For States, by States: State Policymakers' Efforts to Reform Elementary Science Education

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Acknowledgements

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

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Abstract

Developing as a national policy movement, the "for states, by states" approach to the development and implementation of the Next Generation Science Standards (NGSS) intends to give states formidable discretion in whether and how to pursue science education reform. This article explores how state education agencies (SEAs) engaged with these national efforts and worked to incentivize and support school districts in building educational infrastructures to promote the instructional vision advanced by the NGSS. Based on our analysis of interview data and documents from 18 SEAs, we document the critical challenges SEAs face in reforming elementary science education and detail how SEAs sought to school districts in bridging from standards, assessments, and accountability to the teaching, learning, and organization of instruction inside classrooms. Given our analysis, we argue that the school subject is a critical explanatory variable in understanding SEA efforts to support the implementation of ambitious learning standards and advance a reframing of the relationship between state/federal government policy and local school districts as educational system-building. This study contributes to the growing research base on the role of state policy in supporting the implementation of ambitious learning standards.

Keywords: instructional reform, educational infrastructure, educational system, state education agency, NGSS

Introduction

The Next Generation Science Standards (NGSS; NGSS Lead States, 2013) and the accompanying *Framework for K-12 Science Education* (National Research Council, 2012) from which the standards were developed represented a new iteration of standards-based reform. Specifically, evolving as a national (rather than federal) policy movement, the "for states, by states" approach to developing and implementing the NGSS intended to give states formidable discretion in whether and how to pursue science education reform (NGSS Lead States, 2013). Like other standards-based reform efforts, such as No Child Left Behind Act (NCLB) and Common Core State Standards (CCSS), the NGSS set expectations for what students should know and be able to do. Unlike some standards-based reforms, however, the NGSS centered on state discretion, rather than federal mandate, in organizing and implementing the reform of elementary science education.

Scholarship on instructional reform in science and other subject areas over the past three decades points to the central role of educational infrastructure to school districts' efforts to improve instruction in ways that are responsive to ambitious learning standards (e.g., Cohen et al., 2013; Cohen & Spillane, 1992; Elmore, 1995; Hopkins & Woulfin, 2015; Penuel, 2019; Peurach, 2011; Peurach et al., 2019). Educational infrastructure refers to the structures and resources school districts mobilize to support and improve instruction (Cohen et al., 2018; Hopkins & Spillane, 2015; Johnson et al., 2014; Peurach et al., 2019; Spillane et al., 2019). Within this body of research, a recent line of scholarship documents how leaders in school districts (re)build and deploy educational infrastructures in the effort to guide, support, and improve a vision for instruction, sometimes in response to standards-based reform policies (e.g. Austin et al., 2006; Cohen et al., 2018; Johnson et al., 2014; Marsh et al., 2005; Peurach et al., 2019; Spillane et al., 2019; Weast, 2014). (Re)building and deploying educational infrastructures is central to the work of educational systems-building—that is, school districts' efforts at re-organizing around their core educational function – instruction (Peurach et al., 2019; Spillane et al., 2019).

With regards to implementation of the NGSS, a challenge for states, then, involves priming and supporting school districts in (re)building their educational infrastructures to support the teaching of elementary school science. Increasingly, state education agencies (SEAs) are playing a larger role in policy implementation given the new demands of standards-based reform (Brown et al., 2011; Herrington & Fowler, 2003; Timar, 1997; VanGronigen et al., 2022; Weiss & McGuinn, 2017). These organizations, however, continue to be lean and under resourced with respect to the demands of their new roles (Brown et al., 2011; Jochim & Murphy, 2013; Sunderman & Orfield, 2007; Weiss & McGuinn, 2017) and vary in their capacity and motivation to support school districts in policy implementation (Weiss & McGuinn, 2017). Despite these realities, state-level actors, nevertheless, will play an important role in efforts to implement the NGSS. This is particularly true in elementary science where, absent federal policy incentives, state-level actors have broad discretion over whether and how to pursue science education reform.

In this study, we explore whether and how SEAs incentivized and supported school districts in (re)building educational infrastructures to support the instructional vision advanced by the NGSS and *Framework for K-12 Science Education* (hereafter referred to as the *Framework*). We focus on elementary science because of the unique challenges of standards implementation in this subject area, namely the recent focus of federal and state reform efforts on English language arts (ELA) and mathematics (e.g., NCLB, CCSS) and the limited instructional time historically dedicated to science teaching in elementary classrooms (Blank, 2013; Plumley, 2019). With the SEA as the unit of analysis, we compare how 18 state governments engage school districts in (re)building and deploying educational infrastructure to support elementary science education. Our findings contribute to a growing research base on the role of state policy in supporting the implementation of ambitious learning standards. Specifically, this paper explores (a) what challenges SEAs perceive in implementing ambitious learning standards for elementary science education and (b) how, if at all, SEAs attempt to bridge from standards, assessments, and accountability to the teaching, learning, and organization of instruction inside classrooms.

We begin by anchoring our work in the literature on intergovernmental relations and instructional reform. Next, we describe our cross-case research design and methodological approach. We then develop and support two main claims based on our data analysis: First, SEAs face two central challenges - motivating local education leaders and teachers to engage with reforming elementary science education and building the capability of teachers and school leaders for improving elementary science. Second, in addressing these challenges, whereas all states developed standards, assessments, and (to a lesser extent) accountability mechanisms many states went further to support school districts in connecting these standards and assessments with classroom teaching and learning by mobilizing three key instruments - high-quality instructional materials (HQIM), professional development opportunities (PD), and codified messages.

Analytic Framework

Our analysis is motivated and framed by the literature on intergovernmental relations and instructional reform. We draw on the concept of educational infrastructure to reframe how state governments engage (or not) school districts in large-scale, standards-based instructional reform efforts in elementary science education. While some have argued for thinking about the relationship between state government policy and school districts as “interactive policymaking” rather than policy implementing (Spillane, 1996), we frame the relationship in terms of educational infrastructure building (Spillane, et al., 2022). School districts engage in educational infrastructure building when they purchase or design instructional programs, support the enactment of these programs by creating professional learning opportunities, and work to manage and monitor the success of their improvement efforts.

Intergovernmental Relations

The U.S. political system was designed to frustrate the centralization of power by dividing authority within and among local, state, and federal governments thereby constraining the coordinated action of any central government (Kaufman, 1969). While state governments have all the constitutional authority for education, historically they have delegated most authority to local government (Cohen & Spillane, 1992; L. M. McDonnell & McLaughlin, 1982). Despite these segmented governance arrangements, federal and state governments have become more active in making instructional policy over the past several decades (e.g., No Child Left Behind, Common Core State Standards, Every Student Succeeds Acts), defining learning standards and using test-based accountability to hold local districts and schools accountable for student achievement (Mehta, 2013; M. S. Smith & O’Day, 1990). Still, more educational policymaking at the federal level has contributed to an increase rather than a decrease in policymaking at the state and local government levels (Cohen, 1982; Fuhrman & Elmore, 1990; Sunderman, 2010). It has also contributed to the expansion of a vast extra system of interest groups and non-governmental organizations that offer services critical for implementation including curricular materials, student assessments, and professional development (Burch, 2009; DeBray-Pelot & McGuinn, 2009; Marsh & Wohlstetter, 2013).

