

A Synthesis of Math/Science Teacher Leadership Development Programs: Consensus Findings and Recommendations

BSCS Technical Report No. 2017-02

A Report of
*The Developing Math/Science Teacher Leadership: A Consensus
Approach to Evaluating Program Quality and Supporting
Teacher Leader Workforce Development Project*

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A Synthesis of Math/Science Teacher Leadership Development Programs: Consensus Findings and Recommendations

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A report of the Developing Math/Science Teacher Leadership: A Consensus Approach to Evaluating Program Quality and Supporting Teacher Leader Workforce Development Project, a collaboration of BSCS, the Knowles Teacher Initiative, and the Education Development Center

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The two-year project represented a collaboration among BSCS, the Knowles Teacher Initiative (formerly Knowles Science Teaching Foundation, KSTF), and the Education Development Center (EDC). Horizon Research, Inc. provided evaluation services. The synthesis project unfolded across four phases: Synthesis Preparation, Symposium, Consensus-building Review, and Dissemination (figure 1). Project staff included a leadership team; project evaluator; symposium team including advisers, a facilitator, and participants; and BSCS staff.

Figure 1. Synthesis project phases.



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1. Executive Summary

Teacher leadership represents a powerful strategy for educational improvement (National Research Council [NRC], 2011). Yet, building a national pipeline of math/science teacher leaders ready to serve in a variety of roles is very much a work in progress. If teacher leadership development becomes standard practice, math and science teachers would have multiple opportunities to exercise formal and informal leadership across their careers (National Comprehensive Center for Teacher Quality, 2010) and more fully contribute to systemic improvement efforts.

With this aspiration in mind, BSCS in collaboration with the Knowles Teacher Initiative (formerly KSTF) and the Education Development Center (EDC) embarked on a project supported by a grant from the National Science Foundation (NSF ECR grant number 1534698) to synthesize research and practice focused on math/science teacher leadership development programs.

Of the 89 research abstracts and 70 program descriptions vetted, 18 research articles and 15 programs met the criteria for the study. The combined sample of research articles about programs and program descriptions served as the basis for face-to-face and online discussions among leaders in math/science teacher leadership development. Through the synthesis process, four focal areas emerged as organizers for consensus statements and recommendations.

Four Focal Areas and Recommendations Emerging from the Consensus-Building Process

Focal Area 1: <i>Programs and the teacher leadership development landscape</i>
Consensus Statements
Consensus statement 1.1: The landscape of teacher leadership development includes varied combinations of leadership roles and development opportunities nested within the larger educational system.
Consensus statement 1.2: Formal programs are more likely to appear in research studies and evaluation reports; however, they represent only part of the broader mathematics and science teacher leadership development landscape.
Consensus statement 1.3: Teacher leadership development, in this study, generally does not reflect the dynamic and complex nature of a teacher professional continuum.
Consensus statement 1.4: Equitable access to teacher leadership development opportunities is an important, but understudied, dimension of teacher leader development.
Recommendations
Program designers and researchers seeking to improve teacher leadership development should collectively attend to all four quadrants of the teacher leadership development landscape depicted in figure 2 (p.11).
Funders should consider supporting research and programs in all four quadrants of the teacher leader landscape.
Program designers and researchers need to attend to a range of leadership development opportunities that meet the needs of teachers along a professional continuum in an effort to recruit, retain, and grow a strong collective workforce.
All stakeholders must work together to ensure teachers from underserved and underrepresented areas have equitable access to leadership development opportunities.

Focal Area 2: Purposes of teacher leadership development programs

Consensus Statements

Consensus statement 2.1: While to date the majority of teacher leadership development programs position teacher leaders as implementers of reforms conceived by others, teacher leaders will need multiple pathways for leadership and leadership development to advance and support their capacity to drive improvement efforts.

Consensus statement 2.2: The use of teacher leadership models was not evident in the research or programs reviewed nor were there clearly articulated teacher leadership frameworks across research or programs.

Recommendations

Program designers and researchers should articulate, beyond a definition of teacher leadership, the conceptual models and frameworks they use to develop, study, and support teacher leaders.

Program designers and researchers should develop opportunities to support teachers along multiple pathways in the landscape and particularly programs that help teacher leaders drive improvement efforts.

Focal Area 3: Attributes of teacher leadership development programs

Consensus Statements

Consensus statement 3.1: A limited number of teacher leadership development programs met criteria for inclusion in this synthesis, and those that were reviewed provided uneven descriptions of program attributes and outcomes making it difficult to aggregate findings.

Consensus statement 3.2: Most of this study's research and programs addressed two general categories of leadership content—leadership identity and skills—but specifics varied across individual research and programs.

Consensus statement 3.3: Most teacher leadership development programs in this study included enhancing quality teaching through deepening pedagogical content knowledge in their designs, and many also focused on deepening discipline-specific content knowledge.

Consensus statement 3.4: The majority of teacher leader development programs in this study served state-, district-, and/or school-level needs to improve performance in a particular content area.

Consensus statement 3.5: Teacher leadership development programs in this study tended to be designed so that teacher leaders committed a significant amount of time toward learning, practicing, and implementing skills.

Consensus statement 3.6: Teacher leadership development programs in this study used various designs (summer institutes, school year workshops/seminars, cohorts, professional learning communities, design cycles, and internships/fellowships) to provide time and space for teacher leaders to work with each other and their colleagues during implementation.

Consensus statement 3.7: Most teacher leadership development programs in this study included expanding teachers' knowledge base, investigations into practice, practice with enactment, and reflection using a variety of processes.

Focal Area 3: <i>Attributes of teacher leadership development programs</i>
Recommendations
Program designers should be explicit about the key features of interventions used in their programs linked to expected outcomes so that evaluators and researchers can study the aspects of the intervention most effective in particular contexts.
Program designers and researchers need to better articulate the nature of leadership content and processes as defined and developed in the program.
Program designers and researchers should be attentive to the program structure and how the program supports initial implementation and sustains practice over time.
Measures of program outcomes need to attend to specific component(s) of the program but particularly move beyond content (i.e., leadership content, disciplinary content, and pedagogical content knowledge [PCK]).

Focal Area 4: <i>Research on teacher leadership development programs</i>
Consensus Statements
Consensus statement 4.1: The research on teacher leadership development in mathematics and science that met the criteria for this study is limited.
Consensus statement 4.2: Teacher leadership development programs draw from a limited repertoire of valid instruments to study program impacts and rely mostly on program-specific instruments and self-report surveys to measure effectiveness.
Recommendations
Program designers should make concerted efforts to share findings from their evaluation reports.
Efforts should be made to design and disseminate valid instruments to examine different attributes of teacher leadership development.
Researchers should work toward identifying the causal links between program attributes and outcomes for teacher leadership.
Policymakers and funders should support research collaborations or program-level evaluations.

Implications for STEM Teacher Workforce Development

Math and science teacher leadership development is an important contributor to developing a strong science, technology, engineering, and mathematics (STEM) teacher workforce. A strong STEM teacher workforce provides a foundation for ongoing school improvement efforts. Moreover, math and science teacher leaders can contribute both to specific reform efforts and to overall capacity for organizational growth and improvement as they lead from the classroom.

To realize these benefits of a strong teacher workforce, the STEM education community must take a systems approach to STEM teacher leadership development. We must offer formal and informal teacher leadership opportunities for growth with consideration given to where teachers are along a professional continuum as well as at multiple entry points and pathways along the continuum.

To make the case for investment in offering such opportunities, we must also offer evidence of impact of teacher leadership development grounded in rigorous qualitative and quantitative studies. Such studies would seek to uncover attributes of development opportunities that are most effective given clearly articulated outcomes measured by valid and reliable instruments.

2. Introduction

In the last decade, much attention has been paid to teacher leadership as a powerful strategy for realizing educational improvement (Curtis, 2013; Hopkins, Spillane, Jakopovic, & Heaton, 2013; Lord, Cress, & Miller, 2008; Murphy, 2005; NRC, 2011). The heightened interest in teacher leadership comes at a time when K-12 math and science education is transitioning to new standards and expectations for students and their teachers. A number of states and districts adopting the new standards are also launching initiatives to build math and science teacher leadership capacity (e.g., California Teachers Association Instructional Leadership Corps, West Tennessee Master Teacher Corps). Programs to develop math and science teacher leaders are beginning to populate the teacher professional development landscape. However, it is difficult to tell how many and what kinds of programs exist, let alone how programs support teacher leadership development or how effective they are.

A piecemeal approach to teacher leadership development will do little to strengthen leadership capacity within the STEM teacher workforce. At present, there is no coordinated effort to build an infrastructure that supports a new kind of workforce where teachers, including math and science teachers, have multiple opportunities and pathways for teacher leadership and leadership development without necessarily leaving the classroom. These new visions for teachers' career paths, and their promise for improved teaching and learning, transcend individual teachers or programs and will require capacity building throughout the system in research, practice, and policy (National Comprehensive Center for Teacher Quality, 2010).

A first step in realizing new possibilities for STEM teacher leadership and leadership development is to have a clearer picture of what presently exists. To address this need, educators and researchers from BSCS, the Knowles Teacher Initiative (formerly KSTF), and Education Development Center (EDC) collaborated to synthesize theory, research, and practice on math and science teacher leadership development. This work builds on the NSF-funded Math and Science Partnership Knowledge Management and Dissemination (MSP-KMD) project that synthesized findings about teacher leadership and its development from empirical research published between 1990 and 2009 and from insights from practice from MSP teacher leadership projects funded between 2002 and 2009 (Schiavo, Miller, Busey, & King, 2010a; Schiavo, Miller, Busey & King, 2010b).

