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Leading Systemwide Improvement in Elementary Science Education: Managing Dilemmas of Education System Building

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Reforming instruction is challenging. In this comparative case study of 12 school districts, we investigated the dilemmas that emerged for system leaders as they engaged in system building for elementary science and the approaches leaders took in managing them. We found that system leaders' efforts to manage their environments contributed to the preferential treatment of literacy and mathematics relative to science. Leaders managed this dilemma using

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three strategies: (a) integration of science with other subjects, (b) specialization of teachers, and (c) adopting curriculum materials. This study contributes to literature on dilemma management by showing that dilemmas in education system building are school-subject sensitive, emerge in relation to system building for other subjects, and are embedded in school and education systems' structural/organizational arrangements.

Keywords: system leadership, dilemmas, instructional reform, elementary science education

Introduction

Reforming instruction is challenging. Reforms that press ambitious transformations of *what* and *how* students should learn face especially daunting implementation challenges, including local educators constructing understandings of the instructional ideas that fail to reflect their underlying intent, teachers lacking the capability (e.g., pedagogical content knowledge) to teach in ways consistent with the reform ideals, and a lack of curricular material resources (D. L. Ball & Cohen, 1996; Coburn, 2001). Successful education reform depends on local educators having rich and ongoing opportunities to unlearn and relearn about teaching (Cohen & Mehta, 2017; Rubin et al., 2017).

School districts play a prominent role in instructional reform by building infrastructure that supports opportunities for standards-aligned implementation at a local level, offering professional development (PD), managing students' and teachers' performance, developing and distributing instructional leadership across system levels, and bridging to and buffering from environmental influences (Little, 1989; Lyle et al., 2023; Peurach, Lyle, et al., 2022; Polikoff et al., 2020). For example, some systems have purchased reading and writing curricula aligned to the Common Core State Standards, created systemwide pacing guides, compiled district-approved supplemental resources while discouraging the use of teacher-created resources, offered PD focused on these resources, and used teacher evaluation frameworks aligned with the prescribed curriculum (Spillane et al., 2019). As such, district leaders are key midlevel reformers in *educational systems*, supporting school leaders and teachers in implementing instructional reform through a web of infrastructure, supports, and feedback loops that allow leaders to continuously monitor progress and make improvements over time (Peurach, Yurkofsky, et al., 2019). Still, historically few districts have coherent, system-wide structures to support such reforms, focusing mostly on one or two improvement levers—such as new curriculum materials, PD, or coaching (Cohen et al., 2018). Recent research suggests something of a change as school districts (re)build *educational systems* to provide more comprehensive support for teachers and administrators to develop their capability to enact ambitious instructional reforms, albeit mostly in tested subjects such as mathematics and English language arts (ELA; Peurach, Cohen, et al., 2019).

Educational system building is still challenging, and the empirical knowledge base for the work is limited. While some challenges entail relatively straightforward problem solving, others do not lend themselves to technically rational conceptions of problem solving. Rather, they pose dilemmas for educators to manage rather than solve. Dilemmas refer to ''messy, complicated, conflict-filled situations'' where the alternative solutions are roughly equally desirable (or undesirable), necessitating compromising on some fundamental values: Choosing one alternative over the other is difficult, if not impossible (Cuban, 2001, p. 10). Instructional reform poses dilemmas for system leaders that they must manage, for example, between explicitly directing teachers' instructional practice in line with a reform and respecting their professional autonomy and expertise (Morris, 1997; Stornaiuolo et al., 2023). Indeed, system leaders' responses to reform are limited in many, sometimes contradictory, ways; and as such, their management responses are also limited and require ongoing management. We argue for attention to dilemma management not as an alternative to conventional notions about problem solving but as a central, if mostly ignored, aspect of educational system building and system leadership in an era when technical-rational problem solving and evidence-driven decision-making dominate the discourse (see What Works Clearinghouse, from Institute of Educational Sciences, n.d.; Majone, 1989).

Dilemmas emerge in system leaders' efforts to manage their institutional environments that are often subject-specific (Burch & Spillane, 2005). Institutional environments form around particular school subjects differently, shaping instruction in these subjects (Spillane & Burch, 2003). Some subjects—notably ELA and mathematics—receive considerably more attention from policymakers and institutional actors than others, such as science and social studies (Burch & Spillane, 2005). Several federal policies and programs, such as Title 1 and No Child Left Behind (NCLB), focus on some subjects to the exclusion of others. National and state content standards and accountability mechanisms in literacy and mathematics were developed well before science or social studies (Burch & Spillane, 2005; Peurach, Lyle, et al., 2022). These contemporary mechanisms sit within a legacy of ELA and mathematics as foundational to elementary education, with early science instruction relegated to nature study using children's literature (Peurach, Lyle, et al., 2022). Furthermore, institutional environments are not limited to government actors: Commercial publishers, professional associations, and higher education also treat school subjects differently (Spillane & Burch, 2003). As such, system leaders encounter different demands by school subject as they manage relationships with their environments.

Recognizing that the school subject matters for education system building and dilemma management, coupled with ELA and mathematics dominating the system-building literature, our article focuses on elementary science.

Specifically, we examine the dilemmas that system leaders encounter as they build education systems to reform elementary science in response to the *Framework for K-12 Science Education* (National Research Council, 2011) and the accompanying Next Generation Science Standards (NGSS; National Research Council, 2013). The *Framework* and the NGSS challenge elementary teachers to engage students in doing science and figuring out how or why natural phenomena occur rather than simply reading about science and learning about phenomena (Schwarz et al., 2017). Given elementary teachers' comfort with teaching literacy, especially relative to their comfort and preparedness for teaching science (Banilower et al., 2013), supporting NGSS ambitions in classroom practice will require districts to build educational systems for elementary science that can adequately prepare and support teachers to engage with these instructional shifts. However, district science leaders report that they have limited authority to enforce policies, with district superintendents and principals acting as gatekeepers (Whitworth et al., 2017). Further complicating this landscape, elementary principals have limited understanding of, and capacity to support, NGSS-aligned instruction (McNeill et al., 2018), and we are unaware of literature that represents superintendents' knowledge of the NGSS. In addition, the institutional environments in which elementary science reform is taking place differ from those around ELA and mathematics reform; in particular, getting attention to science in elementary schools is challenging (National Academies of Sciences, Engineering, and Mathematics [NASEM], 2022), in contrast to ELA and mathematics.

Our article is organized like this: We frame our work with the literatures on education system building, problem solving and dilemma management, and the school subject-specific nature of instructional reform. Next, we describe our research approach. We then report our findings by explicating the dilemmas system leaders faced in their system-building efforts, and then describing three interrelated approaches they used to manage these dilemmas. We conclude with a discussion of our findings and their implications for research, policy, and practice.

Conceptual and Empirical Framing

Bringing three literatures into conversation, we motivate and frame our analysis. First, while districts respond to educational reforms in their environment by system building, current organizational structures, often created in response to past efforts to manage the environment, turn up challenges for system leaders (Cohen et al., 2018). Second, whereas some of these challenges involve relatively straightforward problem solving, others pose more difficult problems—dilemmas—that do not lend themselves to technically rational problem solving. Third, while the school subject shapes teachers' and school leaders' practice, knowledge about how the school subject influences education system building and the dilemmas therein is scarce. Hence, we engage the literature on the domains of system building, the dilemma management involved therein, and how the school subject shapes this work.

Education System Building

Our analysis focuses on system leaders' efforts to lead improvement in elementary science. While attending to system leaders' responses to the NGSS, rather than centering narrowly on policy implementation, we instead focus on education system building broadly to understand the interacting components of that work. Education system building involves district central offices and school leaders collaborating with teachers to organize, support, and manage the core work of schooling—instruction (Peurach, Cohen, et al., 2019; Spillane et al., 2019).

Educational system building involves five core work domains distributed across levels of the system including central offices, schools, and classrooms (Datnow et al., 2022; Peurach, Cohen, et al., 2019; Spillane et al., 2019):

1. *Building educational infrastructure* by devising and coordinating designs for instructional practice, formal instructional resources (e.g., instructional models, curriculum materials, and assessments), and social resources (e.g., norms, values, and relationships among students, teachers, and leaders).
2. *Supporting the use of educational infrastructure* in day-to-day classroom work via coordinated workshops, practice-based coaching, and collegial learning.
3. *Managing environmental relationships* by mediating among the many institutional—cultural, policy, political—and technical environmental influences bearing on the pursuit of excellence and equity.
4. *Managing practice and performance* both for continuous improvement and accountability by assessing and advancing the work of building infrastructure, supporting use, and managing environments.
5. *Developing and distributing instructional leadership* by establishing formal and informal leadership roles, teams, and structures with responsibility for performing, coordinating, and managing all of the above.