Intergovernmental relations, then, continue to be a key consideration in analyzing the implementation of instructional policy because policies *enacted* at any one level (e.g., national) can face major implementation hurdles at 'lower' levels (e.g., state or local). This was evident most recently in the case of the Common Core State Standards (CCSS) where the politics around developing the CCSS were relatively smooth, but state and local implementation were much more contentious as the number of decision venues and interest groups expanded (McDonnel & Weatherford, 2016).

Policy scholars have focused on the policy instruments that different levels of government use to influence one another and street-level work. Specifically, this approach examines how interdependent mechanisms, such as authority, markets, and persuasion, exercise influence and promote social coordination (Bardach, 1977; Burch, 2009; Lindblom, 1982; McDonnell, 2009; McDonnell & Elmore, 1987; Weiss, 1990). While we draw on these mechanisms broadly in this study, we take a somewhat different perspective by reframing the work of school districts as educational infrastructure building and focusing on the efforts of state governments to incentivize and support this work for elementary school science education.

Educational Infrastructure Building

Scholarship over the past three decades underscores the central role of educational infrastructure to school districts' efforts to improve teaching and learning (e.g., Cohen & Spillane, 1992; Elmore, 1995; Cohen et al., 2013; Peurach, 2011; Hopkins & Woulfin, 2015, Peurach et al., 2019). Recent research documents how leaders in local school systems respond to systemic reform policies by (re)building and deploying educational infrastructures in the effort to guide, support, and improve a vision for instruction (e.g. Austin et al., 2006; Cohen et al., 2018; Johnson et al., 2014; J. Marsh et al., 2005; Peurach et al., 2019; Spillane et al., 2019; Weast, 2014). (Re)building educational infrastructure involves establishing formal positions, procedures, routines, materials (e.g., curricula, student assessments) and norms that support instructional improvement, as well as the coordination and alignment of these different elements and system-wide efforts to support their use in schools (Cohen et al., 2013; Hopkins et al., 2013; Peurach et al., 2019; Peurach & Neumerski, 2015). Other core functions of educational infrastructure include creating PD, monitoring instructional quality, and leading and managing instruction (Johnson et al., 2014; Peurach et al., 2019; Spillane et al., 2019). In (re)building and deploying educational infrastructures, school districts move beyond operating as administrative entities and toward more instructionally focused education systems that engage centrally with guiding, supporting, and improving instruction (Austin et al., 2006; Cohen et al., 2018; Johnson et al., 2014; Marsh et al., 2005; Peurach et al., 2019; Spillane et al., 2019; Weast, 2014).

We can think about the components of educational infrastructure in terms of exo- and endostructure (Cohen & Mehta, 2017; Duff et al., 2018). Whereas the exostructure refers to standards, assessments, and accountability, the endostructure refers to teaching, learning, and the organization of instruction. One critical challenge in building educational infrastructure involves designing and mobilizing the "instruments" that connect the exo- and endostructure: These instruments include things like curriculum, teacher education, funding, school and system organization, and leadership (Cohen & Mehta, 2017). With reference to standards-based reform broadly, Cohen and Mehta (2017) argue that reformers worked on the assumption that crafting an exostructure would prime and support a transformation of schools' endostructure of teaching despite a failure to develop and deploy the instruments to connect the two.

With respect to supporting the implementation of the NGSS, then, the challenge for SEAs can be framed as priming school districts to build educational infrastructures to support the teaching of elementary school science. For most schools, new and ambitious learning standards, such as the NGSS, challenge teachers and school leaders to depart, quite markedly, from highly institutionalized methods, norms, and routines of teaching and learning to more ambitious instructional practices. This shift requires teachers and leaders to unlearn and relearn a great deal to enact these new instructional ideals (Cohen & Barnes, 1993). Research on both ambitious science instruction and standards-driven instructional reform in ELA and mathematics suggest that all but a small number of unusually capable teachers will need considerable support in transforming instruction to enact the learning ideals of the NGSS (Blumenfeld et al., 2000; Cohen & Ball, 2007; Cohen & Hill, 2001; Duke, 2000) and that all but a small number of unusually capable schools will need support in developing the capabilities of their teachers (Spillane et al., 2016, 2018). The development of an exostructure alone is unlikely to produce the desired or intended changes in the endostructure of teaching. Rather, teachers and schools will need help to actualize the aims of ambitious learning standards and that will depend in important measure on their school districts' educational infrastructures for science education.

The challenge of actualizing ambitious learning standards is particularly acute in elementary science because most federal and state reform efforts over the past several decades have focused on ELA and mathematics (e.g., NCLB, CCSS). Because ELA and mathematics have long dominated the elementary school curriculum (Banilower et al., 2018; Marx & Harris, 2006), the national efforts for ambitious teaching in elementary science puts new pressures on teachers, schools, and districts. These pressures are even more demanding considering the limited instructional time historically dedicated to science in the elementary classroom (Blank, 2013; Plumley, 2019). Compared to ELA and mathematics, then, state and local governments are likely to encounter unique challenges in improving elementary science.

A key issue, then, concerns whether and how SEAs are working to incentivize and support school districts in building educational infrastructures to support the instructional vision advanced by the *Framework* and the NGSS. We ask two research questions:

1. What challenges do SEAs perceive in implementing ambitious performance standards for elementary science education?
2. How, if at all, are SEAs working to bridge from the exostructure of standards, assessments, and accountability to the endostructure of teaching and what instruments are they using in this work?

Methodology

This study is part of a larger, five-year National Science Foundation-funded study exploring the work of developing coordinated school- and system-level elementary science learning environments in response to the *Framework* and NGSS. The analysis reported in this paper is based on data collected in the first year of the project that focused on state-level efforts to improve elementary science. We used a qualitative, cross-case design of 18 SEAs to explore state-level policy and practice around elementary science education.

Sample Selection

We selected a diverse sample of states that varied along a set of dimensions in order to sample across a range of state-level policies and practices for elementary science. We began our sample selection by asking experts and leaders in elementary science to identify leading states and individuals engaged in elementary science reform. Using a snowball sampling method, we gathered nominations and input from 62 elementary science leaders. We then ranked the states based upon number of nominations to identify those states that had more and less active environments for elementary science as identified by leaders in the field.

We developed a comparative matrix of all 50 states and the District of Columbia that included data in the following categories: type of science standards, number of nominations, population, geographic location, political leaning, and whether the state served as a lead state in the development of the NGSS. Using this data, we selected a diverse sample of states. We first varied our sample based upon the type of science standards in each state by including (a) states that adopted the NGSS, (b) states that did not adopt the NGSS but developed standards based on the *Framework*/NGSS, (c) states that were in the process of revising their standards based on the *Framework*/NGSS, and (d) states that had neither adopted the NGSS nor developed standards based on the *Framework*/NGSS. We then varied our sample based on number of nominations, population, geographic location, and political leaning (Table 1).

Data Collection

We conducted nineteen 60-minute, semi-structured interviews with 22 state science coordinators (SSCs) in 18 SEAs.[1] We collected a range of publicly available documents including state science standards, curricular resources, implementation guidance and tools, and other resources identified by participants as important to elementary science. We also conducted a review of SEA websites to gather data on publicly-available elementary science resources and information provided by these agencies.

