several studies indicate that teaching practices and student learning are unlikely to improve unless professional development is sustained (Desimone, 2009; Garet et al., 2001), thereby enabling the continued investigation of particular instructional issues and the opportunity to try ideas in the classroom and reflect on the results (Darling-Hammond et al., 2009; Kazemi & Hubbard, 2008; Stein, Silver, & Smith, 1999).

Second, high-quality professional learning activities focus on the problems that teachers encounter in their daily work (Putnam & Borko, 2000; Stein et al., 1999; Wilson & Berne, 1999). Several studies indicate the importance of situating professional development in the context of teaching by using artifacts that originated in the teachers' classrooms, such as student work samples (Borko, Jacobs, Eiteljorg, & Pittman, 2008; Cobb, Zhao, & Dean, 2009; Kazemi & Franke, 2004).

A third and related characteristic is that professional learning orients teachers to focus on student thinking. In both mathematics and science education, researchers call for teachers to use evidence of student thinking to assess progress toward learning disciplinary ideas and to adjust instruction continually in ways that support and extend their learning (NCTM, 2014; NGSS, 2013). Orienting teachers to attend to their students' thinking and reasoning can have strong

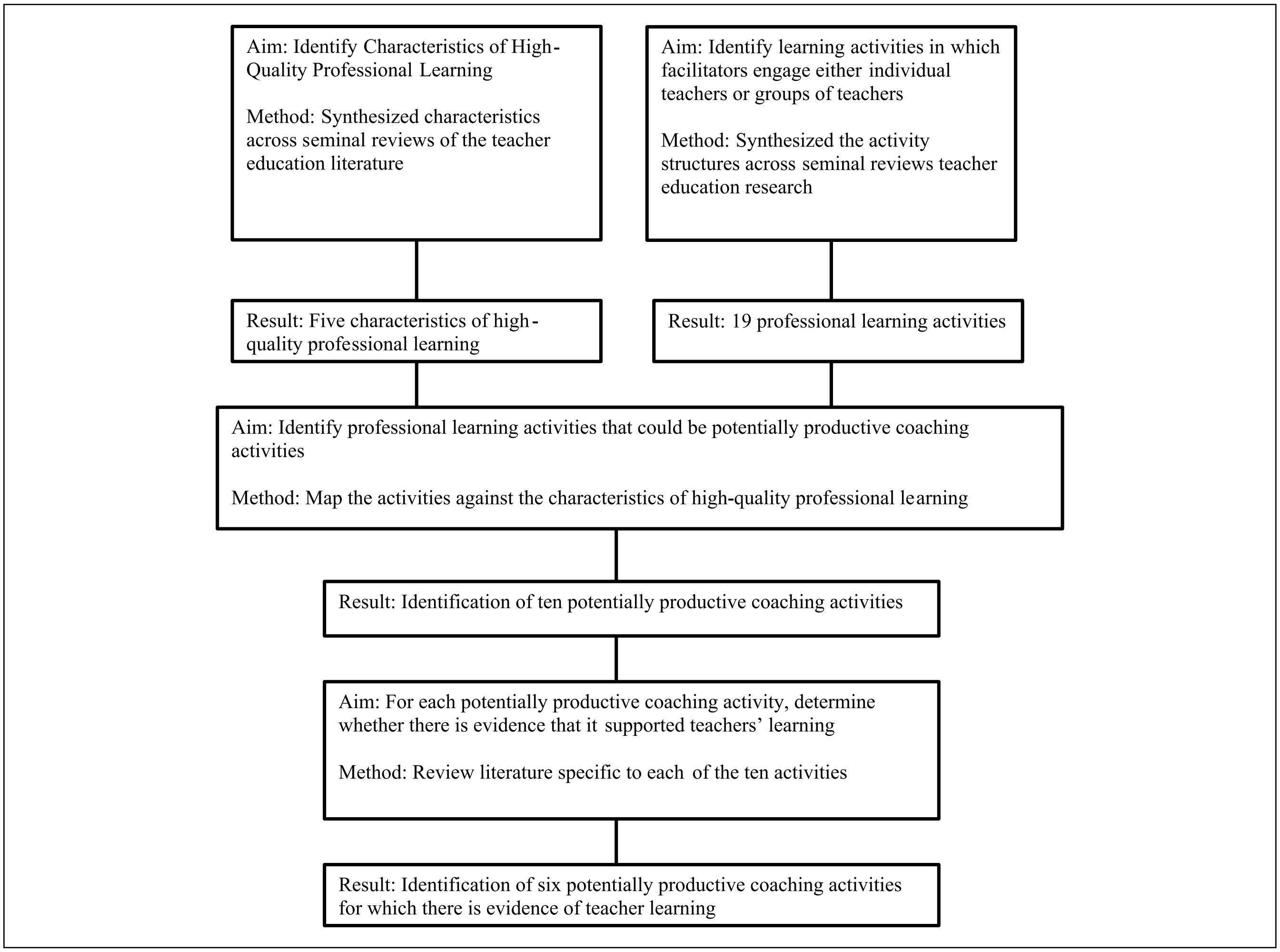

Figure 1. Approach to identifying potentially productive coaching activities.

positive effects on practice, such as the ability to elicit and build on students' thinking (Kazemi & Franke, 2004; Rosebery, Warren, & Tucker-Raymond, 2015).

Fourth, high-quality professional learning fosters the development of teacher communities, which provide opportunities to develop a common professional discourse that names critical aspects of instructional practice and student learning (Ball & Cohen, 1999; Cobb, et al., 2009; Darling-Hammond et al., 2009; Desimone, 2009; Garet et al., 2001; Horn & Little, 2010; Kazemi & Hubbard, 2008; Putnam & Borko, 2000; Stein et al., 1999). Ball and Cohen (1999) argued that the development of professional discourse is essential for productive discussions about teaching and learning. Furthermore, professional communities can both support teachers in taking the risks necessary to reorganize their instructional practice and result in a greater consistency in instruction (Horn & Little, 2010).

A fifth characteristic is that high-quality professional learning provides opportunities to both investigate and enact specific pedagogical routines and practices (Grossman et al., 2009), a process that has been termed "active learning" (Desimone, 2009, p. 183). Pedagogies of investigation involve analyzing and critiquing artifacts and representations of classroom practice, such as video-recordings and student work. Pedagogies of enactment involve planning for, rehearsing, and enacting high-leverage practices, thereby supporting teachers in translating their insights while engaging in pedagogies of investigation into practice.

We view these characteristics of high-quality professional learning as essential. We note that these features are applicable to coaches working both with groups of teachers and with individual teachers one-on-one in their classrooms.

Potential Productive Coaching Activities

In the second phase of our analysis, we used these characteristics as criteria for potentially productive coaching activities. Our first step in this phase was to generate a comprehensive list of different types of activities in which coaches might engage either groups of teachers or individual teachers. We did so by examining studies that systematically

Table 1. Teacher Learning Activities Identified Before Analysis.

