Leading Within and Beyond the Schoolhouse: Taking a Multilevel Distributed Perspective to Analyze the Practice of Leadership for Elementary Science

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Acknowledgements

Work on this article was funded by the National Science Foundation (Core grant number DRL-1761057). The authors gratefully acknowledge those who shared comments on earlier manuscripts and presentations on which the analysis draws, as well as the members of the research team: Elizabeth Davis, Anna Foster, Donald Peurach, and Emily Seeber. All opinions and conclusions expressed in this article are those of the authors and do not necessarily reflect the views of any funding agency.

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Introduction

For the past two decades the field of educational administration and leadership has centered a distributed perspective of leadership practice as a means of understanding, examining, and supporting improvement in schools (Bolden, 2011; Bush, 2013; Gronn, 2008; Gumus et al., 2018; Harris, 2009; Tian et al., 2016). While some perspectives on educational leadership focus on understanding the actions or behaviors of individual school leaders, such as principals or head teachers, a distributed perspective of leadership conceptualizes educational leadership practice as unfolding in the interactions between leaders, followers, and situations (Gronn, 2002; Spillane et al., 2001, 2004). A distributed perspective centers the *practice* of educational leadership by framing our attention on what leaders and followers do together and how they do it (Gronn, 2003; Spillane, 2006; Spillane et al., 2004).

Much of the empirical work to date taking a distributed perspective uses the school as the unit of analysis and focuses mostly on the horizontal distribution of leadership practice as it is carried out among staff and stakeholders *within* schools (Spillane et al., 2023). This body of research contributes to our understanding of leadership practice within schools in important ways, including, for instance, identifying the role of distributed leadership in instructional change (e.g., Camburn & Han, 2009), school improvement (e.g., Leithwood & Mascall, 2008), organizational performance (Harris & Spillane, 2008), and teacher values and beliefs (e.g., Liu, 2020). While this research advances our understandings of educational leadership practice within schools, much of the theoretical and empirical research in this area has yet to consider leadership practice more broadly as it is enacted vertically across levels of the educational system (Spillane et al., 2023).

Recent theoretical work extends previous conceptions of distributed leadership practice by conceptualizing leadership practice as a multilevel phenomenon spanning classrooms, schools, systems, and the educational sector (Spillane et al., 2023). This work recasts the distributed perspective as not just involving leadership practice occurring *horizontally* at the school level, but also *vertically* across levels of the education system. As Spillane and colleagues hypothesize, compartmentalizing leadership by level (e.g., principal leadership, teacher leadership, system leadership) may silo our knowledge and may contribute to a disjointed portrayal of educational leadership practice. This perspective, however, has not yet been investigated empirically and warrants empirical examination. We take up that call here by exploring how various sources of leadership, sometimes operating at different levels and typically studied independently of one another, interact to shape leadership practice inside schools.

In this comparative case study of 13 school districts, we explore leadership practice in elementary science from a multilevel distributed perspective to understand the interrelationships among different sources of educational leadership operating at various levels - from classrooms, to schools, to educational systems, and, beyond, to the educational sector. More specifically, we focus on the practice of educational leadership in elementary science in the United States as states implement new and ambitious instructional standards informed by the Next Generation Science Standards (NGSS; NGSS Lead States, 2013) and the accompanying *Framework for K-12 Science Education* (National Research Council, 2012) from which the NGSS were developed.

We begin by anchoring our work in the literature on multilevel distributed perspective and leadership in educational systems. Next, we describe our cross-case research design and methodological approach. We then develop and support three main claims based on our data analysis. Educational leadership practice in elementary science involved three key components: (a) garnering attention for elementary science instruction in a context that prioritized ELA and mathematics; (b) cultivating and channeling relationships and resources to (re)build an educational infrastructure for elementary science instruction; (c) activating the educational infrastructure by supporting its use in practice.

Theoretical Framework

Our analysis is motivated and framed by the literature on multilevel distributed practice and leadership in educational systems.

Educational Leadership Framed from a Multilevel Distributed Framework

A multilevel distributed framework seeks to conceptualize leadership as spanning classrooms, schools, systems, and the educational sector. Moving beyond focusing on educational leadership at any one level of an education system, such as the grade level, school, district office, or state level, a multilevel distributed framework frames the practice of educational leadership as stretched over the interactions of actors and artifacts, both within different levels and spanning different levels, as these interactions are enabled and constrained by aspects of their situation (e.g., tools, routines, norms, regulations) (Spillane, 2006; Spillane et al., 2001, 2004). Drawing on Spillane and colleagues' conceptualization of multilevel distributed practice, we see leadership practice as a multilevel phenomenon stretched over: (a) teachers, students, and materials; (b) formal and informal school-based leadership (i.e., principals, coaches, and teachers); (c) educational systems (i.e., school districts); and (d) educational sectors (e.g., government agencies, support providers, and professional organizations) (Spillane et al., 2023).

Teachers, Students, and Materials. At its core, teaching is a distributed practice that unfolds in the interactions between teachers and students around educational materials (e.g., textbooks) (Cohen, 2011; Cohen & Ball, 1999; Delpit, 1995; Freire, 2018). These interactions are shaped by teachers' intellectual and personal resources, students' experiences, understandings, interests, and engagement, and the substance of the educational materials themselves (Cohen & Ball, 1999). Given this conceptualization of teaching, educational leadership can enable improvement in student learning by creating conditions that shape interactions among teachers, students, and educational materials in the classroom. Educational leadership, then, is fundamentally about cultivating and channeling relationships to access and activate the human, social, material, and cultural resources essential for teaching (Spillane et al., 2023).

From a multilevel perspective, teaching as a distributed practice acknowledges that the relationships and resources critical for supporting teaching extend beyond the classroom and school to relationships with, and among, an array of other stakeholders such as educational system leaders, governmental and non-governmental organizations, parents, community members, among others. These overlapping and interacting relationships are critical because they shape the resources that teachers and students have access to and condition what teachers and students notice and the choices they make in the classroom.

