Leading learning in content areas

A systematic review of leadership practices used in mathematics and science instruction

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Abstract

Purpose – The purpose of this paper is to report findings from a systematic literature review that explore how recent research on instructional leadership has addressed the role of mathematics and science instruction.

Design/methodology/approach – Using Hallinger's (2014) approach to conducting systematic reviews, the review included 109 peer-reviewed articles published since 2008 in leading mathematics and science education journals. An *a priori* coding scheme based upon key leadership behaviors articulated in Hitt and Tucker's (2016) unified leadership framework informed the analysis presented.

Findings – Results indicate that leaders support content area instruction by facilitating high-quality instructional experiences through curricular and assessment leadership. Leadership frequently involves establishing organizational conditions that support teachers' efforts to improve their own practice instead of direct leadership action on the part of instructional leaders. This support takes different forms and can include distributing leadership to teacher leaders with content area experience as well as using resources strategically to provide professional development or instructional coaching.

Originality/value – The review strengthens the connections between the instructional leadership, mathematics and science literatures, and identifies some of the leadership practices that these literatures deem important for instructional improvement. The review also reveals the potential for future research exploring the influence of a particular content area on supervisory practice and leadership discourse.

Keywords Instructional leadership, Mathematics instruction, Content-specific leadership, Science instruction

Paper type Research paper

Educational administration scholars define instructional leadership practice as it relates to the improvement of teaching and learning (Edmonds, 1979; Andrews and Soder, 1987; Hallinger and Heck, 1996; Hitt and Tucker, 2016). Researchers note a strong, positive relationship between effective instructional leadership practices and improved student achievement outcomes, which are often measured by standardized achievement tests (Witziers *et al.*, 2003; Leithwood *et al.*, 2010). Scholars determine this relationship exists whether administrators engage in leadership individually or collectively, as is the case with distributed leadership (Leithwood and Mascall, 2008). Scholars position these leadership actions as occurring independently of particular content areas and thus have not spent considerable time conceptualizing how different content areas might demand different leadership actions. We found that few leadership scholars have embraced this line of inquiry (e.g. Burch and Spillane, 2003; Gamoran *et al.*, 2003; Grossman and Stodolsky, 1995; Lochmiller, 2015, 2016; Nelson and Sassi, 2005; Spillane *et al.*, 2001; Spillane, 2005; Stein and Nelson, 2003; Theoharis and Brooks, 2012). Collectively, this research suggests supervising different content areas may require leaders to take different actions to impact classroom teachers' instructional practices. We find this to be particularly true about mathematics and science instruction, which scholars have historically positioned as more challenging subjects for administrators without content area expertise to lead (Gutierrez, 2012;

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Southerland and Sampson, 2012). What is striking is scholars who study instructional leadership note administrators may, for example, be reluctant to share advice and information regarding mathematics instruction (Spillane and Hopkins, 2013) or participate in organizational routines that focus specifically on mathematics instruction (Hayton and Spillane, 2008). As we prepared to conduct this review, we noted educational administration scholars have not strongly associated research on instructional leadership with emerging understandings of classroom instruction in mathematics or science. We found this gap surprising since scholars have called on the field to make more explicit connections between various bodies of leadership research, including those related to teacher and coach leadership (Neumerski, 2013). More importantly, teacher beliefs, instructional quality considerations and access issues related to mathematics and science may potentially explain well-documented inequities in student achievement outcomes, particularly among students who are Black, Latino, indigenous or English Language Learners (National Center for Education Statistics, 2017; Paschall *et al.*, 2018; Saw and Chang, 2018; Zilanawala *et al.*, 2017). A central motivation for understanding and improving leadership related to mathematics and science instruction is thus to engage leaders in systemic efforts to ameliorate persistent inequities that have undermined the economic and social opportunities afforded to students from traditionally under-served populations (Battey, 2013).

Recognizing the limitations of current research and the inequities that motivate leadership action, the purpose of this review is to begin identifying connections to literature focused on effective mathematics and science instruction to inform our current understanding of effective instructional leadership. More specifically, we address a single research question:

RQ1. What does research focused on mathematics and science instruction suggest educational leaders should do to support instructional improvement within these content areas?