[1] In three states, we interviewed more than one science coordinator at a time, and in one state, we interviewed two science coordinators separately.

Table 1: State Characteristics

State	Type of science standards	Number of nominations	Population **	Geographic location ***	Political leaning ****	Lead state
1	NGSS adopted	29	large	West	Democratic	x
2	NGSS adopted	18	large	Midwest	Democratic	x
3	Framework-based	16	mid-sized	South	Republican	
4	Framework-based	16	mid-sized	South	Republican	
5	NGSS adopted	14	large	West	Democratic	x
6	Framework-based	14	large	East	Democratic	x
7	Framework-based	9	small	Midwest	Republican	
8	NGSS adopted	8	small	East	Democratic	x
9	NGSS adopted	8	mid-sized	Midwest	Republican	x
10	NGSS adopted	7	mid-sized	South	Republican	x
11	NGSS adopted	7	large	East	Democratic	x
12	Framework-based	4	mid-sized	Midwest	Republican	x
13	Framework-based	1	mid-sized	Midwest	Republican	
14	Framework-based	1	large	West	Democratic	x
15	Under revision	1	large	East	Split	
16	Framework-based	0	small	Midwest	Republican	
17	Under revision	0	large	South	Republican	
18	Neither NGSS/Framework-based	0	large	East	Democratic	

* At the time of this study, 20 states had adopted the NGSS, 24 states had developed their own science standards based on recommendations in the *Framework*, and six states had science standards not based on the NGSS or the Framework.
** Large states include those in the top one third in terms of population, mid-sized states include those in the second third of population, and small states include those in the bottom third of population.
***Geographic location distinctions include; Northeast and Mid-Atlantic (East), Midwest and Plains (Midwest), South and Southwest (South), West and Northwest (West).
****Political leaning is based on state U.S. Senate delegation from 2020.

Analysis

We began analysis by writing descriptive memos for each state based upon our review of SEA websites. These memos included data on state science standards and accountability, plans for implementation, and resources provided for elementary science, such as curriculum, tools, PD, and other resources. We then established a set of provisional codes that describe policy contexts for elementary science by reviewing recent publications on elementary science education (Achieve, 2019, 2017a, 2017b; Committee on STEM Education, 2018; National Science Teachers Association, 2018). Using the qualitative analysis software, NVivo (QSR International Pty Ltd, 2018), we piloted the provisional codes by open coding two interview transcripts. We discussed our interpretations of the data and codes in order to build greater reliability among coders. As we coded the remainder of the transcripts, we continued meeting to discuss the codes, adding and revising as needed based on what surfaced in the open-coding process (Table 2). We then coded the memos generated during the review of SEA websites using the same coding scheme.

Table 2: Coding scheme

1.	**Standards and accountability**
1.1.	The state has recently adopted new science standards, based on the *Framework* and/or NGSS
1.2.	The state has high-quality assessments, aligned to the state standards, which signal student performances are consistent with expectations of the standards.
1.3.	Elementary science is included in state accountability and/or certification systems.
1.4.	The state has set statewide achievement goals for improving science education.
2.	**Resources for implementation**
2.1.	The state develops and enriches strategic partnerships and collaborations with external partners which may be community-based, with universities, across districts, across states, across educators, with informal educators, with local businesses, etc.
2.2.	Management of implementation efforts is handled carefully and intentionally through the formation of a science leadership team, publishing strategic plans and budgets, and so on.
2.3.	The state leverages some form of internal partners (i.e., intermediate school districts, districts, schools, groups of practitioners) in its implementation efforts.
2.4.	One or more agencies or organizations play an active role engaging with the state and/or districts or schools in elementary science reform efforts.
3.	**Elementary science education**
3.1.	The state has a policy related to elementary science instructional time.
3.2.	The state advocates for engaging students in interdisciplinary learning opportunities.
3.3.	Instructional materials are curated for districts (i.e., through the creation of an inventory, articulation of beliefs and policies around procurement, provision of objective criteria to use for evaluating materials, training of educators to evaluate materials, etc.).
3.4.	Materials for implementation are curated for districts (i.e., supports for practice including tools, documents, resources, plans, protocols, etc.).
3.5.	Equity and access are policy priorities for elementary science.
4.	**Professional learning opportunities**
4.1.	Sustained opportunities for professional learning for teachers are supported by the state.
4.2.	High-quality professional learning opportunities for administrators are supported by the state.
4.3.	Professional learning opportunities for state-level science specialists are in place.
5.	**Context**
5.1.	Information on the political climate is in the state for science education reform.

5.2.	Historical context for elementary science reform.
6.	**Challenges**
7.	**Vision for elementary science instruction**

We then developed analytic memos for each state that organized the data by code (Yin, 2009). We used these analytic memos to construct a series of comparative analytic matrices based upon our research questions. We concluded with additional analytic memo writing to summarize key distinctions and similarities based upon our research questions.

Limitations

We identify two key limitations to this work. One limitation is the small number of interviews conducted in each state. In all but one state, we conducted a single interview. We focused on interviewing across a larger number of states instead of interviewing more deeply within states to explore potential variation across states. A second limitation is that we have not yet triangulated our state-level data with data from districts, classrooms, or external partners. This is the focus of ongoing work as part of the larger study.

Findings

Our findings are organized around two issues pertaining to SEA responses to national efforts to reform elementary science education. The first concerns the challenges that state science coordinators (SSCs) identified in their efforts to advance national ideas for reforming elementary science. These included a first-order challenge of motivating local education leaders and teachers to engage with reforming elementary science education and building the capability of teachers and school leaders for improving elementary science. Second, in addressing these challenges, SEAs sought to engage districts by developing (or supporting districts in developing) key components of an educational infrastructure for elementary science. While all states developed standards, assessments, and, in some states, accountability systems (an exostructure), many states also supported school districts in connecting the exostructure with their endostructure through the use of three key instruments; HQIMs, PD, and codified messages.

Challenges in Advancing Elementary Science Reform

Though eager to advance national ideas for reforming elementary science education in their states (Haverly et al., 2022), SSCs identified a range of challenges in engaging school districts in elementary science improvement efforts.

Motivation Challenge. By and large, SSCs struggled with getting districts to prioritize science given the competing demands for instructional time in the elementary school curriculum. Thus, a first-order challenge for SEAs seeking to improve elementary science involved motivating districts and schools to give attention and time to science instruction given the many other demands placed on elementary teachers with respect to teaching.

All but three SSCs acknowledged that science was not a priority in elementary schools as evidenced by the limited instructional time for science teaching. Fifteen SEAs identified limited instructional time for science as a critical challenge regardless of state size, location, political leaning, and NGSS adoption status. As one SSC described, “most teachers spend less than 30 minutes a week teaching science in [our state] and many do not teach science at all”. Another SSC described, “we are still in the battle of getting science taught” and a major change in their state would be, “just teachers teaching science”.

Many SSCs attributed the inattention to elementary science to state and federal policies that emphasized ELA and mathematics instruction and, consequently, contributed to minimizing instructional time for science. As one SSC described, “From a state perspective, when it comes to elementary the focus is early literacy, early numeracy. A lot of the effort is towards reading, early reading, and early mathematics”. Similarly, other SSCs described science as a “backburner subject” because there is “such a strong emphasis on math and language”.