Educational Leadership in Schools. Educational leadership can shape relationships among school staff about teaching in ways that impact the resources available for teaching. Research suggests that the school's formal organization, such as leadership positions and grade level assignments, shape social networks in schools (Moolenaar et al., 2011; Spillane et al., 2015). For example, school leaders can strategically cultivate new relationships among staff by formally assigning new staff members a mentor or coach or can connect a teacher who is struggling with teaching a particular subject with a successful colleague, thus impacting the resources available for teaching.

As school leaders strategically broker relations to provide access to particular resources for teaching, a key matter involves how resources are coordinated in pursuit of high-quality teaching. Coordination involves getting resources into an interactive system and structuring interdependencies among relations and resources in ways that support teaching practice over time (Lampert et al., 2011). A key lever for coordination is an *educational infrastructure* which consists of the structures and resources that support and coordinate teaching, maintain its quality, and enable improvement (Cohen et al., 2013, 2018; Hopkins et al., 2013; Peurach & Neumerski, 2015; Spillane et al., 2019). Much of the work of creating an educational infrastructure occurs outside of schools, such as access to skilled and knowledgeable teachers or instructional materials. For all these reasons educational leaders in schools depend on their environments for not only access to, but also the coordination of all sorts of relationships and resources that are essential for supporting teaching in schools (Scott & Davis, 2015).

Educational Systems. An educational system is concerned with the educational function of schooling and schools; that is, the day-to-day teaching and learning occurring in schools. Educational systems include the set of central organizations that drive efforts to support instruction and its improvement; these could include district offices, charter management organization, a diocese office, or even a national or provincial ministry of education (Peurach et al., 2019). One way in which educational systems matter to educational leadership is that they attempt to coordinate the resources and relationships essential for supporting teaching. Education systems coordinate the designing and building of educational infrastructures, work to support the use of that infrastructure in school and classroom practice, and manage educational infrastructure and its use in order to improve and maintain the quality of teaching and reduce inequities in opportunities to learn (Peurach et al., 2019; Spillane et al., 2019). Specifically, educational infrastructure includes instruments and tools that are the material of teaching, such as curricula and student assessments. It also includes the formal positions, procedures, organizational routines, and tools that educational systems design, acquire, and deploy to support teaching and its improvement. Further, it includes the coordination of core educational functions, including building a technical culture anchored in consistency among the components of infrastructure, and representing a shared vision for teaching and learning.

With regards to educational leadership then, we must also take the educational system into account. People in educational systems perform key leadership functions and take on important responsibilities, such as articulating a coherent vision for instruction and for improving teaching. Systems leaders develop, provide access to, and support the use of critical resources, such as curricular materials or professional development (Cobb et al., 2018). The extent and quality of work by system leaders and how they are organized impacts leadership in schools.

Educational Sectors. Scholars frame the environments in which schools and other organizations operate as educational sectors. A sector – such as the health sector or the education sector – consists of the set of actors and organizations operating within a given domain, supporting those who provide a product or service. The educational sector comprises a hodge-podge of actors and organizations in addition to schools and educational systems, including government agencies, professional development providers, community and professional organizations, unions, philanthropy, research firms and institutes, supplemental educational providers, and others. These organizations typically play a supportive role in providing resources (human, social, material), sometimes directly in school or classroom practice (Rowan, 2002). Other organizations serve regulatory functions regarding resources (e.g., curricular materials) and services (e.g., teacher preparation). In some educational sectors, the same organization performs more than one of these functions. How schools are embedded within an educational sector is a critical consideration for educational leadership in schools because it shapes which resources are available, how they can be accessed, and their use supported in practice.

In this study, we seek to empirically test the multilevel distributed perspective as a theoretical construct in the context of exploring leadership for elementary science reform. We address the following research questions:

1. How do educational leaders work to improve elementary science?
2. How is this work distributed across classrooms, schools, systems, and the educational sector?

Methodology

This study is part of a larger, five-year National Science Foundation-funded study exploring the work of developing coordinated elementary science learning environments in response to the *Framework for K-12 Science Education* (National Research Council, 2012) and the Next Generation Science Standards (NGSS; National Research Council, 2013) at the state, district, school, and classroom levels. Using an embedded, comparative case study design (Yin, 2009), we analyzed leadership practice for elementary science reform in 13 school districts in six states as district and school leaders worked to bridge from NGSS learning ideals to classroom instruction.

Sample Selection

We began our sample selection by first identifying states that had active policy environments for elementary science reform. To select these states, we asked experts and leaders in elementary science, including leaders in state departments of education, higher education, and national and regional organizations, to identify states and individuals engaged in elementary science reform. Using a snowball sampling method, we gathered nominations and input from 62 elementary science leaders. We then ranked the states based upon number of nominations to identify those states that had more and less active environments for elementary science as recognized by leaders in the field. We conducted interviews with state science coordinators in a subset of those states to further learn about their efforts to improve elementary science education (see Haverly et al., 2022; Lyle et al., in press for state-level analyses). From our analysis of state-level data, we selected six states that we identified as having state policy contexts conducive to district effort to reform elementary science education, from which we built our district sample.

We then identified and recruited school districts in each of our case study states. Our aim was to recruit districts that were actively engaged in elementary science reform. We began by reaching out to leaders in science education reform within these states (~n=150) to gather recommendations for districts engaged in elementary science reform. From these recommendations, we researched and spoke with district-level leaders in roughly 45 districts to learn about their reform efforts in elementary science. We also gathered demographic data and other information about district departmental organization for each district under consideration, and our team engaged in frequent conversations on district selection. Using this data, we selected a sample of 13 districts that varied along a range of dimensions including district type, size, urbanicity, demographics, and designs for elementary science reforms (Table 1 and 2).