To inform our analysis, we drew upon Hitt and Tucker's (2016) recent review of key leadership practices. This conception describes what research suggests leaders should do to support classroom instruction. Hitt and Tucker's (2016) model integrates 56 empirical research studies conducted between 2000 and 2014. Based on these previous studies, they found leadership involves five overarching domains, and 28 specific practices that prior research suggests are essential to effective leadership. First, leaders endeavor to establish and convey a vision for teaching and learning. Second, leaders facilitate high-quality learning experiences, with a particular emphasis on developing and monitoring the curricular, instructional and assessment program. Third, leaders build professional and organizational capacity that enables teachers to provide high-quality learning experiences. Within this, leaders facilitate professional development that supports the development of communities of professional practice. Fourth, leaders create conditions within the school organization that support learning. Prior research suggests that learning may relate to students, professionals or the whole system (Copland and Knapp, 2006; Knapp *et al.*, 2014). Finally, leaders connect with external partners to strengthen learning experiences for students. Collectively, these five domains define the actions leaders take to improve instruction without explicating how responses might differ within specific content areas. What Hitt and Tucker's (2016) review does not address, which we do within this review, is the extent to which these practices differ when leaders engage with different content areas. The paper unfolds with a brief discussion of the research methods followed by our review of the research literature. The paper concludes with a discussion of key leadership actions, future research directions and identification of unanswered questions.

Methods

We based our review on peer-reviewed literature, book chapters and scholarly books published since 2008. We used Hallinger's (2014) approach to conducting systematic reviews of literature in educational leadership to inform our analytic strategy. As illustrated in Table I, Hallinger's approach assesses literature using five questions relating to the study's purpose, conceptual perspective, data sources, analytic orientation and major results. These questions assisted us in selecting studies for inclusion in our review. We selected Hallinger's approach to systematic reviews as it represents one of the most established approaches in the field of educational leadership. Further, this approach was used by Hitt and Tucker in the development of their systematic review and thus offers methodological parity with this piece. Specifically, we used criteria established by Hallinger to identify studies that broadly described the conditions necessary for effective mathematics and science instruction or which spoke directly to leadership activities that support mathematics and science teachers. To the literature we retrieved, we also supplemented some studies that published before 2008 but which the authors had previously cited in their research. These largely represent seminal studies that had previously discussed leadership in relation to specific content areas, especially math or science. We included these studies when more recent research had not fully accounted for prior claims. We found these articles helpful in shaping the narrative about leadership that supports mathematics and science instruction.

Search process

We used the ERIC Database, which the US Department of Education maintains, to facilitate our collection of articles. We used ERIC as both the first and second author had access to this search engine, thus avoiding using other search tools that could produce remarkably different search results. To further refine our search procedures, the authors each employed a set of common search strings. We developed these strings collaboratively using the ERIC Thesaurus to guide our selection of terms indexed within the ERIC Database. As illustrated in the list "Mathematics and science ERIC search terms," the standardized search we employed in this review related one of the two content areas we studied with terms describing common leadership behaviors. The first author combined search terms with "math instruction" to produce a corpus of articles related to leadership in mathematics. The second author combined search terms with "science instruction" to produce a corpus of articles related to leadership in science. In two instances, we employed a more extensive search string that included three terms instead of two. We found these more sophisticated strings often produced similar results to those we initially derived using less complex strings.

Question posed by Hallinger	How addressed in this review
What are the central topics of interest, guiding questions and goals?	What does research focused on mathematics and science instruction suggest educational leaders should do to support instructional improvement within these content areas?
What conceptual perspective guides the review's selection, evaluation and interpretation of the studies?	We informed our analysis of the literature using Hitt and Tucker's (2016) leadership framework. This framework encapsulates recent research about effective leadership practices
What are the sources and types of data employed in the review?	We review empirical articles published in peer-reviewed journals since 2008
What is the nature of the data evaluation and analysis employed in the review?	We included articles published in learning peer-reviewed journals since 2008. We sought studies that used a rigorous methodology, addressed leadership practice(s) related to mathematics or science instruction, and did not describe pre-service or teacher education programs
What are the major results of the review?	Principal leadership in relation to mathematics and science instruction tends to emphasize high-quality learning experiences and creating supportive organizational conditions for instruction

Note: We modeled this table after Hallinger (2014). Hitt and Tucker (2016) used a similar approach in their systematic review of leadership literature

Table I.
Questions posed by Hallinger (2014) to inform the completion of a systematic review

In all, we identified 1,936 peer-reviewed articles using the ERIC Database that key word searches suggested aligned with or partly focused on leadership related to mathematics and science instruction. Of these, 1,021 peer-reviewed were published since 2008 and thus fell within the scope of our review. Based on an initial review of abstracts we then reduced the number of studies included in our review substantially. We ultimately identified 58 studies relating mathematics instruction with instructional leadership and 51 studies relating science instruction with instructional leadership and based our review from findings within articles across this collection of studies. The majority of articles we identified employed a qualitative research methodology.