For a majority of SSCs (n=11), state-level accountability policies and other mandates also contributed to marginalizing science at the elementary level. Seven SSCs, for example, noted how the lack of state accountability for districts tied to elementary science contributed to the marginalization of time for the subject. One SSC said:

> How students do in science doesn’t really impact school grades […]. The [State Department of Education] is trying really hard to say, you know, we really want you to provide those rich science experiences for students. Yet, there are a lot of signals from the, you know, basically respective of how they’re graded or pieces like that, that marginalize science instruction at the lower grade levels.

Other SSCs identified state mandates, such as 90-minute reading and mathematics blocks and student retention laws tied to reading, as further incentivizing schools to prioritize ELA and mathematics over elementary science. Moreover, some SSCs saw an increasingly crowded and complex state policy context as further undermining efforts to improve elementary science including, among other things, revising and implementing standards in multiple subjects simultaneously and the constant rollout of new initiatives to support literacy and mathematics improvement. Thus, a critical, first-order matter for SSCs was figuring out how to motivate teachers as well as school and district leaders to attend to both getting elementary science taught and the improvement of extant science teaching, and doing this in a policy environment that was increasingly skewed toward literacy and mathematics.

A further complication was declining and unstable funding for science. Many SSCs identified the absence or termination of funding for science education as thwarting their elementary science improvement initiatives. Four SSCs identified the drying up of federal funding for science, in particular Math Science Partnership funding from the National Science

Foundation, as creating funding gaps that undermined state science education programming and services. One SSC explained:

> With few exceptions, [Math Science Partnerships] have not been maintained with state support. Therefore, the different initiatives do not have any sustainability piece…and those projects come and go, and they produce some really good things, but once a project ends, it all seems to end.

Other SSCs described how the termination of federal and state funding for science left SEAs with limited budgets or no budgets at all for science.

For SSCs seeking to motivate district and school attention to elementary science, these arrangements coalesced to create a compounding dilemma. At the state-level, an increasingly complex and crowded education policy environment pressed districts to respond to multiple priorities for elementary education simultaneously, prioritizing ELA and mathematics mostly. Shrinking and uncertain funding for science further complicated the situation for SEAs. With some states wholly dependent on special programs and funding to support elementary science, changes in these funding streams undermined their capability for ongoing, sustained support for elementary science.

Capability Challenge. Beyond motivating school districts to teach elementary science and make it a priority given competing demands, states also grappled with how to build the capability of local educators - teachers, school leaders, and district leaders – to improve elementary science education. All SSCs identified the need to support elementary teachers and school leaders in building the necessary knowledge and skills to engage in ambitious science instruction as a central challenge.

For SSCs, building teacher capability for ambitious elementary science instruction involved developing their content and pedagogical content knowledge, as well as their comfort with teaching science. Several SSCs suggested that teaching all subject areas coupled with the limited attention to science in their preparation programs were reasons why elementary teachers needed to build their capability for elementary science improvement. As one SSC explained:

> Elementary teachers are generalists. They are trained to cover a great many subjects. Therefore, they don’t go into it as deep. And so, for them a lot of it depends upon what the focus is of the particular university that those teachers would happen to attend.

Another SSC described, “teacher preparation systems, especially for K-5, are very science light. Teachers just simply don't have the pedagogical content knowledge to feel comfortable to teach science”. Yet another SSC said, “elementary [teachers]—their pedagogy is strong with learning how to read, learning how to count, numeracy, things of that nature. But they don’t have the science content”. Several SSCs described grappling with how best to develop teachers’ knowledge. As one SSC described:

> We notice, especially with the adoption of the new standards that a lot of our elementary teachers do not feel like they have the content background to effectively implement some of the curriculum. We’ve really taken a huge stance in making sure that the professional developments are not just centered on general pedagogy, but that teachers have an opportunity to also build content knowledge, background knowledge they may need to know, in order to effectively implement the standards in the classroom.

For these SSCs, and others, building teacher capability for elementary science involved teachers further developing instructional knowledge and expertise necessary for ambitious science teaching, including, among other things, knowledge of the new standards, pedagogical content expertise, and scientific content knowledge.

In addition to building teacher capability, SSCs also identified building school leader capability as a critical challenge facing their improvement efforts. SSCs described that developing school leaders’ capability involved building their knowledge of the new standards and supporting leaders in using these standards in their leadership practice. For example, one SSC explained, “there's a lack of understanding among administrators about science and what quality science learning looks like”. Another SSC described that some leaders do not understand how teaching evaluation tools (e.g., Marzano and Danielson models) apply specifically to science. Several SSCs explained that part of building school leaders' capability involved helping leaders to reimagine how elementary science could be taught by using it as a venue for also supporting ELA and mathematics learning. For instance, one SSC described:

> This idea of integration [of literacy and mathematics], but thoughtful integration, is something that we're really pushing for. It's not just reading about science and ELA and calling that a science class […]. The other strategy is helping district leaders to really see that you don't need to do an hour-and-a-half—90 minutes of ELA, 90 minutes of math, and then there's no time left in the day for anything else. Opening the door to different ways to approach learning all the subjects. Our work with the principals has been trying to get them to think outside the box a little bit.

For this SSC, helping school leaders to reimagine elementary science instruction involved pushing against familiar notions of how, where, and when the subject could be taught.

For SSCs, the challenges in building teachers' and school leaders' capability were further complicated by few state-level staff in science to do the work. Most states had only 1 or 2 people supporting K-12 science instruction, while other states had small teams of 3-5 people. More specifically, in several states this meant there was one SSC to support anywhere from 1500 to 2600 schools. Many SSCs explained that the limited state-level science staff made it difficult to reach all schools in the state, particularly in rural areas. One SSC described, "I've been doing this for a year, completely solo, so having the capacity to build this and really support all educators in [the state] has been a challenge, while also supporting another set of standards". Another SSC explained:

> …right now, reaching everybody about the intent of the new standards and the new curriculum framework. That is a huge challenge. We're talking about, in ways, equity. How do you make sure that we're equitable in terms of providing PD? How are you in terms of equity in providing support? It is a huge concern. I guess that would be my biggest concern right now. I lose sleep over that one.

As these SSCs saw it, few state science staff limited their ability to support improvement efforts in science resulting in some districts not receiving state-level support.

Our analysis suggests that SSCs were committed to improving elementary science and appreciated that this necessitated more than just adopting new standards but also building the capabilities of an array of educators across different levels of the system. Specifically, building capability involved developing teachers' and school leaders' knowledge of science content and pedagogy as well as helping them reimagine how science instruction might fit into elementary education. At the same time, this challenging work was exacerbated by limited state resources, shrinking federal funds for science, and an increasingly complex policy environment that favored ELA and mathematics over science. Small, unstable budgets, few science staff members, and a saturated state policy context skewed toward ELA and mathematics conspired to create challenging circumstances for SSCs focused on reforming elementary science education in their states.

Engaging Districts in Elementary Science Improvement

Though keenly aware of the complex, multifaceted challenges facing elementary science, SSCs did not shirk from the task. We found that all SSCs sought to engage school districts in improving elementary science by developing (or supporting districts in developing) key educational infrastructure components. Whereas all states developed an exostructure for elementary science education by establishing instructional standards, state assessments, and (in some cases) accountability structures in an effort to engage districts in improving elementary science, some states also worked to engage districts in connecting this exostructure with districts' endostructure for elementary science by providing instructional materials, PD, and codified messages on elementary science (Table 3). We examine state efforts related to developing educational infrastructure for elementary science education below attending first to the exostructure and then to efforts to connect the exostructure and endostructure.