The goal of this project was to synthesize findings on key attributes of math and science teacher leadership development programs using published research and externally evaluated reviews of teacher leadership development programs. The major components of the work included a research and program review (see Math and science teacher leadership development: Findings from research and program reviews); a symposium that included 20 expert math and science teacher leadership researchers, practitioners, and the project team; and a review of findings by the project team, project advisors, and symposium participants (a detailed methodology is included in Appendix A). Each participant contributed an area of expertise to the symposium. This report, which resulted from the synthesis work, is intended to provide a foundation to strengthen the system's capacity for teacher leadership development in service of improved STEM teaching and learning for all students.

The report is organized into three sections: Focal Areas, Implications for Workforce Development, and Recommendations. The first section shares findings from the synthesis work, organized into four focal areas. The focal areas represent significant topics emerging during the research and program reviews, the symposium, and the subsequent review process. As we share these focal areas we offer consensus statements that represent general agreement about findings from our data sources, which include the research and program reviews (see Math and science teacher leadership development: Findings from research and program reviews), symposium proceedings, as well as feedback from the advisory and symposium teams. The second section of the report describes implications of these focal areas for workforce development. The final section includes recommendations to program providers, researchers, and other audiences interested in improving and broadening our knowledge of teacher leadership development programs.

3. Focal Areas Emerging from Research and Program Reviews and Symposium

A main source of information for this report is a research and program review of current and recent math and science teacher leadership development programs. The literature and program reviews served as a starting point for discussions with the symposium and advisory teams, where further questions, ideas, and concerns emerged. Taken together, four significant areas of interest surfaced, which we call “Focal Areas”.

1. *Programs and the teacher leadership development landscape*

An early and critical step in this synthesis project was to situate teacher leadership development programs within the larger landscape of teacher leadership development.

2. *Purposes of teacher leadership development programs*

The summary and analysis of program descriptions and research revealed that programs were developed for different purposes. One lens for organizing the findings was using a framework to differentiate programs based on their purpose.

3. *Attributes of teacher leadership development programs*

One goal of this synthesis project was to uncover patterns in program attributes. We organized the attributes using the following program design components: content, context, structure, and process.

4. *Research on teacher leadership development programs*

Evidence of program effectiveness is critical for program developers and decision-makers. While the evidence is insufficient to make claims that link effectiveness and program attributes, we did uncover patterns in instruments and methodologies.

While all four Focal Areas draw upon the research and program review and the symposium, there is a shift in what is foregrounded as we explain the consensus statements. Focal Areas 1 and 2 developed significantly during our discussions with the symposium team based on the findings and gaps in the research and program reviews. The consensus statements derived, in large part, from our symposium process and proceedings, with the statements further supported as we refined the research and program reviews. Focal Areas 1 and 2 also represent our work on the bigger picture of teacher leadership development and respond to discussions and concerns from experts during the symposium. A shift in what is foregrounded happens in Focal Areas 3 and 4, which are rooted in the research and program reviews specifically. These two Focal Areas include as a key data source the analysis of the 27 programs we examined. Focal Area 3 is significantly longer than the other Focal Areas given its centrality to the goal of examining program attributes, an important goal of the project.

At the conclusion of the Focal Areas section, we transition to the Implications for Workforce Development section. While workforce development is touched upon at different points in the Focal Areas, we highlight important take-away messages in the Implications section.

Focal Area 1: Programs and the Teacher Leadership Development Landscape

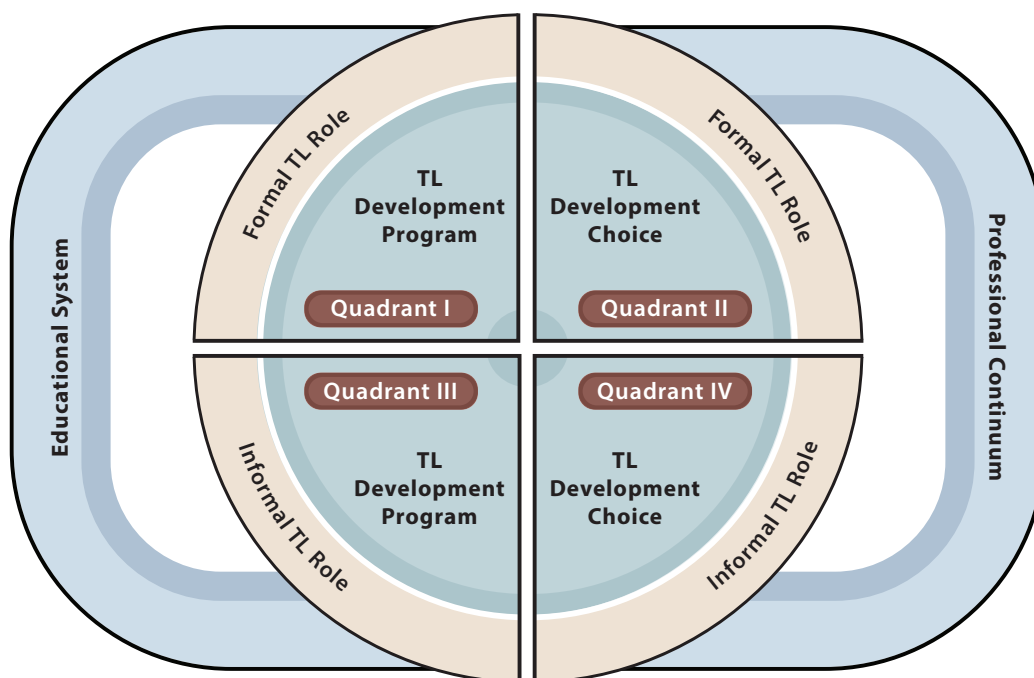
Teacher leadership is described variously in the literature and in K-12 education settings. The working definition of teacher leadership used in this synthesis effort is taken from Holland, Eckert, and Allen (2014), “[T]eacher leadership encompasses the practices through which teachers—individually or collectively— influence colleagues, principals, policy makers, and other potential stakeholders to improve teaching and learning” (p. 435). Many forms of teacher leadership, many incarnations of teacher leaders, and thus many instantiations of teacher leadership development are possible within the terrain of this definition. This “landscaping” of teacher leadership was one of the outcomes of the May 2016 symposium, reflecting the

lived experience of those expert practitioners and researchers. As such, we see it as a useful contribution to our understanding of teacher leadership and its development. It also situates the empirical research and program reviews that informed this synthesis.

Consensus statement 1.1: The landscape of teacher leadership development includes varied combinations of leadership roles and development opportunities nested within the larger educational system.

Figure 2 represents the landscape of teacher leadership development generated through the synthesis work. Our intent with this figure is not to represent all teacher leader roles or all manifestations of teacher leadership development. There is too much variation and volume to do that. Rather, it is to offer a way to think about the landscape of teacher leadership and its development, to situate this teacher leadership development synthesis.

Figure 2. Teacher leadership development landscape (TL: teacher leader).



We distinguish two major kinds of teacher leadership roles: *formal roles* (i.e., publicly held) and *informal roles*. Formal or informal is not a commentary on the significance or utility of teacher leadership roles; simply, it is a statement of the extent to which a teacher leader role is formalized with a job description or a named position within a school or district. An elementary science specialist is a formal teacher leader role in that it reflects a state certification and is typically a named position within a school. A math coach might be a formal teacher leader role, with a job description. It is also possible that a teacher might provide the equivalent of coaching—advice or guidance to colleagues—in an informal way, reflecting the responsibility an individual teacher might assume to provide support to colleagues or the request a principal makes of a specific teacher to offer guidance to a colleague. A department chair is a formal teacher leader role in that it is often a publicly acknowledged role with specified responsibilities and sometimes a pay differential. An advocate for science education would be an informal role—few districts have such a named position—with responsibilities on curriculum committees or in other school or district activities that support or promote science education. A National Board Certified Teacher (NBCT) generally becomes an informal teacher

leader, offering or tapped for his or her expertise to work with colleagues; in some situations, an NBCT may be tapped to play a formalized teacher leader role. Our intent here is to contrast formal and informal teacher leader roles; these examples are in no way a comprehensive representation of those roles.

Understanding whether the role is formal or informal offers some insight into the nature and structure of teacher leadership development. Some teacher leadership development exists as a program with identifiable activities occurring at prescribed times, often with explicit goals and named providers. These programs for teacher leadership development may exist at the school, district, state, or national level. Teacher leadership development also occurs outside of such programs. It can consist of activities such as courses or workshops that an individual teacher leader puts together or accumulates to support his or her professional growth or to build particular skills. It reflects the various teaching or leadership experiences in which a teacher leader has engaged. This kind of teacher leadership development is marked by the teacher leader's choice of how to foster his or her development and is often more ad hoc than programmatic in nature.

We recognize that teacher leader roles, be they formal or informal, are shaped by the school and district context in which they are enacted. Various policies and practices, at both the school and district level, have a powerful impact on the nature and efficacy of teacher leader roles. These include policies and practices regarding the authority and responsibilities of leaders in a system, including teacher leaders as well as teacher leaders' relationship to other leaders (notably, principals). Expectations about the kind of support provided to teachers to improve practice or implement curriculum, instruction, or assessment programs (areas where teacher leaders are often active) shape the roles that these teacher leaders play. Policies and practices about form, duration, and locale of teacher professional learning (another area of teacher leader work) inform how teacher leaders are active in designing, delivering, and/or sustaining professional development with teachers. What teacher leaders do *as* teacher leaders is greatly informed by the school and district systems in which they work. Thus, teacher leaders' roles (and, we argue, the development of teacher leaders) are shaped by the systems in which they work. In the sections that follow, we expand on two dimensions of the system that are particularly important for teacher leader development.

Consensus statement 1.2: Formal programs are more likely to appear in research studies and evaluation reports; however, they represent only part of the broader mathematics and science teacher leadership development landscape.