Mathematics and science ERIC search terms used in article selection are as follows:

- "[content area] instruction" AND "teacher effectiveness";
- "[content area]" AND "administrators";
- "[content area]" AND "leadership";
- "[content area]" AND "principals";
- "[content area]" AND "teacher evaluation";
- "[content area]" AND "supervision";
- "[content area]" AND "instructional leadership";
- "[content area]" AND "school administrator";
- "[content area]" AND "observation" AND "principals";
- "[content area]" AND "instructional supervision"; and
- "[content area]" AND "instructional development" AND "principals."

Selection criteria

We used four criteria to select published articles for this review. First, we selected articles published since 2008 that reflected practices consistent with recent reforms aimed at improving mathematics and science instruction (e.g. Common Core State Standards (CCSS) and Next Generation Science Standards (NGSS)). Second, we included articles that employed a qualitative, quantitative, or mixed methods approach. We excluded articles that used either an action research or single subject design. Third, we included articles broadly addressing principal's responsibilities for supporting classroom instruction. As such, we included articles that described studies of leadership practice, professional development interventions, teacher perceptions of administrators, as well as studies describing other in-service activities within elementary or secondary schools. We excluded studies that described pre-service or teacher education programs as these studies often referred to activities that were beyond the scope of a principal's leadership and thus seemed unrelated to this review. Finally, we included studies that focused on programs and practices in the USA, Canada, Europe, Australia and New Zealand. We found these mathematics and science programs similar to those in US schools and thus an appropriate point of analysis.

Analysis of the literature

To complete our analysis of the literature, we used ATLAS.ti to store the articles we retrieved electronically and to encapsulate the results of our coding activities. Our analytic approach was consistent with recent literature pertaining to electronic literature reviews (Paulus *et al.*, 2016). We completed our analysis in four steps and drew upon descriptive coding strategies commonly found in other forms of qualitative inquiry (Saldaña, 2016).

First, we loaded PDF copies of each article into a data file. Second, we developed a coding scheme that mirrored the questions recommended for systematic literature reviews by Hallinger (2014) with key leadership behaviors identified by Hitt and Tucker (2016). For example, we developed codes that specifically addressed: "What specific leadership behaviors or actions does the author identify as the most important for mathematics or science instruction?" "With which aspect of Hitt and Tucker's unified leadership model do these behaviors or actions most closely correspond?" "How do these behaviors or actions contribute to or further expand Hitt and Tucker's model?" Additionally, we added simple document descriptors within our coding scheme for organizational purposes (e.g. article title, journal name, methodology, data sources, etc.). These were useful in both reducing the data corpus as well as considering how claims differed across the various sources we reviewed. Third, we applied the codes from our coding scheme to the documents. Fourth, we used coding frequencies derived from ATLAS.ti to determine which leadership behaviors identified by Hitt and Tucker (2016) appeared dominant across the literature we reviewed.

Based on frequencies, we determined that three leadership behaviors identified in the Hitt and Tucker framework appeared particularly important, these included: facilitating high-quality learning experiences, building professional and organizational capacity for learning, and building a supportive organization for learning. Finally, we reviewed coded passages to identify key leadership behaviors and select illustrative passages for direct quotation. In particular, we searched for passages that described the principal's responsibility for mathematics and science instruction directly (e.g. principals should do this) or passages where a principal's responsibility could be reasonably inferred (e.g. teachers might benefit if principals did this).

Results

Our review indicates mathematics and science education scholars have primarily discussed principal leadership related to two of the five dimensions of leadership practice articulated within Hitt and Tucker's (2016) leadership framework. As illustrated in Table II, we found most recent studies emphasized responsibility for facilitating high-quality learning experiences in mathematics and science. This responsibility most often entails developing and monitoring a curricular, instructional, and assessment program appropriate for these

	Mathematics references	Science references	Combined references
Total codes applied	1,214	851	2,065
Facilitating HQ instructional experiences	475	160	635
Developing and monitoring a curricular program	271	61	332
Developing and monitoring an instructional program	119	70	189
Developing and monitoring an assessment program	85	29	114
Creating a supportive organization	739	691	1,430
Distributing leadership	186	44	230
Strategically acquiring and using resources	128	63	191
Supporting professional growth	102	396	498
Building collaborative processes for decision making	96	10	106
Supporting equity and diversity	84	9	93
Strengthening school culture	65	47	112
Establishing and conveying a vision	64	100	164
Connecting with external partners	14	22	36