Activities with groups of teachers	Activities with individual teachers
Analyzing classroom video[a]	Enacting the coaching cycle
Analyzing test data	Co-teaching[a]
Facilitating book studies[a]	Observing and providing feedback[a]
Conducting classroom visitations	Modeling instruction[a]
Co-designing instruction[a]	
Compiling teacher portfolios	
Conducting action research	
Engaging in the discipline[a]	
Examining student work[a]	
Journaling about teaching experiences	
Engaging in lesson study[a]	
Mapping the standards to the curriculum	
Leading one-time workshops about a particular teaching strategy or disciplinary idea	
Rehearsing aspects of instructional practice[a]	
Writing math tasks/developing curriculum	

[a]Those activities that satisfied all five essential professional learning characteristics.

reviewed the research on professional development, looking for trends or patterns across studies (e.g., Darling-Hammond et al., 2009; Loucks-Horsley & Matsumoto, 1999; Wilson & Berne, 1999). Our review resulted in a list of 15 activities that coaches could use to engage groups of teachers and four activities for engaging individual teachers (see Table 1).

Our second step was to evaluate the potential of the 19 activities by assessing whether a high-quality enactment of each satisfied the characteristics of high-quality professional learning that we identified (see Figure 2 for a list of all 19 activities and the characteristics each has the potential to meet). For each study, we assessed which of the characteristics of high-quality professional learning the activity met. We judged an activity as potentially productive if it satisfied all five essential characteristics we had established based on our review of the literature: ongoing and intensive, focus on the problems that teachers encounter in their daily work, orient teachers to focus on student thinking, foster the development of teacher communities and professional discourse, and involve either a pedagogy of investigation or enactment. As an illustration, we determined that the activity of examining student work is potentially productive because it can be ongoing, is integrated into teachers' daily work, focuses on student thinking, can foster a common language for describing students' reasoning, and is a pedagogy of investigation. In contrast, although mapping state standards to the instructional materials teachers are using can be integrated into daily work and might cultivate a professional discourse, it is unlikely to meet the other characteristics. We judged 10 of the 19 coaching activities to be potentially productive because they satisfied the criteria.

Our final step was to search ERIC, Education Full Text, Google Scholar, and ProQuest Dissertations to identify studies that investigated each of the 10 potentially productive activities. Our search terms included variations of the 10 activity names (e.g., co-planning for co-designing instruction). This search yielded reports of more than 250 empirical studies conducted using a wide range of methodologies. We systematically reviewed the reports to determine whether and to what extent there was empirical evidence indicating that each activity supported teachers' learning, and documented what was learned. In the case of four of the activities, facilitating a book study, co-designing instruction, rehearsing aspects of practice, and observing and providing feedback, there was insufficient evidence in the current literature of what teachers might learn. We therefore eliminated them from our analysis. We decided not to include the coaching cycle on the grounds of feasibility, even though it is frequently discussed in the coaching literature. When the coaching cycle is enacted as intended, coaches typically work intensively with two to three teachers at a time for several weeks (Literacy Collaborative Trademark Committee, 2006). However, research to this point indicates that it is rarely fully enacted because coaches and teachers find it difficult to schedule the desired three-step process of planning, observing or modeling, and debriefing (Atteberry & Bryk, 2011; Bean et al., 2010). We note that its inclusion might be warranted if the logistical challenges could be resolved, and if there were evidence of its effectiveness at some level of scale.

Four of the remaining six potentially productive activities involve coaches working with groups of teachers: (a) engaging in the discipline, (b) examining student work, (c) analyzing classroom video, and (d) engaging in lesson study. The remaining two activities involve coaches working with individual teachers: (e) co-teaching and (f) modeling instruction.

We next focused on the studies that investigated each of the six activities to clarify both how a high-quality enactment of the activity can support teachers' development of ambitious instructional practices and the facilitator's role in enacting the activity at a high level. While we contend that these activities could be enacted by coaches, we analyzed each activity as it was described in the literature. Thus, we used the original terms from each study (e.g., "mentor" or "facilitator") to denote the professional educator who is supporting either preservice or inservice teachers' learning. In the next section, we report the findings of this review for each of the six types of activities.

Findings

Activities Conducted With Groups of Teachers

Engaging in the discipline. Engaging teachers in mathematical and scientific inquiry has featured prominently in the teacher education literature for over two decades.

Possible Activities with Groups of Teachers					
	Intensive and Ongoing	Integrated into Problems of Practice	Pedagogies of Investigation or Enactment	Cultivates Common Language	Focus on Student Thinking
Analyzing classroom video *Discussing excerpts of classroom videos (Loucks-Horsley & Matsumoto, 1999)*	**x**	**x**	**x**	**x**	**x**
Analyzing test data *Analyzing test data, typically to identify which students need remediation or what teachers should reteach (Darling-Hammond, et al., 2009)*		x			
Facilitating book study[a] *Examining narratives and case discussions (Loucks-Horsley & Matsumoto, 1999)*	x	x	x	x	x
Conducting classroom visitation *Observing other teachers' instruction (Darling-Hammond, et al., 2009)*		x	x	x	x
Co-designing instruction[a] *Collectively identify instructional tasks and develop assessments (Darling-Hammond, et al., 2009)*	x	x	x	x	x
Compiling teacher portfolios *Collecting artifacts and reflections that document a teacher's professional practice (Wilson & Berne, 1999)*		x			
Conducting action research *Documenting and analyzing teaching experiences (Wilson & Berne, 1999)*		x	x		x
Engaging in the discipline *Engaging in disciplinary content with other teachers (Loucks-Horsley & Matsumoto, 1999)*	**x**	**x**	**x**	**x**	**x**
Examining student work *Examining students' responses to mathematical tasks (Loucks-Horsley & Matsumoto, 1999)*	**x**	**x**	**x**	**x**	**x**
Journaling about experiences *Recording observations and reflections (Wilson & Berne, 1999)*	x	x			x
Engaging in lesson study *Collaboratively planning, teaching, observing and critiquing a small number of lessons (Darling-Hammond, et al., 2009)*	**x**	**x**	**x**	**x**	**x**
Mapping the standards to the curriculum *Examining standards to identify which mathematics to teach (Loucks-Horsley & Matsumoto, 1999)*		x		x	
Leading one-time workshops *Leading workshops aimed at implementing new curriculum materials or teaching strategies (Loucks-Horsley & Matsumoto, 1999)*				x	
Rehearsing aspects of instructional practice[a] *Trying out new instructional practices, without students present, while receiving feedback (Kazemi et al., 2009)*	x	x	x	x	x
Writing math tasks/curriculum development *Adapting or creating curriculum materials (Loucks-Horsley & Matsumoto, 1999)*		x		x	
Possible Activities with Individual Teachers					
Coaching cycle *Engaging teachers in a preobservation discussion, observation, and postobservation discussion (Bean et al., 2010)*		x	x	x	x
Co-teaching *Working collaboratively with coaches to co-construct and co-teach lessons together (Poglinco et al., 2003)*	**x**	**x**	**x**	**x**	**x**
Debriefing challenges of implementation[a] *Being observed by experts in order to receive critical feedback (Putnam & Borko, 2001)*	x	x	x	x	x
Observing instruction (Modeling) *Observing coach and engaging in discussions about goals, tasks, teaching strategies, and student learning (Putnam & Borko, 2001)*	**x**	**x**	**x**	**x**	**x**

Figure 2. Potential coaching activities.
Note. The activities in bold have met all of the characteristics and are discussed in this analysis.
[a]Those activities that met all five characteristics of effective professional development; however, the description in the research of what teachers had opportunities to learn from these activities was insufficient to include in final analysis.