The design of programs for teacher leadership development—with an identifiable context, structure, goals, participants, and activities—often responds to the need for preparation of teachers for specific teacher leader roles (quadrant I in figure 2). These explicit programs, addressing formal teacher leader roles, are more likely to appear in the empirical research literature; indeed, most of the research reviewed for this synthesis was of this kind (78%). Over one-third of the research studies (39%) looked specifically at how to develop teacher leaders as professional development facilitators during scale-up efforts for reform-based curriculum. Another third looked at building leadership capacity among science and math coaches and mentors. As such, the research tells us much more about quadrant I than it does about other quadrants in the leadership development landscape. Our findings from the program review are not as clear as what we observed in the research. We found that teacher leaders in the programs we reviewed (81%) were classroom teachers who did not necessarily have leadership experience or a designated teacher leadership role in their schools or districts but who certainly could have a role which was not reported. While this may lead us to believe the programs targeted teacher leaders with no formal role or position, the lack of publicly available information prevented us from determining this with certainty.

Consensus statement 1.3: Teacher leadership development, in this study, generally does not reflect the dynamic and complex nature of a teacher professional continuum.

Teacher leadership is an important component of the teacher professional continuum (Feiman-Nemser, 2001; National Board for Professional Teaching Standards, 2016). We did not see attention to this continuum in the studies and programs we reviewed. Programs and research studies reported teacher leader characteristics as years of teaching experience, grade level, and content area, but the previous professional learning experiences (e.g., prior leadership experiences, content knowledge preparation, pedagogical content knowledge preparation) or needs of teacher leaders were not clearly articulated. This information could contribute to our understanding of the teacher leadership development as part of a teacher's professional continuum. The characteristics of teacher leaders reported by program designers may be influenced, in part, because they design programs to work for specific populations of teachers (e.g., middle school math teachers) and/or for specific purposes (e.g., leading the implementation of a new middle school math curriculum). What is missed by reporting only basic demographic information on teacher leaders is a readiness component that includes the teacher leaders' interest in and confidence to take on new leadership roles.

While not all programs provide information about the teaching and leadership background of their participants, we found that most programs set a minimum of three to five years teaching experience to participate in the program. Setting a minimum of years of classroom teaching indicates a certain expectation of classroom experience before leadership development and suggests that program designers recognized the importance of teachers' varied experiences on their leadership development. It was not uncommon, however, to have a teacher leader with three years of experience working alongside a teacher leader of ten or more years teaching experience in the same program. For some teacher leaders, the program was their first leadership experience, while other teacher leaders had experience with a variety of leadership programs in the past. These varied experiences present a challenge for program designers. Our examination of the research and programs indicated that programs have not found systematic ways to deal with this challenge and that years of experience alone is not a sufficient proxy for leadership development readiness or leadership capacity.

The focus on years of teaching experience prior to leadership begs the question of when teachers are ready for leadership opportunities and where leadership fits in the teacher professional continuum. Feiman-Nemser (2001) describes the teacher professional continuum as progressing through teacher preparation, induction, professional learning, and leadership. The National Board for Professional Teaching Standards (2016) also describes the professional career continuum for teaching as moving from preservice teacher to novice teacher, professional teacher, board-certified teacher, and teacher/school leader. In both cases, leadership is hypothesized as an advanced stage of the teaching continuum. A recent report on science teacher professional development (National Academies of Sciences, Engineering, and Medicine, 2015) argues that a linear approach to a teacher professional continuum based on career years falls short of the dynamic and iterative nature of teacher learning and development. The same may be true for leadership development. However, the research and programs reviewed did not specifically address the fit between teacher leadership development and a teacher professional continuum.

Consensus statement 1.4: Equitable access to teacher leadership development opportunities is an important, but understudied, dimension of teacher leader development.

From our examination of research and programs, we have limited information about equitable access to teacher leadership development opportunities. We know that half the programs we reviewed specified that they served teacher leaders from a mix of urban, suburban, and rural schools/districts; the remaining programs included only urban (3) or suburban (3) or rural (1) teachers (six programs did not specify

whom they served). We do not know much more about the populations of teacher leaders served by the programs, nor do we know about the populations of teachers with whom teacher leaders would engage. The question was raised during the symposium about whether all teachers have access to programs or whether current programs favor certain populations of teacher leaders. We know from research on professional development (e.g., Loucks-Horsley, Stiles, Mundry, & Hewson, 2010) that there is not equitable access for all teachers to high quality professional learning, so it could be a similar concern for teacher leadership programs as well. For example, Banilower and colleagues (2013) found that teachers in small schools report less access to high quality programs compared to teachers in large schools, but no significant difference was found based on community type or proportion of students eligible for free or reduced lunch (see chapter 3, p. 38). Banilower and colleagues also reported that teachers in small schools have significantly less access to study groups and coaching in both math and science. Teachers in rural schools report less access to coaching compared to teachers in urban schools (see chapter 3, p. 49–50). However, when looking at schools with the highest quartile of students eligible for free and reduced lunch, teacher access to study groups, coaching, and assistance was higher than the other quartiles. The findings from the national survey by Horizon Research (Banilower et al., 2013) indicate that equitable access to programs for teacher leadership is a valid concern but not yet answered by the information we have from leadership programs.

Summary of Focal Area 1: A more comprehensive understanding of teacher leadership and its development would address all four quadrants of figure 2 as well as issues of equity and the professional continuum. While that was beyond the charge for, and resources devoted to, this teacher leadership development synthesis, the symposium team stressed the need for future work that would provide a more complete understanding of the entire landscape.

Focal Area 2: Models of teacher leadership

As described in the Focal Area 1 section, leadership development and the roles of teacher leaders mutually influence each other. We also wanted to understand how teachers positioned themselves or were positioned by various roles and development efforts. We adopted Lukacs and Galluzzo's (2014) models of teacher leadership as a conceptual tool to examine teachers' positioning within the development programs reviewed. Lukacs and Galluzzo looked at teacher leaders' roles in reform historically and proposed three teacher leadership models that reflect varying degrees of teacher agency, ownership, and authority. Although the models do not have perfectly clear boundaries that exactly fit the teacher leadership development programs reviewed, they did offer a framework for examining the kind of leadership work that programs prepared teacher leaders to assume.

Consensus statement 2.1: While to date the majority of teacher leadership development programs position teacher leaders as implementers of reforms conceived by others, teacher leaders will need multiple pathways for leadership and leadership development to advance and support their capacity to drive improvement efforts.

In Lukacs and Galluzzo's Model One of teacher leadership, teachers are recipients and implementers of reform strategies. Teachers learn a strategy from reform designers (often university researchers) and implement it in their classrooms. We found that none of the programs included in the review matched Model One. By definition, Model One programs solely support teachers in enacting reforms with their own students. These types of programs did not fit the definition of teacher leadership, described above, used for the review selection process.

In Model Two, which has emerged during the last two decades, teachers assume leadership roles that traditionally have been the principal's domain, particularly instructional leadership. Teacher leaders formally or informally facilitate their colleagues' professional learning (as coaches, mentor, committee chairs, and so forth) with little or no input into the instructional vision itself. For this reason, Model Two is much like the roles assumed in quadrant I or II—as teacher leaders with more clearly defined roles participate in or advocate for a named program or initiative. The majority of programs reviewed fit Model Two (instructional leadership), although there was variability in the agency and autonomy teachers had for leading improvement.

Lukacs and Galluzzo's Model Three, which is just beginning to gain traction, positions teachers as change agents who not only improve their own classrooms but also drive continuous improvement in their schools and beyond. To explicate Model Three, Lukacs and Galluzzo offer a comparison between teachers as implementers of others' reform ideas and teachers as change agents:

We argue the difference can be seen when comparing the teacher who returns from the latest meeting of the school improvement committee and says, "Here's what we have to do next" with the one who initiates a literacy program for recent immigrant families in the school and seeks external funding to get it started. While the former is arguably a teacher leader, she/he is not necessarily actively working to improve the school with the agency, creativity, and license of the latter (p. 103).

The authors go on to make the point that teachers, who are the closest to student learning, are best positioned to take up continuous improvement work. Teachers "... have areas of expertise that allow them to take initiatives in a 'bottom up' design with the school as the unit of change" (p. 103). In this vision of teacher leadership, which is still taking shape, teachers are the ones driving change within and beyond their classrooms. Quadrant III aligns somewhat with the informal roles that Model Three teacher leaders might take on as they advocate for change. The overlap between quadrant III and Model Three is not one-to-one given that Model Three teacher leaders might also be in formally recognized roles. Five of the 27 programs we examined reflected Lukacs and Galluzzo's description of Model Three teacher leadership.

The purpose here is not to set the three teacher leader models of Lukacs and Galluzzo up against each other. The work of educational reform requires the contributions of all involved. There is certainly a need for those located outside of classrooms to share their ideas and support those who teach students every day. However, if continuous improvement is the goal, a teacher workforce with the commitment, professional judgment, and collective authority to drive improvement efforts is essential (Hargreaves & Fullan, 2012; Lukacs & Galluzzo, 2014).

Consensus statement 2.2: The use of teacher leadership models was not evident in the research or programs reviewed nor were there clearly articulated teacher leadership frameworks across research or programs.

Teacher leadership models can offer fresh perspectives and conceptual grounding for teacher leadership development. While symposium participants found Lukacs and Galluzzo's leadership models useful for explicating the purposes of teacher leadership development (e.g., scaling a reform effort, building teacher leader agency and identity), they also wondered what perspectives other leadership models might bring and discussed the need for conceptual models that could guide design and research of math and science teacher leadership programs with intentionality about goals and outcomes. For example, recent models of teacher leadership emphasize the importance of attending to social capital in leadership development, something symposium participants pointed out is emerging as a key component in studies of teacher social capital and educational improvement (Pil & Leana, 2009).

Summary of Focal Area 2: Models of teacher leadership, like the one developed by Lukacs and Galluzzo (2014), can be valuable conceptual tools for studying and designing teacher leadership development programs. Articulating conceptual frameworks for teacher leader development and/or examining different teacher leader models is critical for the field. There are multiple pathways to advancing this work, but making frameworks and models explicit is key to building understanding of the implications and effects of different models of teacher leadership development.