Notes: [a]For this review, the authors have collapsed three domains originally identified by Hitt and Tucker. These include "Establishing and Conveying a Vision," "Building Professional Capacity," "Creating a Supportive Organization for Learning" and "Connecting with External Partners"

Table II. Coding frequencies based on final coding scheme used in analysis subject areas. Additionally, we found the literature stresses a principal's responsibility for creating an organization that supports mathematics and science instruction. This responsibility includes configuring leadership structures to maximize their connection to content area expertise as well as providing resources to support instructional improvement. We discuss the principal's responsibility within each of these areas in greater detail below.

Facilitating high-quality instructional experiences

Mathematics and science education scholars argue that instructional leadership drives a school's ability to facilitate high-quality instructional experiences for students (Jackson *et al.*, 2015) and presume effective supervision requires significant pedagogical and content area understanding. Scholars characterized this understanding previously in terms of a leader's leadership content knowledge and positioned this understanding as important for administrator's supervisory practices (Stein and Nelson, 2003). For example, Greenes (2013) argued that mathematics supervisors, including school principals and department chairs, must be well trained in at least four main areas when engaging in supervision. First, supervisors must have an understanding of "big" mathematical ideas and how those ideas interrelate across the curriculum. This implies mathematics supervision is partly anchored within a leader's content area understanding as this understanding is ultimately used to inform curricular and pedagogical decisions. Second, supervisors must understand mathematical concepts, skills and reasoning methods. This understanding should be sufficient for the supervisor to determine whether teachers present mathematical concepts clearly and students apply methods correctly. Third, supervisors should understand computer-based and online instructional resources that extend mathematics learning in both school- and home-based settings. While this does explicitly aligned to the work of instructional leadership itself, it may be important in schools serving students who require additional remediation to meet ambitious mathematics learning goals or which serve students with individualized mathematics learning needs. Finally, supervisors must possess an understanding of "best practices in assessment, pedagogy, and professional development" (p. 45).

Developing and monitoring a curricular program in mathematics and science. Administrator's supervisory responsibilities often extend to the development and monitoring of the school's curricular program. Indeed, we noted that the literature positions the school's curriculum as one of the primary leverage points principals might use to influence what teachers teach within the context of the school's mathematics or science program. The state's accountability expectations and the district's influence in curriculum adoption shape a principal's influence in this area. However, scholars suggest this may be an area where principals can wield significant influence as current curricular frameworks used for accountability (e.g. CCSS and NGSS) provide relatively limited guidance about what kinds of curricula should be adopted (McDuffie *et al.*, 2017). We noted that mathematics education scholars suggest there are four curricular conditions necessary to provide effective mathematics instruction for students: a stable and high-quality curriculum; stable, knowledgeable and professional teaching community; assessments that are well aligned with curricular goals; and stability in curricula, assessments and professional development (Eogdawatte *et al.*, 2011). Clearly, administrators have a primary responsibility in establishing and sustaining these conditions within their schools. Indeed, we noticed the importance of the decision-making capacity of leaders at the district- and school-levels regarding curriculum and assessment choices. For instance, Cobb and Jackson (2011) assert that "the provision of instructional materials and tools designed to support teachers' development of focus practices" (p. 13) is an important leadership responsibility and a critical component of a coherent instructional system. For example, findings from one study of leading curricular programs, including those at the secondary level (Slavin *et al.*, 2009) suggest curricular programs, which directly affect teaching practice as well as influence student interactions, have a more robust influence on mathematics achievement than the content of the mathematics curriculum alone. As Slavin *et al.* (2009) carefully note, "This is not to say that curriculum is unimportant. There is no point in teaching the wrong mathematics or using curriculum that does not reflect current conceptions of what students should know and be able to do" (pp. 886-887). We take this to mean that leaders cannot assume exercising leadership over curriculum alone can influence the direction of the school's curricular program. Rather, leaders, when seeking to influence their mathematics program, must identify other practical entry points that influence how teachers think about their instruction.