Table 1: School District Characteristics

District	*Total enrollment (K-12)*	*# of elementary schools*	*Type of district*	*Urbanicity*
Bartlett	3,000	5	Public school district	suburban
Brookeport	45,000	75	Public school district	urban
Chester	35,000	30	Public school district	urban
Fairby	30,000	25	Public school district	suburban
Hartwell	700	1	Public school district	rural
Hillman	3,000	5	Public charter district	urban
Jasper	12,000	5	Public school district	suburban
King Park	5,000	5	Public charter district	urban
Lockeford	4,000	5	Public school district	rural
Norhaven	14,000	15	Public school district	suburban
North Valley	6,000	5	Public school district	suburban
Rivercrest	500	1	Public school district	rural
Silverbay	100,000	100	Public school district	urban

Note: School & enrollment counts have been approximated for anonymity

Table 2: District Student Demographics (K-12)

District	*African American/ Black*	*Asian (any Race)*	*American Indian*	*Hispanic (any Race)*	*Multiple Races*	*White*	*English Learners*	*Students w. Disabilities*	*Socio-economically Disadvantaged*
Bartlett	7%	18%	0%	7%	4%	64%	5%	14%	15%
Brookeport	29%	9%	0%	42%	3%	15%	29%	22%	63%
Chester	21%	2%	3%	58%	5%	12%	41%	19%	58%
Fairby	2%	70%	0%	14%	3%	10%	13%	9%	20%
Hartwell	1%	1%	5%	3%	3%	86%	1%	14%	70%
Hillman	3%	9%	1%	55%	7%	27%	12%	15%	44%
Jasper	7%	13%	6%	13%	11%	50%	15%	19%	35%
King Park	92%	0%	0%	5%	1%	1%	3%	14%	93%
Lockeford	3%	4%	1%	34%	5%	53%	7%	17%	45%
Norhaven	6%	3%	4%	15%	14%	57%	6%	19%	44%
North Valley	7%	48%	1%	5%	3%	36%	20%	6%	12%
Rivercrest	2%	1%	38%	2%	0%	57%	0%	13%	67%
Silverbay	7%	15%	<1%	44%	8%	24%	19%	11%	57%

Note: Race/ethnicity categories vary across states and are synthesized here. Values are approximate percentages.

After gathering data from district-level participants, we then selected one or two elementary schools within each district for school-level data collection. We aimed to select schools that were engaged in science reform and teaching science with some amount of regularity. We also sought to give preference to schools serving marginalized populations, particularly schools serving communities of low-income students, emergent multilingual students, and students of color. We began by gathering publicly-available demographic data on elementary schools in each district, including total school population, racial demographics of students, and the percent of economically disadvantaged, emergent multilingual, and students with special needs (Table 3). We then had informal conversations with each district's science coordinator regarding their recommendations for school selection given our criteria and recorded notes following our conversations. We brought this information to the research team to discuss which schools best met our established criteria and then developed a matrix of candidate schools across all thirteen districts that included pertinent information for each district (e.g., demographics, science instructional time). Finally, we compared across all potential schools with the goal of assuring variability across the data set. We successfully recruited at least one school in every district, and we recruited two schools in eight districts for a total of 21 schools (in two of our rural districts, there is only one elementary school).[1]

[1] District and school recruitment took place in 2020 and 2021. Due to the turbulence caused by the COVID pandemic, we were not able to secure a second school site in three school districts that had multiple elementary schools in the district.

Table 3: School Demographics

District	School/Grades	*Total Enrollment*	*African American*	*Asian*	*American Indian*	*Hispanic*	*Multiple Races*	*White*	*English Learners*	*Students w. Disabilities*	*Socio-economically Disadvantaged*
Bartlett	Crossroads (K-5)	300	2%	19%	0%	7%	6%	67%	12%	21%	15%
	New Rockford (K-5)	500	10%	19%	0%	8%	4%	61%	7%	16%	17%
Brookeport	Clairton (PK-5)	200	14%	15%	0%	37%	7%	26%	31%	13%	55%
Chester	Carlotta Walls (PK-4)	300	68%	0%	2%	13%	10%	4%	6%	23%	83%
	Faraday (PK-4)	300	3%	0%	4%	87%	2%	4%	72%	22%	51%
Fairby	Gartness (K-6)	700	2%	52%	0%	28%	4%	13%	29%	10%	34%
Hartwell	Hartwell (PK-6)	400	1%	0%	3%	5%	4%	87%	0%	16%	76%
Hillman	Mission (K-5)	200	3%	10%	1%	24%	16%	44%	8%	11%	31%
	Upward (K-5)	400	2%	4%	1%	54%	5%	31%	27%	11%	59%
Jasper	Riverview (PK-4)	1000	13%	20%	5%	14%	14%	34%	25%	21%	57%
	Valleyview (PK-4)	1500	10%	21%	4%	19%	9%	37%	32%	20%	58%
King Park	Triumph (K-8)	710	92%	1%	1%	5%	1%	1%	2.5%	28%	84%
Lockford	Brookstone (1-5)	600	3%	6%	1%	29%	4%	57%	2%	7%	23%
	River Ranch (K-5)	600	9%	4%	1%	26%	4%	56%	4%	22%	50%
Norhaven	Lakeview (PK-5)	300	9%	4%	6%	16%	23%	42%	16%	25%	62%
	Willow Park (PK-5)	600	5%	2%	6%	14%	15%	59%	6%	19%	49%
North Valley	Brookland (K-4)	400	2%	56%	0%	3%	4%	35%	29%	6%	4%
	Vernon (K-4)	600	8%	47%	1%	4%	2%	38%	35%	7%	17%
Rivercrest	Rivercrest (K-12)	600	3%	1%	38%	2%	0%	57%	0%	13%	69%
Silverbay	Redwood (PK-5)	300	12%	1%	0%	83%	1%	3%	51%	21%	93%

Note: Race/ethnicity categories vary across states and are synthesized here. Values are rounded percentages.

Data Collection

Data collection for this study took place between 2020 and 2022 and included interviews with central office leaders, school leaders, and teacher leaders, observations of district- and school-level routines in science, and collection of district and school documents pertaining to elementary science (Table 4).