Focal Area 3: Attributes of Teacher Leadership Development Programs

For this synthesis, we examined the attributes of 27 teacher leadership development programs in math and science. In this section, our analysis of research and programs is the central source of information we reference throughout the discussion. We provide descriptive data about the 27 programs we examined, using percent of programs and occasionally number of programs. Some of the programs were described in the published research, while other programs were examined solely through the program's website, published materials, and evaluation studies. The review of research and programs was bound by criteria that were selected to keep the project focused on the development process for teacher leaders in math and science. A key criterion was evidence of effectiveness shared through a research publication or external evaluation study. We believe the peer review or external evaluation process gave adequate assurance that claims were grounded in sound evidence. A description of the criteria and review process is presented in Appendix A. Our analysis of the research and programs was then shared with the symposium and advisory teams for a critical review, which happened before, during, and after the four-day symposium. The consensus statements below represent a compilation of what was learned from our analyses of research and programs as well as the critical review.

Consensus statement 3.1: A limited number of teacher leadership development programs met criteria for inclusion in this synthesis, and those that were reviewed provided uneven descriptions of program attributes and outcomes making it difficult to aggregate findings.

In this study, we found that many math and science teacher leadership programs do not share or have evidence of effectiveness readily accessible. Our initial search of programs, from internet searches and recommendations, yielded 70 possible programs to include in the analysis. Yet, we could access evidence of effectiveness in the form of a peer-reviewed publication or external evaluation report for only 15 of the programs. Simply applying this criterion greatly reduced the number of programs that could be included in the review. The literature search presented different challenges, particularly in terms of finding publications on teacher leadership development in a peer-reviewed outlet. The initial search yielded 89 possible research articles; that number was reduced to 18 articles over 14 programs when applying criteria for peer review and a focus on leadership development. These findings are not altogether unexpected as prior work in this area has shown similar issues with respect to volume of what is available. For example, Schiavo, Miller, Busey, and King (2010a) found only 25 research studies and evaluation reports that met similar criteria. A recent publication by Wenner and Campbell (2017) noted 54 research studies published between January 2004 and December 2013 that met criteria for high quality empirical research on teacher leadership, but only seven focused on math or science teacher leadership.

In our combined sample from the program review ($n = 15$ programs) and the research review ($n = 18$ articles over 14 programs), a more significant challenge presented itself. Programs and research articles did not make clear the link between program attributes and outcomes and often employed the use of program-specific measures of those outcomes. Even though combining the samples from the program and research reviews increased our total sample size, the idiosyncratic nature of the work limited our ability to make strong claims about patterns in attributes of math/science leadership development

programs—one important finding of this project. Dissemination reports, whether through peer-reviewed publications or publicly accessible evaluation reports, tended to focus on program successes and challenges as a whole and not on the causal links between attributes of the program and outcomes for teacher leaders. We found uneven descriptions of the program design, participants, and activities, preventing us from making comparisons across programs with confidence, especially at the attribute level. Our grain size for analysis remained broad due to the nature of the program descriptions that were available in the publications and evaluation reports.

Our combined sample yielded 27 unique programs due to overlap of two programs that appeared in the research literature (original $n = 14$ programs) and the program review (original $n = 15$ programs). With the combined sample, we analyzed, to the extent we could, the program attributes and outcomes at a coarse grain size, focusing on four components of program design:

- Content: knowledge or skills to be developed by teacher leaders
- Context: what is driving the teacher leadership development program, for what purpose, and to what end; program's intended audience and scale of their reach
- Structure: how the program is organized across time, and how time is allocated for an intended purpose
- Process: strategies and activities used to achieve the goals and outcomes for learning

Content of Professional Learning

The content of professional learning was a consistent attribute across teacher leadership development programs. Research and programs were remarkably similar in their attention to disciplinary content knowledge, pedagogical content knowledge (PCK), and leadership content. Even though some shared findings in only one of the areas, all research and programs explicitly targeted two or all three of these broad content areas. We consider these content areas separately, beginning with leadership content.

Consensus statement 3.2: Most of this study's research and programs addressed two general categories of leadership content—leadership identity and skills—but specifics varied across individual research and programs.

Twenty-five of the 27 programs (93%) explicitly addressed aspects of leadership development in their program descriptions (two programs only described efforts to improve content knowledge and/or pedagogical content knowledge). There were few aspects in common across programs, and descriptions tended to be thin, especially in the research. There were 15 different aspects of leadership content mentioned across all programs, although most programs included only two of them. The most common were learning facilitation skills (48%, although the skills themselves varied), developing an identity as a teacher leader (30%), and understanding adult learning theory (26%). The remaining leadership content was a collection of leadership topics and issues, such as mentoring and coaching skills, educational policies, change processes, and presentation skills.

Examining only the 25 programs that addressed leadership content, 80% reported program effects on leadership content development and 60% reported primarily positive findings. Ten of these programs (40%) recorded gains in participants' leadership knowledge and/or skills, most often using teacher leaders' self-report, that included improved facilitation skills (28%), understanding of adult learners (4%), coaching skills (4%), and action research (4%). Five programs (20%) reported an increase in teachers' self-reported leadership activity. Two programs (8%) noted changes in participants' leadership identities as evidenced

by their expanded views of teacher leadership and an increased sense of themselves as leaders. Several programs reported impacts beyond the teacher leaders themselves (20%). All these programs focused on teacher collaboration using teacher leaders' and/or colleagues' reports as evidence of increased collaboration. One program studied teachers' advice networks in schools and, after program completion, saw denser networks with their teacher leaders centrally positioned in the network.

Consensus statement 3.3: Most teacher leadership development programs in this study included enhancing quality teaching through deepening pedagogical content knowledge in their designs, and many also focused on deepening discipline-specific content knowledge.

The argument that specialized content knowledge and knowledge for teaching are central to developing teacher leaders derives from the volume of evidence that content knowledge and PCK are key to teacher professional development (e.g., Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Desimone, Porter, Garet, Yoon, & Birman, 2002). Symposium participants supported this point when they discussed how the content disciplines make teacher leadership programs unique from each other. Because teacher leaders often find themselves supporting content and PCK development among their colleagues, or engaging in professional development or curriculum decision-making, teacher leaders require a deep practical knowledge of disciplinary content teaching. It is not surprising, then, that 25 of the 27 programs (93%) included strategies and activities that targeted teachers' content knowledge and PCK.

While 25 of the 27 programs emphasized PCK, fewer programs (59%) reported activities to deepen content knowledge of teacher leaders. It is not known whether the programs in this study had deep content knowledge as a prerequisite for teacher leaders participating in the program. In some of the programs, however, content deepening was a central feature. One program argued that deepening content knowledge was essential to building confidence in teacher leaders and positioned them not only to delve deeper into students' questions as classroom teachers but to serve as more confident facilitators and coaches to their colleagues. When disciplinary content deepening was emphasized, it was often integrated with PCK. For example, teacher leaders engaged in mathematical tasks as learners first, then considered how students would engage in the same or similar types of tasks (Ball & Cohen, 1999; Carroll & Mumme, 2007).

With respect to content knowledge and PCK development, recruiting and grouping teacher leaders was an important component. Our examination revealed programmatic differences in how teacher leaders were recruited and grouped based on grade level, content expertise, and content area. While our analyses showed that at least half of the programs targeted math or science at a specific grade band, the other programs recruited and combined teacher leaders across grade bands and content areas. Grouping across grade bands presented challenges at times with uneven content preparation of the teacher leaders as well as different goals with respect to content knowledge and PCK for working with students and colleagues. Even with these challenges, the programs' efforts to build content knowledge and PCK of teacher leaders were generally successful, when measured. Programs reported positive outcomes using a variety of instruments that are discussed more in Focal Area 4. A general conclusion, though, is that when measured programs reported gains in content knowledge and/or PCK, and no programs reported declines.

Context for Professional Learning

We examined the context of professional learning with respect to what drove this study's teacher leadership development initiatives and opportunities and found they related closely to previous discussions in Focal Areas 1 and 2. Program contexts included state-level or district-level programs, regional or national programs, or academic programs. Teacher leaders pursued academic programs by

choice, while many of the other programs offered teacher leadership development as part of initiatives developed at the state, district, or school level.

Consensus statement 3.4: The majority of teacher leader development programs in this study served state-, district-, and/or school-level needs to improve performance in a particular content area.

The dominant program context was a specific state-level or district-level reform implementation effort with teacher recruitment bounded by content area and mandated school district involvement. Two-thirds of the programs and research studies we reviewed targeted state or school-district needs, indicating that such leadership programs are still the dominant context in which leadership capacity is being built. This finding is in line with the earlier discussion of programs dominantly supporting Model Two leadership development, where teacher leaders are implementers of a reform initiative. The use of teacher leaders in this capacity is to achieve an outcome set forth by district and state-level administration (e.g., improving math performance on standardized tests).

A smaller number of programs (five programs, or 19%) had regional or national reach and did not directly target specific district- or state-level needs. These programs included participants from multiple states, generally within a US geographic region. Two programs included teacher leaders from across the United States. The two national programs had clear outcomes targeting improvement of teacher leaders' growth and capacity in their home districts, goals that were not tied to school-, district-, or state-level performance goals for students that are more in line with Model Three teacher leadership. Four programs occurred in an academic context (15%), where teacher leaders enrolled in a program to receive a degree, certificate, or credit hours (e.g., M.Ed. programs, continuing credit programs).

Structure of Professional Learning

The structure of professional learning includes how programs allocated time and for what purpose. Teacher leadership programs had a variety of structures, with no two programs exactly alike. The unique design of each program prevented us from aggregating program structure across our sample, yet two important features of program structure stood out: (1) the duration of programs required significant time investment from teacher leaders and (2) the implementation phase of the program was important but included varying degrees of support, for example, through the use of cohort models and extended collaborative activities between cohort members.

