

**System Building in Context:
An Exploration of the Complex Environments of Elementary Science Reform and the Ways
Districts Manage Relationships with Those Environments**

by

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Dedication

For my teachers.

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Abstract

Many major reforms underway in American public school districts' elementary science programs are the result of the release of the Next Generation Science Standards (NGSS) in 2013. More than a decade later, many districts are continuing to put the vision of those standards into practice. A problem for districts pursuing these changes is the complexity of their environments; that is, the array of governmental, commercial, research, community, and other organizations and interests seeking to influence improvement in elementary science. The purpose of this three-paper dissertation is to support efforts to improve elementary science by conceptualizing the environments of elementary science reform; exploring the intersection between those environments and specific strategies for district-level improvement; and analyzing strategies for reconciling new approaches to improving elementary science with legacy approaches

The first paper examines the ways district leaders engage those environments as they work to improve elementary science instruction in ways responsive the NGSS. Drawing on historic accounts of districts engaged in elementary science reform, this paper makes the claim that the organizational field supporting science education reform consists of specific categories of organizations that have maintained currency for decades and that subsets of these organizations appear to be more immediately salient to districts. The primary contribution of this paper is an organizational taxonomy that represents field-level organizations seeking to influence science education in elementary schools and that represents their relative salience for districts.

The second paper explores how districts engage in system building to support NGSS aligned instruction in complex environments, the component parts of which are uncoordinated and variably aligned to these new standards. This paper draws on data collected as part of a comparative case study of system-building efforts in 13 districts including interviews, observations, and artifacts. Findings from this paper show that districts coordinate across a wide array of organizations in their environment, regardless of the specifics of their system building approaches. In doing so, organizations that are more proximal and/or more directly related to

districts' day-to-day functionality are more salient and may filter the more distal parts of their environment. This paper makes the claim that districts engage with a wide array of organizations, regardless of the approach they take to improving elementary science.

The third paper examines how districts are working to put the vision of the NGSS into practice in elementary schools where existing structures, norms, and routines may complicate efforts to respond to these challenges. As in the previous paper, this study draws on interviews, observations, and artifacts collected as part of a comparative case study of system-building efforts in 13 districts. Findings from this paper illustrate that there are at least three distinct approaches—integrating, retooling, and skirting—that districts use to manage relationships between new efforts to improve science instruction and pre-existing structures, norms, and routines. Through three cases, this paper illustrates how these approaches help districts leverage internal strengths to mitigate enduring challenges of instructional improvement.

This dissertation provides theoretical and empirical perspectives on the complex **environments in which elementary science reforms are enacted and the ways districts manage relationships with those environments. In addition to providing frameworks for future scholarship, these papers highlight the need for science reformers, science educators, and districts leaders to be mindful of the contexts in which that work is enacted.**

Chapter 1

Introduction

It is often the case that contemporary research on school improvement and reform in elementary science education incorporates only narrow descriptions of either the historical or contemporary macro-level contexts in which that work unfolds, contexts that organizational theorists describe as the *environments* of schools and districts. Yet, these environments are important both for those engaged in reforms and for those interested in learning from reform efforts. For district leaders, these environments—and the ways they understand and engage with them—shape and inform the possibilities available to them and the strategies they use both in their day-to-day work and in their efforts to improve students’ outcomes and learning experiences.

A developing framework for instructionally focused educational system building highlights the need for districts to manage relationships with their environments as one domain of that work (Peurach et al., 2019). That framework describes the work of districts that are endeavoring to reform and transform their enterprise in part as a means to create coherence amidst incoherent environments (Honig & Hatch, 2004). This work of system building responds to the reality that contemporary regulations and legislation have made it increasingly difficult for districts to fully decouple the technical core of their work (daily instruction) from their external environment (Meyer & Rowan, 1978). For elementary science in the United States, the major policy initiative to which many districts are presently responding are the expectations around the

adoption and implementation of the Next Generation Science Standards (NGSS) and their vision for elementary science instruction (NGSS Lead States, 2013).

Since their release in 2013, the NGSS have been adopted or adapted in the majority of states. The new standards call for ambitious and high-quality science instruction, coordinated across grade levels and represent an ambitious and rigorous vision for student learning and achievement in science across primary and secondary grades. Though the standards build on previous recommendations including *Science for All Americans* (1989), *Benchmarks for Science Literacy* (1993), and the *National Science Education Standards* (1996), they call for transformational change in both the content and methods of instruction (American Association for the Advancement of Science, 1989, 1993; National Research Council, 1996).

For district science leaders working toward this goal for wide ranging transformation in elementary science, one challenge will be engaging with organizations in their environment that are variably aligned with this vision. This includes both publishers of instructional materials that are still working to achieve meaningful alignment with the standards, informal learning environments in the community like museums that may only partially align their resources with these learning standards, and grant funders that may hold a vision for science education that diverge from that of the NGSS and its Framework (National Research Council, 2012). Another matter will be implementing their new reforms within districts where existing structure, norms, and routines are likely in place that are the legacies of past reform initiatives and may conflict with the systems district leaders aim to build in support of elementary science.

It is this context that motivates the three papers in this set which, together, explore the environments in which elementary science reforms are pursued. In each paper, I take a unique approach to consider this work. In the first paper, I draw on historical accounts of districts

engaged in elementary science reform and improvement projects to make sense of the categories of organizations influencing elementary science today. Using this literature, I explore the ways districts engaged with these organizations and highlight the relative salience of different parts of the environment for school districts.

In the second and third papers, I use qualitative data collected as part of an NSF-funded study of school districts identified as places working to manage, organize, and support elementary science teaching and learning. That project studied 13 school districts from across the country that were endeavoring to manage, organize, and improve elementary science teaching and learning in line with the visions of the NGSS. In the second paper, I draw on these data to explore the different approaches to system building districts use to organize their science reform efforts and the ways these districts engage with a wide array of organizations, regardless of the approach they take to improving elementary science. In the third paper, I investigate the ways district leaders manage the relationship between their system building efforts around elementary science and the extant structures, norms, and routines in the district.

Together, these papers offer three main contributions. In the first paper, I develop an organizational taxonomy that represents field-level organizations seeking to influence science education in elementary schools and that represents their relative salience for districts. In the second paper, I build on this taxonomy to show that, as part of just one domain of their system building work, districts coordinate across a wide array of organizations in their environment including organizations at local, regional, state, and national levels. That districts engage with a diverse collection of these organizations hold true, regardless of the specifics of their system building approaches. Through this investigation, I find that those organizations more directly related to districts' day-to-day functionality—including those organizations in closer proximity

to their daily work—are often more salient and may act influence their engagement with more distal environmental influences. Finally, in the third paper I describe three distinct approaches—integrating, retooling, and skirting—that districts use alone and in combination to manage relationships between new efforts to improve science instruction in line with the NGSS and these pre-existing structures, norms, and routines.

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Chapter 2

The Contexts of Elementary Science: An Analysis of Field-Level Organizations and their Salience for District-Level Reform

Abstract: Though the Next Generation Science Standards were released more than a decade ago, many districts across the U.S. are still in the process of implementing those standards and working toward achieving their vision in practice. A problem for districts pursuing these changes is the complexity of the environments in which they work. This paper examines the ways district leaders engage those environments as they work to improve elementary science instruction in ways responsive to the NGSS. Drawing on historic accounts of districts engaged in elementary science reform, this paper makes the claim that the organizational field supporting science education reform consists of specific categories of organizations that have maintained currency over the past six decades and that subsets of these organizations appear to be more immediately salient to districts. The primary contribution of this paper is an organizational taxonomy that represents field-level organizations seeking to influence science education in elementary schools and that represents their relative salience for districts.

At any given time, school districts across the United States experience pressures to improve outcomes for students and to reform old ways of working into new visions for instruction. Among these pressures are long-standing calls for improved elementary science instructional practices and learning outcomes. Though part of a wave of reform that has persisted for decades, the call for change in elementary science has been recently amplified with the introduction of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013).

As with past elementary science improvement movements, districts endeavoring to implement these new standards do so in interaction with their policy, resource, community, and other environments. For example, district leaders seeking to improve elementary science instruction in ways responsive to the NGSS are challenged to understand the political and policy dynamics around the NGSS in their state; curricula, assessments, and other resources that align with or support the NGSS; possible sources of technical assistance and professional development; and more.