Substantial evidence indicates that teachers' ability to make disciplinary ideas accessible and learnable by all students depends partly on their own *specialized* disciplinary knowledge, which comprises the content knowledge and pedagogical skills required for effective teaching (Ball et al., 2008; Suzuka et al., 2010). In mathematics, Hill, Rowen, and Ball (2005) found that the relationship between teachers' mathematical knowledge for teaching and their students' mathematics achievement to be significant. One avenue for supporting the development of teachers' disciplinary understandings and influencing how those understandings affect instruction is guided investigations of disciplinary content.

The aim of disciplinary investigations is to challenge teachers' own specialized disciplinary knowledge and their view of disciplinary norms as they engage in rich explorations of mathematics or science. Analyses of these investigations indicate that facilitators placed teachers in the role of student, supporting them to develop a stance of inquiry and cultivate a disposition that examines ideas. However, facilitators supported teachers to engage with the content in deeper ways than would be required if the goal were to solve tasks by developing a single strategy. As a consequence, facilitators supported teachers in thinking through how they might use tasks in their classrooms by pressing them to anticipate students' correct and incorrect strategies and consider how they might respond to those strategies (Borko, Koellner, & Jacobs, 2011). Following is a synthesis of findings from three major professional development initiatives: two in mathematics and one in science.

In the first initiative, Schifter and Fosnot (1993) and Schifter (1998) examined 36 elementary and middle-grade teachers' participation in professional development sessions that spanned 4 years, including summer institutes, biweekly seminars, and biweekly classroom coaching. A major component of the sessions included teachers doing mathematics. Schifter explained that teachers "experience mathematics, often for the first time, as an activity of construction, rather than as a finished body of results to be accepted, accumulated, and reproduced" (p. 65). In one analysis, Schifter focused on two cases in which changes in the teachers' beliefs about mathematics led them to re-organize their classrooms around whole-class inquiry into students' mathematical ideas.

A second initiative led by Borko and colleagues (2005) aimed to support the development of teachers' understanding of key algebraic concepts and their knowledge about teaching algebra in an inquiry-oriented setting. Sixteen elementary and middle-grade teachers attended a 2-week institute and ongoing monthly meetings. The researchers' comparison of preassessments and postassessments indicated that doing mathematics with a skilled facilitator resulted in modest gains in the participating teachers' mathematical knowledge for teaching (see also Ball et al., 2008; Elliott et al., 2009; Lo et al., 2008; Suzuka et al., 2010).

In science education, Rosebery and colleagues (2015) supported teachers' engagement with scientific phenomena as learners so they could experience the meanings, perspectives, and stances that arise in science learning and teaching. Twenty-eight elementary and middle-school early career teachers engaged in 30 hr of professional learning in the domain of plant life cycles as a foundation for learning to focus on students' scientific interpretations and come to value their diverse sense-making. The professional development also emphasized interpreting, critiquing, and creating representations of scientific phenomena. The researchers found that, as a result of engaging in scientific inquiry with a focus on student thinking, teachers understood the science better themselves, more readily considered the students' perspectives, and had a greater appreciation for the complexity of students' thinking.

Several recent studies have investigated efforts to assist facilitators in supporting teachers' learning as they engage in mathematics. Borko and colleagues (2011) and Elliott and colleagues (2009) sought to clarify what effective facilitators need to know and be able to do and concluded that they delineate mathematically worthwhile goals for teachers' learning and select tasks that are relevant for particular groups of teachers. In both studies, facilitators first supported teachers' engagement with the selected tasks and then elicited teachers' solutions and pressed them to question one another. Elliott and colleagues also reported that effective facilitators led productive discussions by intentionally *slowing down* conversations to focus explicitly on mathematical ideas, pressing teachers for explanations and justifications, and stepping back to make some of their practices as facilitators explicit.

The studies reviewed above indicate the potential value in coaches engaging teachers in disciplinary inquiry as it can deepen their specialized disciplinary knowledge. Additional research is needed to clarify how accomplished coaches leverage their access to teachers' classroom practices when they plan disciplinary inquiries with groups of teachers. Further research is also needed to understand how coaches can make explicit connections between teachers' engagement in disciplinary inquiry and teachers' selection and enactment of rigorous instructional tasks with their students. In other words, additional research can address the following question: how can coaches build on this activity to support teachers' development of high-quality instructional practices?

Examining student work. Research conducted over the past 20 years indicates that teachers' understanding of students' thinking is integral to effective instruction (Carpenter, Fennema, & Franke, 1996). Examining student work from teachers' own classrooms has been proposed as a primary activity for learning about student thinking (Carpenter et al., 1996; Cobb et al., 2009; Little, Gearhart, Curry, & Kafka, 2003). Across the studies reviewed below, researchers conjectured that through examining student work, teachers would gain opportunities to learn how students' understanding of particular disciplinary ideas develops. The intent of professional learning activities used in these studies was to support teachers in coming to appreciate the range of their students' ideas and, eventually, to build on those ideas during instruction. Furthermore, researchers took as evidence of teachers' learning the changes in teachers' discourse and group norms during professional development sessions.

In a series of studies, Kazemi and Franke (2004) and Jacobs, Franke, Carpenter, Levi, and Battey (2007) supported a group of elementary teachers' learning about their students' mathematical reasoning in monthly meetings held to examine their students' mathematical work. Teachers used common problems in their classrooms and were supported to infer their students' mathematical thinking using principles and terminology from *Cognitively Guided Instruction* (Carpenter, Fennema, Franke, Levi, & Empson, 1999). As the meetings progressed, teachers increasingly attended to the details of their students' thinking, generated strategies for eliciting student thinking, and developed possible trajectories for instruction and student learning. The researchers argued that these changes could support the development of instructional practices that focus on student thinking but did not assess whether there were improvements in practices.

Windschitl, Thompson, Braaten, and Stroupe (2011) conducted a series of studies with secondary science teachers in which they led monthly meetings that supported teachers to use a protocol for engaging in a cycle of inquiry, reflection, and action that included collecting and analyzing samples of their students' written work. Windschitl and colleagues (2011) and Thompson and colleagues (2009) found that the participating teachers increasingly framed student work as evidence of student understanding and as a resource for instructional improvement. Similarly, Gearhart and colleagues (2006) found evidence that analyzing student work resulted in science teachers selecting tasks that were better aligned with their goals for student learning and built on students' thinking. Furthermore, there was evidence in this and the other studies that teachers began to develop both a common language for describing student understanding and routines for eliciting student thinking.

Most of the studies reported here emphasized the role of the facilitator in making the study of student work productive. In this regard, Little and colleagues (2003) examined three professional development programs that used student work and identified a number of facilitator practices that shaped the conversations. These practices included purposefully selecting student work samples in light of the facilitator's goals for teachers' learning, supporting teachers to situate the focal lesson within the encompassing instructional sequence, and orienting teachers to analyze students' thinking rather than merely evaluate their solutions (Cobb et al., 2009; Little et al., 2003). This orientation involved pressing teachers to consider what students did to solve the problem, why they solved it in particular ways, and what their strategies revealed about their understanding of key ideas. There was also evidence across the studies that effective facilitation involved supporting teachers to elicit students' thinking and to determine which student strategies to highlight in whole-class discussions in light of their goals for students' learning (Gearhart et al., 2006; Kazemi & Franke, 2004; Thompson et al., 2009).