Table 4: District- and School-Level Data Collection

	Interviews	*Observations*	*Documents*
District			
Bartlett	18	4	13
Brookeport	19	4	11
Chester	23	3	53
Fairby	14	3	4
Hartwell	17	2	8
Hillman	13	3	11
Jasper	23	8	58
King Park	15	2	21
Lockeford	10	0	3
Norhaven	17	10	22
North Valley	15	5	8
Rivercrest	8	2	2
Silverbay	20	2	23

In total, we conducted 134 interviews of central office staff and 55 interviews with school-level leaders across the 13 districts. Interviews were semi-structured (Glesne, 2011) and lasted between 30- and 60-minutes in length. Participating central office leaders included district superintendents; assistant superintendents; directors of special education, student support, curriculum and instruction, and English language development; district data managers; coordinators for science, mathematics, and English language arts; and others. Interviews with central office leaders focused on district priorities, organizational structure, district community, and instruction and instructional improvement in science and other content areas. We also interviewed governmental and non-governmental technical assistance providers that worked with districts. Participating school-level leaders included principals, assistant principals, instructional coaches, and formal and informal teacher leaders. Interviews with school leaders focused on district and school priorities, school community, school routines, and instruction and instructional support in science and other content areas.

Observations focused on district- and school-level routines for science. Examples of district-level observations included elementary science professional development (PD) provided by the central office or by technical assistance providers and district curriculum adoption meetings for elementary science. Examples of school-level observations included grade-level or vertical team meetings and school-based PD. Additionally, we collected agendas, handouts, slide decks, and evaluations as relevant to the observations. Research team members recorded field notes using an observation protocol along with analytical reflections on the observed session (Emerson et al., 1995).

We also gathered documents that included sources detailing district demographics and priorities, curriculum materials for use by teachers, district and school improvement plans, and school schedules. Our field notes, as well as organizational documents collected from district and school leaders, provided triangulation for emerging themes from our interviews (Miles & Huberman, 1994).

Analysis

The data collection and analysis were integrated, allowing the research team to identify patterns and working hypotheses as they emerged from the data while refining data collection strategies as the study progressed (Miles & Huberman, 1994). Our first analytic iteration was with the district-level data in advance of gathering school-level data, and we then made a second iteration with the school-level data. We began each analysis by first developing provisional analytic memos (Yin, 2009) for each of our districts and schools (N=32 memos) that synthesized interview notes, observation field notes, and documents to establish preliminary understandings of how each district and school engaged in elementary science reform. As they were developed, memos were shared and discussed with the research team. We then moved to deductive and inductive coding of the data (Miles & Huberman, 1994). Using the qualitative analysis software, NVivo (QSR International Pty Ltd, 2018), we deductively coded our interview data using a research-established analytic framework for educational system-building (Appendix A). We then analyzed the data by code to revise and expand our analytic memos. Research team members met to share and discuss the revised analytic memos.

We then analyzed the coded data to construct a second set of analytic memos (one per district) that identified leadership practices across multiple levels and we triangulated this data with the previously developed district- and school-level memos. We organized these analytic memos by drawing on key concepts identified by Spillane et al.'s (2023) multi-level leadership perspective and allowed space to memo on topics that emerged in individual districts as salient leadership practices not otherwise included. This included describing the formal and informal leadership roles within and beyond the district and school, routines in which leaders worked together, and artifacts used in the context of leadership practice. We then developed an analytic matrix to compare leadership practice across districts (Yin, 2009). We used this matrix and additional memo-writing to summarize key distinctions and similarities in order to answer our research questions.

Findings

Based on our analysis, we develop and support three claims. First, we argue that a core component of educational leadership practice in elementary science involved garnering attention for science in a situation that prioritized the instruction of English Language Arts (ELA) and mathematics. In this way, the situation of elementary science fundamentally shaped the practice of leading its improvement. Second, in part reflecting the situation of science, another component of leading elementary science involved cultivating and channeling relationships within the system, including the district-, school-, and classroom-levels, and within the education sector to (re)build an educational infrastructure for elementary science instruction. Third, educational leaders not only worked to (re)build an educational infrastructure, but also to support the use of this educational infrastructure in practice. We organized this section by these claims.

Garnering Attention for Elementary Science Instruction

With regards to a multilevel perspective of distributed leadership, the practice of educational leadership is shaped not just by people, but also key aspects of the situation that shape how they interact with one another and other stakeholders. In the case of leading elementary science education, the positioning of elementary science relative to ELA and mathematics fundamentally shaped the practice of leading elementary science reform. Specifically, the educational infrastructure for elementary ELA and mathematics was more developed than for science, marginalizing the work of elementary science instruction and its improvement. For educational leaders, then, a key challenge in their work involved garnering attention for elementary science instruction in a context that prioritized the instruction of ELA and mathematics.

Across the districts, leaders pointed to state-level assessments and accountability systems as prioritizing ELA and mathematics instruction. In all but one school district, leaders explained that state assessments and accountability systems pressured districts to improve ELA and mathematics scores and this had districts prioritizing ELA and mathematics instruction over other subject areas at the elementary level. For instance, a central office leader in King Park, a mid-sized charter district, explained:

> One challenge specific to science is our school score is weighted towards ELA and math pretty heavily. Science and social studies combined are not even close to equaling to math or ELA in our final grade. […] I think it makes it very challenging for schools even when they are invested.

A central office leader in Brookeport, a large urban district, echoed these sentiments by saying, "I think that our state assessments make it really hard for schools to focus on science because all of them are happening in ELA and math, especially in elementary school. That tends to be the focus for everybody". For these leaders, state-level pressures to improve ELA and mathematics scores had elementary schools prioritizing these subject areas and this left little space for elementary science instruction. The prioritization of ELA and mathematics, in turn, created a central challenge for leaders trying to reform elementary science instruction; to persuade their colleagues to include time for science teaching.