A problem for district leaders, however, is the complexity of US educational environments. One matter is the number and variety of governmental and non-governmental organizations and interests in these environments (Rowan, 2002). Another is incoherence and turbulence in their agendas and activities (Crowson, 2003). Yet another is that environments aren't specific to any single, current reform context (such as the NGSS) but instead have taken shape over longer periods of time and include vestiges of past reform efforts.

Thus, there is a need for research examining the ways district leaders engage their environments as they work to improve elementary science instruction in ways responsive the NGSS. The purpose of this paper is to develop a provisional framework for supporting such research, with a specific focus of drawing from the literature on science education reform to understand why district leaders privilege certain organizations and influences in their environments over others.

The paper is structured in four parts. I begin by developing an analytic perspective for thinking and reasoning about the relationships between district-level instructional improvement efforts and educational environments. Drawing from literature on the history and policy contexts of elementary science improvement efforts, I then explore the environments described in those

literatures to identify categories of organizations that operate as an organizational field for elementary science. In the third part of this paper, I identify the set of those organizations district leaders appear to routinely engage with in their improvement efforts by reviewing research that attends to district-level efforts to improve elementary science. Finally, I analyze case studies of elementary science improvement to explore the district-level concerns that lead districts to focus their attention on certain categories of organizations over others.

By way of preview, my primary claim is that the set of organizations that districts engage in their work on elementary science includes the key actors in the broader organizational field. However, this set goes beyond the categories of organizations that have motivated the broader organizational field of elementary science reform as represented in the research literature. My analysis of district case studies suggests that districts prioritize certain relationships with organizations in their environment over others because of such concerns as the salience of local and state contexts, and the need to coordinate work on science with other initiatives in the district. This provisional framework, in turn, suggests a need for further empirical research that takes the district as the unit of analysis to further explore district/environment relationships in efforts to improve elementary science.

Analytic Perspective

This paper is premised on an understanding of districts as open systems that exist in complicated environments that have developed over time. Districts building systems to manage, organize, and improve elementary science teaching and learning engage with different parts of these environments. In this section, I develop an analytic perspective to guide thinking and reasoning about relationships between educational environments and district-level instructional improvement efforts. I begin by drawing on concepts from organizational theory to further

conceptualize educational environments. I then discuss the value of taking a historical perspective to understand these environments as having developed over time.

Conceptualizing Educational Environments

The premise that districts' improvement efforts happen in relationship to their environment draws on a recognition of school districts as *open systems* (Scott & Davis, 2007). In open systems, organizations are interdependent with their environments. This interdependence often steers districts into cycles of transformation or change, output, and feedback from their environments (Morgan, 2006). External environments, therefore, can both motivate and complicate district change efforts. Indeed, as open systems, organizations may be more likely to change due to factors in their environment than to change as a result of internal planning (Scott & Davis, 2007).

There are many ways researchers have framed their analysis of organizations as open systems that operate in relationship with their environments. Examples of these approaches include studying organizational populations, fields, and sets (Scott & Davis, 2007). In this paper, I leverage two conceptual perspectives from organizational theory—organizational fields and organizational sets—that provide different ways of understanding the environments and the ways districts engage them.

One way to conceptualize the environments influencing districts work on elementary science is to consider the *organizational field* of elementary science. DiMaggio and Powell (1991) define organizational fields as “those organizations that, in the aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies, and other organizations that produce similar services and products” (p.64-65). In the case of elementary science, this perspective focuses on the broad array of organizations at the

national, federal, state, regional, and local levels seeking to support or influence elementary science instruction in districts, schools, and classrooms.

Another way to conceptualize the environments influencing district' work on elementary science is that of the *organizational set*. This perspective considers the environment from the perspective of a specific focal organization, and it focuses on the set of organizations in the broader environment with which that specific, focal organization engages and interacts (Scott & Davis, 2007). As adapted for purposes of this paper, the organizational set perspective would identify and examine the organizations at the national, federal, state, regional, and local levels with which a focal district interacts as it works to improve elementary science instruction.

Organizational Fields and the Importance of a Historical Perspective

I continue the development of my analytic perspective by further considering the concept of an organizational field: that is, the collective of organizations seeking to influence or support efforts to improve elementary science instruction in districts, schools, and classrooms. Typically, organizational fields do not materialize quickly, in response to individual policy initiatives or reform movements. Instead, organizational fields emerge, evolve, and mature over time (Farnham et al., 2020; Hinings et al., 2017; Van de Ven et al., 1999). The organizational field working to influence elementary science education has been forming since at least the turn of the 20th century.

Despite these historical roots, it is uncommon for science educators or researchers who study science education reforms to engage with these histories. In 1991, George DeBoer, a science education historian, wrote:

It is rare for science educators to discuss in any depth early twentieth-century science education, let alone the ideas of the nineteenth century. For science educators who were

trained during the 1960s and 1970s, there is the pre-curriculum-reform period, characterized by rote memorization and meaningless cookbook laboratory exercises, and the post-curriculum-reform period, characterized by inquiry, conceptual understanding, and, more recently, societal, and technological concerns. For science educators being prepared today, many do not even know in any depth the significance of the curriculum reforms of the 1960s. (DeBoer, 1991, p. xii)

When one considers these histories, evidence begins to emerge that both contextualizes and complicates current science education reform efforts like those championed by the NGSS. In his review of the history of the science standards movement, DeBoer (2006) highlighted that “most of what we are trying to do is not new. Many current ideas can be found in an earlier time.” (p.8). Among the examples he cites of current movements (including ideas that are embraced by the NGSS) that have historical antecedents are calls for inquiry teaching (Spencer, 1864), efforts to deemphasize rote memorization in science education (Herbart, 1901), and movements toward a common curriculum based on the work of the National Educational Association’s (NEA) Committee of Ten research conducted in the late 19th century (NEA, 1893).

Beyond recognizing the heritage of current reforms, scholarship on the history of school reforms more broadly has made the case that ahistorical arguments for reform may understate the difficulty in achieving meaningful, lasting change (Tyack & Cuban, 1995). Recognizing this, a literature has developed that works to understand why some reforms have succeeded, others have failed, and many have landed somewhere in the middle (e.g., Cohen & Mehta, 2017; Payne, 2008; Tyack & Cuban, 1995). This research has investigated past reform movements to help identify attributes that enable successful change and warnings about common challenges. For

example, Tyack and Tobin (1994) highlight the need for reforms to align with the functional, political, and cultural beliefs and needs of school districts.

Cohen and Mehta (2017) elaborated that list, highlighting the need for reforms to: address something educators see as a problem; align with the dominant perspectives on the purpose and organization of public schools; offer educators with practicable support to achieve their goals; and be responsive to the political, cultural, and economical circumstances of schooling. Thus, taking an organizational field level perspective on the environments shaping district-level response to the NGSS is strengthened by incorporating a historical perspective of that field's evolution and development.

Organizational Sets and the Matter of Enacting Environments

I conclude the development of my analytic perspective by further considering the concept of an organizational set. If one were to focus on a single district that was actively engaged in improving elementary science to meet the vision of the framers of the NGSS, one might expect to observe that district actively engaged with the organizations that developed and championed the NGSS along with other organizations that have aligned themselves with those standards and the vision for elementary science they're aimed at achieving. However, while those organizations may be a prominent part of the organizational field for elementary science, it is unlikely that they are the only organizations that influence how the district approaches elementary science instruction. Districts likely engage with organizations with a broader focus than just science (e.g., non-science related offices in departments of education, local philanthropies, parent groups) in addition to organizations that may be engaged with science but that have not aligned their work with the NGSS (e.g., informal science education programs, local museums, science and engineering units at local universities).

This entire, complex organizational field of elementary science education reform does not present itself to any given district comprehensively, as some sort of objective reality. Rather, there is an increasing recognition that organizations and their members have individual and collective agency and can thus manage and interpret influences from their broader environments (Ocasio & Gai, 2020; Pfeffer & Salancik, 1978; Weick, 1979). Indeed, managing relationships with broader environments is understood as one of the core domains of activity in districts working to build *instructionally focused education systems* that manage and organize teaching and learning (Peurach et al., 2019; Peurach & Yurkofsky, 2018), with districts selectively buffering and bridging influences as they determine necessary (Honig & Hatch, 2004).