Each domain of system building work entails problems for system leaders to address. Furthermore, the approaches leaders take, and have taken historically, have consequences for current system-building efforts (Yurkofsky & Peurach, 2023). System building in elementary science, for example, operates within structures, both contemporary and historic, that privilege literacy and mathematics with past federal and state policies prompting leaders to develop asymmetrical structural arrangements across central offices, schools, and classrooms that sideline elementary science in everyday practice (NASEM, 2022; Peurach, Lyle, et al., 2022). This line of thinking suggests that uncertainty arises in system building work both as shifting institutional environments need to be managed, and at the intersection of subject specific efforts taking place in different school subjects, although what this entails in practice is less well understood.

Problem Solving and Dilemma Management in Educational System Building

Education system building, then, entails problem solving. Indeed, education leaders and teachers are increasingly pressed to be problem solvers and evidence-based decision-makers (S. J.Ball, 2003). Over the past quarter century, education policymakers have pressed technical-rational approaches to problem solving on education systems (Gorard & Cook, 2007). System leaders must find solutions to all sorts of problems from what curricula to adopt, the best professional learning for supporting teachers, how to enact curricula in culturally responsive ways for different students, what assessments to use for monitoring practice and performance, how to distribute finite resources, and so on.

Under a technical-rational approach, problem solving involves a unitary decision-maker (or unit) gathering evidence, setting decision-making criteria, predicting, evaluating possible outcomes, and selecting an optimal solution (Majone, 1989; see also Shklar, 1964). Problem solving is about selecting the ‘‘best’’ means to achieving that given end.

Still, scholars, dating back to March and Simon's work on ‘‘bounded rationality’’ (March & Simon, 1958; Simon, 1957), have critiqued technical-rational notions about problem solving for positing a unitary decision-maker or unit, assuming the objectivity of data, and treating problem solving as a singular event rather than as an ongoing process (Gonza´lez et al., 2005; Deal & Kennedy, 1982; Majone, 1989). For example, a district's science unit might see instructional time for elementary science as key to addressing inequities in students' opportunities to experience the joy and wonder of science. At the same time, the ELA unit, constructing and drawing on different data, might see time for literary as essential for addressing inequities, especially for poor students, and work to maximize time for ELA instead, giving rise to uncertainty over how to promote equity.

Problem solving and management in educational organizations differs from technical-rational portrayals of the process. For example, several scholars have documented the centrality of managing dilemmas in practice from teaching to school and district leadership (Ogawa et al., 1999). Lampert (1985) critiques technical-production pressures on teachers and argues for embracing the messiness and uncertainty of dilemmas and living with and managing them rather than solving them. Cuban (2001) describes how educational leaders face choosing among two or more prized values, where choosing one would lead to sacrificing something else, making matters worse. Dilemmas rarely rest solely on the educators' personal or professional preferences, but instead are conditioned and constrained by structural arrangements (Bidwell, 1965), especially pressures from the institutional environment (Spillane & Lowenhaupt, 2019). Public schools, for example, operate in pluralistic institutional environments where they must attend to diverse, often conflicting, demands of various stakeholders. Parents, community members, local and state policymakers, teachers, and students all place demands on education systems that educators cannot easily ignore as they depend on these stakeholders for key resources, including legitimacy, critical to their operation (DiMaggio & Powell, 1983; Suchman, 1995).

Under these circumstances, problem solving is often not about choosing the one best solution but, rather, managing two or more ''acceptable'' solutions that ''satisfice'' rather than ''solve''—solutions that are sufficiently satisfying considering the opportunities and constraints involved (March & Simon, 1958; Simon, 1957). Compromise is essential as educators wrestle with the dilemmas arising from the uncertainty, ambiguity, and often competing values that pervade their work. Managing a dilemma is not an event but an ongoing process (Cuban, 2001; Lampert, 1985; Spillane & Sun, 2020).

Given the need to operationalize problem solving approaches in educational organizations that move beyond technical-rational, we consider the affordances and limitations of a continuous improvement (CI) framework. Work falling under the umbrella of CI offers an alternative framing of the problem-solving process (see Yurkofsky et al., 2020, for a comprehensive and critical review). Though CI approaches differ, as Yurkosfky et al. (2020) argue, problems are understood as emerging from networks of underlying local conditions and problem solving is an iterative process involving practitioners theorizing about those conditions, negotiating about potential points of intervention, crafting and implementing solutions, evaluating outcomes, and centering on satisficing demands. Despite this, CI can fall prey to the allure of technical rationality when participants adhere to normative expectations for reform and fail to engage with uncertainty around values (Ishimaru & Bang, 2022). In their work on solidarity-driven codesign, Ishimaru and Bang (2022) advocate for amplifying rather than silencing uncertainty in CI system-building efforts by including a range of community and youth voices to disrupt any tendency for CI to reify modal practices that fail to engage with issues of power. As such, a principled CI approach works to uncover and engage the uncertainties that permeate education system building, making space for and attending to (rather than avoiding) value-laden ''wicked problems'' or dilemmas.

The School Subject Matters

Focusing on elementary science, we take a subject specific approach to system building. The school subject matters both for how teachers think about teaching *and* its improvement (S. J.Ball, 1981; Little, 1993; McLaughlin & Talbert, 1993; Siskin, 2013; Stodolsky & Grossman, 1995) as well as for school and system leaders' efforts to lead and organize instructional improvement (Spillane, 2005; Spillane & Hopkins, 2013).

Educational system building is intimately tied to system leaders' efforts to manage their institutional environment, and these differ substantively across school subjects, with different policy contexts, access to commercial resources, and so on (Peurach, Lyle, et al., 2022). Furthermore, as institutional environments shift novel subject specific dilemmas emerge; for example, system leaders may need to manage tensions between enacting new standards while adhering to extant district norms and values around in instruction (Ogawa et al., 1999). The NGSS represent a significant change to historic norms in elementary science instruction away from *learning about* science to *figuring out* explanations for scientific phenomena, engaging students more deeply in such scientific practices as asking questions and designing and carrying out investigations (Schwarz et al., 2017). As such, it seems reasonable to anticipate dilemmas emerging within the NGSS policy context. For example, McNeill et al. (2018) note tension between NGSS-aligned ‘‘hands-on’’ approaches focused on student investigation and prior instructional norms, such as ‘‘hands-on’’ literacy activities for learning scientific terminology.

Reflecting how educational systems developed to manage their different environments, district central offices’ structural arrangements differ across subjects (Burch & Spillane, 2005; Peurach, Lyle, et al., 2022). One study of three urban school districts, for example, documented systematic differences both in the distribution of instructional leadership and in how leaders conceptualized and organized instructional improvement (Burch & Spillane, 2005). Nested within these structural arrangements at the central office level, school arrangements for supporting and improving teaching also differ by subject (Price & Loewenberg Ball, 1997; Spillane & Hopkins, 2013). School administrators with no subject-specific leadership position are more likely to participate in organizational routines related to ELA than other subjects (Spillane, 2005). For other subjects, school leaders construct their role as connecting lead teachers to external partners (e.g., commercial curriculum providers, professional organizations) rather than supporting instruction directly (Burch & Spillane, 2003).

Taken together, the available evidence suggests that system leaders seeking to improve elementary instruction face different education system-building challenges, uncertainties, and dilemmas, depending on the school subject. Further, these differences must be understood in relation to system leaders’ efforts to manage their environment and the historic privileging of ELA and mathematics in educational system-building efforts.

Together these three literatures frame and motivate our research questions:

1. What core dilemmas do system leaders face as they engage in problem solving to build educational systems for supporting elementary science education?
2. How do system leaders manage these dilemmas?

Research Approach

We use data from a 5-year National Science Foundation (NSF) study exploring the work of instructionally focused system building in elementary science. Our analysis is based on data focused on system leadership. As a research team with academic interests and professional experiences spanning elementary teaching, leadership, system building, science teaching, and teacher learning, we share an interest in how leaders involved in elementary science education engage in their day-to-day work, ultimately to support students' learning.

Study Design

We used a qualitative comparative case study design (Yin, 2014) involving 13 school districts across the United States, with a particular focus on district leaders' instructional decision-making about elementary science in response to a shifting policy environment.

Through snowball sampling, we selected six states that had either adopted the NGSS, or developed standards based on the *Framework*/NGSS, and had a policy context that (a) could be favorable to system building efforts at the district level around elementary science; and (b) had political, analytic, and demographic variation (Haverly et al., 2022). Within each state, we used further snowball sampling to select up to four case study districts by asking science education experts to recommend contacts, who in turn nominated candidate districts that were doing system building work in elementary science and also put us in touch with additional state contacts who made further recommendations. We then researched nominated districts' elementary science programs from their websites and reached out to district science leaders to discuss their program designs. We attended to variation in size, urbanicity, and demographics of the districts, as well as diversity in approaches to system building in elementary science education in making the final selection of 13 case study districts. Our recruitment process carried into the COVID-19 pandemic, so our selection was also determined by which districts had the bandwidth to participate. In this article, we report our findings from 12 districts, as in one small rural district the only central office leader declined to be interviewed. We use pseudonyms for each district, as well as select other identifiers, for example, the names of curriculum vendors.