In addition to state assessments and accountability pressuring districts to prioritize ELA and mathematics instruction over other subject areas, leaders also identified district- and school-based infrastructure as skewed toward ELA and mathematics. All 13 districts showed evidence of having educational infrastructure that prioritized ELA and mathematics instruction compared to science which, in turn, contributed to the marginalization of science instruction in elementary schools. Across the districts, leadership roles in science were less prevalent than in ELA and mathematics. For example, a central office leader in Silverbay, a large urban district, described the disparity between science staffing in the central office compared to ELA and mathematics. They explained:

> ELA has always been the driver, mathematics second to that. Math, you can imagine, has much more staffing. […] I mean in the last five years we have only had one particular individual that is supposed to support science TK through 12 and without a lot of resources do that job. It's a pretty daunting, heavy job to roll out new standards, new trainings without a lot of resources as one person to represent 5,000 teachers.

For this leader, having one individual to support science in a large urban district was incommensurate with staffing in ELA and mathematics and made the job "daunting". For other districts, instructional coaches supported teachers in ELA and mathematics, but not in other subject areas. For instance, North Valley, a mid-sized suburban district, employed six literacy specialists to support schools, but provided no comparable support for science.

Leaders also identified that school scheduling prioritized the teaching of ELA and mathematics at the elementary level and marginalized the teaching of science. For example, a central office leader in Brookeport stated that, "The instructional day is incredibly short. It's like a six-hour day. When they're trying to fit in the literacy work, the math work, time for social-emotional learning…being able to squeeze the science in there is challenging". In Chester, a large urban school district, a central office leader identified the state mandated 90-minute reading block as a key challenge facing elementary science instruction. She said, "Well, [the 90-minute reading block legislation], it gets us. A 90-minute reading block is a big chunk of the early learning day". Other leaders suggested that the rigor of the curriculum in ELA had teachers needing to give substantial instructional time to ELA. A district leader in Fairby, a large suburban district, explained:

> Literally, I could teach [our ELA curriculum] all day. That's how curriculum-heavy it is. I could teach it all day. Then I have to carve out 30 minutes for math. There's no time to teach anything else, unless it's embedded in the curriculum.

One district, King Park, only taught science beginning in third grade given the demands in ELA and mathematics. One district leader explained that, "our bottom line is everything is geared towards test scores. It's all about the state test, which is why third and fourth grade is separated in our region from Pre-K-2 because third grade is when state testing starts." For these leaders, it was difficult to find time for elementary science instruction given the other demands for instructional time placed on teachers, and these demands often marginalized the time teachers had to teach science.

Other leaders identified district- and school-based routines for instructional support, such as professional development (PD) and professional learning communities (PLCs), as prioritizing ELA and mathematics. For instance, in North Valley, a teacher leader explained that district PD focused primarily on ELA and mathematics support. She explained:

> K-2 is focused on math, and 3-4 is focused on literacy. I had math [PD] when I taught first grade, and then this year has been focused more on literacy. I wish we would do it in science. That way, I could understand everything more before I have to figure it out myself, but we just don't have that.

In other districts, PLC structures favored ELA and mathematics instruction. For instance, in Rivercrest, a small rural district, the elementary school used its PLCs to support ELA and mathematics instruction exclusively. A school leader in the district explained:

> [PLCs are used for] reading and math. We have PLCs that happen during the day. They're half-days, and we dig into reading and math data. Last year the focus was more

> on math. This year the focus is more on literacy again. We dig into the data and make a plan for how we are going to help kids get to proficiency.

Similarly, a teacher leader in Norhaven, a large suburban district, explained a similar focus of PLCs in her school:

> It's typically reading and math. Science just does not lend itself as much to collecting the data. Most of our PLCs, it's like, "Well, here's my pre-test scores. Here's my post-test scores," or, "Here's progress report on this student. Here's what we need on this." It's more covering data. Where with the science, you have the science notebooks, but you don't typically pick them up.

In both Rivercrest and Norhaven, PLCs served as a context for collaboration and inquiry with regards to student data. Unlike ELA and mathematics, elementary science did not have a comparable infrastructure for collecting and analyzing student data in science and therefore did not fit within the data-focused norms of the schools' PLCs.

For these leaders, the educational infrastructure for elementary ELA and mathematics was more developed than for elementary science and contributed to the marginalization of elementary science instruction systemwide. State assessments and accountability pressures in ELA and mathematics had districts prioritizing the teaching of ELA and mathematics, and staffing, scheduling, and school-based routines often focused on ELA and mathematics instruction. In this regard, the developed educational infrastructure in other subject areas created a situation that in turn defined leadership practice for elementary science. Given the marginalization of elementary science systemwide, a key task for educational leaders involved garnering attention for elementary science instruction in a context that prioritized ELA and mathematics instruction. As we discuss in detail below, garnering attention for elementary science instruction involved (re) building an educational infrastructure for elementary science and supporting the use of this infrastructure in practice.

(Re) Building an Educational Infrastructure for Elementary Science Instruction

Given the prioritization of ELA and mathematics instruction in elementary schools and the paucity of extant infrastructure for science, a key task for leaders involved persuading their colleagues to include time for science teaching and developing an educational infrastructure to support that teaching. One way that leaders sought to garner attention to elementary science was by (re)building an educational infrastructure for elementary science that signaled to educators the importance of elementary science instruction and provided critical resources for instruction.

In all 13 school districts, no one relationship provided the resources needed to establish an educational infrastructure to support instructional reform in elementary science; rather, leaders drew on a range of relationships within the educational sector, system, schools, and classrooms to access resources. These relationships included those in the educational sector, such as with curriculum and materials providers, foundations and philanthropies, governmental organizations, technical assistance providers, and university partners, and with those internal to the system, including with new and existing leadership positions in schools. For leaders, this work involved (a) strategically initiating and developing these relationships to access resources for elementary science and (b) managing multiple relationships and associated resources to build an educational infrastructure to support elementary science reform. Across the districts, leaders primarily sought to cultivate and channel relationships to access resources needed to establish three key components of educational infrastructure: (a) vision for elementary science instruction, (b) curricular resources, and, to a lesser extent, (c) science leadership roles and responsibilities.