Organizational theorists describe this selective attention in terms of organizations “enacting” their environments (Pfeffer & Salancik, 1978; Weick, 1979), with organizations actively constructing their (subjective) environments rather than receiving (objective) environments. Organizations enact their environments by observing their environments; selecting and prioritizing organizations, influence, and interests that require attention (while ignoring or failing to notice others); pooling interpretations of those environments; deciding on and pursuing courses of action; and gauging ways that others respond (Weick, 1979).

Therefore, an organizational set perspective encourages focusing on specific districts and, then, examining the concerns and perspectives that influence how and why they engage with certain subsets of all possible actors in the organizational field of science education reform as they work to improve elementary science instruction.

Analyzing the Organizational Field of Elementary Science Reform

Drawing on the preceding, I continue with an analysis of the organizational field seeking to influence elementary science instruction. Rather than specific organizations, my aim is to

identify categories of organizations that make up that field. Later in the paper, I will explore patterns in the ways that districts sample from these categories of organizations in their efforts to improve elementary science instruction. I anchor my field-level analysis in a historical perspective of elementary science reform activities since the turn of the century aimed at identifying different categories of organizations that have sought to influence elementary science education.

The organizational field of school improvement is complex and active. Prior organizational and educational research provides a starting point for thinking about the field of science education reform (DiMaggio & Powell, 1991; Rowan, 2002; Scott, 1991). Possible categories of organizations include:

- publishers of tests, textbooks, and curriculum materials;
- providers of instructional services & staff development providers (e.g., supplemental instructional service providers; consultants);
- research and development organizations (e.g., universities, non-profit research outfits, think tanks)
- advocacy groups (e.g., Gay, Lesbian & Straight Education Network; American Civil Liberties Union; American Association for the Advancement of Science);
- professional and trade associations (e.g., labor unions, National Science Teachers Association);
- critical exchange partners & regulatory agencies (e.g., teacher preparation programs, health and safety partners, state and federal departments of education, regional & intermediary educational agencies; accreditation agencies, certification groups like International Baccalaureate, charter authorizers);
- providers of non-instruction services and supplies (e.g., accounting, insurance, payroll management, food service, transportation, classroom furniture, smartboards, lab equipment);
- consumers (e.g., students, families, post-secondary institutions, local employers).

While these categories are suggestive, they tell us less about the organizational field of elementary science education reform, specifically.

To elaborate the categories of organizations specific to the organizational field for elementary science, I drew on historical accounts of science education reform to highlight the different categories of (and examples of) actors that have developed in the organizational field of science education reform. The historical accounts I used were identified in collaboration with colleagues at the University of Michigan as we analyzed the history of elementary science reform in the last century. This work started with two editions of the *Handbook of Research on Science Education* published in 2007 and 2014 respectively (Abell & Lederman, 2007; Lederman & Abell, 2014). Chapters in these handbooks helped in constructing a historical timeline of science education initiatives, trends, and reform movements and cited other works to enrich our understanding. These included book-length accounts, reports from commissions and professional organizations, and research articles.

From these sources, I sketched a perspective of the organizational field for elementary science as it has emerged and evolved since roughly the turn of the 20th century. In the sections that follow, I describe what appear to be the dominant categories of actors in that field including:

- Textbook publishers and curriculum developers,
- Government agencies
- Universities and teacher preparation programs, and
- Professional organizations.

In describing how organizations in each category have influenced elementary science reform, I endeavor to share both how these organizations have worked to shape elementary science but also how their influence has evolved over time.

What becomes evident in considering the organizational field is how it resists clean categorization. This is not surprising given that a foundational premise of this research was that

the environments of schools are complex and thus, by definition, consists of “parts or elements not simply co-ordinated, but some of them involved in various degrees of subordination; complicated, involved, intricate; not easily analysed or disentangled.” (Oxford University Press, n.d.). As a result, there are examples of specific organizations across these categories that appear across categories. For example, the federal government invested heavily in elementary science curriculum development including programs developed by universities and professional organizations. Thus, these categories can be understood as analytically distinct, but practically entwined.

Textbook Publishers and Curriculum Developers

The first category of organizations that emerged from this analysis were publishers of textbooks and curriculum developers. Included in this category were commercial vendors who produced elementary science textbooks for the national market and the teams that developed the curricula they released. In some instances, these were organizations that provided materials to like science kits and prepackaged consumables. In others, curricula were developed by one organization and published or made available by another.

Orra Underhill (1941) used textbooks dating back to the mid-18th century as the main data for his work *The Origins and Development of Elementary-School Science*. His work, which finds that that science was not discrete subject in elementary schools until the turn of the 20th century, highlights the persistent role of the textbook industry in the organizational field of elementary science reform. Though science subject matter appeared in early hornbooks and didactic readers, it was not until the end of the 1800s that science-specific texts developed. As described by Underhill (1941), a popular text was *How to Teach Natural Science in Public Schools* by William T. Harris. The material was initially released as part of his superintendent’s

report in 1871 but was published as a book in 1887. That material is credited as the first publication of a detailed plan for an elementary science curriculum (Underhill, 1941). Rather than a textbook for students, Harris's book was intended as guidance for teachers, providing a framework for organizing elementary science instruction based on contemporary educational theory (Underhill, 1941).

In the 1920s, Gerald Craig, as part of his dissertation, began developing for use at the Horace Mann school in New York what has been described as the first age-graded, science curriculum for grades one to six (Champagne & Klopfer, 1980). In 1932, Craig and six teacher-collaborators published that curriculum as the six volume *Pathways in Science* textbook series. Underhill (1941) described the series as emerging from "the first serious and scientific attempt to define a curriculum that would enable some functional relationship to be seen between purpose and procedure" and one that soon came to be reflected in elementary science instruction throughout the country (p.220).

From the 1920s through the 1940s, a number of leading textbook publishers began to offer their own elementary science textbooks. The title pages of textbooks released by the publishers that Whitten and Whitten (1997) describe as dominant in this era show that these series were developed by teams that included university faculty; past presidents of the National Association for Research in Science Teaching (NARST) including Gerald Craig; and educators affiliated with schools, and local- and state departments of education. Examples of these texts include: Ginn and Co's first commercial release of Craig's *Pathways in Science* in 1932.; Heath and Co.'s *Science Readers* authored by William L. Nida (River Forest, IL and State Teachers College, San Diego) and Stella H. Nida in 1926; MacMillan's *Nature Study and Science* written by Gilbert H. Trafton (Minnesota State Teachers College at Mankato) in 1927; D. Appleton-

Century Company's *Elementary Science by Grades* edited by Frank Ballou (Washington, DC Public Schools) and authored by Ellis C. Persing (Western Reserve University) along with co-authors based in public schools in Pittsburgh, Philadelphia, Detroit, and Washington, DC, in 1927; and Scott Foresman and Co.'s *Discovering Our World* written by a team including Wilbur Beauchamp (University of Chicago) and Glenn O. Blough (Colorado State and University of Chicago).

Materials shortages during the Second World War had a substantial, adverse impact on the textbook publishing industry (Whitten & Whitten, 1997). However, once shortages eased, the industry rebounded fueled by both the G.I. Bill and the Baby Boom. This is reflected in the sales over time of textbooks. While 1947 saw \$131 million in textbook sales, by 1958 \$280 million was spent to elementary textbooks alone (Whitten & Whitten, 1997).

In 1956, the National Science Foundation (NSF)—itself established only in 1950—began supporting the development of science curriculum and textbooks. These efforts started in secondary science education with the Physics Sciences Study Curriculum (PSSC) led by Jerrold Zacharias (Dow, 1991). This work led to the realization that improvement at the secondary level began in elementary schools. As it had become clear to many science reformers that reforms in secondary science were needed to support their vision of post-secondary science, it eventually became clear that reforms in elementary science were needed to support the vision of secondary science (Hein, 2005).