Consensus statement 3.5: Teacher leadership development programs in this study tended to be designed so that teacher leaders committed a significant amount of time toward learning, practicing, and implementing skills.

From our reviews of programs and research, it was clear that teacher leadership development program designers and researchers emphasized the need for significant contact with teacher leaders as they learned, practiced, and implemented skills as part of the program. Synthesis of high quality professional development calls for significant time investments near or around 50 to 80 hours (e.g., Darling-Hammond et al., 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Extending this finding to teacher leadership development, we can expect that teacher leaders also need substantial time to master new skills and practices. The programs in our reviews extended over years as opposed to days, with only one program that lasted less than a week (an anomaly in our analysis) and almost all others requiring significantly more time. Most programs (63%) promoted long-term (two or more years), sustained engagement of teacher leaders with the program, which is in line with what experts recommend (Loucks-Horsley et al., 2010). That number increases to 93% when also including programs that were one year in length.

Consensus statement 3.6: Teacher leadership development programs in this study used various designs (summer institutes, school year workshops/seminars, cohorts, professional learning communities, design cycles, and internships/fellowships) to provide time and space for teacher leaders to work with each other and their colleagues during implementation.

An additional aspect of program structure is the purpose for the time teacher leaders spend with programs. Research has shown that the time investment should be significantly shifted toward the implementation phase because initial implementation of new practices is messy and often fails, but with repeated practice and support, teachers master those new practices and see productive changes (Desimone et al., 2002; Yoon et al., 2007). Our sample of programs included some degree of support in implementation, though this varied widely across programs.

Teacher leader development programs used a variety of programmatic structures, including week-long or multi-week institutes in the summer and school-year workshops and seminars. Some programs also provided structures to support coaching and mentoring experiences during the year and regular meetings as a professional learning community with other teachers or teacher leaders. While institutes tended to front-load the content and processes for teacher leaders during an intensive summer experience (30%), other programs organized most of the learning experiences around a monthly workshop or seminar schedule (26%). This is not to say that programs did not adopt both structures, for example, beginning the program with an intensive summer institute followed by ongoing workshops during the school year, which was clear in two programs.

Programs described using a cohort model so that teacher leaders could build relationships with fellow teacher leaders, learn from each other, and act as a support network, particularly during the implementation phase. Collaborative participation is a key feature of effective professional development in general (National Academies of Sciences, Engineering, and Medicine, 2015) and was apparent in the teacher leadership development programs we examined. Some of the cohorts gathered as a professional learning community (PLC), in which one or two teacher leaders met to discuss their practice with the larger group. One program used this structure exclusively, but programs more often paired PLCs with other structures, such as institutes and workshops. In some cases, engagement with teacher leaders during implementation was intensive, particularly in three design-based workshop programs in which researchers worked closely with teacher leaders to practice skills and plan for implementation followed by an enactment and then subsequent reflection and redesign. The iterative design cycle allowed for regular, ongoing support for teacher leaders as they tested out and implemented different components of the program. However, because programs and measures were so different, it was not possible to assess the impact of variations in implementation support or design cycles on teacher leadership development or effectiveness.

Some programs employed an internship or fellowship structure, in which teachers engaged in broad activities beyond their classrooms. We observed this structure in five programs (19%), with two programs requiring teacher leaders to leave their own classroom for a full school year. A key feature of these programs was the focus on aspects of education beyond local curriculum design or professional development for colleagues, such as educational policy, conference presentations, community advocacy, and shadowing and learning from veteran teacher leaders.

Process for Professional Learning

Programs used a wide range of development processes, including strategies and activities for professional learning, which ranged from analyzing curriculum documents to practicing coaching skills to engaging in

group reflections. Because the variety of processes or strategies in any given program may not have been shared in publications about the program or website materials, our review is limited to what we could access publicly. A conclusion across programs is that the development process of teacher leaders is consistent with strategies and activities used in the professional development of teachers (Desimone et al., 2002; Garet, Porter, Desimone, Birman, & Yoon, 2001; Loucks-Horsley et al., 2010; Yoon et al., 2007), with researchers and designers admittedly drawing from the professional development literature to design the programs.

Consensus statement 3.7: Most teacher leadership development programs in this study included expanding teachers' knowledge base, investigations into practice, practice with enactment, and reflection using a variety of processes.

To expand teacher leaders' knowledge base, programs shared new information with teacher leaders through presentations and readings on reform-based teaching methods (41%), readings on educational research (33%), presentations and discussion on leadership roles and identities (30%), research on educational change and systems thinking (19%), research on adult learning theories (15%), lectures by content experts (8%), research on equitable teaching practice (8%), and studying community engagement (4%).

Advocates for high quality professional development argue that teachers (and thus, teacher leaders) need to be engaged in strategies closely tied to practice. Programs supported teacher leaders to investigate their own practices as a classroom teacher through observation and analysis of classroom videos (26%) and/or analysis of student work and assessment data (30%). In addition, some programs had teacher leaders analyze their content standards (8%), review curriculum documents (11%), and engage in lesson planning (11%). Two programs encouraged pedagogical inquiry in which the teacher leaders developed a question to investigate in their classroom practice.

Another common process during development was support and time for teacher leaders to practice the new strategies they were learning. It is now widely recognized that opportunities to practice new strategies is a critical bridge between learning the strategies and subsequently implementing them in practice (Darling-Hammond et al., 2009). We found that programs emphasized practicing facilitation strategies (52%), coaching strategies (48%), and mentoring strategies (19%). One program supported teacher leaders in practicing teaching strategies with students, while another program actively engaged participants in role-playing different leadership scenarios. Three programs (11%) included practicing presentation skills (e.g., presenting at conferences). Prior to practicing these strategies and skills teacher leaders tended to observe an expert or more practiced teacher leader demonstrating those strategies to them (48%). Most programs attended to enactment of new strategies in some form or another.

Twenty of the 27 programs (74%) explicitly mentioned a reflection component as a key element of the development process (e.g., reflecting on a new strategy just learned, re-evaluating progress on a leadership plan). Eight programs (30%) used individual reflection, nine programs (33%) used reflection through study groups, and seven programs (26%) used reflection through online communities of practice. Several programs used combinations of individual and group reflection, for example, reflecting in a study group first, followed by an individual reflection. Seven programs (26%) had teacher leaders design their own leadership goals and action plans, and review their progress on those plans **intermittently throughout the program**.

Summary of Focal Area 3: An important conclusion emerging from program attributes is the attention given to developing and supporting quality teaching and how that relates to development of leadership capacity. The majority of programs included in their content and process design enhancing quality teaching through building PCK and content knowledge and investigating classroom practice. There was general agreement from symposium experts that good teaching is foundational for effective leadership, but it was not clear whether the needs to develop good teaching practice come before leadership or if they can be developed together.

Likewise, some symposium team members argued that some of the content, disposition, and skills of an effective teacher are ones we want to continue to cultivate with teacher leaders. The consensus, however, was that there are some unique content, disposition, and skills that teacher leaders need in addition to the leadership that is already inherent in being a great teacher. The field still has unanswered questions about what makes a great teacher leader versus a great teacher and how programs can respond to those differences in terms of their content and process focus.

Focal Area 4: Research on Teacher Leadership Development Programs

In this section, we consider how researchers defined and measured program effectiveness and the tools they used for measurement. With our focus on research, the sample of programs we examine in this section is limited to the sample that emerged for our research literature review (n = 18 over 14 programs). In a few cases, the researchers published multiple articles about different parts of a program or different years of implementation, and because the research questions, participants, and findings were different in different publications, we coded the studies as separate even though the program was the same.

In the research review we focused on how researchers articulated their research questions, the data sources and analysis employed, and the interpretation of the results. This section of the report takes up notable findings from this research review, particularly as it relates to methodologies employed and measurement tools.

Consensus statement 4.1: The research on teacher leadership development in mathematics and science that met the criteria for this study is limited.

Analyzing and synthesizing the research on math and science teacher leader development was a challenge on two fronts: in terms of volume of research available and the nature of the research in our sample. The available research that met the criteria for this study is small. Of the 89 research studies that we identified through internet and library searches, almost half (47%) were not eligible because the research study did not focus on leadership preparation, learning, or development. Another 33% percent were published in outlets that did not conduct peer-review or ended up not being an empirical research study with research questions, methods, and data analysis. What resulted was 18 publications over 14 programs, a fraction of the large volume of research articles we found in our initial searches.

While the sample size is small, a more significant issue appeared with respect to the nature of the research in this study. In our sample, linking program attributes to outcomes for teacher leaders was difficult because the descriptions of the program attributes were not comprehensive in the articles. There are many reasons researchers cannot provide a comprehensive description of program design, implementation, and outcomes given restrictions on published research. It is also likely that a research publication takes form from an interesting observation in a program, thus, naturally foregrounding certain elements of the program and backgrounding others. This foregrounding and backgrounding allows researchers to tell a story about one aspect of the program but limits what we understand of the program in its entirety. When reviewing the research, we knew there was likely more to the story, particularly with respect to the program attributes. To avoid mischaracterizing programs based on the limited information gleaned from a published article, we documented the attributes that researchers called attention to in the article. Sometimes these attributes were mentioned in a sentence or two, and other times they were described in more detail. The uneven description of program attributes prevented us from conducting a systematic comparison across programs and also from looking for causal connections between attributes and outcomes.

The symposium team was surprised by the limited number of studies available but also recognized that reports on program quality and effectiveness appear in evaluation studies that are not publicly accessible, are not written to clearly articulate methods and analysis, and/or are not peer reviewed. While the

information from evaluation reports could enhance our understanding of program quality and program attributes, at present this information is difficult to access. There is concern that evaluation studies may suffer from the same idiosyncrasies observed in the published research, so volume may increase if evaluation reports were added to our research sample, but aggregation across studies would still be a significant challenge.

Consensus statement 4.2: Teacher leadership development programs draw from a limited repertoire of valid instruments to study program impacts and rely mostly on program-specific instruments and self-report surveys to measure effectiveness.