In all districts, leaders cultivated and channeled relationships both within the school district (e.g., classrooms, schools, central office), and beyond the district (e.g., educational sector) to access the resources needed to establish a vision for elementary science instruction.

North Valley, for example, participated in a strategic work group organized through the county department of education to plan for implementation of the new state science standards. As part of this group, a team of North Valley central office leaders and teachers worked together with science leaders from other local districts to establish a vision for science instruction that aligned to the NGSS. Silverbay, as another example, participated in a five-year grant-funded network focused on supporting implementation of the NGSS. As part of this grant, a team of central office, school, and teacher leaders worked with a technical assistance provider and other school districts to build their understandings of the NGSS. Leaders in Silverbay pointed to this partnership as helping them develop a common vision for science education that centered on "inquiry-based learning", "student engagement and learner-centeredness", and "students as curious, creative change makers". Other districts, like Jasper, a midsized suburban district, established a vision for elementary science in the context of their curriculum adoption work as the curriculum adoption committee established criteria for resource adoption drawing on state resources and guidance.

In these districts, leaders strategically initiated and managed relationships within the district (with groups of teachers and teacher leaders) and beyond the district (with governmental agencies, professional networks, external support providers) to access the resources needed to establish a vision for elementary science instruction. In so doing, leaders developed a central, guiding vision for elementary science instruction around which districts could organize their work.

In 11 of the 13 school districts, leaders cultivated and channeled relationships in the district and beyond the district to access the resources needed to establish the curricular materials for elementary science.[2] In most cases, establishing curricular resources for elementary science was not just a matter of finding a curriculum; rather this work involved simultaneously cultivating and channeling multiple relationships to access these resources. For leaders in North Valley, for example, the work of procuring curricular materials involved cultivating and channeling relationships with the county department of education, a professional network, commercial curriculum providers, teacher leaders, and a science materials management company. These leaders leveraged a professional network - the science strategy team organized by the county education office - to identify potential curricula to adopt. Teacher leaders then worked with the district science coordinator to pilot, evaluate, and choose among the recommended set of curricula. After curriculum adoption, leaders partnered with a science materials management company to provide the science materials needed to enact the adopted curriculum. Other districts, like Bartlett, a small suburban district, and Silverbay cultivated and channeled relationships within and beyond the district as they developed their own curricular materials in-house. In Bartlett, for example, district leaders leveraged school-based relationships with teacher leaders to write their curriculum. District and teacher leaders drew on a range of resources as they wrote the curriculum, including modifying purchased curricular modules and collaboratively writing units with community partners. In Silverbay, the central office hired three science leaders from another local school district to develop an elementary curriculum. As part of this work, the science team collaborated with various central office departments, including the Performing and Visual Arts and Teaching and Learning Technology Teams, to build the

[2] Of the two districts that did not engage in this work, one district began efforts to adopt curricular materials, but the efforts stalled due to lack of funding during COVID. The other district used an interdisciplinary, project-based learning design that had teachers developing their own curriculum.

curriculum, and leveraged external grant funding to provide schools with the physical materials needed for instruction.

Leaders in these districts strategically initiated multiple relationships within and beyond the district to access the resources need to (re)develop the curricular materials needed for elementary science instruction. In each case, leaders established different relationships to access different types of resources. For example, in North Valley, leaders leveraged the science strategy team for knowledge about curriculum, the commercial providers for the curriculum, and the teacher leaders for knowledge about curriculum use. As part of this work, leaders coordinated these relationships and fashioned the associated resources into the curricular materials for elementary science instruction.

In some districts, leaders cultivated and channeled relationships within and beyond the district to access the resources needed to establish leadership roles and responsibilities for elementary science. For example, in Rivercrest the elementary school principal initiated a strategic partnership with a regional STEM network for support and guidance in reforming elementary science instruction. As part of this strategic partnership, the principal worked closely with the STEM network director who assisted the district by brokering a relationship with a local curriculum provider for resources and PD, facilitating a professional network of science teachers and leaders, and developing practical tools, such as implementation guides, to support elementary science instruction in the district. As such, the STEM network director served a key leadership role in elementary science in the district. The school principal explained:

> [The Director] been an instrumental part in getting our school aligned science-wise and making sure that grade levels are teaching what they are supposed to be teaching, and we have that transition into grade levels where it flows smoothly. […] We've done meetings where we go through and talk about each teacher level of science, and the capacity we need to continue to build, and what we as a school need for science, what we lack. [The

Director] is a big support. Any questions I have with science I go to [the Director].

For this small rural school district with limited central office staff, cultivating and channeling a relationship with the regional STEM network provided access to important knowledge, expertise, and tools for elementary science, and served a key leadership function in the district. In Brookeport, leaders used local corporation funding to establish a new STEAM department in the central office and hired instructional coaches for elementary science. While a central office position, these coaches were school based for a two-year period "to support science instruction", before moving on to another school. The STEAM Director noted that the team's mission is "to build teacher capacity for delivering high-quality science instruction that is culturally responsive, that meets the science and engineering practices, that creates an inclusive culture". Other districts, like Lockeford and North Valley, accessed resources, from grant funding and federal title funds, to pull classroom teachers into key leadership roles responsible for leading elementary science reform efforts in the district. This had teachers serving as quasi-central office staff in charge of leading elementary science reform.

In each of these districts, leaders cultivated and channeled relationships within and beyond the district to access the resources needed to establish new leadership roles and responsibilities for elementary science. The roles varied in terms of being leveraged from within the district or from beyond the district, but in each case these roles established new ways of working across multiple levels of the system in pursuit of elementary science reform.