The studies reviewed here suggest the potential of coaches engaging teachers in analyzing student work. A high-quality enactment of this activity can support teachers in developing a common language for describing students' reasoning, including naming different types of student reasoning and the strategies that students use. Future research might investigate how coaches can support teachers across grade levels to develop common formative assessment tasks that elicit students' thinking. Research might also clarify how coaches can support a group of teachers in examining the resulting data to link their insights about their students' reasoning to their prior instruction. Future research can also clarify how coaches can support teachers in building on their insights about students' current ideas when planning upcoming instruction, including how they identify instructional goals. Finally, additional research is needed to understand how coaches can use this activity to support teachers in more effectively eliciting and responding to students' thinking.

Analyzing classroom video. In recent years, the use of classroom videos as a representation of practice has become increasingly common in professional development and teacher education (Borko et al., 2008; van Es & Sherin, 2010; Zhang, Lundeberg, Koehler, & Eberhardt, 2011). Across the studies reviewed here, researchers conjectured that video can support teachers' collective analysis of pedagogical strategies (Brophy, 2004) and their development of an interpretive perspective that relates instruction to students' thinking and learning opportunities.

Sherin and colleagues (Sherin, 2004; Sherin & Han, 2004) conducted a series of studies that examined the "Video Club" professional development model in which university mathematics educators supported a group of elementary teachers from an urban school as they viewed and discussed excerpts of videos from their classrooms in 10 sessions over the course of a year. During the sessions, facilitators supported teachers in using evidence from video segments to support their claims about the students' mathematical understandings. The participating teachers' analyses shifted from an initial focus on classroom management to student mathematical thinking, with increased discussion of the importance of attending to student ideas during instruction (see also Borko, 2004; Borko et al., 2005). Van Es and Sherin (2010) examined the teachers' classroom practices and found an increase in the extent to which teachers supported students in making their thinking public, elicited multiple strategies from students, and probed students' underlying understandings.

Zhang and colleagues (2011) researched a video-based professional development model for science teachers across Grades K-12 that included a 7-day summer workshop and a year-long teacher research project. This study complements Sherin's work by examining the affordances and constraints of supporting teachers' analysis of three types of classroom video: commercially published video, teachers' own video, and peers' video. Teachers also developed a research plan to study their own practice in which they had autonomy in outlining a teaching dilemma, hypothesis, and data collection plan. Teachers reported that the video viewing activities allowed them to see multiple models of teaching, reflect on their own teaching by watching their own video multiple times, and address the difficulties they encountered in implementing new instructional practices. In a case study analysis of participating teachers, the researchers found that video supported the teacher to learn and gain images of inquiry-based teaching strategies (e.g., how to probe for student thinking) and identify areas they wanted to improve in their own teaching (e.g., "How to assess students' retention of the big ideas? . . . During inquiry instruction, what amount of instruction/explanation must or should come from the teacher?" p. 461). However, Zhang and colleagues did not examine whether there were improvements in teachers' practices.

Although the findings of these studies are encouraging, it is also clear that teachers do not necessarily gain new insights about practice merely from watching classroom videos (Brophy, 2004). It appears essential that facilitators first establish a clear purpose for viewing a video that is based on specific goals for teachers' learning (Borko et al., 2008; Brophy, 2004; van Es, Tunney, Goldsmith, & Seago, 2014). In this regard, Borko and colleagues (2008) found that effective facilitators selected video clips and identified foci that would stimulate discussion of key issues. Effective facilitators also clarified the classroom context when they introduced a clip by asking participants to specify key contextual features, including (a) the instructional goals for and big disciplinary ideas of the lesson, (b) student characteristics, and (c) the place of the lesson in a larger instructional sequence. In addition, researchers identified a series of facilitator moves that supported teachers to conduct a substantive analysis of teaching (Borko et al., 2008; van Es et al., 2014). Finally, effective facilitators posed structured discussion questions and routinely pressed the group to take a more critical look at the videoed teacher's practices (e.g., "How did the teacher's questions help him to understand how Kaitlin derived her expression?" (Borko et al., 2008, p. 428). There is evidence that this press on relations between instructional practice and student thinking supports teachers in explaining students' contributions (Sherin & Han, 2004), inferring possible reasons for the videoed teacher's instructional decisions (Sherin, 2004), and formulating questions that uncover student thinking (Borko et al., 2008).

Findings of the studies reviewed here indicate the value of coaches engaging groups of teachers in examining videos of their instruction. The studies suggest that coaches' skilled enactment of this type of activity can support teachers in developing a common language for talking about student mathematical thinking and in attending to their students' thinking during instruction. In this regard, van Es and Sherin's (2010) findings suggest that teachers might increasingly elicit students' explanations and probe students' underlying understandings. Research is needed to understand how accomplished coaches capitalize on their access to teachers' classrooms and current instructional practices when selecting video episodes to use with teachers and to establish purposes for their use. Further research is also needed to understand how coaches can build on the analysis of videos when they subsequently work with teachers in their classrooms. How does analyzing video support coaches to influence what teachers notice as they enact a lesson and to refine their instruction?

Engaging in lesson study. In the past decade, considerable progress has been made in grounding professional development in teachers' classroom practice (Morris & Hiebert, 2011). Lesson study and variations thereof ("Studio Days" or "Learning Labs") have been influential in this regard. Lesson study typically involves a small group of teachers working together for several months, often with an expert (e.g., a university facilitator or school-based coach), to improve a particular lesson (Morris & Hiebert, 2011). In the lesson study cycle, teachers collaborate to develop a detailed lesson plan, then one teacher presents the lesson while others observe, and finally the group analyzes the observed lesson to further improve the lesson plan (Hart, Alston, & Murata, 2011; Lewis, Perry, & Murata, 2006). This cycle is then repeated, with another one of the teachers implementing the revised lesson plan. The process of developing the initial lesson plan involves specifying learning goals for the lesson, reviewing relevant literature, and discussing instructional approaches for helping students attain the learning goals (Hart et al., 2011; Lewis et al., 2006; Morris & Hiebert, 2011).

Similar to lesson study, Studio Days and Lesson Lab both involve a cycle of collectively planning for, enacting, and debriefing instruction. However, Studio Days place less emphasis on refining a lesson and instead prioritize making teaching public as a way to refine evidence-based teaching routines (Teachers Development Group, 2010). In the Lesson Lab variation, teachers learn to enact classroom routines of relatively short duration (e.g., a number talk) rather than an entire lesson, and the group of teachers co-enact activities rather than observe a demonstrated lesson (Gibbons, 2017; Kazemi, Hintz, Gibbons, Lewis, & Lomax, 2014). Across the studies reviewed below, researchers conjectured that lesson study and variations thereof would support teachers' development of particular aspects of high-quality instructional practices. For example, in science, the aim of multiple Studio Days was to develop teachers' ability to press for evidence-based explanations (Thompson, Barchenger, & Hagenah, 2014).

In mathematics, for example, facilitators of multiple Studio Days intended to support teachers' ability to "understand and identify student talk and actions that reflect the practices of justification" (Lesseig, 2014, p. 6).