The NSF's approach to supporting elementary science was to fund curriculum development projects. Following a philosophy to "let a 100 flowers bloom" (Hein, 2012), the federal government awarded funding to multiple curriculum projects, each with a different vision for science education. By 1967, there were more than two dozen elementary-level curriculum

funded by NSF (Lockard, 1967). Among the most well-known of the elementary science projects were the Elementary Science Study (ESS), also led by Jerold Zacharias and developed at the Educational Development Center; Science: A Process Approach (SAPA) developed by psychologist Robert Gagné and the Commission on Science Education of the American Association for the Advancement of Science (AAAS); and the Science Curriculum Improvement Study (SCIS) developed by Robert Karplus, a physicist at the Lawrence Hall of Science at the University of California, Berkeley (Atkin & Black, 2007; Gagné, 1966).

After a move away from funding curriculum projects in the 1970s and much of the 1980s, the NSF began to invest in elementary science curriculum projects again in 1987 and 1988 (Bybee, 1993). In response to some of the challenges the earlier curriculum projects had faced with publishing and disseminating their materials, these new programs were required to have established partnerships with publishers before beginning development, some of whom matched the federal contribution to the project (Bybee, 1993; Warner, 1987). Familiar actors were involved in these projects including the Education Development Center and the Lawrence Hall of Science. BSCS, which had started as the Biological Sciences Curriculum Study in the 1950s era of NSF curriculum development, expanded what had been a high school level project to support elementary science. With financial support from IBM and the NSF, the BSCS curriculum project drew on elements of the earlier SCIS curriculum to develop its “5E” model for instruction (Bybee et al., 2006), an instructional model for elementary science instruction that remains popular today.

Reform movements in the decades that have followed continue to recognize the influence of textbook publishers and curriculum developers. As described by Stern and Roseman (2006), textbooks are “the de facto curriculum of most schools: they largely determine what topics and

ideas are taught in the classrooms and how these topics are taught” (p.303). Yet, prior to the release of the NGSS in 2012, there was considerable variation in state science standards making it difficult for publishers (most of whom operate at the national rather than the state level) to align their material with any one set of standards (DeBoer, 2014). In 2012, three textbook publishers (Pearson, Houghton Mifflin Harcourt, and McGraw-Hill) accounted for more than three-quarters of elementary textbook market share while only 10 percent of elementary classrooms used NSF funded instructional materials (Banilower et al., 2013).

While the authors of the Framework behind the NGSS noted that “in order to realize the vision of the framework and standards, it is necessary that aligned instructional materials, textbooks, and computer or other media-based materials be developed” (NRC, 2012, p. 246), a challenge remains about how to move newly-developed, NGSS-aligned instructional materials into classrooms (and to displace older, unaligned materials) as they become available. In 2018 (five years after the release of the NGSS standards), 71 percent of elementary classrooms were using textbooks published in 2012 or earlier (Banilower et al., 2018). Presently, only two K-5 curriculum are available that meet the alignment criteria used by EdReports, a nonprofit that reviews curriculum.

Government Agencies and Government-Sponsored Projects

The next category of organizations that emerged from this historical analysis were government agencies involved in education. The policy literature focuses on the federal government’s involvement in elementary science including both the legislature and offices in the executive branch. At times, these agencies fueled the publishers described in the last section. These agencies also sponsored research and development projects to advance elementary

science. In doing so, they had both direct and indirect influences on elementary science reform movements.

The funding provided by the NSF to support elementary science curriculum development was part of an influx of federal spending—and involvement—on public education. As early as 1945, the Office of Scientific Research and Development had been advising the White House to attend to issues of schooling including science instruction in connection to national defense concerns of the Cold War (Bush, 1945). In 1958, congress passed the National Defense Education Act (NDEA) which authorized more than a billion dollars in federal spending to insure that “additional and more adequate educational opportunities be made available” (NDEA, 1958, Title I Sec. 101). While the NDEA was a historic shift in the federal involvement public education, the law was clear that education remained a matter for individual states to control noting “nothing contained in this Act shall be construed to authorize any department, agency, officer, or employee of the United States to exercise any direction, supervision, or control over the curriculum, program of instruction, administration, or personnel of any educational institution or school system” (NDEA, 1958, Sec. 102).

In 1965, the Elementary and Secondary Education Act (ESEA) was passed by congress, further expanding federal investment in schools. While NDEA had been motivated by issues of national security, the ESEA was a part of the Johnson Administration’s War on Poverty. Because of this, the ESEA included a number of funding initiatives including Title I (which supported schools in low-income communities) and Title II (which supported the purchase of instructional materials). The funding package maintained the NDEA’s commitment to local control over schools by allowing districts flexibility in how they used their funds. The ESEA has been reauthorized (and amended) regularly since it was enacted in 1965.

Though the federal government continued to invest in public schools, it temporarily backed off of funding curriculum projects through the NSF in the 1970s. In the early 1970s, Congress was critical of the NSF for its failure to achieve broad dissemination and usage of the curricula it had funded (Dow, 1991). Indeed, the success of those curriculum projects was mixed and contested. For example, though ESS reported it had reached three-million students between 1961 and 1971 (Lockard, 1975), researchers from the ESS team also found that “two years after a highly organized large-scale effort at implementation, it is very difficult to identify any lasting effects [of ESS]” (Nicodemus et al., 1969, p. 1). The subject of NSF funded curriculum made its way to the floor of Congress in connection to public criticism of *Man: A Course of Study* (MACOS), a social studies curriculum that had received support from NSF (Dow, 1991).

Federal funding for the development of new curriculum through NSF resumed in the 1980s. After the establishment of the Department of Education in 1979, reports like *A Nation at Risk* (National Commission in Excellence in Education, 1983) amplified concerns about the status of science and engineering education in the U.S. relative to other countries and, in particular, the educational programs in nations seen as our economic and political rivals.

The NSF was not the only federal agency outside the Department of Education to get involved in science education reform projects. A 2008 report from the National Research Council noted that, more than a third of a billion dollars was allocated by federal agencies other than the Department of Education for K-12 STEM programs in 2006 (National Research Council, 2008). While the bulk of this spending came from the NSF (more than \$241 million), other investments came from the Department of Health and Human Services (over \$52 million) and the National Aeronautics and Space Administration (NASA) (\$23 million).

Many of the K-12 science programs sponsored by NASA have emerged in the last two decades including the NASA Explorer Schools (NES) project, Education Flight Projects (EFP), Educator Astronaut Project (EAP), Science, Engineering, Mathematics and Aerospace Academy (SEMAA) Project that all launched in 2003, and the Digital Learning Network (DLN) that launched in 2004. Two other programs at the agency have longer legacies. These are the Aerospace Education Services Project (AESP) that launched in 1962 and the Interdisciplinary National Science Project Incorporating Research and Education Experience (INSPIRE) which replaced the Summer High School Apprenticeship Research Program (SHARP) that was launched in 1980. All of these programs work across grade levels except for INSPIRE/SHARP which is a program for high schoolers. Many of these programs provide curriculum materials for teachers.

The preceding has focused on the government agencies that have shaped elementary science and science education reforms at the national and federal levels. Because of the authority states maintain over most parts of education, it is likely that there is and has been substantial variation both in how individual states have pursued reforms in science education and in how state governments and departments of education have mediated and implemented federal initiatives. While state leaders have been involved in national and federal reform movements (as was the case when the National Governors Association collaborated with President George H.W. Bush in 1989 to agree on the goals for American education that would later become America 2000), the literature on educational reforms at the national level included few references to state governments as national actors.

Universities and Teacher Preparation Programs

Another major category of organizations that emerged from this analysis were universities including their teacher preparation programs. Like publishers, universities that were home to curriculum development projects like SCIS received some government sponsorship for that work. But universities, which increasingly took over responsibility for teacher preparation in the 20th century (Labaree, 2008), also appear in these literature for the ways in which elementary teachers are prepared to teach science.

A trio of studies were sponsored by the NSF in the 1970s to determine whether two decades of effort and millions of dollars spent had strengthened science and math education (Ingison, 1978). One of the three studies was the 1978 National Survey of Science, Mathematics, and Social Studies Education (NSSME)¹—a survey of state, district, and local school personnel—found that only 31 percent of districts were using one or more of the federally funded curriculum materials in their K-6 classrooms (Weiss, 1978a, p. 8). Among these, only ESS, SAPA, and SCIS were being used in more than 5 percent of districts (Weiss, 1978a, p. 9). Among the survey items included in the initial NSSME was one that directly spotlighted another matter in elementary science—teacher training. In the 1978 survey, less than one-quarter of teachers reported feeling “very well qualified” to teach science compared with two-thirds of teachers who felt very well qualified to teach reading (Weiss, 1978).