In sum, the prioritization of ELA and mathematics instruction in elementary schools and the comparatively underdeveloped educational infrastructure for elementary science had leaders needing to garner attention to elementary science instruction. Leaders did this, in part, by cultivating and channeling relationships to access the resources needed to (re)develop an educational infrastructure for elementary science. In so doing, leaders signaled to educators the importance of and provided resources for elementary science instruction.

Activating Resources for Instructional Support

While educational leaders cultivated and channeled relationships to access resources for elementary science instruction and coordinated these relationships and resources to build an educational infrastructure for science, the work of leadership went beyond *accessing* and fashioning resources into an educational infrastructure. Leading elementary science also involved *activating* the educational infrastructure in classrooms across the district by supporting its use in practice. Activating educational infrastructure involved leaders leveraging relationships within the district and beyond to support infrastructure use in practice. While there was variation across the districts, leaders primarily used three main approaches for supporting use: PD, coaching, and adapting curricula.

PD served as the primary context through which leaders supported teachers in activating its educational infrastructure in practice with all 13 districts providing some form of PD to teachers for elementary science. In some districts, leadership practice involved planning, organizing and leading PD for teachers, while in other districts leadership practice involved strategically leveraging relationships and resources to bring PD into the district. In King Park, for instance, the district science coordinator organized and led PD approximately every six weeks to support teachers in preparing to teach upcoming science units. As observed in one PD session, the coordinator used activities to norm teachers on the key commitments and principles driving elementary science instruction in the district and led teachers through "internalization" where teachers made sense of the curricular materials in preparation to teach a unit. In North Valley, the district science coordinator leveraged key relationships to access PD for teachers in the district.

The coordinator did this by soliciting the curriculum provider to run PD sessions for teachers and organizing release time for teachers to work as grade-level teams to make sense of and plan for the use of the curricular materials. In each case, PD served to coordinate the district's educational infrastructure with classroom instruction by supporting teachers in making sense of the district's vision of instruction and using the curricular and instructional materials as they worked with leaders within the district and beyond.

Fewer districts (n=5) used coaching to help activate the district's educational infrastructure in practice. In King Park, for example, the district science coordinator and school-based instructional coaches met with elementary science teachers weekly to plan and reflect on their science instruction. In these sessions, coaches helped teachers to develop science content knowledge or plan and prepare to use the curricular resources, or they observed science teaching and provided feedback on their instruction. In Hartwell, a small rural district, the principal leveraged the district's longstanding relationship with a Regional Educational Cooperative to provide coaching to teachers on an individual, as needed basis. In Brookeport, the grant-funded STEAM coaches worked with individual teachers across the district on modifying the science curriculum and integrating ELA instruction with science. In each case, instructional coaching served to coordinate the district's educational infrastructure with classroom instruction primarily by supporting teachers in using the curricular and instructional materials as they worked with leaders from within the district and beyond.

Four districts sought to activate the district's educational infrastructure in practice by providing support for adapting the curricular and instructional materials to meet the needs of classroom students. For instance, in King Park, the district science coordinator worked with a teacher curriculum fellow to adapt the commercial science curriculum for classroom use. This work involved explicating the instructional materials by developing pacing guides, daily lessons developed from the curriculum, and interim assessments. The district science coordinator described the importance of the supplemental resources for teachers:

> My summer was pulling the units and putting them into actual lessons for teachers to use because it's just hours of prep, especially in elementary school where teachers have multiple jobs as teachers. That was just a huge barrier that we could get in front of. […] We focused on not adding or taking away too much, but making the existing curriculum accessible so that a teacher could just open up a document that's just a couple of pages. Just simplifying the existing curriculum.

This coordinator was sensitive to the amount of time needed for teachers to prepare the instructional materials and sought to manage this challenge by abridging the instructional materials in a way that minimized the time teachers need to plan and prepare for instruction. In Brookeport, instructional coaches worked directly with teachers to adapt the curriculum to meet classroom needs, in this case to integrate elementary science and literacy instruction. As described by a school leader, a goal for instructional coaches is to increase access to science and increase science integration into daily learning, in part, by helping each teacher design and teach integrated units. Moreover, leaders in Brookeport also leveraged funding from the National Science Foundation to enlist university partners to help teachers "contextualize" the curriculum to meet the needs of their students. As part of this partnership, the local university worked with classroom teachers to, as one district leader described, "make the curriculum their own for the students in front of them." For both King Park and Brookeport, the leadership task was not just finding standards aligned materials, but also adapting these materials for classroom and student needs.

Discussion

Our study took a multilevel distributed perspective to analyze the practice of leadership for elementary science. Based on our analysis of data from 13 school districts, we developed and supported three assertions. First, we argued that a core component of educational leadership practice involved garnering attention for elementary science instruction in a context that prioritized the instruction of English Language Arts (ELA) and mathematics. Second, another core component of educational leadership practice centered on cultivating and channeling relationships within and beyond the system to (re)develop an educational infrastructure for elementary science instruction. Third, another core component of leadership practice focused on activating educational infrastructure for elementary science by supporting its use in practice.

In this section, we advance two central arguments regarding leadership practice for elementary science based on our analysis. First, we argue that the school subject is a critical factor in understanding leadership practice in elementary science. Second, we argue that leadership practice in elementary science involves coordinating a range of relationships and resources within and beyond the school district to advance elementary science reform. We discuss these two central matters in this section.

Leadership Practice as Rooted in Subject-Matter Challenges

As described previously, scholars taking a distributed perspective have shown that the practice of educational leadership is shaped not just by people, but also key aspects of the situation that enable and constrain how leaders interact with one another and other stakeholders. In the case of elementary science, a central challenge facing leaders involved the complex dynamics of educational infrastructure (re)building in science compared to other subject matters. We found that the educational infrastructure for elementary English Language Arts (ELA) and mathematics was more developed than for science, and this disparity marginalized the work of elementary science instruction and its improvement. Leaders across the districts referenced the limited instructional time allocated for elementary science as a central barrier to improving elementary science instruction. Leaders identified state-level infrastructure, namely state assessments and accountability structures, and district- and school-based infrastructure, such as schedules, leadership roles, and district- and school-based routines, as prioritizing ELA and mathematics instruction and marginalizing science instruction at the elementary level. These findings are consistent with research that documents an overall decline in science instructional time in elementary schools (Banilower et al., 2013; Blank, 2013; Smith, 2020) and the prioritization of literacy and mathematics over science at the state- and district-levels (Lyle et al., in press; Marx & Harris, 2006; NASEM, 2021; Seeber et al., under review; Spillane & Hopkins, 2013).