Data Collection

We conducted 116, 60-minute, virtual, semistructured interviews, with 101 district leaders, including science coordinators, ELA/math and Title coordinators, data managers, and superintendents in 13 school districts. We report data by district rather than by participant. Interviewing leaders, beyond those with exclusive responsibility for science, was necessary to understand education system building. The interview protocol for science leaders was designed for eliciting each district leader's practices in reforming elementary science. We asked questions on (a) their roles, responsibilities, and background; (b) state, district, and community context; (c) current priorities and visions for

Table 1
Features of Case Study Districts and the Number of District Leaders Interviewed

	Size[a] and Urbanicity	Number of District Science Leaders Interviewed	Number of Nonscience Leaders Interviewed
Hartwell	Small, rural	1	3
Fairby	Large, suburban	1	8
Hillman	Small, charter	1	7
Lockeford	Midsized, rural	1	5
Silverbay	Large, urban	3	9
Kings Park	Midsized, charter	1	5
Bartlett	Small, suburban	2	6
Brookeport	Large, urban	5	6
North Valley	Midsized, suburban	3	5
Chester	Large, urban	2	11
Jasper	Midsized, suburban	3	4
Norhaven	Midsized, suburban	1	7

[a]We consider a district large if its enrollment is over 12,500 students, midsized if its enrollment is between 3,500 and 12,500 students, and small if its enrollment is less than 3,500 students.

elementary science instruction; (d) infrastructure in place supporting elementary science instruction; (e) plans for continuing elementary science reform; and (f) challenges they were experiencing in this work. For nonscience district leaders, the interview focused more on how their role interfaced with science system-building efforts.

Data Analysis

We began data analysis by coding the interviews deductively into broad analytic categories based on the domains of system building described in our framework, as well as references to challenges and dilemmas system leaders were facing in system-building work for elementary science, ensuring an 80% interrater reliability (IRR). We double-coded 10% of the interviews, and when IRR was not achieved in any given domain, the coders met to reconcile their differences. Then, working inductively as a team, we coded the references within the challenges and dilemmas to identify key themes and dilemmas across different systems (Saldana, 2021). Having identified four central dilemmas (see Table 2), we approached the challenges and dilemmas data in layers, coding for each dilemma, and distinguishing codes into identifying (a) how the dilemma was talked about and (b) how the dilemma was managed. By working in layers, with some sections double- or triple-coded, we were able to see how the four dilemmas intersected for system leaders.

Table 2
Examples of Coded Data

Main Code	Subcode	Example(s)
Prioritization of ELA/math over science	Characterization	I think one thing—one challenge specific to science, is our school score is weighted towards ELA and math pretty heavily. It's science and social studies combined barely equal up to, or they're 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, and like the curriculum, and think the coaching is good, and all of those things to when it gets close to a test and not freak out, and be like, ''We're not gonna do this. We've got to go all in on math and ELA.'' (King Park)
	Management	What we've tried to do is . . . show that we can tie content into the literacy period by pulling in texts that are tied to the projects and the phenomena that we're trying to explore. We've actually seen a lotta teachers learning how to integrate inquiry throughout the day and then also using science texts. We use fiction probably just as often as we use nonfiction not just in a science block, but outside in the literacy block as well. (Silverbay)
Capacity and capability of teachers and leaders	Characterization	I guess I'm a little wondering about if we do get this instructional material, it was almost hinted at that teachers—how can we help teachers with this new material, align it to these ELA and math frames as well? The concerns I expressed, or my questions I guess, were more okay, so, we already have some, not insignificant portion of elementary teachers not really teaching science, and haven't done it for a long time, and now we're going to provide them with materials and that's a huge lift, right? (Lockeford)

(continued)

Table 2 (continued)

Main Code	Subcode	Example(s)
	Management	We're very support-heavy right now because most teachers are—last year was the last year of implementation, meaning that there are still teachers who have only taught a unit for a year—once. There are teachers who are teaching unit this year for the second time, and that takes time for them to come—become comfortable and do things with. Then we change and revise it, and then they have to learn those changes and revisions. It's a never-ending wheel of stuff. (Bartlett)
The nature of science teaching	Characterization	Not all teachers—I think I had continuing affirmation that not all teachers are really comfortable with messiness of science. (Jasper)
	Management	We try to give them some lessons that they can do really well......... 've written, possibly, 25 lessons or so. We've shared those. I've tried to write them at different levels so that the teacher can use those. She can use them in the classroom, or she can send them out virtually, and the kids can do it with parents, take pictures, and send it back. We've had a real positive return with people talking about how helpful that is. The teachers are using a lot of it in the classroom. (Hillman)
Intersection of equity with the other three dilemmas	Characterization	I think time, for one thing. Science requires some time to set up. Even if you have a separate science room, you have to take down from one class, and you have another group coming in. So many of our science classrooms—or even at the middle school—are not equipped. They don't have water—just the basics. That's a challenge for a teacher if you're in a room and it's nothing but desk and a board and the traditional stuff in the classroom. The kids need a place they can clean up stuff, they have place for storage, and then the teacher has to have some time to prepare. (Hartwell)

(continued)

Table 2 (continued)

Main Code	Subcode	Example(s)
	Management	Yeah, we didn't want to create a situation where parents would find their kid in a class that didn't have what the vast majority of the rest of the students on the campus had access to. To us and to me and across the board, it's really important that all kids have an equitable science-learning experience. We just put agreements in place that actually helped us skirt union aggrievances and agreements as well. Because it was a site agreed-upon initiative, we could ask teachers to share data. We could ask teachers to attend training as well as principals as well. We could ask principals to attend additional trainings that other principals were not required to attend. We have strong unions in Silverbay. There are different workload issues. (Silverbay)

Finally, we wrote analytic memos about each district, using the dilemma around prioritization of school subjects as a lens into the entangled work of dilemma management (Charmaz, 2014) because it surfaced the most frequently in our data and appeared foundational to the other dilemmas. Most frequently, the sidelining of elementary science was entangled with leaders' reflections on teachers and school leaders' comfort with teaching science, so we organized our coded data to focus on these two themes, with dilemmas related to equity and the nature of science teaching subsumed into these themes where they intersected. We identified three themes in how leaders managed the intersecting dilemmas—integration across disciplines, teacher specialization, and (commercial) curriculum adoption—and arranged our coded data within our analytic memos to reflect these approaches. These memos were then workshopped with the entire research team to triangulate across investigators and search for disconfirming evidence, including one-on-one consultations with the lead interviewer for each district. We also triangulated across data sources using documents and observations collected as part of the broader project, adding to our analytic memos at each stage, although we recognize that engaging these additional data sources at the outset, as well as a formal process of member checking, would likely have enriched our analysis.

Findings

Based on our analysis, we organize our findings as follows: First, we identify core dilemmas that system leaders grapple with, tied to the preferential treatment of ELA and mathematics relative to science, and in doing so argue that these dilemmas are fundamentally structural, embedded in the formal organization around school subjects and supported by system leaders' efforts to manage their institutional environment. Second, we examine system leaders' efforts to manage these dilemmas emerging from the preferential treatment of ELA and mathematics over science in their efforts to support improvement in elementary science education. In this section we discuss cases that (a) operate within distinctive institutional and organizational environments and (b) hold specific core instructional values; and we explore how these values shape the dilemma management approaches system leaders pursue as a result.

Dilemmas of Building Education Systems for Elementary Science: Coping With the Sidelining of Elementary Science

For system leaders, improving elementary school science poses several connected challenges, most prominently (a) getting attention on, and resources for, elementary science education; and (b) addressing teachers' and school leaders' lack of comfort in science instruction. We situate the preferential treating of ELA and mathematics over science at the intersection of system leaders' efforts to manage their environments and their school systems' structural arrangements. Specifically, we focus on two *interrelated* structural arrangements, rooted in school systems' efforts to manage their environments and contributing to the privileging of mathematics and ELA over science: test-based performance metrics, and teachers' preparation and support for elementary science instruction. Although less prevalent, we identified two further dilemmas related to (c) the nature of science teaching—in particular its material demands, its messiness—and dilemmas emerging from (d) the intersection of equity issues with the above dilemmas. Both dilemmas (c) and (d) emerged in intersection with dilemmas (a) and (b) above and are discussed as such in the findings: For example, the materiality of science instruction posed high demands for scarce resources in an institutional environment that prioritized acquiring ELA and mathematics resources, as well as on teachers' and leaders' knowledge and practice.