Lesson study and, to a lesser extent, the two variations have been widely implemented in the United States. We found several 100 studies that examined lesson study. Due to limited space, we report only findings from some of the most frequently cited studies. Lesson study has been shown to improve student achievement in elementary mathematics on end-of-the-year assessments (Gersten et al., 2014). There is evidence that teachers' participation in lesson study can enhance their knowledge of content, pedagogy, and students' thinking (e.g., support teachers in understanding how children think about the equal sharing problems and in selecting subsequent tasks to further their thinking; Fernandez, 2002). There is also evidence that lesson study can strengthen professional community through the development of collaborative norms, mutual accountability, and shared frameworks for enacting and analyzing practice (e.g., common lesson plans or instructional tasks; Gibbons, Kazemi, & Lewis, 2017 Lesseig, 2014).

Taken together, these findings make it clear that an accomplished facilitator is essential. However, only a few studies have investigated the role of the facilitator in supporting teacher learning across the lesson study cycle (Gallucci, Van Lare, Yoon, & Boatright, 2010; Gibbons, et al., 2017; Lesseig, 2014). Lesseig's (2014) findings indicate the importance of facilitators supporting teachers' learning through guiding the establishment of group norms, as well as summarizing, rephrasing, and recording ideas generated by the group, and by pressing teachers to provide either evidence or a rationale for their decisions. There is also evidence that when facilitators pushed teachers to think more deeply about the disciplinary goals of the lesson and the trajectory of students' learning, teachers subsequently designed more conceptually oriented lessons that involved more challenging instructional tasks. Finally, it is important for facilitators to focus teachers' observations and subsequent debriefing conversations on student thinking (Gibbons et al., 2017; Lewis, Perry, & Murata, 2006).

The studies examined provide evidence that lesson study is a potentially productive coaching activity that enables coaches and teachers to plan lessons and analyze their enactment together. It provides opportunities for coaches to help teachers deepen their knowledge of content, orient teachers to focus on their students' thinking, and support them in enacting high-quality lessons. Additional research is needed to understand how accomplished coaches determine the aspects of practice to work on during lesson study and how they help to establish norms that support learning and improve practice. We also need to understand how coaches can determine which tools can assist them in facilitating lesson study and which coaching routines enable them to continue to support teachers one-on-one in their classrooms.

Activities Conducted One-on-One With Teachers in Their Classrooms

The activities we have discussed thus far involve coaches working with groups of teachers. We also examined a set of studies that investigated the provision of support for teachers one-on-one in their classrooms as a form of ongoing follow-up support. One-on-one coaching activities that appear to be potentially productive include (a) co-teaching and (b) modeling. Although these activities appear frequently in the coaching literature (Bean et al., 2010; Neufeld & Roper, 2003; Poglinco et al., 2003), they are rarely justified in terms of their potential to support teachers' development of ambitious instructional practices.

Co-teaching. Researchers who have examined how people develop complex professional practices have emphasized the importance of participating in practice with a more knowledgeable other (Lave & Wenger, 1991). Tharp and Gallimore (1988) argued that co-participation supports the learner in ways that language alone cannot: "The development of common understanding of purposes and meanings of the activity, [and] the joint engagement in cognitive strategies and problem solving are all aspects of interaction that influence each participant" (p. 89). Through co-participation, the more knowledgeable other works alongside a less accomplished teacher in authentic situations, and they both influence classroom events and then negotiate interpretations of these events (Roth & McRobbie, 1999).

Very few studies have investigated the conditions under which co-teaching is productive in supporting practicing K-12 teachers' learning. However, a number of studies have focused on co-teaching as a support in either teacher education or teacher induction (Eick, Ware, & Williams, 2003; Roth & McRobbie, 1999; Scantlebury, Gallo-Fox, & Wassell, 2008; Tobin & Roth, 2006). Across the studies reviewed below, researchers conjectured that planning and teaching with the mentor teacher supports student teachers to reflect more deeply about their practice, identify important problems of practice, and internalize specific high-leverage practices such as orchestrating classroom discussions (Eick et al., 2003; Roth & McRobbie, 1999).

Eick and colleagues (2003) examined how co-teaching could support student teachers to reflect on instruction by examining 10 secondary science student teachers' co-teaching experiences over an 8-week period. The student teachers were paired with experienced mentor teachers for two consecutive class periods. During the first period, student teachers observed and assisted the mentor teacher by working with small groups or individual students. During the second period, the student teachers taught the same lesson, and the mentor teachers provided assistance. Most of the student teachers reported that they felt supported when they attempted to implement specific instructional practices (e.g., how to phrase a question or represent a student's idea) and manage the classroom. The researchers did not assess changes in the student teachers' knowledge or practice. They concluded, however, that the activity of co-teaching allowed student teachers to both learn in the context of practice and engage in critical reflection about inquiry-based teaching.

Eick and colleagues (2003) also examined how the mentors supported the student teachers and found that assistance during instruction included logistical support (e.g., assisting with the setting up materials) and ongoing verbal interjections throughout the lesson (e.g., asking students questions to help the student teacher assess students' understanding). The findings of several other studies indicated the importance of focusing post co-teaching dialogues on aspects of practice that impact student learning and on generating solutions to problems of practice (e.g., when planning a science lesson, considering the feasibility of doing an experiment with students; Scantlebury et al., 2008). Tobin and Roth (2006) also suggested that mentors should ground debriefing conversations with teachers in a specific lesson, and recommend focusing on both how the lesson could be improved and what should take place in subsequent lessons.

The studies reviewed here provide evidence that coaches might be able to support teachers in improving how they plan instruction and enact particular practices by co-teaching with them. Future studies should seek to understand how accomplished coaches develop relationships with teachers to allow for engagement in co-teaching. Also important to consider are the following: which aspects of practice are most open to refinement during co-teaching, when is it productive for coaches and teachers to confer about aspects of practice, and what types of questions and feedback are useful to teachers during subsequent debriefing discussions.

Modeling. While co-teaching is a potentially important means of support, there is evidence that observing a more accomplished colleague enact particular practices can also be productive. Modeling typically involves an accomplished teacher intentionally demonstrating certain teaching practices with the aim of providing student teachers with images of what is possible (Tharp & Gallimore, 1988). Evidence indicates that modeling can support teachers in developing an image of accomplished enactment of those practices (Feiman-Nemser, 2001; West & Cameron, 2013) and might therefore be appropriate as a starting point for teachers' development of particular instructional practices.

Several studies have examined how teacher educators model "new visions learning" to preservice teachers (e.g., Bronkhorst, Meijer, Koster, & Vermunt, 2011; Lundenberg, Korthagen, & Swennen, 2007). Feiman-Nemser (2001) examined how an accomplished teacher's mentoring practices, which included modeling, supported eight beginning elementary teachers in an 2-year induction program. Feiman-Nemser conducted interviews with the beginning teachers and the mentor teacher and observed beginning teachers' practices to understand the mentor's practices. The mentor described modeling as a way to give a "living example" of teaching. Through his modeling, he hoped that the student teachers would begin to identify characteristics of good teaching (e.g., responding to students' ideas). To accomplish this, he often paused during the lesson to highlight key aspects of his practice and to explain what he was doing and why. After the lesson, the mentor asked the beginning teachers to interpret what they had seen. Feiman-Nemser did not investigate what the beginning teachers learned from observing the mentor teacher.