The disparity between educational infrastructure in elementary ELA and mathematics compared to science created a critical challenge for leaders as they needed to garner time, interest, and attention for elementary science in a context that prioritized the teaching of ELA and mathematics. Yet, the comparatively underdeveloped educational infrastructure in elementary science compared to ELA and mathematics created steep barriers for persuading educators to give time and attention to elementary science instruction. For example, at the state-level, assessments and accountability systems incentivized districts and schools to focus on ELA and mathematics, and this had districts establishing and leveraging school-based infrastructure, such as schedules, roles, and routines, primarily for those subject areas. In this regard, educational infrastructure was a barrier to elementary science reform in that established structures, resources, and routines signaled attention to ELA and mathematics. At the same time, educational infrastructure was also a means through which to bring attention to elementary science. In bringing in critical resources for elementary science (e.g., curricula, training, PD, leadership roles, funding) and coordinating these resources to establish an educational infrastructure for science, leaders signaled to educators the importance of elementary science instruction through the allocation of critical resources for instruction. While still incommensurate with the educational infrastructure for ELA and mathematics, the work of leaders to establish an educational infrastructure for elementary science served to garner attention and persuade educators to give time and attention to elementary science among the many other competing demands.

As such, the role of the subject-matter in elementary science reform was a critical factor in understanding leadership practice. Understanding how key aspects of the situation, in this case the dynamics involved in instructional reform in ELA and mathematics, shaped how leaders engaged in elementary science reform.

Leadership Practice as Coordinating Relationships and Resources

As we presented in this paper, leadership practice in elementary science involved cultivating and channeling a range of relationships and resources within and beyond the district to access and activate an educational infrastructure for science. In all districts, no one relationship provided the resources needed to support elementary science reform; rather, leaders leveraged multiple relationships within and beyond the district to (re)build and support an educational infrastructure for science. In many cases, accessing and activating an educational infrastructure for elementary science involved coordinating across a range of relationships in the educational sector (e.g., commercial curriculum providers, professional networks, philanthropies) and within the district (e.g., science committees, grade-level teams, central office departments), each of which provided a unique set of resources that bore on the work of elementary science instruction. With regards to leadership practice, the work of leaders involved simultaneously coordinating these relationships and resources across multiple levels of the system in ways that advanced elementary science reform.

Yet the work of coordinating these relationships and resources in pursuit of elementary science reform unfolded over time as relationships and resources shifted and as new challenges and needs emerged in the work of elementary science reform. As such, coordination was not a task to be completed; rather, coordination was an ongoing process in which leaders continually managed relationships and resources within the district and beyond. This dynamic reflects research on policy coherence in education that conceptualizes coherence as a dynamic process by which schools use multiple external demands to strengthen students' opportunities to learn (Honig & Hatch, 2004). While we began to explore the work of leaders coordinating relationships and resources to advance elementary science reform in this paper, there is much to uncover regarding how educational leaders coordinate vertically across multiple levels of the system. In particular, future work in this area might consider how leaders manage relationships and resources amidst shifting policy environments and local demands.

Conclusion

Our account contributes to the research base on leadership practice by exploring elementary science leadership from a multilevel distributed perspective. In this article, we empirically tested the multilevel distributed perspective to understand how leadership practice stretches vertically, across classrooms, schools, systems, and the educational sector, and horizontally within levels to understand efforts to lead elementary science reform. In particular, we argue that the school subject is a critical factor in understanding leadership practice in elementary science and that leadership practice in elementary science involves coordinating a range of relationships and resources within and beyond the school district.

We see real promise in leveraging the multilevel distributed perspective to understand educational leadership practice. In the case of elementary science, the multilevel distributed perspective allowed us to identify and explore the range of relationships and resources that shape leadership practice in elementary science, including those within the system and those beyond the system, and enabled attention to the key aspects of the situation that shaped interactions. This research yields further questions about how leaders manage these multilevel relationships and resources, particularly in the context of shifting policy and local environments that may complicate how leader cultivate and channel relationships within the system and beyond.

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Appendices

Domain	Description
Managing environmental relationships	To selectively bridge, buffer, and reconcile among competing influences and resources in local and broader environments that bear on how the district understands and pursues excellence and equity in classroom instruction: e.g., family/community aspirations and values, federal and state policies, philanthropists' agendas, and educational research and resources (Honig & Hatch, 2004; Spillane, 2009).
Building educational infrastructure	To coordinate visions for instructional practice, formal instructional resources (e.g., instructional models, curricula, and assessments), and social instructional resources (e.g., understandings, norms, values, and relationships among teachers, leaders, and students) (Hopkins et al., 2013; Leithwood et al., 2004; Peurach & Neumerski, 2015).
Supporting the use of educational infrastructure in practice	To develop teachers' professional knowledge and capabilities through such means as workshops, practice- based coaching and mentoring, and collegial learning (Cohen, 2011; Cohen et al., 2003).
Managing performance	To manage both for continuous improvement (e.g., via iterative, evidence-driven design, implementation, and evaluation) and for accountability (e.g., via the use of evidence and standards to assess instructional processes and outcomes) (Boudet et al., 2005; Bryk et al., 2015; Mintrop, 2016).
Distributing instructional leadership	To distribute beyond established administrative roles to new leadership roles and teams responsible for performing, coordinating, and managing all of the preceding (Elmore, 2000; Spillane, 2006).