Getting Elementary Science on the Radar and Procuring Resources: The Pervasive and Pernicious Effects of Test-Based Performance Metrics

System leaders in 11 of the 12 systems argued that ELA and mathematics were prioritized over elementary science in terms of instructional time and institutional support, and the majority blamed test-based accountability measures in these two subjects. As a Silverbay leader stated, ''ELA really tends to drive the bus.'' A Jasper leader similarly noted that ''one area that I constantly battle with [is] the focus on literacy.'' A King Park science leader lamented, ''My biggest frustration is the conversation that I have to have every spring to defend why we should teach science and why we should continue to dedicate the same, if not more, time to teaching science.'' Reflecting on teachers not prioritizing science, a Brookeport system leader explained,

> The biggest challenge when we talk to teachers is time. It's really not time! It's what their priorities are, and especially in first grade, second grade, their priority still really has to be on literacy. We got to get those kids learning how to read. Time spent in the classroom doing literacy, foundational literacy skill stuff, is always going to be their priority. I would say that's the number one reason why teachers still say that they can't do science is because they just don't have time to do it.

For system leaders, the prioritization of literacy (and mathematics) constrained their efforts to support high-quality science instruction and build educational systems. This is a problem with deep structural and historical roots.

The focus on ELA and mathematics manifests in the asymmetric structure of the school day. State legislation in some states (e.g., Oklahoma) mandates instructional time for ELA and mathematics but not for science, and those system leaders need to manage this institutional environment as they design and manage science instruction. A Norhaven system leader explained that ''[while] there is some legislation that affects the amount of time [that] ELA and math have to be taught, there's not that same legislation for science,'' so time for science had to be scheduled within these constraints. ELA and mathematics are blocked and taught daily; but in many districts, science is taught in rotation with social studies, or within the ''special'' block, akin to art, music, and physical education. A Brookeport system leader explained,

> The instruction day is incredibly short. It's like a 6-hour day. When they're trying to fit in the literacy work, the math work, time for social-emotional learning, and—being able to squeeze the science in there is challenging. [A]lso for school leaders, they—the way at least now in a lot of schools, because science is taught within the specialty, the only way they can get more science is if kids get less of other things like art or music. That's not a battle you want to have with families.

This lack of attention to science creates a dilemma for system leaders intent on system building for elementary science as they balance their efforts to create time and space for elementary science while coping with parents', teachers', and school leaders' prioritization of ELA and mathematics *and* desire to have a broad elementary curriculum. So, while the NGSS presses ambitious demands with respect to instructional time for elementary science, these demands are not embodied in legislation or classroom practice; and, after all, it is impossible to improve the quality of science teaching if science is not taught in the first place.

Alongside procuring instructional time, system leaders also spoke about systemic differences in the central office-level support and social infrastructure available for science compared with ELA and mathematics. A Silverbay leader explained,

> ELA has always been the driver, mathematics second to that. Math, you can imagine, has much more staffing. For science, we've . . . had one individual that [was] supposed to support science TK [transitional kindergarten] through 12 and without a lot of resources do that job. It's pretty daunting . . . to roll out new standards, new trainings without a lot of resources as one person to represent [*laughter*] 6,000 teachers or 5,000 teachers.

This difference was reflected in other districts, particularly large urban districts where Title I funding was used for ELA and math staff. In Brookeport, 8 of the 12 of the instructional coaches focused on ELA, and only 1 had a science background. As the STEM director said, ''There'll never be a day when there are science coaches in every building.'' This asymmetry was not exclusive to urban districts, however. North Valley, a midsized suburban district, employed six literacy specialists to support schools, with no commensurate position for science.

This limited capacity in systems' central offices to support elementary science created new dilemmas for system leaders to manage as they implemented initiatives to prioritize science. A Silverbay system leader described the dilemma of implementing new curriculum materials:

> I don't know my teachers and I don't know their students as well as I wish I did. The challenge of getting to know all of the teachers and students that we work with is huge. . . . [How] can we build . . . that relationship in a way where teachers feel supported and that we actually can say we know what implementation looks like across the board? . . . I don't know how we're going to do that on a system level, but that would be my goal.

As both an effect of the historic sidelining of science, and a limiting factor in efforts to prioritize science, differences in central offices' and schools' resources contribute to the dilemmas system leaders face *and* refract upon the actions they can take to manage these dilemmas.

While the above illustrates that the sidelining of elementary science has deep structural and historical roots, the test-based performance metrics that emerge from, and bolster, these roots have themselves further sharpened the dilemma. System leaders in 8 of the 12 systems pointed to how test-based accountability, linked mostly to ELA and mathematics, posed a major challenge for reforming elementary science. A King Park leader explained,

> I think it makes it very challenging for schools even when they are invested [in science reform], and like the curriculum, and think the coaching is good, . . . when it gets close to a test and not freak out, and be like, ''We're not going to do this [science]. We've got to go all in on math and ELA.'' That's just a hard reality I think we have to face. Our [system] leaders—we have put a stake in the ground around math and ELA.

As this leader noted, even in schools working to improve science teaching, maintaining the focus on science is difficult, especially as standardized testing season approaches. Although science is tested in all states, it is often weighted less than ELA and mathematics in accountability mechanisms. A Hartwell system leader pronounced,

> Our biggest priority is just getting science education to be included . . . school administrators want to concentrate in literacy and mathematics. They will spend all of their time on that because you have the high-stakes testing. It . . . includes very little, science education. In Arkansas, we use Aspire Testing I would estimate that less than 10% of the questions have to do with science. As a result, we're on the backburner.

In Hillman, a charter network founded ''in opposition to standards'' according to one system leader, we might expect ELA and mathematics not to be privileged above science and social studies to the same extent as other systems. However, over the last 5 years the charter authorizer has placed Hillman under increased scrutiny, with some system leaders arguing for increased prioritization of ELA and mathematics. While science system leaders initially refused to engage in the sidelining of science, the use of performance data for ELA and mathematics as part of this external audit process has forced science leaders to capitulate. As policymakers hold leaders and teachers accountable for their performance on a handful of metrics tied to student achievement, mostly in ELA and mathematics, these subjects command teachers' and school leaders' attention, crowding out time and resources for science.

Performance metrics connect with and inform other structural arrangements, including routines for evaluating teachers and school leaders. A North Valley system leader explained that teachers were more likely to teach ELA or mathematics than science when being evaluated:

> When we do teacher evaluations, it is agnostic of curriculum and instruction focus, in the sense.........they've [teachers] gotten to choose when they've been evaluated........our K–6 people generally don't pick to be evaluated while they're teaching science unless they spend the bulk of their day teaching science.

School leaders' evaluations also center on ELA and mathematics, as a King Park system leader noted in describing the dilemma faced by the system's science leader:

> It puts the school leader in a hard spot when someone who's like, ''Why aren't you doing more science?'' When they're like, ''I have to stay—I'm up for [charter] renewal.'' It's a really tricky balance and I think one that we have not figured out. I don't really know that we will any time soon.

As this leader explained, because science is not a primary consideration in evaluating school leaders, it contributes to school leaders prioritizing ELA and mathematics as their own job security relies on these performance metrics. The sidelining of science in teacher and principal performance management routines contributes to the dilemmas that science system leaders struggle with in improving elementary science.

While the sidelining of elementary science is partly a function of the high-stakes incentives tied to ELA and mathematics achievement, the availability of student performance data in and of itself may also contribute to privileging ELA and mathematics. A Brookeport system leader expounded how readily available performance metrics contribute to focusing school leaders' and teachers' attention and time in school routines:

> I know that there's a lot of data collected around literacy . . . so that's how a lot of leaders look at what's happening in schools. That's the surface level. They can see the data. They can see how much progress has been made in the year. That's why it's a priority because it's easy to show progress.

For this system leader, the absence of similarly accessible data for science contributes to making the marshalling of evidence to demonstrate progress with science more difficult and, in turn, its sidelining. These arrangements are rooted in state and federal policies that that not only assess student performance in science less frequently, but either do not include science or include it less prominently in their accountability regimes, forming a subject specific institutional environment that leaders must manage in their system-building efforts. Incentives and sanctions aside, then, the mere availability of data contributes to sidelining of science.

System leaders argued that the inattention to elementary science and the challenge of procuring essential resources was largely due to test-based accountability linked to ELA and mathematics. These performance metrics are pervasive in that they impact the structural arrangements of districts, schools and classrooms, including school schedules, the distribution of leadership, and core organizational routines (e.g., teacher evaluations); and pernicious in that they define progress in terms of what is measured, excluding science in the process. While the preferencing of ELA and mathematics predates the accountability era, this movement has sharpened this dilemma for leaders engaged in system building in science.