Although less developed than the mathematics literature, science education scholars have also positioned curriculum as a significant leverage point for leaders to influence their school's science program. The science literature suggests leaders play a role in monitoring curriculum and offer evidence that principals are well-positioned, due to their formalized position to support and lead quality science education by making curricular decisions about their science program (e.g. Casey *et al.*, 2012; Halverson *et al.*, 2011). As part of this process, science scholars encourage leaders to choose science curricula that promote "innovations that stretch existing capacity in interesting and important ways" (p. 35). This might include selecting a program that focuses on scientific inquiry processes and/or includes thematic foci (e.g. engineering, computer science, biomedical health sciences, etc.). Alignment is also an important responsibility for school leaders when selecting a curriculum. Casey *et al.* (2012) suggest principals should consider the "importance of alignment of science instruction between the grade levels" (p. 58), such that the curricula adds to the overall coherence of the science program and provides clarity across classrooms and stakeholders. Then, when implementing the curriculum, Bair and Bair (2014) indicate that effective implementation requires full administrative support coupled with appropriate investments in teacher professional learning. Indeed, across the science literature, we observe that one of the ways leaders can support the implementation of science curricula is to ensure adequate levels of school-based investment in professional development for science teachers (Blonder and Mamlok-Naaman, 2016; Fitzgerald and Schneider, 2013).

However, unlike mathematics instruction, it bears noting that leaders' abilities to use curricula as a leverage point to improve science instruction might depend somewhat on the current policy environment. Science education scholars have expressed concerns that the current policy context allows leaders to provide relatively little attention to subjects that do not directly contribute to a school's accountability measures and science appears to be one of these subjects (Carrier *et al.*, 2013; Carrier *et al.*, 2014; Halverson *et al.*, 2011). In fact, it could be that principals may intentionally lessen their focus on science curriculum to respond to external accountability pressures and instead focus on English or mathematics. Further, evidence suggests a constraint on instructional time now encourages leaders to implement science in a way that melds science within literacy (e.g. Halverson *et al.*, 2011; Fitzgerald and Schneider, 2013; Sandholtz and Ringstaff, 2014). This clearly impacts how leaders might approach the selection of curricula and support of the science agenda.

Developing and monitoring an instructional program in mathematics and science. Beyond their role as a curriculum leader, the research also positions leaders as having the opportunity to influence mathematics and science by monitoring classroom instruction. However, this may be the most challenging aspect of a leader's work as scholars suggest it requires an enhanced understanding of the content teachers are covering. Indeed, one of the premises of the current literature is that principals must have sufficient knowledge of both content and pedagogy to guide teachers toward improved instructional practices. For instance, Hill *et al.* (2008) studied the effect of teacher's mathematical knowledge for teaching (MKT) and the mathematical quality of instruction (MQI). They defined MKT as "not only the mathematical knowledge common to individuals working in diverse professions, but also the subject matter knowledge that supports teaching" and the MQI as "several dimensions that characterize the rigor and richness of the mathematics lesson, including the presence or absence of mathematical errors, mathematical explanation and justification, mathematical representation, and related observables" (p. 431). This acknowledges that effective instruction rests on both subject matter knowledge and knowledge of pedagogy and raises key questions about the ways principals engage in classroom observation. As Nelson (2010) observed, "Principals who use the process of classroom observation and teacher supervision to support teachers in developing and using their mathematics knowledge for teaching […] may therefore indirectly enhance students' mathematics achievement" (p. 50). Not surprisingly, this has important implications for the ways in which principals engage in instructional leadership and raises questions about the extent to which principals can detect mathematical errors, determine whether teachers are responding effectively to students, identify connections between practice and mathematics, assess the richness of presented mathematical concepts and use mathematical language appropriately (Hill *et al.*, 2008).

Numerous studies indicate this may be especially challenging for leaders who supervise mathematics and science. Both subjects historically present unique challenges for teachers and administrators alike. For instance, science is traditionally a content area where classroom teachers, particularly at the elementary level, are not confident in their instruction (e.g. Fitzgerald and Schneider, 2013; Sandholtz and Ringstaff, 2014). This highlights the need for quality guidance and support from leaders. However, leaders' levels of science efficacy influence the amount of guidance in science they provide (Lochmiller, 2016). As Halverson *et al.* note (2011), "the transition from good ideas about K-12 science teaching and learning to systemic improvements in K-12 science classrooms is the responsibility of school and district leaders" (p. 13). School administrators may themselves need support in developing in this capacity.