That elementary school teachers lacked confidence or training in teaching science was not to say that these subjects weren’t a part of teacher training programs. During the later part of the 19th century, some normal schools emphasized training in elementary science (Kuslan,

¹ Follow up national surveys—now known as the National Survey of Science and Mathematics Education (NSSME)—were conducted in the 1985-86 school year, and then again in 1993, 2000, 2012, and 2018 (Weiss, 1987; Weiss et al., 1987; Weiss et al., 1994; Weiss et al., 2001; Banilower et al., 2013; Banilower et al., 2018).

1959), the NEA recommended that districts appoint science specialists to support elementary teachers (Underhill, 1941), and in states like Illinois, state legislatures even required training in science as a condition of teacher licensure in the 1870s (Underhill, 1941). Yet, elementary teachers continued to be seen as underprepared to teach science. In the preface to Gerald Craig's science textbook series, the author writes "many elementary-school teachers have felt considerable embarrassment in the past because they realized the meagerness of their training in this field" (Craig & Hurley, 1932, p.v). In *Thirty-First Yearbook of the National Society for the Study of Education* (1932), it was noted that "evidence in hand point rather clearly to the fact that in current practice in state teachers colleges an adequate attainment of these standards for the education of teachers is not secured or even closely approached." (NSSE, 1932, p. 325). The NSSE report notes that the science courses offered in teacher training programs in 1927-28 were idiosyncratic to their instructors and not coordinated at either the school or national level.

In the 1985-6 NSSME, questions were added to further probe teacher preparation. One of these questions explored whether teachers had achieved the standard outlined by the National Science Teachers Association (NSTA) that called for teachers to have had at least one course each in the biological, physical, and earth/space sciences (Weiss, 1987²). This recommendation was itself informed by the findings from the NSSME and Case Studies of 1978 and subsequent research conducted by the Division of Teacher Education of the NSTA (Mechling, 1982). That survey of teacher preparation programs was conducted in the 1981-82 school year. It found that about one in ten teacher training programs required future teachers take courses from all three of these areas of science and about half of programs required only one or two of these courses

² This standard from the NSTA is described in NSSME report from 1987. However, the earliest NSTA document that I was able to find about this expectation was from 1998. I believe the original NSTA position statement may have been published in 1982 or 1983.

(Mechling, 1982). Questions to determine whether teachers were meeting the NSTA's perpetration recommendation appeared in subsequent administrations of the NSSME. In 1987, 31 percent of grades K-3 teachers and 42 percent of grades 4-6 teachers had met this standard (Weiss et al., 1987). In both 1993 and 2000, slightly more than half of teachers in grades 1-4 and K-4 respectively reported having met this standard (Weiss et al., 1994; Weiss et al., 2001). However, this number then dropped back toward 1980s levels with only about a third of teachers in 2012 and 2017 reporting having had this coursework (Banilower et al., 2013; Banilower et al., 2018).

In addition to training future teachers, universities conduct research on elementary science education and work with districts and schools to test and experiment with new ideas in education. For example, Gerald Craig's development of an elementary science course of study mentioned earlier in this paper was enabled by the relationship between Teachers College, Columbia (where Craig was a graduate student) and the Horace Mann School, a demonstration school associated with the university (Court Upholds Closing of Horace Mann-Lincoln School, 1947).

In 2002, federal legislation established the Math Science Partnership (MSP) program. Funds were mostly apportioned to the NSF with some funding going to the Department of Education. MSP sites included partnerships between K-12 systems, higher education institutions, and other community partners including businesses, community organizations, state education agencies, and informal science education organizations. According to the legislative record, the MSP projects funded through NSF were intended to support the development of model programs in which science, math, and engineering departments at colleges and universities would partner with school districts "to improve math and science proficiency for K-12 math and science

teachers and students” (*Implementation of the Math and Science Partnership program*, 2003, p.4). The portion of funding allocated to the Department of Education was intended to support bringing promising programs from the NSF funded projects to scale by implementing and disseminating the “new teaching materials, curricula and training programs” those projects had developed (p.5). According to the database on MSPnet, the program’s online hub, 274 projects were funded through MSP between 2002 and the end of the program in 2019.

Professional Organizations

Across the categories of environmental influences that I’ve described so far, there are examples of the sway of another category of influences—professional organizations.

Professional organizations are often membership-based groups outside the formal structures of schooling that support teachers, administrators, and other schooling professionals. These groups sometimes write policy briefs, offer professional development opportunities, publish journals and magazines, or lobby on behalf of their members or vision. Examples of these organizations include national groups like the National Science Teachers Association and state chapters of national groups like the Michigan Science Teachers Association. Other professional groups include state associations of superintendents or school principals. National-, state-, and local teachers unions are also professional organizations.

Professional and trade organizations have supported and advocated for elementary science improvements and reforms since the turn of the 20th century. Examples of their influence have already been mentioned including the NEA’s Committee of Ten (NEA, 1893), the 31st yearbook of the NSSE (1932); the development of the SAPA curriculum by the AAAS between 1960-1974; and the recommendations for elementary science teacher preparation from the NSTA in the early 1980s. After their work on SAPA, AAAS advocated for elementary science through

Project 2061 and Science for All Americans. Among the projects led by Project 2061 were *Benchmarks for Science Literacy* (1993) and *Science for All Americans* (1989), both of which were among the foundational materials for the NGSS.

Another organization, the National Research Council (NRC) of the National Academies of Sciences, Engineering, and Medicine developed the *National Science Education Standards* (1996)—another set of science standards that influenced the NGSS—and later the *Framework for K–12 Science Education* (2012). The Framework was created by the NRC as a guiding document for the development of new standards for K-12 science education, standards that would be released the following year as the NGSS.

Summary

This history not only introduces the legacy on which the NGSS is built, but it suggests a framework that can be used to being thinking about the categories of organizations that constitute the organizational field of elementary science reform. One conjecture is that districts engage this broader organizational field in constructing the specific set of organizations on which they draw in their efforts to improve elementary science education. This organizational field includes textbook publishers and curriculum developers, the federal government including federally funded projects, universities and teacher preparation programs, and professional organizations. All of these categories of organizations have had lasting impacts on elementary science and have influenced reforms of elementary science in many ways including through advocacy, policy setting, market forces, and supplemental district supports.

Analyzing Patterns in Organizational Sets & Enacted Environments

I continue by analyzing patterns of district engagement with their environments in their efforts to improve elementary science instruction. This is not a strict application of the organizational set perspective, as it does not focus on a specific district. Rather, it is a review of studies that a) attended to district-level considerations in their analysis, and b) examined the field-level organizations that districts engaged in their improvement efforts. In this sense, the analysis is suggestive of patterns in the set of organizations with which districts engage in improving elementary science instruction.

Searching the Literature

For this analysis, I drew on case studies focused on science education reform since the 1960s. Identifying literature that included rich descriptions of the environments in which districts pursued elementary science reforms was challenging because there is a scarcity of research on implementation of elementary science programs more generally (Kelly & Staver, 2005). As a result, it was difficult to use standard search terms to find literature that dug deeply into the environments in which those programs were pursued and that both a) worked at the level of school district, and b) described the context of that work. One exemplar collection of research was *Case Studies in Science Education* (Stake, 1978) sponsored by the NSF along with the NSSME. Published as collected volumes in 1978, the case study project was anchored in in-depth case studies of the state of science in 11 districts around the country during the 1976-77 school year. The two-volume final report for the project is over one-thousand pages long and includes rich profiles of the districts studied and the contextual factors pressing on education in those places ranging from descriptions of fuel shortages, teacher strikes, population movements,

and social concerns. One case even included photographs of the community including homes of different families and comparisons between the private and public-school plants.