The Comfort and Capability Challenge: Coping With Current and Past Efforts to Manage Institutional Environments

Leaders in 10 of the 12 systems reported that most elementary school leaders and teachers are less comfortable and less prepared to teach science compared with ELA, contributing not only to science not being taught regularly but also inattention to science in school and system organizational routines. Systems leaders identified this as a major challenge in their efforts to (re)build education systems to support elementary science.

System leaders depend on their institutional environment for essential resources, including teachers and leaders. Hence, system leaders must attend to their institutional environment, and they embed at least some of what they learn from managing their environments in their in their organizational arrangements over time, such as in the routines that structure leaders' and teachers' everyday work. Such learning is ongoing and, thus, must be understood historically. For example, system leaders shared how external teacher education programs impacted their efforts to improve elementary science. A Jasper system leader noted,

> I think one thing is just the teacher's comfort level in the content. Depending on the teacher training program that they've gone through, some may only have spent one class on elementary science. That doesn't get into the breadth of the content that teachers will be expected to address. . . . it's just the teacher comfort level compounded with time. The time to make them comfortable with those concepts.

This perceived lack of preparation to teach elementary science is heightened by the privileging of ELA and mathematics in providing resources for, and uptake of, PD. A Fairby leader reported,

> In terms of math and science, teachers don't feel confident enough. We have to build their confidence in both. That's similar. The difference is that they do need to know how to teach math. We can get them to come to PD [for math]. Science is harder to get teachers to come to PD.

Despite the need for PD being greater in science, time for professional learning is scarce, and teachers were more likely to devote time for PD on ''essential'' ELA or mathematics. In some systems, such as Hillman, system leaders even changed the marketing and messaging about science PD to avoid directly mentioning science in the hope of engaging elementary teachers. A system leader explains that ''we got some feedback around our science literacy day tomorrow where people said, 'Oh, you shouldn't call it science literacy. You should call it non-fiction literacy because then people will be more excited to learn about that.''' While this system leader notes that her ''jaw kind of dropped'' at this advice, she went along with the recommendation in the hope it would persuade more teachers to participate in elementary science PD. Moreover, as described above, system-level resources for supporting elementary science teaching, including central office leaders, are scarcer relative to ELA and mathematics, adding to the challenge of supporting the use of educational infrastructure, a key domain of system building, through PD.

Hartwell school district is an outlier in this case. As a small rural district, Hartwell engages an external provider to support teachers in developing and utilizing professional learning community (PLC) structures in ELA and mathematics. While the external partner did not engage with science, system leaders explicitly involved science teachers and used the model infrastructure from ELA and mathematics to develop a PLC structure for science. In this sense, Hartwell managed to leverage resources from prioritized subjects to provide PD for science.

Institutional environments that privilege ELA and mathematics for teachers often both reinforce and are reinforced by the subject specializations of principals, with ELA and mathematics expertise being important in selecting school principals. A Silverbay system leader explained,

> We have a lot of leaders that come from, especially an early literacy background. ....It's safest to go with what you know [*laughter*], and it's easiest for you to coach and to implement around things you know.

These specializations of elementary school staff, especially instructional leaders, contribute to the preferential treatment of ELA and mathematics over science. For system leaders, these circumstances created a dilemma about how to convince teachers and school leaders to invest time to a subject they collectively felt uncomfortable with and believed they lack capability with rather than subjects where they felt both capable and comfortable.

The comfort and capability challenge is deeply intertwined with the asymmetrical capacity for supporting science instruction relative to ELA and mathematics rooted in the institutional environment of test-based accountability. In Chester, for example, following NCLB in 2001, the central office was reorganized to make literacy the sole focus:

> The fact that they got rid of the curriculum department and only had the few people, and they were only focusing really on literacy, that's communicating to the schools what we are deeming as important.

Another Chester system leader explained that support at the district level for other content areas remained nonexistent until 2014, when math became a ''must teach'' subject, with science following in 2016. While the curriculum department was subsequently reintroduced, the interceding years limited teachers' opportunities to improve their science teaching iteratively through practice and experience. With the most experienced teachers in schools out of practice in teaching science, they may have been less able to support novice teachers in the district with their science instruction. In other words, a legacy of 14 years sidelining science had implications for contemporary efforts to build school-level capacity for science instruction.

The availability and regular use of performance metrics tied to student achievement in ELA and mathematics assessments and teachers' and school leaders' lack of comfort in science instruction contributes to prioritizing ELA and mathematics relative to science. Rather than assume that science is somehow inherently less important for elementary school children to learn, we show, based on our analysis, how the preferential treatment of ELA and mathematics over science is a social construction emerging at the intersection of system leaders' efforts to manage their institutional environments and their school systems' structural arrangements. To dwell only on the preferences of individual school and system educators is to fail to recognize how environmental constraints interact with organizational arrangements and fundamentally shape the work of education system building. Structural arrangements, such as core organizational routines that serve evaluative and agenda-setting functions, and professional development that privileges ''foundational'' subjects, reinforce and legitimize the privileging of ELA and mathematics relative to science in practice from the classroom to the system level and are reflected in time for science, distribution of instructional leadership, and opportunities for professional learning. This systemic privileging contributes to a series of dilemmas for those system leaders involved with reforming and engaging in system building for elementary science.

Managing Dilemmas: Integration, Specialization, and Curriculum Adoption

System leaders manage dilemmas of reforming elementary science, as distinct from solving them, using three coping strategies. One prominent dilemma management approach, observed in 8 of the 12 systems, involved integrating science instruction with ELA, and in some cases mathematics. Another dilemma management approach, used in five systems, involved differentiation by using science specialists to teach some or all science, or by departmentalizing so that teachers within a grade level took responsibility for different school subjects. A third dilemma management approach, explicitly acknowledged as a dilemma management strategy in three systems (and tacitly in another eight as part of system building efforts), centered on adopting elementary science curriculum as an attempt to prioritize elementary science and cultivate responsibility for teaching it in elementary classrooms.

Integration

In eight systems, leaders mentioned an integration approach in efforts to get time for elementary science. Specifically, system leaders reported working to persuade school leaders and teachers about the importance of teaching science by arguing that it could improve literacy and math skills. A Brookeport leader argued, ‘‘Science is the place where kids can apply what they're learning in math and ELA. Not only that, it can contextualize math and ELA learning.’’ A Silverbay system leader elaborated,

> What we've tried to do is not butt heads with [the focus on literacy], but also show that we can tie content into the literacy period by pulling in texts that are tied to the projects and the phenomena that we're trying to explore. We've actually seen a lot of teachers learning how to integrate inquiry throughout the day and then also using science texts.

A Norhaven system leader explained that ‘‘any time I can double count minutes for science and ELA, I call that a benefit.’’ For these system leaders, the integration strategy directly challenged technocratic notions of time as a zero-sum game such that time for science necessitates time away from ELA and math, and instead works to create space for science to grow with, in and through other subjects. Whether it does or not is an entirely different empirical question.

At the same time, efforts to manage dilemmas associated with the sidelining of elementary science surfaced new dilemmas for system leaders. In Bartlett, for example, while getting attention to elementary science by creating cross-curricular projects linked with ELA, concerns emerged about whether science learning goals were being addressed in practice.

> Ideally, . . . [cross-curricular inquiry projects will include] the science perspective on, say, weathering and erosion, or natural disasters, and then the social studies aspect will be, ‘‘How did society respond to that?’’ . . . The struggle is that we have [legislated reading time]. That means that . . . we can't have them do a lot of the reading and writing in ELA time that they would usually be able to do, so they do a little bit of it, but it's more ELA-directed than us directing it. Even the conversations they would have about it are about the literary part. The teachers actually have different groups for [science and] social studies and for ELA, different groups of kids at different times.

As such, integration did not ‘‘solve’’ the problem of instructional time for science. Instead, dilemma management efforts that focused on integration encountered the competing values of different decision-makers as well as the asymmetry of school subjects, in which learning goals relating to ELA were prioritized over those goals in science (including in how students were grouped), with ELA system leaders adopting the *de facto* leadership of cross-curricular efforts.

Not all school systems engaged in managing the dilemma of the sidelining of science through integration. In one system, Jasper, the science leader worked to avoid integration: During a science curriculum materials adoption process, she buffered members of the committee from publications that focused on integrating the teaching of science with reading. She explained,

> I choose carefully the articles . . . that talk about the doing of science because there's so much pressure to spend so much time in reading that not everybody is committed to the power of the doing part of science and then layering on the learning. Maybe we'll read something together, but the doing [of science] is as important. ''We are going to read science and respond to questions at the end of the chapter.'' We're not going to go back to doing that. Even if your day is stretched with trying to get everything in, we're going to do science with our students because this is what sparks commitment to learning.