Table 3: Infrastructure Elements by State

Infrastructure Elements							
	State Standards in Science	Number of grades assessed in elementary science	Science Assessment included in accountability determinations	Instructional Guidance Materials (e.g., curricular framework, sample lessons, scope & sequence)	Vets Quality Curriculum or Provides Tools for District Vetting	Professional Development for Teachers and/or Leaders	Codified Messages on Science
States							
1	x	1	In process	x		Teachers	x
2	x	1				Teachers	x
3	x	1	x	x	x	Teachers Leaders	
4	x	3	x	x	x	Teachers	
5	x	1	In process	x	x	Teachers Leaders	
6	x	1	x	x	x	Teachers Leaders	x
7	x	1		x			
8	x	1	x	x		Teachers	
9	x	1	x				
10	x	3	x	x		Teachers	x
11	x	1	x		x	Teachers	
12	x	1				Teachers Leaders	
13	x	1		x	x		
14	x	1		x		Teachers	x
15	x	1	x	x		Teachers	
16	x	1		x		Teachers	
17	x	1	x	x			
18	x	1		x	x	Teachers	

The Exostructure: Standards, Assessments, and Accountability. All states in our sample developed instructional standards and state assessments in science to motivate and incentivize school districts to engage in improving elementary science education. Fewer states, however, established state accountability structures that held districts accountable for elementary science achievement.

Though all states leveraged state standards and assessments to engage districts in elementary science improvement, states varied in the type of science standards they established and how frequently they assessed science. As previously described, the 'for states, by states' approach to the development and implementation of the NGSS provided for state discretion in establishing state science standards. States exercised this discretion, in part, by deciding whether to adopt the NGSS outright or adapt the standards to meet the particular needs of their states. At the time of this study, seven states in our sample formally adopted the NGSS, eight states based their state science standards on the *Framework* but did not adopt the NGSS outright, two states were in the process of adapting their state science standards based on the NGSS/*Framework*, and one state had neither adopted the NGSS nor based their state standards on the NGSS/*Framework.* For some states, NGSS adoption decisions were, at least in part, political. For example, several states had reservations about adopting a new set of national standards given the political pushback to the adoption of the CCSS. This had some states developing standards based on the *Framework* in order to distinguish these standards from the national movement.

The states also differed in how they assessed students on state science standards at the elementary level. All states assessed students at least once in elementary science, typically in either grade four or five. Two states, however, assessed elementary science more regularly by assessing students in grades three, four, and five.[2]

While all states established instructional standards and assessments in elementary science, fewer states developed structures to hold districts accountable for student achievement in elementary science. At the time of this study, nine states had established accountability structures that included elementary science as part of their state's accountability formula and two states were in the process of including science for purposes of accountability. Five states did not include elementary science in its accountability formula, but did report elementary science proficiency scores publicly. Two states neither included elementary science in its accountability formula nor reported elementary science proficiency scores.

Despite variation in the type of standards, assessments, and accountability structures for elementary science among states, there was wide-scale attention by states to developing an exostructure to support elementary science. Yet, whereas all states focused on developing an exostructure for elementary science education to engage districts in improving elementary science, two states used *only* standards, assessments, and accountability systems to engage districts. SSCs in these states offered two rationales for using only standards, assessments, and accountability structures as mechanisms for engaging school districts. One rationale focused on political arrangements. Specifically, one state had a strong preference for maintaining local control over education and, thus, limited interfering with local decision-making on instructional matters. As one SSC explained:

> We don't really have a whole lot of role because [our state] believes very strongly in local control. We don't have any kind of a statewide scope and sequence. I believe, by

[2] This data draws on interview data, information found on SEA websites, and Achieve's analysis of state assessment resources in science (https://www.achieve.org/files/Grades_3-8_Science_Assessments_Table_2018-19_final.pdf)

> statute, we're not allowed to create that or to say anything about how standards are supposed to be taught.

For this SSC, the preference for strong local control reflected deeply ingrained notions of intergovernmental relations on matters of education and served to justify a more district-centered, hands-off approach for elementary science improvement. This SSC saw the role of the state as establishing standards and assessments for elementary science, while providing any additional guidance and support was beyond their jurisdiction.

Another rationale focused on resource constraints; that is, scarce resources at the state-level constrained one SEA's ability to provide elaborate support to districts for elementary science. Consequently, improving elementary science was left to school districts to organize and manage within the parameters established by state standards and assessments. For example, one SSC described that the lack of funding for elementary science meant that her work shifted from providing what she described as "boots on the ground" support to districts and schools to relying on state standards and assessments to motivate local improvement in elementary science. They explained:

> Right now, a lot of what I'm doing is because of lack of funding and lack of personnel. A lot of what I'm doing is answering questions that people have, sending out resources that are available. […]. I will send them resources such as NextGen storyline to give them a sampling of what I'm talking about. I'll send them to NSTA/NGSS hub so that they can see where there are some vetted lessons and other types of resources.

For this SSC, the scarce funding had their role shifting from providing direct instructional support to district and schools to the role of information broker where they connected individual teachers with instructional resources to support their work. Resource and politically constrained, these two SEAs confined their efforts to developing an exostructure for elementary science in the hope that this would prompt school districts to build endostructures that would connect with their state exostructure.

Connecting the Exostructure and Endostructure: Materials, Professional Development, and Codified Messages.

While some SEAs focused only on developing an exostructure for elementary science, 16 SEAs developed an exostructure for elementary science and also supported school districts in connecting the exostructure with their endostructure. These SEAs used three key instruments to help districts connect the exo- and endostructure; High-quality instructional materials, PD, and codified messages.

High-quality Instructional Materials. Sixteen of the 18 states sought to engage districts in improving elementary science by designing, curating, and/or vetting high-quality instructional materials (HQIMs) that districts could use locally to support elementary science. SSCs in these states recognized that districts struggled to cultivate the instructional resources to support standards-aligned elementary science education and believed that providing HQIMs could help to (a) motivate districts to engage in the teaching of elementary science and (b) develop local capability for ambitious elementary science instruction. While the states varied in the types of materials they provided, all states worked within the norm of local control to engage districts in using HQIMs.

Most states focused their efforts on developing curricular and instructional materials, such as curricular frameworks, scopes and sequences, sample lessons, and models of instruction, that districts could use in the planning and teaching of elementary science. Many SSCs understood these materials as helping to enhance the capability of educators to engage in high-quality elementary science by providing guidance for instruction that teachers could use to build their understanding of standards-aligned science education. Some SSCs explicitly focused on the educative potential of these materials by designing these resources to enable local educators learning from and about science instruction. As one SSC described:

> We have in our model science curriculum in K-5, we put in examples of what they can be doing in class and built-in links so if they didn't understand matter and its interactions they could go to a few websites and learn about matter and its interactions. If they didn't understand what asking questions was about, we linked them to asking questions resources.