The literature indicates an important pre-requisite for leaders to engage with instructional issues is to attend to their understanding of mathematics and science instruction. Indeed, there is a relatively robust line of research that describes how principals can engage in professional learning related to these subjects as one strategy to develop their capacity for leadership (Steele *et al.*, 2015; Stein and Nelson, 2003; Whitworth and Chiu, 2015). Part of this learning might involve acquiring an understanding of the cultural norms bound within a specific content area. For instance, Lochmiller (2016) noted that leaders might have difficulty identifying the cultural norms associated with mathematics and science instruction evolved from prior instructional experiences. Additionally, scholars note that mathematics teachers work within particular traditions related to teaching, learning, grouping, assessment and collaboration (Eogdawatte *et al.*, 2011). Each of these likely shapes how teachers view their practice and thus shapes what leaders should do to inform, influence or guide teacher's practice (Lochmiller, 2016).

Creating a supportive organization for mathematics and science instruction

Mathematics and science education scholars also emphasize how principals and other school-based leaders develop an organization that supports mathematics and science teachers in providing high-quality instructional experiences. Indeed, these scholars note school-based conditions significantly shapes how mathematics and science teachers engage in their work and whether they adopt innovative instructional practices. For example, mathematics and science education scholars note that leaders have an important role in creating a trusting and safe environment that enables classroom teachers to take risks within their pedagogy (Childs *et al.*, 2013). Further, leaders directly shape the school environment to provide opportunities for collaboration (Carrier *et al.*, 2014). Bartolini *et al.* (2014) highlight the need for school leaders to foster "an intellectual, supportive, and trusting relationship" (p. 54) with teachers. Other researchers emphasize the importance of principals supporting teachers individually by helping them increase their self-efficacy specifically with science instruction (Blonder and Mamlok-Naaman, 2016; Carrier *et al.*, 2013), providing the necessary resources to support teacher efforts (Bartolini *et al.*, 2014) and sharing the responsibility of decision making (Halverson *et al.*, 2011). Since school leaders have the authority to establish a supportive organization for learning, principals can "foster an environment that encourages self-reflection on personal classroom practices and the effects of their research efforts" (Blonder and Mamlok-Naaman, 2016, p. 349).

Distributing leadership to facilitate improvement in mathematics and science. Part of a leader's work to create a supportive school environment relates to efforts to distribute or share leadership with classroom teachers. The literature tends to position leaders' efforts to create a supportive organization for learning as being partly a function of shared leadership. This finding mirrors previous research showing both principals and teacher leaders matter for teacher learning (Printy, 2008). Mathematics education researchers tend to treat shared leadership with content area teachers as an important pre-requisite for improved instructional practices. In their study of leadership that supports mathematics instruction, Higgins and Bonne (2011) observed distributed leadership configurations were effective in supporting classroom teachers at the elementary level. Specifically, they found a lead teacher (i.e. an assistant principal, department chair, instructional coach, etc.) can be instrumental in supporting a school's mathematics reform goals. They found that the "combination of a classroom teacher and a senior management member to lead numeracy in the school is likely to have ensured numeracy had a 'voice' in a wide range of contexts at the school" (Higgins and Bonne, 2011, p. 816). This voice seems essential to ensuring teachers receive adequate collaboration time, professional development support, instructional resources and other investments necessary to ensure the success of the school's program.

Interestingly, we found that mathematics and science education scholars describe how teachers engage in leadership but have not fully considered how principals enable teacher leadership within their schools. Many mathematics and science education scholars appear to be grappling with definitions of teacher leadership (Yow, 2013), with most definitions acknowledging the content expertise held by teacher leaders. Further, scholars argue that administrators should enable teacher leaders to exercise influence beyond their classrooms as part of a school-wide approach to improving mathematics and science instruction. The distribution of leadership responsibility necessarily impacts administrators (i.e. assistant principals, deans of instruction, etc.), formalized teacher leaders (i.e. instructional coaches and department chairs) and classroom teachers (i.e. veteran teachers with content area knowledge superior to their peers). Indeed, principals established the school-based environment to allow teachers to tap science department chairs, coaches, or curricular specialists (Childs *et al.*, 2013; Halverson *et al.*, 2011). Much like their colleagues in mathematics, science education scholars suggest it may be especially beneficial when principals allow teachers to lead one another (Halverson *et al.*, 2011) or when they work together with teachers to make instructional decisions (Casey *et al.*, 2012). Doing so shifts the burden of changing instructional practices from the administrator alone and instead invites teachers to collaborate in critical pedagogical matters (Bartolini *et al.*, 2014).