Recognizing the pressure on teachers to focus on reading at the expense of science instruction, especially due to the state's version of a third-grade reading law and despite the focus on hands-on instruction in the NGSS, the system leader tried to ensure the materials Jasper's science adoption committee read did not center on integration. At the same time, she recognized that some compromise was necessary in managing this dilemma, so in selecting the [Grow Science] curriculum materials, the system also purchased the program's leveled readers. She explained,

> I bowed to a little bit—I wouldn't say it's pressure, desire—the [Grow] program comes with leveled readers. Now, fifth and sixth grade [teachers] did not want them, but K–4 wanted them, but we are not using them during science. We are using them during the reading block, or as an inquiry project and they're available to dip into, to grow, whatever you're researching for your inquiry-based investigation.

Compromise is central in managing dilemmas as system leaders attempt to balance competing values around what matters in students' learning.

Differentiation: Specialization and Departmentalization

Another strategy district leaders use to manage the dilemma is leaning into differentiation, as distinct from integration, with teacher specialization for elementary science. This involves either employing separate science specialists within schools to teach some or all science, or departmentalizing so that teachers within each grade level take responsibility for different content areas, including science. Five of the 12 school districts employed a specialization or departmentalization model in some elementary schools, and 1 other district reported considering this approach. A key motivation for this was that specialists can ensure that science is taught to all students, as a Brookeport leader shared:

> That's my concern, that making sure that every school has a science teacher limited to the grade level. The homeroom teacher that can teach ELA, math, and science is tough. Science never—is not given that kind of priority or attention that it deserves. We know that the suggestion and many hours of science a week is not done. If you give into a higher priority to ELA, mathematics, where do they have time for science if they don't have a science specialist that the kids can go to?

By designating a teacher for science who is not managing competing instructional priorities, system leaders argued that they could guarantee and protect instructional time for science and improve the quality of instruction. A science specialist model is ‘‘absolutely done with the best of intention,’’ a Fairby system leader explained, to ensure ‘‘elementary students would have science teachers who were trained in science and science that was learned in a lab.’’ For some district leaders, like this one, who saw science as intrinsically different from other school subjects and believed that NGSS-aligned science instruction required content expertise in ways that were both challenging and uncommon for elementary teachers, specialization was an attractive strategy.

Specialization was also attractive to the science leader in Norhaven, who argued that as a high-turnover district with weak central office capacity for supporting elementary science (just himself), a science specialist model would be effective:

> I looked at . . . [s]elf-contained. I looked at departmentalization. I looked at science specialists. I knew I wasn’t going to be able to do a science specialist because we’d never be able to commit the resources there. That’s what I’d really love to do. It cuts down the number of teachers that I would be responsible for doing PD for.

Constrained by limited resources, this science system leader established a Science Advisory Board, a representative subset of teachers who provided feedback from classroom teachers on how science instruction was progressing, consulted on proposed changes, and received more direct professional development to pass on subsequently to their colleagues in schools. The leader hoped that these teachers would act as ‘‘the science experts in their building,’’ an initiative he described as ‘‘moderately successful.’’ In doing so, this science leader compromised on his goal of having a specialist model, and instead designed a structure to support teachers in developing their science instruction. This was not a problem solved, but an ongoing strategy to manage the dilemma the leader faced in supporting many teachers with limited resources.

Even in districts using science specialists as part of their system-building efforts for elementary science instruction, structural factors still limited the extent to which science was prioritized. In King Park, science was taught by specialists in third, fourth, and fifth grade as these grades were departmentalized, and those specialists prepared students for the fifth-grade state science assessment. In K–2, homeroom teachers were encouraged to teach science once a week, but literacy instruction took priority; one system leader confided that ‘‘no one really teaches science in K-2 because it’s not required.’’ The legacy prioritization of literacy goals in structural arrangements shaped how central office leaders managed dilemmas to build systems for instructional improvement in science so as to work around established goals.

The science specialist coping strategy intersected with historical and structural arrangements in schools prioritizing ELA and mathematics. Specializing science instruction did not solve system leaders' problems with any finality but created new dilemmas to manage over time. For example, in King Park, a system leader lamented that science specialists were not treated the same way as literacy or math specialists:

> In elementary it feels very much like even science teachers that their job is focusing, mostly, on science, they're still pulled to do X or Y or to do this, or they have to sit in on this math training because they have to give this assessment, or something like that. That's just pulling them away from deeply knowing science and feeling respected, to be honest, as a science expert, as a deeply important part of the school team, and as an equal for other subjects.

For this leader, the differential treatment of science specialists undermined the point of departmentalizing in the first place, as it limited opportunity for genuine specialization.

In Brookeport and Fairby, different approaches to specialization across school sites were challenging for system leaders. In Brookeport, significant autonomy at the subdistrict and principal levels contributed to some schools having science specialists, others being departmentalized, and still others with teachers in self-contained classrooms. A system leader equated this autonomy with ''rolling the dice'' for students and their science learning:

> [Some schools use] a model I suggested where we, at least, group math and science together, and ELA and socials studies together, starting at Grade 3 so that we could get these teachers just concentrating on math and science and become the experts of math and science. Then the other teachers can be experts in ELA. Some principals like that idea, and some principals just keep it the way it is, and we just roll the dice and hope that they're spending the time and really implementing the curriculum.

In Fairby, this decision was left to teachers, who voted on the number of science specialists per school along with whether to hire a PE or music teacher. As a result, the roles of science specialists varied, with science specialists assuming full responsibility for science instruction in some smaller schools; whereas in others, specialists shared responsibility with classroom teachers or only taught certain grade bands. As the challenge of supporting science teaching varied across schools, and over time, the work of ensuring science was prioritized as part of system building efforts was renegotiated and managed from school to school and year to year. For system leaders, managing this dilemma was an ongoing aspect of their work.

Not all system leaders within these systems were enamored with science specialists as a means of prioritizing science. Some leaders critiqued how this model compartmentalized and limited science instructional time to time with the science specialist. For example, Brookeport is a large district with five science leaders, and their opinions diverged: While most system leaders advocated for the districts' specialization approach (as shown above), another leader lamented,

> In Brookeport [we] have this crazy model, I think, in elementary school where science is often taught by a science specialist so that the classroom teacher doesn't teach science and—but that also means the students only get science twice a week. The idea that students are only getting to interact with science just for two 50-minute periods a week is completely crazy.

Further, in Fairby, where science instructional time was formally split between science specialists and classroom teachers, leaders argued that having specialists tacitly legitimized some classroom teachers to not prioritize science. As one leader reflected,

> Yeah, I think [having science specialists] absolutely complicates [science teaching] because if I'm a teacher who loves science, I'm going to find ways to teach it in my classroom. If I'm a teacher who doesn't love it or is a little bit intimidated by it, it's easy for me to say, ''Well, I don't need to be teaching that in my classroom because they're getting that in the science lab.'' I do think there are situations where it means that there's less coverage by the person who is with them most of their day.

Another Fairby leader argued that this was not just about teachers lacking confidence in teaching science, but reflected the historic inattention to elementary science:

> I know that teachers are afraid of math, and they're afraid of science. Both of those. They have to teach math. They know that. They don't have to teach science, and they know that. They're supposed to teach science, but they have a science specialist, usually, who they can offload a lot of that to.

In using science specialists to get elementary science taught, then, Fairby leaders balanced two goals: (a) institutionalizing and protecting time for science instruction, and (b) providing opportunities for all elementary teachers to grow in experience and confidence teaching science. Balancing these competing value-laden goals required ongoing dilemma management.

Managing dilemmas with a science specialist approach is largely incommensurable with the integration strategy: One focuses on protecting and compartmentalizing science into specific spaces, at specific times, taught by specific people; and the other focuses on blurring the boundaries between science, ELA, and mathematics. When district leaders lean into one approach, other potential strategies become more challenging to leverage, if not impossible.

Systemwide Elementary Science Curriculum Adoption

Leaders in 11 districts discussed the central role curriculum materials played in their ongoing efforts to improve science instruction. In three districts, leaders explicitly described this as a means of managing dilemmas related to the prioritizing of science, and another four as an effect of district efforts to prioritize science. However, all 12 districts, including Lockeford, which had been unable to adopt the curriculum materials they had selected due to funding shifts at the district level, discussed the importance of robust curriculum materials for their instructional reform efforts. A King Park leader, for example, described the district's decision to adopt Catalyst, a commercial curriculum, as ''the first big investment in elementary science . . . [in] the history of King Park.'' While investments in curricular materials signaled a shift in institutional valuing of elementary science, other district leaders envisaged high-quality curriculum materials as a means of system building for science. As a Fairby system leader summarized, ''Curriculum alone doesn't drive the change in our district, but without it, change is really hard.'' System leaders talked both explicitly and tacitly about using curriculum materials as more than instructional resources for classroom teaching, but also as leadership tools. In this way, curricular materials as a component of education infrastructure served multiple purposes for system leaders, including to (a) coordinate instruction and provide accountability and (b) develop teachers' capabilities in science instruction, both important aspects of system building.