Another SSC described:

> We are doing videos to accompany the science instructional plan so that we can have teachers in action engaging in those plans so people can see what it looks like in the classroom and they can get an idea. We're also doing all sorts of videos from our end supporting all the different new things in the curriculum framework.

These SSCs, and others, viewed these materials not only as providing guidance for instruction, but as also serving a capability-building function. In part, these materials provided models of instruction that helped SSCs to exemplify for districts and teachers what high-quality elementary science entailed. In some cases, educative features of the materials helped to build teachers' subject-matter knowledge and capability for standards-aligned science instruction.

Seven states went beyond providing instructional guidance materials to districts to focus on helping districts vet and select HQIMs for elementary science. SSCs explained that most districts struggled to find HQIMs for elementary science and that, among other things, supporting districts in finding and adopting these materials would increase the likelihood of local engagement in elementary science. The SSCs pointed to gaps in funding, limited availability of HQIMs in the market, and the prioritization of purchasing ELA and mathematics materials as reasons why many districts lacked HQIMs for elementary science. One SSC explained:

> Our idea is that if we put good curriculum in the hands of districts and teachers, there'll be more learning that's happening. We know that districts spend so much money on math and ELA curriculums and they hardly ever spend money on a science curriculum. We're

> hoping that one of the things we can do is actually elevate some science curriculums so districts will find it easier to say, “Oh, there are actually curriculums out there that we could choose”.

These SSCs sought to support districts in navigating the commercial market to find HQIMs for elementary science, although the states used different approaches for doing so. Some SEAs vetted commercial curricula and provided state-generated lists of approved or recommended curricula to districts. In one case, a SEA directly connected districts with commercial curricula publishers through state-wide curricula events. Other SEAs developed tools and guidance that districts could use to vet curricula themselves. Some SEAs facilitated state-wide textbook and instructional materials review following the standards revisions.

While most SEAs sought to engage districts in elementary science by making HQIMs, available to them, these SSCs accepted local control over instructional materials and did not mandate districts use particular resources. Recognizing and working within norms of local control, SSCs instead focused mostly on motivating, persuading, and enabling districts to engage with these HQIMs. One SSC described how they viewed their role as supporting districts in curricular decision-making:

> […] we have worked with organizations to provide a vetted list of STEM curriculum. We are looking to expand that list, but just to serve as a reference as schools are either looking to make curriculum shifts or ensure that what they’re doing has evidence-based tied to it. So that is one way that we’re helping to guide districts as they make curricular decisions, not to say that they couldn’t adopt something that’s not on that list. It’s still certainly a local decision, but just another way that we’re sort of providing guidance in that area.

Another SSC explained:

> Because we’re a locally-controlled state, we don’t have any mandates. The only mandates we have is them taking the state assessments, and those are driven by the standards. Even the standards are technically optional, so we’re trying to be really strategic about giving really good guidance documents.

These SSCs saw their role as primarily involving providing guidance to districts around curricular decisions and acknowledged that districts maintain authority over this decision-making.

SSCs used various means to encourage, persuade, and enable districts to engage with HQIMs for elementary science. One approach that SEAs used was to align these materials to state ELA and mathematics instructional programs and priorities. One SSC, for example, described strategically aligning elementary science scope and sequence documents to support state literacy priorities:

> Our sample scope and sequence documents, we were very strategic about looking at our ELA shift and making sure that we incorporated some of the non-fictional reading tasks that our ELA team is using and imbed those into our science resources so that teachers could see how they can pull in those different reading assignments to support science instruction.

They go on to describe:

> [We say to leaders] Hey, if you implement this quality [science] curriculum that supports ELA and math through disciplinary literacy and by infusing Common Core throughout the program, that you are supporting your students in math and ELA, so you don't have to spend three hours on ELA or have a two-hour block for math.

For this SSC, and others, motivating and persuading districts to take up elementary science involved explicitly organizing HQIMSs to support the integration of ELA and mathematics with science and being strategic about the ways in which science instruction supported ELA and mathematics priorities.

Another SEA encouraged district use of HQIMs by making it burdensome to adopt non-state approved curricula. This SSC explained:

> When we review curricula resources, we go under state contracts with those resources which makes it very easy for our districts to adopt. If districts opt not to adopt a program that's on that list, then they have to go through our review process themselves and have that documented. The contracting is a heavier lift on the district's end, so a lot of our districts do review and take our reviews and use them because the process is much easier for them and they trust the process a lot more.

Most SEAs, however, sought to motivate districts to utilize these HQIMs namely through messaging to districts and school administrators. One SSC explained:

> We have been begging, pleading, cajoling, training people to use the EQUIP Rubric to evaluate sample lessons in proposed curriculum that they're thinking about adopting, prior to purchasing it or adopting it. We've been recommending very strongly that they take a look at Ed Reports and the peer review panel results from Achieve. We've been asking them to push their vendors to show them a third-party analysis of the coherence that their curriculum has with the NGSS.

While these SSCs used different approaches to encouraging district use of HQIMs, they recognized and worked within the existing dynamics of local control. That, in turn, had the SSCs leaning on persuasion and messaging to encourage district use.

Professional Development. Fourteen of the 18 SEAs sought to engage districts in building educational infrastructure by providing professional development (PD) to build district capability for high-quality, standards-aligned elementary science instruction. While the SEAs varied substantially in their designs for PD, we identified three trends in SEA approaches to PD including; (1) a focus on teacher-based PD; (2) a focus on out-of-district PD; and (3) SEA collaboration with external providers for PD support.

A majority of SEAs focused their efforts on providing PD opportunities directly to teachers. Of the 14 SEAs seeking to engage districts in elementary science through PD, ten SEAs focused exclusively on providing direct-to-teacher PD. Four SEAs provided PD to audiences other than teachers, such as school leaders and, in one SEA, even informal educators. The rationale for directly targeting teachers in PD efforts echoed SSCs' belief that developing teachers' content knowledge and knowledge of the standards was a core challenge in implementing standards-aligned elementary science. One SSC described:

> Really understanding what those standards mean and understanding those shifts and what's different--I think that's really important for the elementary spaces. The leap from

> what our previous standards look like to what they are now is hugely different. So, you know, the professional learning required in order to successfully implement them is actually pretty large.

Another SSC explained:

> For elementary [teachers], we need really to provide enough of a background for them to be able to allow for the opportunities to happen. Not only just providing samples of lessons, but providing that content background to help the teachers. I'm not saying all of them don't understand, but enough don't that it could be an obstacle in making sure that kids get those engaging experiences.

For these SSCs, the cognitive and pedagogical demand of the new standards had the SSCs directly supporting teachers to build the capability for elementary science. Other SEAs sought to build the capacity for elementary science among other district staff, particularly school principals and other district science leaders, and provided PD opportunities for these groups. Several SEAs, for example, facilitated PD networks where school and district science leaders met regularly to collaborate on issues related to elementary science.

While most SEAs focused on providing PD for teachers, limited state resources for elementary science complicated their efforts to engage teachers at scale statewide. Several SSCs described struggling to reach all teachers in their states. One SSC explained:

> Because we're such a large state, we have pockets of excellence. We don't have saturation yet. That's one of the challenges we're working with. How do we get our teachers in rural areas access to high-quality professional learning around the NGSS? That is something that we are working through.