Recognizing that the richness of the data included in those studies was in part a function of their research design as case studies, I chose to focus my search of the literature on identifying other case studies. Using that filter, I found reports of other large-scale projects that included richer descriptions of the contexts and environments of districts than I had previously been finding (though admittedly none quite so far reaching as those of the NSF studies). For this reason, I moved forward trying to identify additional case-studies in the literature.

Ultimately, my search strategy in ERIC focused on articles that a) discussed elementary science, b) were focused on American, public-school districts (not individual teachers or classrooms), c) were focused on reforms within schools rather than reforms to pre-service preparation of teachers, and d) included mention of leaders, administrators, or superintendents. The resulting cross section of research on elementary science includes examples starting in the 1960s and with at least one example in every decade thereafter. Though most of the identified cases focused on school districts, a few described state-wide findings across districts. The sample was not exhaustive, nor does it serve as a foundation supporting general claims. Even so, it served the purpose of scoping the landscape to identify patterns and to establish a starting point for future research.

While each report in the sample explicitly spoke to elementary science, this was not always the exclusive focus of the authors. The NSF cases studies, for example, were each primarily focused on high school science (which they defined as inclusive of the social sciences and math) but conducted observations in the elementary school(s) that fed the focal high school and generally included rich descriptions of those spaces specifically. Other studies looked at

math and science, science K-12, or took some other focus. It also bears noting that over the decades included, there was a shift in what was considered an ‘elementary school’. In the earliest cases, elementary schools served students up to grade 8. In the 1980s, districts began shifting to a middle school model (a trend that has been reversing in some places; Pardini, 2002).

Analyzing the Literature

While reading each article, I noted and coded each instance of an environmental influence. This coding was emergent, capturing the ideas from the research without the use of any previously developed coding scheme. Sometimes, these influences were described as such. For example, the authors mentioned a state assessment as influencing district efforts around elementary science. In other cases, external influences were mentioned as something other than a pressure. For example, they might have described teacher professional development being provided by the state without characterizing this as an external influence.

After collecting the codes from all the articles together, I sorted them into groups. For example, I grouped ‘parents’ and ‘Parent Teacher Organizations (PTOs)’ and mentions of ‘community’ and ‘businesses’ into a cluster labeled ‘parents and community.’ I aimed to balance a desire for specificity with the need to be able to share these findings in a meaningful way. In the end, I condensed dozens of codes into 9 categories. A review of these 9 codes along with examples of the subordinate codes that each captured is included in the appendix. I used the literature found prior to the literature search and through following intext citations to provide additional details but did not include those texts in coding.

Limitations of the Analysis

Among the key limitations of this work was the challenge of finding literature that provided descriptions of the environments in which districts pursued reforms. By searching for case study literature, I was able to identify texts that contained richer descriptions of these environments. Yet, this approach also meant I excluded many studies that may have had important—if fleeting or brief—descriptions of the environment in which elementary science was pursued.

An additional limitation to this work was that these literature largely represent the environments as understood, filtered, and described by external researchers. While the NSF case study reports often included descriptions of the environment and some reflections on that environment from district staff, most research shared only the parts of the environment that are most salient to the focal issue because of page limitations, publishing expectations, or researcher judgement. As a result of this filtering and interpretation, my understandings of environmental pressures were limited by what previous researchers have shared and interpreted.

Findings: Patterns of Engagement Between Districts and Field-Level Organizations

Reviewing these case studies highlighted categories of field-level organizations that appear to be especially important to districts engaged in elementary science reform. The reviewed literature spanned many years of research and reform and described efforts to improve elementary science teaching and learning that varied in both setting and structure. The environmental influences were similarly varied, as was the specificity with which these environments were described. While the set of organizations districts engaged with reflected the broader organizational field as sketched from the literature, this set perspective also highlighted actors beyond the organizational field elaborated so far.

In the following sections I identify categories of organizations that district leaders appear to routinely engage in their improvement efforts. I begin by examining the categories of organizations that were held in common between the field- and set- perspectives. These included districts' engagement with textbook publishers and curriculum developers, the federal government, university-based teacher preparation programs, and professional organizations. Then I highlight some additional categories of organization that appeared as important organizations in districts' environments including funding sources beyond those provided by the federal government, resources in the community that support elementary science, and the parents and broader community in which districts operate.

Textbook Publishers and Curriculum Developers

Publishers and developers of instructional materials like textbooks, curriculum, and classroom materials were field-level organizations that the districts in the reviewed studies attended to while working on elementary science. For example, one study (Banilower, 2007) included references to districts sourcing and managing the relationship with vendors of science kits, textbooks, consumable science equipment, and reusable classroom supplies. Though districts often rely on the availability of commercially available teaching materials, there can be a disconnect between the materials available and district visions. This was true in a recent study where a lack of NGSS-aligned materials challenged district improvement efforts (Jaciw et al., 2020). But it was also a challenge faced by districts in the late 1980s when the Tennessee State Board of Education adopted a new hands-on science curriculum framework while no such curriculum materials were available commercially (Prather & Hartshorn, 1989). In another instance, teacher-created curriculum frameworks based on new standards had to be modified when no suitable texts could be found that matched those frameworks (Lorsbach,

2008). In one district, the curriculum adoption committee struggled to find materials that were aligned to both the grade-level science standards and their students' reading levels (Moore, 2006). Districts engage not only with the content of commercially available teaching materials but also their cost (Kelly & Staver, 2005).

Not all curricular materials were a product of the commercial market. Districts in one study were part of a state-level curriculum building initiative in which teacher teams developed exemplar units to share with other schools and districts (Zucker & Shields, 1995). In other districts, materials were created within the district. Mimeographed lessons made by district staff were used in combination with purchased textbooks in one district (Denny, 1977) and teachers in another district were allowed sabbatical time to develop curriculum and course materials that later were published commercially as textbooks, units, and filmstrips (Smith, L. 1977).

Government Agencies

The federal government has motivated and invested in many of the reform movements in elementary science and is a prominent actor in the organizational fields for elementary science as developed within the literature on the history of science reforms. From the perspective of the organizational set, the federal government was most salient as a source of funding for the districts in the reviewed studies. Specific federal entitlement programs like Title III (Reiser, 1968) and the Eisenhower Math and Science State Grant Program within Title II (Zucker & Shields, 1995) supported districts' work on elementary science as did competitive federal programs including NSF grants (e.g., Anderson & Horn, 1970) and the Investing in Innovation (i3) Development Grant (Jaciw et al., 2020).

While the organizational field of elementary science reform has developed with substantial federal involvement, the government agencies more regularly engaged with by

districts working on elementary science appear to be at the state and local level. This included state learning standards and curriculum guides (e.g., Banilower, 2007; Lorschach, 2008; Moore, 1999; Prather, 1989; Rodriguez, 1997; Zucker & Shields, 1995), graduation requirements (Peshkin, 1977), instructional time requirements (Serrano, 1977), and textbook approval processes (Firestone et al., 2002; Kelly & Staver, 2005; Serrano, 1977).

State involvement in elementary science varied by context. Puerto Rico, like Hawaii and the District of Columbia, is a place where the district and state educational authorities are one and the same resulting in the state being more closely involved in school improvement work there (Rodriguez, 1999). Though districts in the reviewed studies engaged more with state agencies than they did federal ones, the control exerted by states over districts varied. For examples, some states had few or no rules about which textbooks could be adopted (Firestone et al., 2002; Lorschach, 2008) while districts in other states saw waves of legislation that were much more prescriptive (Carlos & Kirst, 1997). Yet, policies put in place by a legislature (e.g., state takeover of poor performing districts) were sometimes sufficiently unpopular that researchers saw leaders recognize that it was unlikely they would be fully implemented (Firestone et al. 2002).

Universities and Teacher Training Programs

The reviewed studies provided evidence that districts engage directly and indirectly with universities as they work on elementary science. Indirectly, the preparation teachers received to teach science during their pre-service education at colleges and universities appear across the reviewed literature (e.g., Jaciw et al., 2020; Leslie, 2011; Moore, 2006; Welch, 1977) up through to the most recent study in the sample where the author references longitudinal evidence of this as a persistent issue (Jaciw et al., 2020). Teacher preparation appears in these literature as a

matter of both instructional practices and science content knowledge. Pre-service experiences that started with science content and then moved to methods posed challenges in districts working toward inquiry-based elementary science instruction that approached science teaching and learning in the reverse order (Kelly & Staver, 2005). More generally, district-focused research recognized that many elementary teachers had inadequate preparation in science (Moore, 2006).