Strategically acquiring and using resources to support mathematics and science. Mathematics and science scholars position principals as being fundamentally responsible for the acquisition and use of resources to support instructional improvement in these subject areas. While Hitt and Tucker's (2016) framework refers to the strategic acquisition of resources, which economists often define as hiring classroom teachers, we found that mathematics and science education scholars also accentuate the importance of strategic resource use. For example, scholars stress the importance of deploying resources in a sustained manner while also aligned with a principal's vision for instruction (Cobb and Jackson, 2011). Further, we noted that leaders are essential in providing meaningful professional development activities to teachers (Jackson *et al.*, 2015; Higgins and Bonne, 2011). This seems especially true about science instruction. Within the literature, we also noticed subtle critiques of principals' inconsistent investment in instruction, especially in studies focused on elementary mathematics coaches (Campbell and Malkus, 2011; Chval *et al.,* 2010; Mudzimiri *et al.,* 2014). As one example, research about the roles and responsibilities of elementary mathematics coaches cited the shifting demands placed on coaches by principals as a significant barrier to achieving the full potential of the coaching intervention (Chval *et al.*, 2010). In response, Walkowiak (2016) advocated that principals and coaches collaborate early in the academic year to determine the coaches' responsibilities relative to their work with teachers and avoid placing non-instructional responsibilities on coaches. This suggests when principals and coaches establish a clear understanding of the roles and responsibilities of coaches, the investment in coaching can be protected from ancillary administrative duties that diminish their capacity to provide instructional assistance to teachers.

Scholars also discuss science-related investments (Knapp and Plecki, 2001). Within the current literature, we find there are numerous references to patterns of resource use that enable effective science instruction. For example, principals support science teachers' development by utilizing available specialists in the school or district to support science instructional improvement (Carrier *et al.,* 2013) and when they offer regular opportunities for discussion as well as feedback from observations that help teachers improve their science instruction (Casey *et al.*, 2012). Science education scholars were particularly vocal in their advocacy for principals to provide adequate collaboration time (Akerson *et al.,* 2014; Bair and Bair, 2014; Carrier *et al.*, 2014), professional development opportunities (Bartolini *et al.,* 2014), appropriate staffing decisions (Casey *et al.*, 2012) and school-based instructional supports (Bartolini *et al.,* 2014; Blonder and Mamlok-Naaman, 2016; Whitworth and Chiu, 2015). We also noted that science education scholars argue that principals must provide materials necessary for successful science instruction (e.g. lab materials) (Bartolini, *et al.*, 2014). School leaders can encourage their teachers to maintain their determination in and dedication to science education. For example, Halverson *et al.* (2011) suggest making a connection with experts in the community may prove to be a lucrative partnership in that it can offer necessary resources for the science education agenda. An example of how schools can do this is connecting with a local business to invite volunteers to present to students or acquire donations of materials to support the science agenda (Carrier *et al.,* 2013). Just as Bartolini *et al.* (2014) showed the determination of a science teacher in her persistence in working to improve upon and incorporate an inquiry approach to science and was supported by her administrators in this pursuit, school leaders too can take an active role in acquiring resources so it the burden does not fall solely on a teacher or group of teachers.

Conclusion

Our review indicates that mathematics and science education scholars position school principals as important stewards of a school's effort to provide high-quality instruction and as the primary architect of school-level structures to support mathematics and science teachers' work. Notably, the literature does not suggest principals are the sole actors in this effort. Rather, the literature acknowledges that principals must work in consultation with other school staff to improve mathematics and science instruction. Indeed, both mathematics and science literature position instructional coaches and teacher leaders, such as department chairs, as being key to school improvement efforts. How principals work with these individuals becomes an important consideration. The most important conclusion we draw from our review is that mathematics and science education scholars do not excuse leaders from knowing what good mathematics- and science-specific instruction entails. Rather, they position school leaders as important stewards for the school's mathematics and science vision. We find that mathematics and science education scholars describe the importance for principals to engage in content area instruction with intention, a conclusion consistent with prior research (Stein and Nelson, 2003). What the mathematics and science literature suggests is leaders should approach this work by supporting and inviting teachers to facilitate and guide the improvement effort.