For these SSCs, the limited state-level resources for elementary science coupled with focusing on providing PD opportunities directly to teachers complicated their efforts to engage all districts, schools, and teachers in meaningful PD experiences.

Most of these SEAs structured PD for elementary science as out-of-district opportunities. The majority of SEAs structured their PD as single or multi-day sessions focused on particular topics in elementary science, such as three-dimensional learning, formative assessments, and others. These PD opportunities typically took the form of "symposia", "institutes", or "workshops" where teachers left their district and engaged in cross-district learning on particular topics. One SEA, for example, offered "deeper learning institutes" for teachers that focused on the integration of science and literacy. The SSC described these institutes:

> [Deeper learning institutes] are one-day professional developments across the state to support especially science and literacy, because we recognize that literacy is being recognized as a need, and how can we build science into that or how can we use literacy in our science classroom to augment the expectations there?

Another SEA provided annual, two-day symposia for teachers across the state to learn about topics in the state standards, such as environmental literacy. A smaller number of SEAs focused their efforts on more ongoing, collaborative PD opportunities through state-facilitated network-based learning communities. In one SEA, for example, the SSC facilitated two professional networks focused on elementary science. This SSC explained:

> I ran two different networks for elementary science. One was for principals. So specifically targeting principals and helping them to get on board with what the new standards are and designing some PD modules for them to run at staff meetings around science. [The other] strategy that we tried last year was running a network of how to integrate math and science standards.

These professional networks organized and facilitated by SSCs typically met several times throughout the school year and focused on cross-district collaboration. While more ongoing and collaborative than single or multi-day sessions, these PD opportunities sought to build the capability of teachers and leaders outside of districts and did not support the development of a PD infrastructure within districts themselves.

Two SEAs sought to enhance the capability for elementary science within districts by building a PD infrastructure that could be used locally. These SEAs typically leveraged virtual learning structures, such as online modules and webinars, that teachers and leaders could use in schools to build their knowledge and capacity for elementary science. For example, one SEA developed an online module sequence focused on introducing teachers to a series of instructional approaches in elementary science (e.g., 5e model, productive talk and student discourse, constructing explanations). The SEA designed these modules to be used by individuals or teams as part of district-based PD and suggested that teacher teams use district-provided PLC time to explore the modules together. In contrast to other out-of-district PD opportunities, this SEA sought to support districts in building a local infrastructure for PD that could be embedded within existing school structures.

Many SEAs leveraged external support organizations to support state efforts for PD. Of the SEAs that provided PD to districts, most collaborated with external support organizations to design and facilitate PD. For instance, several SEAs partnered with their state science teacher associations, local universities, commercial curriculum providers, or other external partners to facilitate PD. This work involved collaborating and sharing responsibilities for the design and facilitation of PD. In several SEAs, SSCs did not provide any PD, but rather delegated this work exclusively to external organizations through specific grant-funded projects. These SEAs provided grants to external partners, such as local museums, commercial and non-profit support providers, and other intermediary organizations, who then provided PD for elementary science directly to school districts.

Codified messages for elementary science. Five of the 18 SEAs also sought to engage districts in supporting elementary science teaching by creating and disseminating codified messages for elementary science to school districts. By codified messages, we mean articulated and ordered communications from the SEA for how districts should engage in elementary science education. These codified messages were not formal requirements or conditions placed on districts, but rather were messages that provided guidance to districts about elementary science. These codified messages predominately focused on motivating and persuading school districts to engage in the teaching of elementary science and offering suggestions for how they might do so.

Several SEAs provided codified messaging about instructional time for elementary science. Three SEAs established recommendations for number of minutes of instructional time in elementary science. Each SEA built these recommendations into the state science standards and recommended a number of instructional minutes in science for each grade level. Although these recommendations were published in the state science standards, SSCs underscored that these were recommendations and not requirements for districts. One SSC explained:

> This instructional time is what we call just a recommendation that would be suggested. It's not a this is what you have to do. […] Those are just suggested from the educators working on the standards, that that's how much time you would need per week or per day.

In addition to building these recommendations into the state science standards, one SEA also developed reference guides for elementary administrators to support science standards implementation which included the recommended instructional times for science. This SSC explained:

> I created a quick reference guide, we call them, for elementary administrators. That's a two-page document that was some of the work that came out of the Elementary Principals Network, but then we took that document and we're expanding it out. […] We give recommendations on how much time science should be. […] Every time I show that table to anyone—I show it to principals, they're like, "Oh, I didn't know—" It gives a little authority for science, so it's nice.

For this SSC, the codified message on recommended instructional time was intended as a mechanism to persuade schools to engage in elementary science, despite being a recommendation and not a formal requirement.

Other SEAs used communications, such as documents and resources, to formally communicate the importance of teaching elementary science to districts. One SEA in particular worked with a non-governmental agency –the state principal association– to develop videos for school leaders that communicated the importance of teaching elementary science. This SSC described:

> We've been working with the Association of [State] Principals and we've co-developed with them a couple of videos for principals that become part of their training. They have to take so many continuation hours so we've developed a video series with the association on why elementary science is important […].

Another SEA sought to codify messages around the importance of elementary science through a vision and belief statement for how science instruction could support student literacy development. As described by the SSC, science provided a rich and "authentic context" in which students could learn literacy and mathematics. The SSC described, "Our beliefs document, which is posted on the [state] site, was intended to call out the attention and the opportunity of the science standards and the literacy standards really aligning and supporting each other well". While these codified messages provided guidance for elementary science, these messages aimed to motivate and persuade (but not require) school districts to engage in supporting the teaching of elementary science.

While some SEAs focused only on developing an exostructure for elementary science, sixteen SEAs developed an exostructure for elementary science and also supported school districts in connecting the exostructure with their endostructure. Using three key instruments – HQMIs, PD, and codified messages – SEAs aimed to help districts connect the exo- and endostructure by priming and support school districts in (re)building their educational infrastructure to support elementary science.

Discussion and Implications

Our study focused on whether and how SEAs worked to incentivize and support school districts in (re)building their educational infrastructures to support the instructional vision advanced by the NGSS and *Framework*. Based on our data analysis, we advanced two claims. First, SEAs faced two central challenges with regards to elementary science reform - motivating local education leaders and teachers to engage with reforming elementary science education and building the capability of teachers and school leaders for improving elementary science. Second, whereas in addressing these challenges all states developed standards, assessments, and, to a lesser extent, accountability, some states went further to support school districts in connecting these standards and assessments with classroom teaching and learning by mobilizing three key instruments – HQIMs, PD, and codified messages.

Our findings contribute to the growing research base on the role of state policy in supporting the implementation of ambitious learning standards. In documenting the unique and acute set of challenges facing elementary science reform, we argue that the school subject is a critical explanatory variable in understanding SEA efforts to support the implementation of ambitious learning standards. Focusing on elementary school science, we show how the school subject shapes state-level engagement and implementation of national reform efforts and we argue that theoretical and empirical work in this area must take the school subject into consideration when examining state- and district-level instructional improvement efforts. Our analysis also argues for framing the relationship between state/federal government policy and local school districts as educational system-building, as SEAs work to prime and support districts in building educational infrastructures with particular attention to HQIM, PD, and codified messages. In this section, we discuss these two central matters in understanding state efforts to support standards-based instructional reform in the context of elementary science – the salience of the subject-matter in SEA designs for standards implementation and the practical convergence of SEA efforts to support ambitious instructional reform through educational system-building.