Despite the persistent challenges districts experienced tied to teachers' pre-service training, districts engaged with local universities and colleges for more than just the development of future teachers. Universities provided in-service learning opportunities for teachers and served as regional hubs for science education. These included a research and development center at University of Delaware (Zucker & Shields, 1995), the Resource Center for Science and Engineering at a campus of the University of Puerto Rico (Rodriguez, 1999), and university-based hub for professional development (Leslie, 2011). The districts were, in some instances, engaged with area universities or their extension programs to offer teachers college credits for their professional development time (Anderson, 1970; Prather & Hartshorn, 1989).

Professional Organizations

Professional organizations appear in these literature as sources of influence and support for elementary school teachers. Districts in the reviewed studies engaged in reforms that were tied to the proposals put forward by organizations like the AAAS, and the National Science Teachers Association (NSTA) including *Project 2061* and *Science for All Americans* (both from AAAS) and the *Scope, Sequence, and Coordination of National Science Education Content Standards* (by NSTA) (Kelly & Staver, 2005; Zucker & Shields, 1995). In addition to those policy documents, the studies provided evidence of district science leaders and teachers engaging

with the magazines and newsletters published by these organizations. This included publications like *Science* from the AAAS and *Science and Children* published by NSTA (Labahn, 1969; Smith, L. 1977).

In addition to these national organizations, districts in these studies were also responsive to state and local teachers unions. Tensions between the unions and district or even state administration occasionally complicated work on elementary science through union opposition to outcome-based education policy initiatives (Carlos & Kirst, 1997) or unpaid curriculum adoption meetings outside the contracted workday (Lorsbach, 2008). Productive relationships between unions and districts, however, made it easier for some districts to navigate difficult situations as was the case when one district superintendent worked closely with the union president to develop the district's pivot to remote learning during a crisis (Sanders & Stufflebeam, 1977).

Sources of Funding

So far, the parts of the organizational set described in the reviewed studies have reflected the organizational environment suggested by the literature on elementary science reform. However, in shifting perspective from the organizational field to the organizational set, new categories of influence are highlighted. One such category is those organizations that provide financial support for schools and their science programs. While the funding received from government agencies was important, districts in the reviewed studies also relied on funding from philanthropic organizations and through corporate philanthropy including sizeable donations and, in some cases, in-kind support (Cerwin et al., 2018; Zucker & Shields, 1995). Though these funding sources helped districts afford their work on elementary science, dependence on them generated concerns about both the replicability of the individual improvement efforts and the long-term financial requirements of maintaining the initiatives (Labahn, 1969). Where funding

was limited, districts faced challenges in implementing their plans for elementary science (Leslie, 2011).

Though districts may seek external support for their work on science, such partnerships have not been without challenges. In some instances, available opportunities were not aligned with objectives of a district (Walker, 1977b) or were seen as insufficient (Kelly & Staver, 2005). As a result, some projects worked to coordinate otherwise disconnected and disjointed external supports for schools including the creation of statewide networks of professional development providers (Zucker & Shields, 1995). Other projects opted to forgo external supports (like the professional development provided by curriculum publishers) (Lorsbach, 2008).

Community Resources for Instruction

Another category of organization with which districts in the reviewed studies engaged were resources in their community that provided professional development for educators, field trips for students, curricular materials, and other supports. The literature described regional consortiums of schools (Labahn, 1969) and neighboring school districts (Cerwin et al., 2018) as providing support and guidance for districts in their work on science. More detached institutions included community resources like museums which provide opportunities for professional development, curriculum materials, and field trip opportunities (Smith, L. 1977; Walker, 1977b). In some places, districts benefitted from proximity to non-profits focused on science education for students, teachers, and families (Zucker & Shield, 1995); could partner schools with working scientists (Zucker & Shields, 1995); or engage with local offices of agencies like the Environmental Protection Agency on labs and field trips (Hill-Burnett, 1977). However rich, these opportunities were not always aligned with the planned curriculum of a district (Walker, 1977b).

Some studies reflected efforts to coordinate otherwise disconnected and disjointed external supports for schools. This included the creation of a statewide network of professional development providers (Zucker & Shields, 1995) and regional support centers that worked with area public and private schools (Labahn, 1969). Regional centers appeared elsewhere in the literature including intermediate school districts that provided support services for teachers, administrators, and students in a number of nearby school districts (Hoke 1977; Smith, M., 1977). Other external partners included consultants hired to write reports for district administrators (Banilower, 2007; Hoke, 1977; Smith, L. 1977) and external researchers and evaluators (e.g., WestEd) (Cerwin, 2018; Jaciw et al, 2020; Zucker & Shields, 1995).

Parents & the Community

In the literature reviewed, mentions of parents and the community were frequent though often ambiguous. These included references simply to ‘parents’ or ‘the community’ as well as references to organized parent groups, Parent-Teacher Organizations and Associations, citizen advisory committees, local businesses and business communities, religious groups or general community religiosity, public support for specific reforms, and local politics and local culture.

Though these references often provided little detail about how districts engaged with parents or the community on matters of elementary science, there were some exceptions. Among these were descriptions of parents forming lobbying groups to push for/against specific pedagogical approaches (Carlos & Kirst, 1997) or middle- and high-income parents concerned that reforms would negatively impact their children (Rodriguez, 1999). In a case study of a district’s adoption of an elementary science program (Kelly & Staver, 2005), teachers described specific perspectives from parents of their students that were both positive and negative. On the positive end, a teacher reported to the authors that “‘Parents are coming in and saying ‘I can’t

believe what they are learning and what they say they know, and they really do know it.” (Kelly & Staver, 2005, p.42). However, other teachers also described parents being frustrated at not being able to support their children with homework “because they had difficulty picking out the vocabulary from the texts” (Kelly & Staver, 2005, p.43).

Both within a community (as just described) and across the papers, parents are shown as both supportive of and adverse to reform efforts in elementary science. In some instances, authors described specific district efforts to reach out to parents to engage them in science learning. In the case of a project in rural Tennessee, this included supporting teacher-leaders as they shared their work with local newspapers (Prather, 1989). In Connecticut, the state-level improvement hub that supported district-level improvement initiatives contracted with a public relations firm to develop a public awareness campaign that included sponsored outreach materials shared through the major television stations, the statewide newspaper, radio, and smaller print media popular in immigrant enclaves and ethnic communities (Zucker & Shields, 1995, p.30). Some authors also highlighted a need to think more broadly about whom to include when imagining a school’s ‘community’ and suggested police, child welfare agencies, public health agencies, court officers, social workers, and probation officers play important roles in the school community (Hill-Burnett, 1977; Hoke, 1977).

Another Consideration: Concurrent Reforms

The preceding sections highlight the field-level organizations that the sample districts engaged with while working on elementary science. Using an organizational set perspective to consider the influences in the environment as described in the reviewed cases shed light on the salience of both the organizations observed in the broader, national-level literature and in other influences that operate in the more specific contexts of individual districts like parent groups and

museums. A foundational proposition behind this investigation was that districts' work on elementary science occurs in interaction with complex policy, resource, social, and other environments. Part of that complexity results from the fact that these environments have developed over time, as highlighted earlier in this paper. However, another part of that complexity is that these environments for science coexist with environments focused on other parts of the schooling enterprise including other instructional initiatives (e.g., English Language Arts (ELA), Math, Social Studies, special education programs) and non-instructional initiatives (e.g., increasing access to mental health support, school sports, school consolidations, safety). Though the analysis for this paper focused on the set of organizations districts have engaged with to support elementary science, it was clear in these studies that these other areas of focus are important considerations for districts working on elementary science reform.