First, adopting curriculum materials was described as a way of improving accountability mechanisms to ensure science was being taught. A Fairby leader explained that ''now that we are doing an adoption and that . . . we do have new standards . . . we do have higher expectations. We always talk about accountability.'' Similarly, in North Valley, the central office monitored whether the science kits that teachers received as part of curriculum materials were being used:

> If the boxes aren't used, I get a report. Then I call the principal and say, ''Hey, help me understand. What's going on with this particular teacher? Is it that I'm ordering too many [kits]? Is this teacher no longer teaching science, or are they not teaching in your building? What's going on?'' We had a couple of those conversations early on in that 1st year. Then in the 2nd year. And now we don't have those conversations anymore.

In this way, adopting curriculum materials that teachers could be held accountable for using provided a mechanism for monitoring whether teachers and principals were prioritizing science in their classrooms and school buildings over time. As a Brookeport leader shared, ''I think there's such an emphasis on curriculum because that's the way we can control and know what's being taught.'' For these leaders, the curriculum materials them did not solve the problem of getting science taught, but provided a mechanism for managing the dilemma over time.

Second, instructional materials were seen as central to supporting elementary teachers with their science teaching. One Brookeport system leader shared,

> When I went to the [Puzzle Science] training, I said to myself, ''This is unbelievable.'' They have taken all the guesswork out of here. They have taken everything that we have complained about with regards to science instruction, and they have made it so easy for teachers and to meet the level of every single student that we have because we have such diversity in Brookeport. I love it.

In this way, curriculum materials were positioned as a means of enabling all elementary teachers to teach high-quality science lessons. Another Brookeport leader elaborated,

> As a new teacher, a substitute teacher, even a teacher that's been there for 20 years but just is not knowledgeable in . . . science, [it makes a difference] having the support network, the curriculum there, having the materials ready to go.

As the logic of differential treatment for ELA and mathematics is deeply entangled with the assumption that elementary teachers are neither comfortable with nor capable of teaching science, these system leaders argued that providing teachers with the resources to be successful undermined the sidelining of science.

For system leaders, curriculum materials alone, however, do not guarantee that science is prioritized; PD around the use of the materials and a way of understanding if and how the materials are being used by teachers is also essential to this dilemma management strategy. As a Bartlett system leader explained,

> I walked into this classroom yesterday, and . . . one of the challenges or worries for me is putting [this curriculum] out there, but is it actually working? Is my curriculum guide—are things ebbing and flowing? Are students actually absorbing and learning what they're supposed to? I'm seeing bits of that, but I think it's still early in our stages where we are. I guess a challenge is, how do we as a district—how do we assess if science is doing well, and how is that value placed within the community? I feel like that's a challenge—a little bit of a challenge.

In terms of system building for elementary science, building educational infrastructure alone is not a ''one-and-done'' problem-solving strategy, but supporting the use of that infrastructure in practice, by monitoring, making tweaks and edits, and designing and implementing PD, is part of managing the dilemma over time. Given the historically weak resourcing for elementary science in central offices, ongoing efforts to support the use of curriculum materials were also comparatively demanding for system leaders in science, with system leaders in the larger school districts struggling to build relationships with all teachers and support them, and many leaders leaning on the commercial curriculum providers to provide this PD for teachers.

One challenge with using curriculum materials to prioritize science recognized by district leaders was that the instructional time allocations within commercial curriculum materials interfered with institutionalized norms for instructional time for ELA and mathematics. For example, in Silverbay, one system leader noted that a challenge in the implementation of novel science curriculum materials designed in-house was the new ''huge'' ELA curriculum in the district. This forced system leaders to make adaptations to the curriculum materials to provide further opportunities for integration. System leaders in many districts adapted curriculum materials and provided teachers with guidance over what to prioritize in instruction. While a system leader in Lockeford was concerned about making changes to the materials before having taught the program with fidelity, the Brookeport central office produced a guide identifying the most essential lessons from their [Puzzle Science] curriculum. While the guide supported teachers in adapting the materials in a systematic and coherent way, it also lowered institutional expectations around instructional time for science by legitimizing a ''minimum requirement.'' As in the integration and specialization strategies, district leaders using curriculum materials to prioritize science system building need to manage the competing demands of established systems for ELA and math, which entails making compromises.

Finally, some system leaders were concerned about the wider connotations of relying on building educational infrastructure, through designing and procuring curriculum materials, as a mechanism for prioritizing science. A Silverbay leader shared her concerns that overly scripted curriculum materials, given a context of limited capacity in the central office for communication and observation, made it hard to know whether teachers are developing their capacity as teachers of science, and modifying resources to make them suitable for their own students, or simply handing out the resources provided by the central office:

> I never wanted what we created to be like here's your curriculum. That's been the narrative of the past. Here are your tools. Here are your resources. Go teach. I want this to be, hopefully, something they feel like, okay, this is a great resource I can use and make my own and help teachers change their practice through using the curriculum, but also adding what they feel is best to meet the needs of all their students.

So, while curriculum materials provided immediate support for teachers who were not confident in teaching elementary science, system leaders were worried about the effects of focusing on distributing resources rather than explicit capacity-building work with teachers for the longevity of their system-building efforts. The competing values of improving science instruction rapidly through distributing materials and prioritizing teachers' learning and development highlight another dilemma that emerges as system leaders engage in system building.

The three dilemma management strategies described here are themselves value-laden, with system leaders choosing strategies based on their beliefs about and goals for science learning. For example, Jasper was deeply committed to science as intrinsically different to ELA and mathematics, and they have been prioritizing hands-on science instruction for the last two decades. While this might suggest they would opt for science specialists, the system leaders were also deeply invested in a generalist model in elementary schools, a commitment reflected in their organizational structure: All instructional coaches in elementary schools worked across subjects, with one director of teaching and learning and one assistant director in the central office responsible for instructional leadership in all content areas, PK–12. Given these twin values that effectively invalidated integration and specialization as management strategies, Jasper instead leant heavily on commercial curriculum materials that they saw as both reflecting their vision for hands-on science instruction and supporting generalist elementary teachers in enacting that vision in their teaching as central to their system building efforts. Where these values are not incommensurable, these management approaches can also be combined. As we saw in Silverbay, for example, integration and the creation of instructional time were central aims of their curriculum redesign efforts, shaping how they designed instructional materials. However, this combined approach can, and does, prove a heavy burden on system leaders as they manage the resulting dilemmas that emerge from their ongoing approaches to dilemma management.

Discussion and Conclusion

Over the past half century, federal and state educational policies (e.g., Systemic reform, Race to the Top) have prompted local school districts to engage in education system (re)building and contributed to promoting technical-rational notions about problem solving while limiting attention to the dilemmas with which educators grapple in practice. Dilemmas denote situations in which choosing one course of action over another is difficult because they are roughly equally (un)desirable, requiring system leaders to compromise on some core values (Cuban, 2001; Lampert, 1985). We documented how managing dilemmas is central to system building for elementary science and how these efforts must be appreciated in relation to system building for other school subjects and efforts to manage institutional environment(s) that systems depend on for their legitimacy and key resources.

Our contributions are fourfold. First, focusing on elementary school science, we build on existing literature (see Coburn, 2001; Cohen et al., 2018; Stornaiuolo et al., 2023) to show how the dilemmas involved in education system building are school subject–sensitive. Hence, work on education system building must take the school subject seriously in theorizing the nature of system building work. Furthermore, considering the scarcity of research on system building in elementary science, our study provides important insights into the nature of that work, the dilemmas system leaders grapple with therein, and how they manage these dilemmas.

Second, though the dilemmas of education system building are subject-specific, our account uncovers how these elementary science–specific dilemmas emerge in relation to and in interaction with education system building for other school subjects. While the school subject matters, the nature and origins of subject-specific dilemmas can only be understood in interaction with system building for other school subjects, especially ELA and mathematics. As such, we argue that the successful enactment of elementary science reforms will require close attention to how the dilemmas and dilemma management strategies for science are deeply entangled with other school subjects. While earlier work on dilemma management centers on the work of individual educators (see Cuban, 2001; Lampert, 1985; Spillane & Sun, 2020), by focusing on the system our account documents how the dilemmas of education system building emerge in the distributed practice of multiple system leaders as they engage in the joint work of organizing and managing instruction not only in science but also in other subjects, as seen above in the dilemmas they encounter in blocking time for science instruction and PD, selecting and adapting curriculum materials, and coping with asymmetric resources in the central office.