There is some indication that modeling might be a useful starting point for coaches as it can support teachers in developing an image of what is possible in mathematics or science instruction. More research is needed to understand how accomplished coaches support teachers to notice particular aspects of instruction when they engage in modeling. Future studies should also seek to understand how modeling instruction in teachers' classrooms can support them to reconsider what their students know and are capable of doing. It is also important to understand the types of tools that accomplished coaches use during debriefing conversations with the teachers after lessons.

Discussion

In this article, we set out to identify potentially productive activities that coaches can enact with teachers to support their development of high-quality instructional practices. Because the current coaching research literature typically fails to justify coaching activities in terms of teacher learning opportunities, we drew on the teacher education literature to identify activities that have the potential to support teachers' development. We identified four potentially productive activities in which coaches might engage groups of teachers: (a) engaging in the discipline, (b) examining student work, (c) analyzing classroom video, and (d) engaging in lesson study. In addition, we identified two potentially productive activities that involve coaches working with individual teachers: (e) co-teaching and (f) modeling instruction. For each activity, we described what teachers might learn as a result of engaging in a high-quality enactment, discussed the implications for coaching, and examined what a high-quality enactment might entail. We regard this analysis as a first step in specifying a technical core of instructional coaching that can provide guidance to coaches and inform the design of coaching initiatives and endorsement programs.

In considering future research, we first note that the majority of the studies we reviewed investigated teachers' learning as they engaged in group activities. In contrast, the research on activities conducted one-on-one with teachers in their classrooms is quite thin. Research is therefore needed to better understand how accomplished coaches engage in modeling and co-teaching with teachers. For example, additional studies are needed to understand which aspects of instructional practice are most fruitful for coaches to work on with teachers in their classrooms and how accomplished coaches make decisions about the aspects of practice on which to focus. The types of feedback that are productive in supporting teachers' learning are also largely understudied. Studies are therefore needed that focus explicitly on the relation between types of feedback coaches give to teachers, the extent to which the feedback is tailored to teachers' current practices, and any subsequent improvements in their instructional practices. Finally, more studies are required to understand how coaches can sequence different types of activities to create a coherent set of supports for teachers that take account of teachers' current instructional practices.

We were able to make some progress in teasing out aspects of effective enactments of the six practices and identified three cross-cutting facets of facilitator practice that are relevant to coaches' enactment of the activities. The first facet concerns the importance of formulating explicit goals for what teachers might learn as a result of engaging in a particular activity. The second facet, which is specific to activities enacted with groups of teachers, involves establishing norms that orient the group toward the improvement of instructional practice. The third facet involves selecting tools, including artifacts from classrooms, that enhance the enactment of particular activities.

However, it is also important to note that only a small proportion of the studies that we reviewed systematically examined facilitators' actions (e.g., Borko et al., 2011; Elliott et al., 2009; Gibbons, et al., 2017; Lesseig, 2014; van Es et al., 2014). Further research is therefore needed to delineate additional aspects of accomplished enactments. With regard to the first facilitator facet of formulating explicit goals for teachers' learning, for example, we need to better understand both how accomplished coaches identify worthwhile goals for specific teachers' learning in group and one-on-one settings, and why they delineate more productive goals than less accomplished coaches. With regard to the facet of establishing productive group norms, it would be helpful to know how accomplished coaches negotiate norms for collective work with teachers who are frequently also their colleagues. With regard to the third facet of selecting appropriate tools, we need to know more about both how and why accomplished coaches make these selections and about how they use the tools to support teachers' learning.

In identifying potentially productive activities, we noted several activities that met the criteria for high-quality professional learning, but for which there is insufficient evidence in the current literature about what teachers might learn. These activities include facilitating a book study, co-designing instruction, rehearsing aspects of practice, and observing and providing feedback. More research is therefore needed on these activities to understand what teachers learn from engaging in them. In addition, we noted that the coaching cycle satisfied the criteria for high-quality professional learning, but that current research indicates that it is rarely fully enacted because coaches and teachers find it difficult to schedule the three-step process of planning, observing or modeling, and debriefing (Bean et al., 2010). Therefore, research is needed that investigates both whether and how the coaching cycle can be implemented as intended, and what teachers can learn from engaging in a high-quality enactment of the activity.

As a final observation, the analytic approach that we used is relevant to researchers who seek to investigate the design and enactment of coaching activities and of professional learning activities more generally. As we have illustrated, this analytic approach involves delineating the goals for teachers' learning, documenting the rationale for the activities in which teachers engaged, and examining evidence of the extent to which learning goals were attained. Because this approach foregrounds teacher learning opportunities, the findings offer empirically grounded specifications of the substance of coaches' work with teachers. The findings are therefore relevant to school and district leaders and teacher educators. For example, they can guide decisions about how coaches might focus their efforts to support instructional improvement, thereby enabling better definitions of coaches' work. In addition, the clarification of what effective enactments of the activities look like serves to delineate goals for coaches' learning. In this regard, our findings have informed the design of mathematics specialists' degree programs for future coaches and can also inform the work of district mathematics specialists and others charged with supporting coaches in working more productively with teachers.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Support for this analysis came from the National Science Foundation under grants No. ESI-0554535 and No. DRL-0830029. The opinions expressed do not necessarily reflect the views of the U.S. Department of Education or the National Science Foundation.

References

Aguilar, E. (2013). *The art of coaching: Effective strategies for school transformation*. San Francisco, CA: Jossey-Bass.

Atteberry, A., & Bryk, A. S. (2011). Analyzing teacher participation in literacy coaching activities. *The Elementary School Journal*, *112*(2), 356-382.

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

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, *59*(5), 389-407.

Bean, R. M., Draper, J. A., Hall, V., Vandermolen, J., & Zigmond, N. (2010). Coaches and coaching in Reading First schools: A reality check. *The Elementary School Journal*, *111*(1), 87-114.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3-15.

Borko, H., Frykholm, J., Pittman, M., Eiteljorg, E., Nelson, M., Jacobs, J., Koellner-Clark,K. & Schneider, C. (2005). Preparing teachers to foster algebraic thinking. *ZDM*, *37*(1), 43-52.

Borko, H., Jacobs, J., Eiteljorg, E., & Pittman, M. E. (2008). Video as a tool for fostering productive discussions in mathematics professional development. *Teaching and Teacher Education*, *24*, 417-436.

Borko, H., Koellner, K., & Jacobs, J. (2011). Meeting the challenges of scale: The importance of preparing professional development leaders (ID Number: 16358). *Teachers College Record*. Available from http://www.tcrecord.org/Content.asp?ContentId=16358

Bronkhorst, L. H., Meijer, P. C., Koster, B., & Vermunt, J. D. (2011). Fostering meaning-oriented learning and deliberate practice in teacher education. *Teaching and Teacher Education*, *27*(7), 1120-1130.

Brophy, J. (Ed.). (2004). *Advances in research on teaching: Vol. 10. Using video in teacher education*. Oxford, UK: Elsevier.