Instruments for teacher leadership development tended to be program specific, with a few exceptions. Program content dimensions were important to demonstrating evidence for effectiveness of the program, which was apparent by the instruments researchers used to measure outcomes. To measure impacts of leadership content, one program administered the *Teacher Leadership Inventory* to assess the participants' pre and post views about teacher leadership. All other programs used program-specific surveys and/or post-interviews to measure change in leadership content and disposition. These included surveys about leadership activities, leadership knowledge and skills, and/or confidence in taking on leadership roles. Programs (or their external evaluators) tended to design or adapt their own instruments. One program reported adapting their teacher leadership survey from one developed by Dozier and Barnes (2003). A few programs analyzed participant-written reflections to assess their leadership development. Several programs collected data about participants' leadership activity or effectiveness from their supervisors, coaches/mentors, or colleagues.

Researchers also looked at changes to teacher leaders' PCK using instruments and classroom teaching observation protocols. There was a preponderance of teacher leaders' self-estimated gains in PCK reported via program-specific surveys and questionnaires. Less than half of the research studies coupled self-report with another data source, like an observation protocol. Specifically, eight programs substantiated the self-report findings with observations of practice using protocols scored by trained researchers. The two named observation protocols that appeared in the research studies were the *Professional Development Observation Protocol* (Banilower & Shimkus, 2004) in one research study and the *Reform Teaching Observation Protocol* (Piburn & Sawada, 2000) used in two studies. The other observation protocols were program specific.

Researchers examined changes in content knowledge using mostly program-specific content assessments. Four programs reported measuring content knowledge gains and did so using pre- and post-assessment of teacher content knowledge but did not name their content assessments. Two programs used a content assessment provided by an external evaluator (no additional information available). One research study examined content knowledge gains comparing teachers and their coaches using an unnamed content assessment.

One particular instrument, the *Mathematical Knowledge for Teaching* instrument (Learning Mathematics for Teaching Project, 2011), looked at both content knowledge development coupled with PCK. Two studies used this instrument. The instrument provides reliability and validity for researchers.

Summary of Focal Area 4: With program-specific research goals, small sample sizes, and the lack of valid instruments, looking for patterns of attributes across research studies and generalizing beyond the studies is a challenge.

4. Implications for Workforce Development

The landscape of teacher leadership, models of teacher leadership, and results from the research and program reviews previously described raise possibilities and concerns for building leadership capacity within the math and science teacher workforce. To summarize, teacher leadership development tended to be role and program focused (quadrant I), lacked differentiation across the teaching career continuum, primarily aimed at teachers implementing instructional reforms envisioned by others (Model Two), and yielded idiosyncratic claims about effective math and science teacher leadership development. These findings indicate more work is needed to understand how to support a math and science teacher workforce that drives ongoing educational improvement.

A workforce development perspective takes a wide view—beyond individuals, discrete practices, or specific contexts to the system of interactive influences that shape a workforce (Smylie, Miretzky, & Konkol, 2004). As symposium participants mapped the landscape of teacher leadership from a systems perspective, the formal roles and formal programs were a small portion of the wider landscape. If leadership is truly embedded within the workforce, math and science teachers would have many opportunities and pathways to develop and exercise formal and informal leadership across their careers (National Comprehensive Center for Teacher Quality, 2010). One implication for STEM workforce development is the need to better understand and support varied leadership opportunities and leadership roles, particularly those opportunities that may not be tied to formally named programs and positions. The supply of formal programs, particularly those funded through federal grants, is far less than the demand for leadership opportunities from teachers. The approach to STEM teacher leadership development will need to rethink how to reach the masses of STEM teachers ready to engage in leadership opportunities and to offer development opportunities for diverse roles and activities.

A companion issue the reviews and symposium participants raised was the undifferentiated nature of teacher leadership work and roles. The programs reviewed tended to be designed without attention to where teachers are in their development. This reflects the United States' approach to teaching more generally, where a first-year teacher does the same work as a teacher in his or her tenth year and differentiating teacher/teaching quality is embroiled in political and measurement controversy. It has also been commonplace that teachers leave the classroom to take on formal leadership roles, even though they are often some of our most effective teachers. The symposium participants recognized that there are many inducements for teachers to leave the classroom to take on school leadership positions. Yet the investment in supporting teachers in becoming effective teachers is not realized if those teachers subsequently leave classroom teaching to pursue their own career advancements outside the classroom. An implication for building a strong STEM teacher workforce is to create a culture in which teacher leaders are enticed to remain in the classroom because there are opportunities for career growth and fulfillment without leaving the classroom. It may mean that the system needs to embrace different ways of thinking about teacher leadership from the classroom. We may have to look to other countries for models of policies and practices that systematically support career pathways in teaching and leadership (Darling-Hammond et al., 2017).

New models of leadership can bring fresh perspectives to understanding teacher leadership development as a system. For example, Lukacs and Galluzzo's (2014) models provided a conceptual framework that brought attention to instructional leadership and the varied levels of teacher agency in the programs reviewed. Other recent leadership models emphasize building and sustaining teacher social capital—the resources inherent in social relations—that facilitates the learning, innovation, and adaptability necessary for organizational growth and improvement (Leana & Pil, 2017; Yoon, Koehler-Yom, & Yang, 2017). Symposium participants noted, from their experience, that teachers' formal and informal professional

networks seem to be emerging more clearly as an important part of teacher leadership. From a workforce perspective, explicit models that provide a collective or system-wide view from which to build leadership development research and practice are especially needed.

Supporting all math/science teachers to engage in leadership as they need and want would help drive continuous educational improvement from within in response to varied or changing conditions. While the evidence is thin, what we do have suggests that there is promise in a more strategic approach to math and science teacher leadership development. However, embedding leadership within the math/science teacher workforce will require a better understanding of goals/outcomes, entry points, learning progressions, and professional trajectories within the full teacher leadership landscape. We discuss how these issues might be addressed in the Recommendations section.

5. Recommendations

We offer recommendations for program designers, researchers, policy makers, and funders organized around the four focal areas. Each recommendation targets one or more of these stakeholders as well as a gap in what we currently understand, which emerged from the review of programs and research and symposium discussions. The recommendations are not listed in order of importance.

Focal Area 1: Programs and the teacher leadership development landscape

First, across the field and through various lines of research **program designers and researchers seeking to improve teacher leadership development should collectively attend to all four quadrants of the teacher leadership development landscape depicted in figure 2.** While individual designers and researchers may focus on development of certain kinds of leadership, the field as a whole should generate knowledge about teacher leader development across the landscape, shedding light on the varied programs and support systems necessary for the diverse roles teacher leaders have in their schools. The focus of this synthesis work was weighted toward teacher leaders in designated positions and participating in formal programs, but there is a great deal to be learned about leadership development of teachers without a formal position at their schools and participating in a variety of leadership development activities. In some contexts, developing informal leadership may be even more critical given limits on formally named positions (e.g., rural school districts, private schools). A related recommendation is that **funders should consider supporting research and programs in all four quadrants of the teacher leader landscape.**

Second, **program designers and researchers need to attend to a range of leadership development opportunities that meet the needs of teachers along a professional continuum in an effort to recruit, retain, and grow a strong collective workforce.** The systems we use to develop our education human capital must recognize that there is a life cycle of teaching and this matters in program design. Our examination revealed that teacher leaders are often recruited to programs and grouped based on programmatic needs. This may be due, in part, to the preponderance of Lukacs and Galluzzo's (2014) Model Two programs, focusing on supporting teacher leaders as implementers of reform efforts. Programs supporting the teacher professional continuum will have a purpose for how teachers are recruited and grouped in ways productive for the teacher leaders' growth. Program designers and researchers should consider the specific qualities, knowledge, and skills that teacher leader candidates can bring to a development program, which is naturally influenced by the teacher leaders' career progression. The stage of career for teacher leaders does not equate to years of experience, which is often a benchmark for acceptance to programs, but rather is influenced by previous teaching and leadership experiences, what teacher leaders bring to the development opportunities they pursue, and contextual factors that shape their leadership. There is opportunity here to consider including, as part of their purpose, developing teachers as change agents whose work goes beyond the scope of the programmatic needs. Attention to

the teacher professional continuum may ultimately offer greater opportunities for teachers to lead from the classroom, rather than leaving the classroom, and contribute to a stronger teacher workforce.

Lastly, **all stakeholders must work together to ensure teachers from underserved and underrepresented areas have equitable access to leadership development opportunities.** There is concern that leadership opportunities may be only available to select teacher populations and not available to other teachers. Program designers and researchers can attend to this concern in their recruitment decisions by including teacher leaders from diverse school and community contexts. Not every program can target and recruit a diverse teacher audience, but across the field we need to attend to uneven access to programs if certain populations of teachers do not have access to high quality programs and development opportunities. Similarly, funders and policy makers can address this concern by prioritizing support for underserved and underrepresented teacher audiences.

Focal Area 2: Purposes of teacher leadership development programs

There was widespread agreement at the symposium that the field could benefit from a shared framework or understanding of teacher leadership models. A recommendation is for **program designers and researchers to articulate, beyond a definition of teacher leadership, the conceptual models and frameworks they use to develop, study, and support teacher leaders.** The field would be well served if designers and researchers more clearly articulated the model for leadership adopted by the program, the expected role of the teacher leaders during the program, and how the program prepares teacher leaders for a given role. Clearly articulated models and frameworks have the potential to increase coherence and focus across research and programs so that findings can be compared or aggregated.

The field would also benefit if, across the field, **program designers and researchers develop opportunities to support teachers along multiple pathways in the landscape and particularly programs that help teacher leaders drive improvement efforts.** Most programs currently support Lukacs and Galluzzo's (2014) Model Two leadership, where teacher leaders implement reform efforts conceived by others. Other leadership roles, activities, and pursuits are also valuable but far less represented in the current leadership development system. Increasing teacher leaders' capacity and supporting their efforts to lead improvement efforts could be expected to improve teaching, learning, and culture throughout the educational system as well as strengthen the teacher workforce.