Third, the dilemmas we document are not entirely a product of system leaders' (limited) capability, unwillingness to reform, or personal preferences and values. Rather, these dilemmas emerge in system leaders' efforts to manage their institutional environments *and* the legacy organizational arrangements that enable and constrain their everyday practice (Cohen et al., 2018). Specifically, while literature has identified managing environments as a core work domain of education system building (Datnow et al., 2022; Peurach, Cohen, et al., 2019; Spillane et al., 2019), our account adds two contributions. First, we show that managing the institutional environment differs by school subject *and importantly* that efforts to manage the environment around one subject (e.g., testing and parental expectations for ELA) are critical to understanding dilemmas and dilemma management for other subjects, including science. Second, to understand relations between institutional environments and the work of education system building, we must move beyond the *here and now*; that is, we need to examine how systems' past attempts to manage their environments are embedded in their current organizational arrangements and structures, thereby enabling and constraining subsequent system-building practice, often in ways that are taken for granted (see Cohen et al., 2018, for a subject neutral account). System leaders' accounts document, for example, how test-based accountability regimes that focus on mathematics and ELA have become deeply embedded in their organizational structures—school schedules, distribution of leadership, and core organizational routines (e.g., teacher and principal evaluations)—contributing to asymmetry in motivation and capacity for supporting system building for elementary science compared with ELA and mathematics. These historic structural and organizational arrangements, in turn, shape the everyday practice of leaders and teachers that contribute to reproducing the preferencing of ELA and mathematics and the dilemmas therein for system leaders eager to reform elementary science. As such, the dilemmas system leaders face in system building for elementary science are in part a response to their efforts to manage their institutional environment historically.

Hence, the challenge for policymakers, intent on reforming elementary science, is not simply about changing the values and building the capability of individual system leaders but also addressing the structural arrangements that shape system building. Deliberations about dilemmas often focus on their discrete manifestations—for example, in science education, stakeholders highlight issues like instructional time or limited PD opportunities (NASEM, 2022). While these issues matter, we argue, based on our account, that it is paramount that these manifestations of dilemmas are analyzed and understood in terms of the layered and interconnected structural arrangements within and beyond local education systems. Focusing only on the preferences of individual educators, such as elementary teachers' discomfort with teaching science, fails to recognize how system leaders' previous responses to environmental conditions interact with organizational arrangements to shape education system-building work. Indeed, Cohen and Mehta (2017) have argued that systemwide reform has predominantly been successful when reformed instruction did not require deep transformation from past practice. But the NGSS does demand such deep changes (Schwarz et al., 2017), and our study further contributes that system leaders' attempts to reform instruction under these conditions gives rise to layered, complex dilemmas to manage. Paradoxically, policymakers' past policies often create local conditions that stymie local efforts to respond to policymakers' most recent reform efforts.

In attending to the underlying, often messy, contingent, and complex local conditions that are necessary to consider in negotiating and theorizing the nature of problems, dilemma management provides a framework for thinking about instructional reform alongside a CI approach. While CI foregrounds the cyclical process of problem definition, iteration, and satisficing of local demands (Yurkofsky et al., 2020), dilemma management foregrounds the value-laden nature of decision-making in educational system building (Cuban, 2001). Used together, attending to dilemma management can support education reformers in avoiding the tendency towards relying on a pragmatic form of organizational legitimacy focused on evaluating initiatives based on their expected value for, responsiveness to, and/or disposition toward particular stakeholders (Spillane et al., 2019). For example, local policymakers advocating for high-stakes test-based accountability in elementary science foreground pragmatic legitimacy by arguing that testing needs to be introduced to get science taught, not because the testing has any intrinsic value. By highlighting the moral compromises leaders and teachers must make in the work of education system building, dilemma management pushes practitioners and policymakers to aim for moral legitimacy: evaluating potential approaches based on whether they are just and striving to satisfice both pragmatic and moral goals. In this way, coupling a CI approach with dilemma management creates an opportunity for a form of principled CI by centering on local problems, engaging diverse practitioner and stakeholder voices on issues of moral legitimacy, and grappling with the complex underlying system of conditions that contribute to problems including dilemmas (Ishimaru & Bang, 2022; Ishimaru et al., 2018; Yurkofsky et al., 2020).

Fourth, our analysis extends the literature on dilemma management by showing how managing dilemmas is also central to the practice of education system building in the central office. We showed, for example, that as system leaders engage in system building around building educational infrastructure by purchasing robust curriculum materials, new dilemmas emerge as leaders struggle to support teachers in using these materials with PD and in-class support. We also showed how teacher specialization as a way of managing teachers' lack of comfort teaching science and ensuring instructional time for science can limit other commensurate efforts, such as school subject integration. As such, system-building efforts in one domain contribute to new dilemmas in other system-building domains.

Implications for Practice, Policy, and Research

Our account suggests that system and school leaders need opportunities to learn about distinguishing dilemmas from problems and, more important still, to learn about managing dilemmas and appreciating how this differs from problem solving. System leaders must learn to live with and *lead with* the uncertainties integral to system building and the dilemmas that emerge. Such opportunities should focus not only on developing local educators' dilemma management strategies but also helping system and school leaders appreciate that managing dilemmas is about *coping with* them over time, and that any one dilemma management strategy (e.g., specialization, integration) will likely contribute to other dilemmas that they will also have to manage. Such learning opportunities should be integrated into the preparation and ongoing professional learning opportunities offered to system leaders.

A potentially powerful, albeit school subject–neutral, framework for such learning, involves embracing, engaging, and enlisting uncertainty in the work of leading education system building (Yurkofsky & Peurach, 2023). Recognizing that uncertainty is contradictory, contingent, and dynamic, they advocate engaging the environmental, technical, and representational paradoxes central to system building and enlisting them in leading. System leaders would need to learn both to mitigate and to leverage uncertainty—and under what circumstances—to organize, maintain, and (re)build education systems. In our analysis, many system leaders prioritized mitigating technical uncertainty by adopting comprehensive curriculum materials that privileged some instructional goals, such as integration with ELA or hands-on and practice-based science instruction. At the same time, system leaders need to learn about and when to leverage uncertainty, embracing and engaging it to disrupt existing structural arrangements and rebuild education systems in ways that transform instruction. It is not a matter of either/or but rather an ongoing dynamic dance between the two strategies (Yurkofsky & Peurach, 2023). In addition, drawing on our analysis showing that the school subject matters for the uncertainties and dilemmas system leaders face, we argue that professional learning on when to mitigate and leverage uncertainty in education system building should take a subject-specific stance, including opportunities in elementary science. Moreover, such professional learning opportunities would benefit from engaging leaders in learning by comparing between education system building efforts in two or more school subjects.

Such efforts have implications for policymaking—local, state, and federal—ensuring that education policymaking moves beyond the reliance on technical-rational frameworks that have dominated for several decades and fixate on finding the one ‘‘best’’ means to achieving a given and often uncontested end. Moving forward, policymakers at all levels will need to embrace a broader array of frameworks that acknowledge and engage with uncertainty around values in decision-making and not only acknowledge but embrace the dilemmas that permeate education system building (Ishimaru & Bang, 2022; Majone, 1989). Further, districts need to rethink the *subject matter siloed approach* that has dominated their instructional policy-making work if they want to engage authentically in managing dilemmas. Reimaging instructional policymaking to embrace multiple school subjects simultaneously and acknowledge the interactions among them will be important if local policymakers are to engage seriously with dilemma management.

Our analysis also has implications for research, and we argue for more research that examines the dilemma management work systems leaders engage with in building education systems, in particular school subjects. Such work should be sensitive to the unique challenges of education system building for each subject while attending to how education system-building efforts in one subject interact with system building for other subjects. Such work would offer an important antidote to research centered on technically rational problem solving. Our account suggests that the field might benefit from comparative research that systematically compares education system-building work in two or more school subjects. Furthermore, we argue that including subjects like science, social studies, physical education, art, and so on is important, as focusing only on ELA and mathematics is likely to obscure the ways system-building efforts in those subjects are privileged by structural arrangements and legacy efforts to manage their institutional environments. Such work could generate rich empirical knowledge on the challenges of education system building, in particular school subjects, and help us understand the similarities and differences in dilemmas and dilemma management work across subjects as well as how that work intersects across subjects. A key component of this research agenda could focus on generating practical knowledge about the work of dilemma management in education system building, creating a subject-specific knowledge base that system leaders could use to inform their everyday practice (Peurach, Foster, et al., 2022; Yurkofsky & Peurach, 2023).

Notes

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