Bryk, A. S., Yeager, D. S., Hausman, H., Muhich, J., Dolle, J. R., Grunow, A., . . . Gomez, L. (2013). Improvement research carried out through networked communities: Accelerating learning about practices that support more productive student mindsets. In A White Paper prepared for the White House meeting on "Excellence in Education: The Importance of Academic Mindsets." Retrieved from http://www.carnegiefoundation.org/sites/default/files/improvement_research_NICs_bryk-yeager.pdf

Campbell, P. D., & Malkus, N. N. (2011). The impact of elementary mathematics coaches on student achievement. *The Elementary School Journal*, *111*(3), 430-454.

Cantrell, S. C., & Hughes, H. K. (2008). Teacher efficacy and content literacy implementation: An exploration of the effects of extended professional development with coaching. *Journal of Literacy Research*, *40*, 95-127.

Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively guided instruction: A knowledge base for reform in primary mathematics instruction. *The Elementary School Journal*, *97*(1), 3-20.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction*. Portsmouth, NH: Heinemann.

Cobb, P., Zhao, Q., & Dean, C. (2009). Conducting design experiments to support teachers' learning: A reflection from the field. *The Journal of the Learning Sciences*, *18*(2), 165-199.

Coburn, C. E., & Russell, J. L. (2008). District policy and teachers' social networks. *Educational Evaluation and Policy Analysis*, *30*(3), 203-235.

Coburn, C. E., & Woulfin, S. L. (2012). Reading coaches and the relationship between policy and practice. *Reading Research Quarterly*, *47*(1), 5-30.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Dallas, TX: National Staff Development Council.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199.

Deussen, T., Coskie, T., Robinson, L., & Autio, E. (2007). *"Coach" can mean many things: Five categories of literacy coaches in Reading First* (Issues & Answers Report, REL 2007-No. 005). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Northwest. Retrieved from http://ies.ed.gov/ncee/edlabs

Eick, C., Ware, F., & Williams, P. (2003). Coteaching in a science methods course: A situated learning model of becoming a teacher. *Journal of Teacher Education*, *54*(1), 74-85.

Elliott, R., Kazemi, E., Lesseig, K., Mumme, J., Carroll, C., & Kelley-Petersen, M. (2009). Conceptualizing the work of leading mathematical tasks in professional development. *Journal of Teacher Education*, *60*(4), 364-379.

Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record*, *103*(6), 1013-1055.

Fernandez, C. (2002). Learning from Japanese approaches to professional development the case of lesson study. *Journal of Teacher Education*, *53*(5), 393-405.

Gallucci, C., Van Lare, M. D., Yoon, I. H., & Boatright, B. (2010). Instructional coaching building theory about the role and organizational support for professional learning. *American Educational Research Journal*, *47*(4), 919-963.

Garet, M., Porter, A., Desimone, L., Birman, B., & Yoon, K. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915-945.

Gearhart, M., Nagashima, S., Pfotenhauer, J., Clark, S., Schwab, C., Vendlinski, T., . . . Bernbaum, D. (2006). Developing expertise with classroom assessment in K-12 science: Learning to interpret student work interim findings from a 2-year study. *Educational Assessment*, *11*(3-4), 237-263.

Gersten, R., Taylor, M. J., Keys, T. D., Rolfhus, E., & Newman-Gonchar, R. (2014). *Summary of research on the effectiveness of math professional development approaches* (REL 2014-010). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southeast.

Gibbons, L. K. (2017). Examining mathematics coaching practices that help develop school-wide professional learning. In M. McGatha & N. Rigleman (Eds.), *Elementary mathematics specialists: Developing, refining, and examining programs that support mathematics teaching and learning*. Charlotte, NC: Association of Mathematics Teacher Educators.

Gibbons, L. K., Garrison, A. L., & Cobb, P. (2011, April). *Teacher networks and the role of the mathematics coach: How institutional factors influence coach centrality*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

Gibbons, L. K., Kazemi, E., & Lewis, R. (2017). Developing the collective capacity to improve mathematics instruction: Coaching as a lever for school-wide improvement. *Journal of Mathematical Behavior*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0732312316300967

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., & Williamson, P. W. (2009). Teaching practice: A cross-professional perspective. *Teachers College Record*, *111*(9), 2055-2100.

Hart, L. C., Alston, A. S., & Murata, A. (2011). *Lesson study research and practice in mathematics education*. New York, NY: Springer.

Hill, H. C., Rowen, B., & Ball, D. L. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, *20*(2), 371-406.

Horn, I. S. (2012). *Strength in numbers: Collaborative learning in secondary mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Horn, I. S., & Little, J. W. (2010). Attending to problems of practice: Routines and resources for professional learning in teachers' workplace interactions. *American Educational Research Journal*, *47*(1), 181-217.

Jackson, K., Garrison, A., Wilson, J., Gibbons, L., & Shahan, E. (2013). Exploring relationships between setting up complex tasks and opportunities to learn in concluding whole-class discussions in middle-grades mathematics instruction. *Journal for Research in Mathematics Education*, *44*(4), 646-682.

Jacobs, V. R., Franke, M. L., Carpenter, T. P., Levi, L., & Battey, D. (2007). Professional development focused on children's algebraic reasoning in elementary school. *Journal for Research in Mathematics Education*, *38*(3), 258-288.

Kang, H., Windschitl, M., Stroupe, D., & Thompson, J. (2016). Designing, launching, and implementing high quality learning opportunities for students that advance scientific thinking. *Journal of Research in Science Teaching*, *53*(9), 1316-1340.

Kazemi, E., & Franke, M. L. (2004). Teacher learning in mathematics: Using student work to promote collective inquiry. *Journal of Mathematics Teacher Education*, *7*(3), 203-235.

Kazemi, E., Franke, M. L., & Lampert, M. (2009, July). *Developing pedagogies in teacher education to support novice teachers' ability to enact ambitious instruction*. Paper presented at the annual meeting of the Mathematics Education Research Group of Australasia, Wellington, New Zealand.

Kazemi, E., Hintz, A., Gibbons, L. K., Lewis, R., & Lomax, K. (2014, February). *Math Labs: Designing high quality school-embedded math professional learning*. Presentation at the annual conference of the Association of Mathematics Teachers Educators, Irvine, CA.

Kazemi, E., & Hubbard, A. (2008). New directions for the design and study of professional development: Attending to the coevolution of teachers' participation across contexts. *Journal of Teacher Education*, *59*(5), 428-441.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lesseig, K. (2014, April). *Developing teacher learning opportunities in mathematics studio*. Paper presented at National Council of Teachers of Mathematics Research Conference, New Orleans, LA.

Lewis, C., Perry, R., & Murata, A. (2006). How should research contribute to instructional improvement? The case of lesson study. *Educational Researcher*, *35*(3), 3-14.

Literacy Collaborative Trademark Committee. (2006). *Literacy collaborative standards*. Retrieved from http://literacycollaborative.org/docs/LCstandards6_2k6.pdf

Little, J. W., Gearhart, M., Curry, M., & Kafka, J. (2003). Looking at student work for teacher learning, teacher community, and school reform. *Phi Delta Kappan*, *85*(3), 184-192.

Lo, J. J., Grant, T. J., & Flowers, J. (2008). Challenges in deepening prospective teachers' understanding of multiplication through justifications. *Journal of Mathematics Teacher Education*, *11*(1), 5-22.

Lord, B., Cress, K., & Miller, B. (2003). *Teacher leadership as classroom support: The challenges of scale and feedback in mathematics and science education reform*. Newton, MA: Center for Leadership and Learning Communities, Education Development Center.