Focal Area 3: Attributes of teacher leadership development programs

Linking program attributes to outcomes for teacher leaders happens to some degree in all the programs we examined, but few pointed to program attributes that seemed to make a difference in program outcomes. One recommended step in this direction is for **program designers to be explicit about the key features of interventions used in their programs linked to expected outcomes so that evaluators and researchers can study the aspects of the intervention most effective in particular contexts.** Researchers should focus efforts to determine which interventions and program components have which impact on the overall program outcomes. While program-specificity is difficult to avoid, we argue that a better understanding of the program attributes that work, under what conditions, and for what purpose (e.g., teacher leader role, expected activities) would greatly benefit the field.

Second, **program designers and researchers need to better articulate the nature of leadership content and processes as defined and developed in the program.** Our synthesis work revealed that teacher leader development programs rely heavily on features of high quality professional development, which includes elements of building disciplinary content, investigations into practice, reflection, and collaboration. What remained unclear was how leadership development programs prepared great leaders versus great

teachers. Almost every program mentioned a leadership component, but the description was thin. While providing more description about the leadership attributes of the program would be beneficial, the designers and researchers should also attend to what sets their teacher leadership development programs apart from other good teacher professional development. Such clarity would contribute to clear lines of research, the results of which could be compared or aggregated.

Building from the previous recommendation, **program designers and researchers should be attentive to the program structure and how the program supports initial implementation and sustains practice over time.** Based on the programs we examined, significant time is invested in teacher leader development, but the support mechanisms and purpose for time during the implementation phase varied greatly. Program designers and researchers will need to carefully consider the balance of program resources to meet the demands for ongoing collaboration and continued learning.

Fourth, **measures of program outcomes need to attend to specific component(s) of the program but particularly need to move beyond content.** Measures of disciplinary content development (including content knowledge and PCK) and some measure of leadership identity, beliefs, and dispositions were apparent. While measurement of disciplinary content, PCK, and leadership content could be improved, attending to context, structure, and process were even less consistent and more the exception than the norm. To effectively attend to the specified component(s), program researchers will likely need to employ both qualitative and quantitative measures.

Focal Area 4: Research on teacher leadership development programs

The lack of publicly available evaluation studies that share evidence of effectiveness led us to recommend that **program designers make concerted efforts to share findings from their evaluation reports.** The symposium team was aware of programs that pertain to our synthesis work but were not included because the evaluation studies were not accessible. This recommendation speaks to a system of evaluation norms that does not support widespread dissemination. While every program supported by a federal grant requires an external evaluator, this information is rarely shared beyond the program staff and funding source. Advancing our understanding of teacher leadership development will require a change in the way program designers and evaluators approach evaluation studies, making the summative reports accessible to the public and articulating clearly the methods, instruments, analyses, and findings in a way that follows many of the same rigors for publishing in a peer-reviewed outlet.

A second recommendation is for **researchers to design and disseminate valid instruments to examine different attributes of teacher leader development.** Instruments, in addition to self-report surveys and questionnaires, can assist program designers and researchers to make connections and comparisons of the content, context, structure, and process of programs to determine the conditions under which approaches are more or less effective. Researchers must combine other types of instruments (e.g., protocols for observation of leadership activities) with the use of self-report to provide stronger evidence of the efficacy of teacher leadership development programs. If such instruments are available and used widely across programs, it may be possible to aggregate information from programs to help designers and researchers better understand the return on investment for taking a leadership development program to scale.

Thirdly, the research base lacked studies showing causal relationships between program attributes and outcomes for teacher leader development. A systematic approach to studies of teacher leadership development should lead to the kinds of evidence needed to take the most promising programs to scale, enhance the coherence of the teacher leadership development landscape, and enhance the teacher workforce along the way. Research on teacher leader development, therefore, **should work toward identifying the causal links between program attributes and outcomes for teacher leaders** to

better identify what works, for whom, and to what end. Policy makers and funders can support this recommendation by prioritizing the development of such measures and methodologies and supporting lines of research into leadership development.

Finally, **policymakers and funders should support research collaborations or program-level evaluations.**

These types of initiatives have the potential to bring together many programs with the same approaches under the same umbrella and provide the context and power for in-depth study of leadership development programs. Borko (2004) noted the need for this type of cross-program research into teacher professional development. This approach has the potential to move the study of teacher leadership development programs in a similar direction.

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Appendix A:

Consensus Building Process

Project Leadership Team

Jody Bintz, M.A., is Co-Director of Professional Learning at BSCS and served as PI for this project. Bintz has over 10 years of experience in science leadership development and over 20 years of experience in teacher professional development and providing technical assistance supporting district-wide improvement efforts. She directed the BSCS National Academy for Curriculum Leadership (NACL) for secondary science leadership teams through a six-year scale-up in the state of Washington involving over 30 districts. This scale-up effort followed the national research and development process supported by the National Science Foundation. Bintz is currently PI of a project to study of the impact on student achievement of the NACL in Washington State. Bintz is currently directing a project to develop and broadly disseminate tools and processes for district leaders to analyze instructional materials and plan for instruction and classroom assessment in light of the Next Generation Science Standards. This work is supported by the Carnegie Corporation of New York.

Jodie Galosy, Ph.D., is a Research Project Manager at the Knowles Teacher Initiative and served as Co-PI for this project. Galosy coordinates and supports research and evaluation of Knowles teaching and teacher leadership programs. Galosy taught middle and high school science for 20+ years and has 15+ years of experience studying teacher learning and professional development.

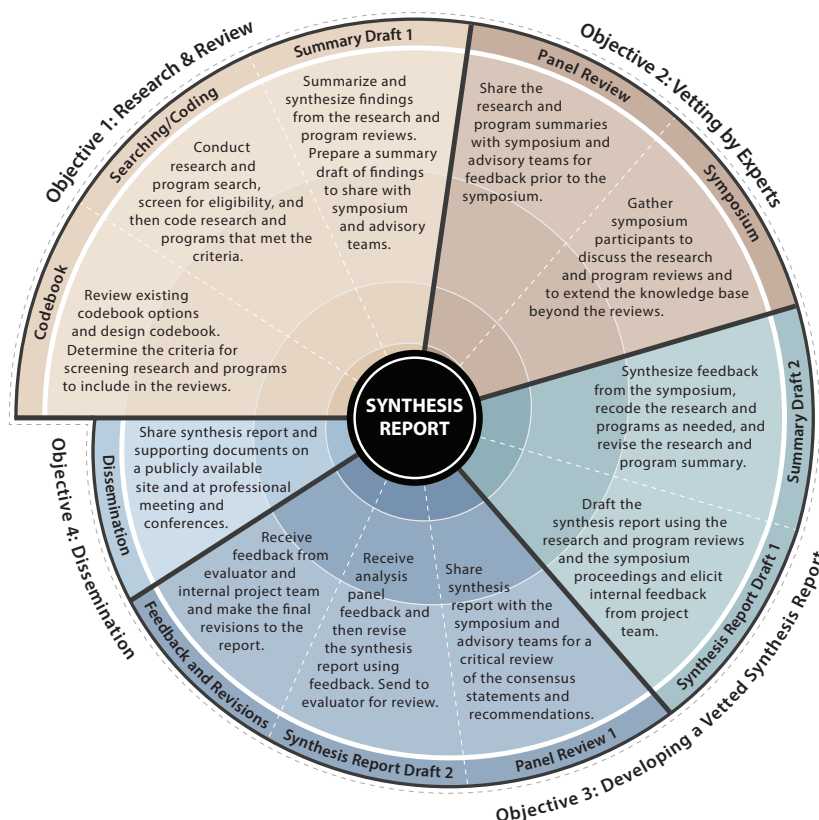
Barbara Miller, Ed.D., is Division Director in the Learning and Teaching Division at Education Development Center (EDC) and served as Co-PI for this project. Miller has over 25 years of experience in professional development and technical assistance for school district and program staff, research on professional development and teacher leadership in mathematics and science, and evaluation of systemic reform efforts. She has conducted research on knowledge management for the National Science Foundation's Math and Science Partnership program by synthesizing and sharing knowledge from the field around teacher leadership and professional learning communities.

Lindsey Mohan, Ph.D., is a Research Scientist at BSCS. Her work focuses on the design of innovative instructional resources and effective teaching practice, particularly in science and geography education. She was a writer for BSCS's *Guidelines for the evaluation of instructional materials in science*. Mohan has conducted research on learning, teaching, and instructional material design in the areas of science learning progressions, environmental literacy, and problem-based learning.

Consensus Building Process

The synthesis project was designed to examine current research and programs in math and science teacher leadership as well as to mine the expertise and experience of experts in the field. The methods used to produce the synthesis report had four objectives. First, we conducted an integrative review of research and programs to generate summaries of the current attributes of teacher leader development programs. Torraco (2005) characterized this synthesis work as one that “reviews, critiques, and synthesizes representative literature on a topic in an integrated way such that new frameworks and perspectives on the topic are generated” (p. 356). The next layer of the consensus building process occurred as the advisory team and symposium team vetted the research and program review summaries and expanded upon those summaries with their expertise and experience before and during a symposium. Revised research and program summaries were produced from this process, which are included in Appendix B. A third objective was to develop an integrative summary of findings from the research and programs combined, along with the symposium proceeding to produce a synthesis report to share with the advisory and symposium teams for vetting. The synthesis report drew heavily from the revised research and program review documents and the symposium discussions and proceedings and underwent a panel review process to elicit feedback from experts. The final objective was to communicate the consensus attributes, along with recommendations, to various stakeholders in the education community. Figure A1 captures a visual depiction of how this process unfolded to meet these objectives.