Identifying key actions for leaders in mathematics and science

Concerning what leaders should do to support mathematics and science instruction, we find the literature offers less clarity than we had hoped. While Hitt and Tucker (2016) offer a clear articulation of key instructional leadership actions based on their unified framework, the mathematics and science education literature offer less clarity. Much like the instructional leadership literature, we find mathematics and science education scholars tend to present leadership as a generic activity that is ancillary to the happenings within individual classrooms. This concern has been voiced previously (Theoharis and Brooks, 2012) and, as stated previously, was one of the major catalysts for this review. Further, it is reflected in leading frameworks that describe leadership in mathematics supervision (National Council of Supervisors of Mathematics, 2008). Quite disappointingly, we found limited guidance for school leaders within much of the literature we reviewed. Mathematics and science education scholars have not articulated a description of content-specific leadership related to mathematics or science. Nevertheless, mathematics and science education scholars have identified key leadership actions that principals can take to support instructional improvement. These actions include co-developing a vision for effective instruction with mathematics and science teachers; distributing or sharing responsibility for mathematics and science supervision; investing resources in teacher learning and professional growth; sustaining a commitment to mathematics and science improvement as part of a larger school reform effort. Further, we find ample evidence in the mathematics and science education literature, which suggests school principals should develop their capacity in these content areas while simultaneously calling upon mathematics and science teachers' expertise.

Where do we go from here? Unanswered questions and future directions

Our review suggests more research is needed to understand how principals engage in content-specific leadership behaviors. First, we think it is important to address questions that define what leadership actions are most closely associated with improved student learning in mathematics and science. It would behoove the field to conduct large-scale quantitative analyses to address this and add to the research that has already been conducted, which produced a robust understanding of the importance of the principal's vision for mathematics instruction (Katterfeld, 2013), for example. Future analyses might examine which leadership practices appear most related to improvements in mathematics and science achievement and which positively influence mathematics and science teachers' perceptions of their school-level working conditions. The need for this research is not exclusive to mathematics and science instruction; the field does not have a robust understanding of the kinds of actions leaders take to improve targeted instruction (Louis *et al.*, 2010). This is especially true with respect to leadership actions that relate to specific student communities, such as students of color and English language learners. The mathematics and science literature is clear that current instructional practices seriously under-serve these students and thus precipitate ongoing inequities between these students and other student groups.

Second, the field suffers from in-depth qualitative studies that define the practice of content-specific leadership in particular school contexts. While some research has sought to distinguish leadership at the elementary vs secondary levels (Burch and Spillane, 2003; Lochmiller, 2016), we think tracing distinctions between elementary and secondary leadership in content areas is an important line of research. Further, qualitative studies that allow researchers to document leadership actions over an extended period would significantly improve the field's understanding of both content-specific leadership activities as well as instructional leadership generally. Rigby *et al.* (2017) noted the dearth of research focused on particular supervisory practices. Examining these practices in greater detail would produce important insights for preparation and practice. We believe it would serve the field well to focus on leadership in schools serving an increasingly diverse but largely under-served student population. For example, understanding how leaders engage in supervision of content area instruction in schools serving a predominately low-income and minority students would illuminate how leaders situate their content-specific leadership in relation to their overarching equity agenda. Likewise, documenting the leadership practices in mathematics and science where the school is undergoing a significant demographic shift could contribute to the burgeoning literature about the unique leadership challenges in these schools (Welton, Diem, and Holme, 2013) as well as identify meaningful practices that best motivate considerations about previously isolated and/or marginalized student groups. Frankly, the literature does not describe concrete, equity-focused leadership actions that leaders could adopt to better serve these students and yet given the shifting demography of educational organizations globally this represents an important line of research. We see this as a significant and glaring omission in the current evidence base.

Finally, we think the field would benefit enormously from research examining how administrators' shift supervisory discourses across content areas. One scholar previously discussed "administrative talk" as an important avenue for study (Gronn, 1983). We see this as a particularly compelling line of research since the field has not closely examined supervisory communication practices let alone about specific content areas. Within this line of research, scholars might explore how issues related to content bear on the administrator's suggestions about instructional planning, classroom management, and student engagement. Further, scholars could also examine how classroom and leadership discourses reinforce inequitable assumptions about mathematics and science achievement that have historically disadvantaged students of color, English Language Learners, and indigenous students among others. At least one scholar has already undertaken research in this area, though it focused on groups of classroom teachers and did not consider the related role of school leaders (Horn, 2007). We believe that this research could contribute greatly to our understanding of school leadership broadly as well as in content areas specifically. Moreover, understanding how math and science are positioned discursively could also provide insights about how best to expand school leaders' repertoires as they seek to support teacher practice and student learning. Collectively, we see these emerging lines of inquiry as being important avenues to further our understanding of the connections between leadership and student learning.

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