SEA Designs as Rooted in Subject-Matter Challenges

In responding to national efforts to reform elementary school science, states face a unique and acute set of challenges. We identified two central challenges in SEA reform efforts in elementary science. One concerned the motivation of local actors for engaging in elementary science reform which SSCs tied to the overall marginalization of science compared to literacy and mathematics in the elementary curriculum. SSCs referenced the limited instructional time allocated for elementary science together with state and federal policies that emphasized ELA and mathematics contributing to declining attention to and funding for science as complicating elementary science reform. These findings are consistent with research that documents an overall decline in science instructional time in elementary schools (Banilower et al., 2013; Blank, 2013; P. S. Smith, 2020) and the prioritization of ELA and mathematics over science (Marx & Harris, 2006; National Academies of Sciences, Engineering, and Medicine, 2021; Spillane & Hopkins, 2013). Another central challenge concerned the capability of educators across different levels of the system including developing teachers' content and pedagogical knowledge and their comfort for teaching science. It also included the need to build school leaders' knowledge of science reform initiatives and developing their ability to support these efforts in schools. These findings underscore scholarship that suggests many school leaders have limited expertise in science or science pedagogy (National Research Council, 2015), have limited understandings of science practices and pedagogy (Cherbow et al., 2020; McNeill et al., 2018), and need to develop greater expertise around science reform efforts (McNeill et al., 2021).

Most research on instructional reform and policy implementation tends to treat teaching monolithically or focus mostly on elementary school ELA or mathematics. Yet, teachers do not just teach, but rather teach school subjects. The available empirical evidence suggests that the school subject shapes not only high school teaching (Ball, 1981; Ball & Lacey, 1984; Siskin, 1991, 2014), but also elementary teaching (Stodolsky, 1988). Specifically, the school subject shapes how elementary teachers and school leaders think about improving their teaching and how they organize for instructional improvement (Burch & Spillane, 2005; Spillane, 2000, 2005; Spillane & Hopkins, 2013). Focusing on elementary school science, we document how the school subject shapes state-level efforts to support the implementation of national reform efforts. More specifically, in identifying the unique challenges faced by states as they work to press for reform of elementary school science, we argue that policy implementation research cannot afford to treat instructional policy and its implementation monolithically, but must take into account the school subject. Moreover, policy analysts cannot treat instruction monolithically, but must instead take the school subject into account as a key explanatory variable in their efforts to study implementation. The challenge for SEA policymakers with respect to science, for example, was not just about reforming extant teaching practice, but also getting science taught in elementary school classrooms in the first place. Theoretical and empirical work on interorganizational relations with respect to the core technical work of schooling—instruction—must take the school subject into consideration because instruction is a subject specific or sensitive variable.

Designed Discretion and Practical Convergence

As a matter of policy design, the "for states, by states" approach to the development and implementation of the NGSS and *Framework* intended to give states formidable discretion in whether and how to pursue elementary science education reform. Yet despite this designed discretion, SEAs converged in how they engaged school districts in elementary science reform efforts. This convergence reflects other research findings that identifies convergence in SSCs' understanding of the central themes in the NGSS and *Framework* (Haverly et al., 2022).

With regards to state-level engagement with national efforts to reform elementary science teaching, SEAs exercised discretion, in part, by making strategic decisions about what type of science standards to pursue in their state. This strategic decision-making had some states directly engaging with the national movement by adopting the NGSS and *Framework* and other states engaging more indirectly by adapting their state standards in ways that aligned with the NGSS and *Framework*. Some states did not engage with the national movement but pursued state science standards neither based on the NGSS nor the Framework. Despite differing levels of engagement with the national movement for elementary science reform, we observed important similarities in SEA designs for standards implementation. Nearly all SEAs sought to motivate and engage school district in elementary science reform by priming and supporting districts in (re)building their educational infrastructure. SEAs did this by leveraging three key instruments to bridge standards, assessments, accountability with teaching and learning in classrooms – HQIMs, PD, and codified messages. SEAs leveraged these mechanisms to engage school districts regardless of the differences among the SEAs, including the type of science standards, size, geographic location, political leaning, SEA size, and more.

This convergence in state efforts to support elementary science reform by priming and supporting of school districts to (re)build their educational infrastructure points to a potential development in state efforts to implement standards-based reform. Scholarship on instructional reform in the standards-based reform era suggests that reform policies often fail to provide the infrastructure and technical guidance that would enable change in teaching practice (Cohen et al., 2007) and that local districts, and most often teachers and school leaders, are responsible for developing many of the technical resources and guidance to support more ambitious teaching (Rentner et al., 2016). Moreover, and as described earlier in this piece, Cohen and Mehta (2017) argue that with regards to standards-based reform little attention is given to the instruments that connect the exostructure of standards, assessments, and accountability with the endostructure of teaching and learning. While much of the work of (re)building educational infrastructure remains local, this study suggests that SEAs might play an important role in engaging school districts in bridging from standards, assessments, and accountability to classroom teaching and learning by priming and supporting districts to (re)build educational infrastructure. For the SEAs studied here, that involved attention to the core work of schools – instruction – as states leveraged the three key instruments to support teaching and learning in districts.

The potential role of SEAs in priming and supporting school districts to (re)build their educational infrastructure underscores what scholars have described as the evolving role of SEAs as policy implementors in standards-based reform era. Historically, the work of SEAs focused primarily on administering state and federal education programs (Brown et al., 2011; McGuinn, 2015; Weiss & McGuinn, 2017). However, contemporary legislation and reform efforts, such as the Improving America's Schools Act, NCLB, and Every Student Succeeds Act, expanded the role of SEAs to functioning as implementors of key policies (Weiss & McGuinn, 2017). The role SEAs played in supporting school districts in elementary science reform observed here points to their potential role as more central players in implementing instructional reform policies at scale than perhaps previously recognized. In particular, it positions the SEA as engaging districts in educational systems-building aimed at re-organizing around their core educational function – instruction (Peurach et al., 2019; Spillane et al., 2019). Thus, understanding instructional reform efforts at scale, in part, requires attention to the interaction of SEAs and school districts around matters of educational infrastructure building.

Conclusion

Our account contributes to the growing research base on the role of state policy in supporting the implementation of ambitious learning standards by documenting how SEAs (a) engage with national instructional reform efforts and (b) prime and support school districts in (re)building educational infrastructure in elementary science. In particular, we argue that the school-subject matters when examining state- and district-level instructional improvement efforts and advance a framing of the relationship between state/federal government policy and local school districts as educational system-building.

While we detail a compilation of challenges SEAs face in engaging school districts in elementary science improvement, we see promise in the evolving relationships between SEAs and school districts focused on educational infrastructure building to support standards-based reform. SEA attention to both the exostructure of standards, assessments, and accountability and the bridging of these standards, assessments, and accountability with the teaching, learning, and organization in classrooms suggests enhanced support for the difficult work of instructional reform through intergovernmental relationships. Yet this research yields further questions about how these relationships play out for those engaged deeply in these systems. Future research in this area would benefit from deeper exploration of these relationships between SEAs and school district as they are enacted in practice and as they bear on the professional work of teachers and school and district leaders.

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