Figure A1. Consensus-Building Process



Objective 1: Produce a research and program review

The first step in the consensus-building process was to examine the research and programs to begin identifying patterns in attributes in programs. This process involved (1) selecting criteria to guide what was and was not eligible for review, (2) determining how to code the eligible research and programs and then coding what we found, and (3) articulating findings through a summary report to the advisory and symposium teams.

Criteria for identifying research and programs. The methodology we used began with selecting criteria for identifying research and programs that aligned to the project goals. Specifically, the research and programs needed to focus on teacher leader development and in the areas of math, science, or STEM. Besides these two criteria, the following additional criteria guided the research search:

- The research built on the Math and Science Partnership Knowledge Management and Dissemination (MSP-KMD) work that summarized the research in the field for the period of 1990–2009. Only literature from 2009 to 2016 was included in the synthesis work for this report (e.g., Schiavo Miller, Busey, & King, 2010a; Schiavo Miller, Busey, & King, 2010b).
- The research addressed an explicit question or topic by examining a bounded data set, with an articulated procedure for data analysis.
- The research took place in the context of K–12 education (i.e., our focus was not on higher education or preschool).
- The research was written in English but could be conducted either within or outside the United States.

Criteria for identifying eligible programs were slightly different than those for the research. The program-eligibility criteria included the following:

- The program's scope extends beyond the local level.
- The program takes a systemic approach, meaning that the program is connected to, and takes into account, the contexts in which math/science teacher leadership is enacted.
- The program has written descriptions of program goals, strategies, and outcomes that are accessible to the public.
- The program has evidence of effectiveness (e.g., external evaluation reports made publicly available or in peer-reviewed research publications).

Rationale for Criteria

2009 to Present

Our work builds from a previous Math and Science Partnership grant called Knowledge Management and Dissemination (KMD) (www.mspskmd.net). One aspect of the KMD efforts included a closer look at teacher leader development in math and science resulting in several published reports we examined closely as the starting point for this review (e.g., Schiavo Miller, Busey, & King, 2010a; Schiavo Miller, Busey, & King, 2010b). Given the extensive reviews of teacher leadership development in math and science by the KMD team, we

sought to build on their work since the time of their published reports. Thus, we searched for empirical research and programs from 2009 to the present that would not have been included in the KMD work.

K-12 Math and Science

There is a preponderance of evidence that teacher leadership development, and professional development more broadly, is rooted in disciplinary content (Ball & Lacey, 2012; Spillane & Hopkins, 2013), which has lead to widespread design of programs for teachers in one disciplinary area, for example, mathematics or language arts. While some argue that design principles for programs may not be content-specific (e.g., Wenner & Campbell, 2017), the programs themselves are closely tied to content area teaching and learning. For this reason, our review targeted research and programs in math and science teacher leadership, although we consulted work that looked beyond disciplinary programs as we developed our conceptual frameworks for analysis (e.g., Lukacs & Galuzzo, 2014; Wenner & Campbell, 2017).

Development Focus

The review targets the activities, practices, and processes for developing teacher leaders in math and science and does not extend to the impact those teacher leaders may have in their schools and districts. The impacts of teacher leaders in schools has been documented elsewhere (MSP-KMD Project, 2010), leading to a growing consensus that developing highly effective teacher leaders is a promising path forward for workforce development for educators. At present, development programs are idiosyncratic in their design, limiting how much can be gleaned about effective program design and outcomes given the various roles teacher leaders may have in the education system. The review in Appendix B does not alleviate this problem, but it is an attempt to better understand the current terrain of program design and research for developing teacher leaders and the lessons learned in the design and research process.

Evidence of Effectiveness

Given that evaluating the quality of research and program claims was not within the project scope, we established eligibility criteria that would support the credibility of findings. The research review had three basic criteria: The published work had to be an empirical study, peer-reviewed, and focused on math and science teacher leadership development. The program selection criteria were similar, but evidence of effectiveness could be in the form of a published peer-reviewed article or a publicly available external evaluation report. The peer-review or external evaluation process gave adequate assurance that claims were grounded in sound evidence even though it meant that only about 20 percent of the research and programs identified were eligible. Each eligible research article and program then received a complete review that included descriptions of the program and findings.

Given the above criteria, the review that follows does not include a synthesis of teacher leadership in the following areas:

- Theoretical or conceptual frameworks or philosophical positions about teacher leaders and their roles in education
- Impact studies showing learning outcomes attributed to teacher leaders in schools or districts
- Programs that did not have evidence of effectiveness readily accessible and available for public review

Data, by the Numbers

Our search yielded 27 unique programs and research studies that met the above criteria. When looking at research studies alone, the data analysis included 18 research studies about 14 programs. In a few cases, the researchers published articles about different parts of a program or different years of a single program, and because the research questions, participants, and findings were different in different publications, we coded the studies as separate even though the program was the same. The program summary analysis included 15 programs. When the research studies and programs were combined into a combined sample there was overlap between two programs. Thus, in Appendix B, when the analysis of research and programs are separate, we report 18 research studies over 14 programs and in the program review we use 15 programs. When combined, the number of unique programs is 27 due to overlap between the research and programs.

Coding Scheme and Process

The eligible research studies and programs were then coded using a modified version of the standards of evidence developed by the MSP-KMD project (Heck & Minner, 2010), with a focus on assessing warrant for claims made in a study. We coded the research and programs for the project's proposed research questions or program goals, the definition of teacher leadership and framework used, description of teacher leaders, and, where possible, the attributes of the programs. The measures of program quality and evidence of effectiveness were also coded, and with the research articles, in particular, we coded the methods and data analysis procedures. Findings from research and program evaluations were open-coded. Once coded, we analyzed the codes for each program and across programs to identify patterns in the data concerning percent of programs with or without certain characteristics. Our analysis produced the descriptive statistics we used to communicate the number or percent of programs in our sample with certain program attributes. When we merged the research sample with the program sample to get our combined sample, we adjusted the codebook so that we coded each program in the combined sample the same. We conducted a second round of coding to verify where, if at all, the coding of individual programs needed to be adjusted. It is important to note that we adjusted the coding scheme from the MSP-KMD project as new categories emerged, especially with program attributes. We added categories that made sense given our sample and only added categories when the new category captured an attribute not in the original coding scheme. The analysis of patterns in our data remained focused on the percent or number of programs with certain attributes. We then added a new layer to our coding scheme looking for patterns in Lukacs and Galluzzo's (2014) Model Two programs versus Model Three programs. Before applying this new layer, we coded a sample of programs together to make sure we agreed on what constituted Model Two or Model Three programs. Appendix B is organized using this new layer.

Producing Research and Program Summaries

The initial reports for the research and programs summaries were then written once all studies and programs were coded. Due to the different criteria used to select research compared to programs and the slightly different coding schemes, the report on research was separate from the report over program summaries. The two reports used parallel sections when possible. For example, characteristics of teacher leaders who participated in research studies were coded in a slightly different way compared to the coding of teacher leaders participating in programs. Thus, the sections about characteristics of teacher leaders in

programs versus research studies were similar enough to parallel each other in the summary reports but not so similar to merge into one section at this point in the process. Merging the two reports occurred after the symposium team reviewed the summary documents and provided feedback.

Objective 2: Vetting by experts in the field

The resulting research and program summaries were then vetted by the advisory team and provided to the symposium team to inform the work of the symposium. Before the start of the symposium all advisory team and symposium team members reviewed and commented on the summaries. Their comments were then examined and categorized to help focus conversations during the symposium. In addition to the research and program reviews, which initiated many conversations at the symposium, a live synthesis of those conversations was carried out. The live synthesis documented the symposium teams' contributions and challenges to extend what was shared in the research and program reviews and to add to it the considerable experience and knowledge of the experts that comprise the symposium and advisory teams. The results of the live synthesis, with the analysis of the research and programs, formed two important sources of information for the final synthesis report.

Immediately following the symposium, the research and program summaries were revisited and revised to add additional interpretive text that was called for by the symposium team. What resulted from this process are the detailed summary reports found in Appendix B.

Objective 3: A vetted synthesis report

Following the symposium, the symposium proceedings were organized, analyzed, and then summarized based on themes and important areas of discussion. The Symposium Proceedings can be found in Appendix C. Combined with the revised research and program summaries, the project team drafted the synthesis report for a panel review by the symposium and advisory teams.

The draft of the synthesis report was developed after the symposium and was the subject of a consensus review process involving the advisory team and symposium team. Achieving consensus about the synthesis report draft was aided through the use of an online panel structure to vet, comment, and respond in an iterative fashion to sections of the report where there is lack of clarity or differences of thought or experience. Each member of the symposium and advisory teams was asked to be part of the online panel. Each panelist responded, in writing within a prescribed period of time, to a set of questions and statements about teacher leadership development (drawn from the draft report and pointing to specific sections of the report). Responses were analyzed by the project team, and the results informed revisions to the synthesis report. This process is an adaptation of the online panel process used in the MSP-KMD project (Miller & Pasley, 2012).

Objective 4: Dissemination

The synthesis report and accompanying appendices were made publicly available to reach a broad audience for math and science practitioners, researchers, and policy-makers using a two-part communication strategy:

1. **Project website:** The project website is publicly available with open access to the final synthesis report and supporting appendices. This website will be hosted by BSCS for a period of no less than two years upon conclusion of the project.

2. Professional networks: We took advantage of outreach to the professional networks of the leadership, advisory, and symposium teams. The latter two teams were chosen for capacity to disseminate findings within their organizations, across their networks, and within their geographic locales.

Future plans to communicate findings include three additional strategies:

3. Website visibility: Information about the project website will be provided to a variety of professional associations for inclusion in their newsletters and/or websites (e.g., NCSM, NSELA, Learning Forward).
4. Presentations at conferences: We plan to make presentations at conferences with large numbers of educators and researchers active in math/science teacher leadership development: NCSM or NCTM, NSTA or NSELA.
5. Preparation of an article: We will prepare an article to a peer-reviewed journal.

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