Lord, B., Cress, K., & Miller, B. (2008). Teacher leadership in support of large-scale mathematics and science education reform. In M. M. Mangin & S. R. Stoelinga (Eds.), *Effective teacher leadership: Using research to inform and reform* (pp. 55-76). New York, NY: Teachers College Press.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teachers of mathematics and science: The state of the scene. *School Science and Mathematics*, *99*(5), 258-271.

Lundenberg, M., Korthagen, F., & Swennen, A. (2007). The teacher educator as a role model. *Teaching and Teacher Education*, *23*(5), 586-601.

Mangin, M. M. (2007). Facilitating elementary principals' support for instructional teacher leadership. *Educational Administration Quarterly*, *43*(3), 319-357.

Mangin, M. M., & Dunsmore, K. (2015). How the framing of instructional coaching as a lever for systemic or individual reform influences the enactment of coaching. *Educational Administration Quarterly*, *51*(2), 179-213.

Matsumura, L. C., Garnier, H. E., & Resnick, L. (2010). Implementing literacy coaching: The role of school social resources. *Educational Evaluation and Policy Analysis*, *32*(2), 249-272.

Morris, A. K., & Hiebert, J. (2011). Creating shared instructional products an alternative approach to improving teaching. *Educational Researcher*, *40*(1), 5-14.

National Council of Teachers of Mathematics. (2014). Principles to actions: Ensuring mathematical success for all. Reston, VA: Author.

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

National Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards for mathematics and literacy*. Washington, DC: Authors.

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core Ideas*. Washington, DC: National Academies Press.

Neufeld, B., & Roper, D. (2003). *Coaching: A strategy for developing instructional capacity, promises and practicalities*. Washington, DC: Aspen Institute Program on Education and Annenberg Institute for School Reform.

Neuman, S. B., & Cunningham, L. (2009). The impact of professional development and coaching on early language and literacy instructional practices. *American Educational Research Journal*, *46*(2), 532-566.

Next Generation Science Standards Lead States. (2013). *Next generation science standards: For states, by states*. Washington, DC: The National Academies Press.

Poglinco, S. M., Bach, A., Hovde, K., Rosenblum, S., Saunders, M., & Supovitz, J. A. (2003). *The heart of the matter: The coaching model in America's Choice schools*. Philadelphia: Consortium for Policy Research in Education, University of Pennsylvania.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, *29*(1), 4-15.

Rainville, K. N., & Jones, S. (2008). Situated identities: Power and positioning in the work of a literacy coach. *The Reading Teacher*, *61*(6), 440-448.

Rosebery, A. S., Warren, B., & Tucker-Raymond, E. (2015). Developing interpretive power in science. *Journal of Research in Science Teaching*, *53*(10), 1571-1600.

Roth, W. M., & McRobbie, C. (1999). Lifeworlds and the "w/ri(gh)ting" of classroom research. *Journal of Curriculum Studies*, *31*(5), 501-522.

Scantlebury, K, Gallo-Fox, J., & Wassell, B. (2008). Co-teaching as a model for successful teaching. *Teaching and Teacher Education*, *24*(4), 967-981.

Schifter, D. (1998). Learning mathematics for teaching: From a teachers' seminar to the classroom. *Journal of Mathematics Teacher Education*, *1*(1), 55-87.

Schifter, D., & Fosnot, C. T. (1993). *Reconstructing mathematics education: Stories of teachers meeting the challenge of reform*. New York, NY: Teachers College Press.

Sherin, M. G. (2004). New perspectives on the role of video in teacher education. In J. Brophy (Ed.), *Advances in research on teaching: Using video in teacher education* (Vol. 10, pp. 1-27). Oxford, UK: Elsevier.

Sherin, M. G., & Han, S. Y. (2004). Teacher learning in the context of video club. *Teaching and Teacher Education*, *20*(2), 163-183.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Snow-Renner, R., & Lauer, P. (2005). *Professional development analysis*. Denver, CO: Mid-Continent Research for Education and Learning.

Stein, M. K., Silver, E. A., & Smith, M. S. (1999). Mathematics reform and teacher development: A community of practice perspectives. In J. Greeno & S. Goldman (Eds.), *Thinking practices: A symposium on mathematics science and learning* (Vol. 14, pp. 21-32). Hillsdale, NJ: Lawrence Erlbaum.

Stein, M. K., Smith, M. S., Henningsen, M. A., & Silver, E. A. (2000). *Implementing standards-based mathematics instruction: A casebook for professional development*. New York, NY: Teachers College Press.

Suzuka, K., Sleep, L., Ball, D. L., Bass, H., Lewis, J. M., & Thames, M. H. (2010). Designing and using tasks to teach mathematical knowledge for teaching. In D. Mewborn & H. S. Lee (Eds.), *Association of Mathematics Teacher Educators Monograph VI: Scholarly practices and inquiry in the preparation of mathematics teachers* (Vol 6, pp. 7-23). San Diego, CA: AMTE.

Teachers Development Group. (2010). *Mathematics studio program*. Retrieved from http://www.teachersdg.org/Assets/About%20Studio%20Brochure%20v.3.0.pdf

Tharp, R. G., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in social context*. Cambridge, UK: Cambridge University Press.

Thompson, J., Barchenger, C., & Hagenah, S. (2014, April). *Teacher learning and co-evolution of tools and practices in job-embedded professional development*. Paper presented as the annual conference of National Association of Research in Science Teaching, Pittsburgh, PA.

Thompson, J., Braaten, M., Windschitl, M., Sjoberg, B., Jones, M., & Martinez, K. (2009). Examining student work: Evidence-based learning for students and teachers. *The Science Teacher*, *76*(8), 48-52.

Tobin, K., & Roth, W. M. (2006). *Teaching to learn: A view from the field*. Rotterdam, The Netherlands: Sense Publishing.

van Es, E. A., & Sherin, M. G. (2010). The influence of video clubs on teachers' thinking and practice. *Journal of Mathematics Teacher Education*, *13*(2), 155-176.

van Es, E. A., Tunney, J., Goldsmith, L. T., & Seago, N. (2014). A framework for the facilitation of teachers' analysis of video. *Journal of Teacher Education*, *65*(4), 340-356.

West, L., & Cameron, A. (2013). *Agents of change: How content coaching transforms teaching & learning*. Portsmouth, NH: Heinemann.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of research in education* (Vol. 24, pp. 173-210). Washington, DC: American Educational Research Association.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2011). Proposing a core set of instructional practices and tools for teachers of science, *Science Education*, *96*(5), 878-903.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878-903.

Zhang, M., Lundeberg, M., Koehler, M. J., & Eberhardt, J. (2011). Understanding affordances and challenges of three types of video for teacher professional development. *Teaching and Teacher Education*, *27*(2), 454-462.

Author Biographies

Lynsey K. Gibbons is an assistant professor of mathematics education at Boston University. Her research seeks to understand how the contexts in which teachers work can be organized to support their ongoing learning and development, and how instructional leaders' and professional educators' practices support teachers' development of high-quality mathematics instruction.

Paul Cobb is a research professor of mathematics education at Vanderbilt University. His research focuses on improving the quality of mathematics teaching and thus student learning on a large scale, and on issues of equity in students' access to significant mathematical ideas.