A recurring challenge for elementary science in these literature was the need for districts and science leaders to coordinate their work on science not only with influences in their environment but with other concurrent, sometimes competing, reforms. The centrality of ELA and math in the elementary school curriculum were repeatedly mentioned in the reviewed case studies including some instances where those subjects were the focus of concurrent curriculum reform projects (e.g., Banilower, 2008; Carlos 1997). In other cases, the focus on ELA and math was motivated by high stakes testing policies (Banilower, 2007). But even before the spread of test-based accountability, concerns around high school level minimum competency tests trickled down to elementary schools and shifted the focus of instruction toward ELA and math (Sanders & Stufflebeam, 1977; Smith, L., 1997; Walker, 1977b). One study in Illinois found that elementary schools were only teaching science in grade 4 when it was part of the state test (Leslie, 2011) while another study of a midwestern district observed that the district had paused

their yearly science assessments in response to NCLB (Kelly & Staver, 2005). In a 1977 case study, one Boston area teacher reported, “A few years ago [...] city schools were very keen on science, and we did quite a lot. Now the pressure is on reading and basic math” (Walker, 1977b, ch.11 p. 28). In another instance, ELA and science intersected when teachers struggled to find science materials that were both accessible to the reading level of their students and aligned with their vision for science reforms (Lorsbach, 2008). In the case of elementary instruction, an added challenge is that elementary teachers often teach all subject areas and therefore can be overloaded with shifting expectations as districts work on more than one subject area at once (Moore, 2006).

Work on elementary science also ran concurrent with initiatives that were more indirectly tied to classroom instruction. These included efforts to reduce class-size, restructure K-8 schools into middle schools, develop bilingual and special education programs, adapt instruction for open-plan schools, and increased competition with charter schools over enrollment (Carlos, 1997; Cerwin 2018; Denny, 1977; Hoke, 1977; Leslie, 2011; Prather, 1989; Serrano, 1977; Walker, 1977b).

These challenges and competing interests impacted how districts engaged with their environment—in some cases limiting their ability to focus on science reform. For example, while millions of dollars were spent nationally on NSF curriculum and their teacher institutes in the 1960s and early 1970s, a southern, rural district in the 1977 case studies *began* working on science around 1976 because the decades prior had been spent embroiled in legal and social issues of race and integration in their schools (Walker, 1977a). The year they began working on improving science was only the second year the district had held an integrated school dance.

The work toward integration described by Walker (1977a) in that school district was not the result of a change in community attitudes. Instead, it was the result of court cases and subsequent policies and directives that requires districts integrate. Accounts of districts' engagement with the courts was largely concentrated in the earlier case studies in this sample, particularly in the 1977 case studies. At that time, districts were responding to the policy and regulatory shifts following cases on segregation, bussing, and English Learner programs and were observant of on-going litigation around special education programs (e.g., Sanders & Stufflebeam, 1977; Walker, 1977a; Walker, 1977b). As with curriculum policies more generally, districts engaged with court rulings that flowed down from federal courts to their local context. In other cases, issues were being adjudicated in the local community. In one district, the regional education agency was facing a lawsuit for lack of Black and Mexican-American representation on its board (Denny, 1977). In another, teachers in an urban, mid-Atlantic district were working with their union to file a class-action lawsuit in response to suspension and expulsion policies that had resulted from another court case (Hill-Burnett, 1977). The last case in these literature to describe districts balancing science with court-motivated or court-mandated activities was from 1995 when districts continued to navigate court orders to desegregate schools (Zucker & Shields, 1995).

All of these examples highlight the complications and challenges districts face in their daily work—complications that can shape how they engage their environments in support of elementary science. Because these literature describe districts engaging with a diversity of environments (both in terms of time and geography) as they work on elementary science, there is not a clear pattern that emerged about how this need to navigate multiple challenges shapes the

environments districts enact for themselves. Nevertheless, these findings highlight and reaffirm that reform movements occur in complicated contexts that shape how districts respond.

Summary

The organizations described as salient for districts in the reviewed studies largely reflect the categories I identified from the literature on the policy contexts for elementary science. This included relationships with actors in the textbook and teaching materials industry, government agencies, universities, and professional organizations. However, the reviewed studies also highlighted organizations and interests beyond those I described as making up that field, that were salient for districts. These included funding streams beyond those provided by the federal government, community partners like museums and regional education agencies, and the parents and community that the district served. Further, this analysis highlighted that districts manage this work while also managing concurrent, sometimes conflicting reforms in other subject areas.

A Framework for Understanding District Engagement with Environments

In addition to describing the categories of organizations with which districts engage while working on elementary science, the reviewed studies also shed light on some of the concerns that lead districts focus on certain categories of organizations over others. Two considerations—functionality and proximity—appeared to describe why districts engaged with some categories of organizations more than others. In this section, I begin by highlighting the ways the need for functionality shaped how districts attended to organizations in their environments. Then, I discuss how districts’ engagement with their environments reflected the importance of proximity for school districts. Finally, I draw these two perspectives together with the patterns of district engagement described in the preceding section to propose a taxonomic framework for supporting

research that examines the ways district leaders engage their complex environments as they work to improve elementary science instruction in ways responsive to the NGSS.

Functionality

In reviewed studies, districts regularly engaged with organizations in their environment which had implications for the day-to-day work of operating schools including organizations who supported classroom instruction and that helped districts address the practical challenges of organizing and managing instruction in elementary science. Many of the external organizations with which districts in these literature engaged were involved with these issues of functionality. These included publishers of textbooks and teaching materials (Banilower, 2007; Jaciw et al., 2020; Kelly & Staver, 2005; Lorschach, 2008; Moore, 2006; Prather & Hartshorn, 1989); sources of funding (Cerwin et al., 2018; Jaciw et al., 2020; Labahn, 1969; Reiser, 1968; Zucker & Shields, 1995); and partners in the community that can help with things like professional development and school field trips including regional educational agencies, colleges and universities, and area resources like museums (Cerwin et al., 2018; Hill-Burnett, 1977; Hoke 1977; Labahn, 1969; Smith, L. 1977; Smith, M., 1977; Walker, 1977b; Zucker & Shield, 1995).

Tyack and Tobin (1994) argued that the success of reform efforts has been related to the ways improvement initiatives have intersected with the functional work of schools, the political dynamics of schools as a quasi-governmental agency, and the cultural expectations communities have of their schools. In their work explaining why some reforms have succeeded, Cohen and Mehta (2017) found that successful reforms had some attributes that echo this functionality including a perception that reforms were aligned with the mainstream perspective on the purpose of public schools and understanding of how schools are organized, that the reforms are practicable, and that they offered educators with support needed to achieve them (Cohen &

Mehta, 2017). Both of these frameworks highlight the centrality of functionality for districts considering or working on reform and improvement projects.

Though districts in the reviewed studies engage with these categories of organizations to support their work around elementary science, this network of supports can also present challenges to those initiatives. This challenge was reviewed in the literature in relation to curriculum that are not aligned with new visions for elementary science, teacher preparation programs from which new teachers leave feeling underprepared to teach science, the need to cover the costs of implementing reforms, and the potential misalignment between area resources (like school field trips or teacher development opportunities) and visions for science reform.

That districts in these literature prioritize function-forward relationships and especially relationships anchored in resources (e.g., textbooks) and resourcing (e.g., funding) also echoes a dominant approach to school improvement observed at the national level. For many decades, resource-forward approaches to school improvement have been supported by a robust resource market and a federally subsidized infrastructure built to produce and put into practice research evidence (Peurach, Foster et al., 2022). The theory of change behind resource-forward approaches to improvement is that more and better resources can improve student outcomes and reduce disparities among populations.

Proximity

When looking across the reviewed literature, districts prioritized more proximal actors compared with national or federal influences. Thus, despite the federal involvement in science education and waves of national attention to science education over these decades, districts prioritized engagement local, regional, and state matters. While districts did engage with the federal government especially in terms of funding entitlements and competitive grants

(Anderson, 1970; Banilower 2007; Jaciw et al., 2020; Kelly & Staver, 2005; Leslie, 2011; Rieser, 1968; Zucker & Shields, 1995), few other aspects of the federal government were mentioned in these studies. Instead, districts attended more to their state government. This included engaging with state learning standards and curriculum guides, graduation requirements, textbook approval processes, and requirements around instructional time (e.g., Banilower, 2007; Firestone, 2002; Kelly & Staver, 2005; Lorsbach, 2008; Moore, 1999; Peshkin, 1977; Prather, 1989; Rodriguez, 1997; Serrano, 1977; Zucker & Shields, 1995).

This may be in part because instructional reform movements must necessarily be translated from policy document into classroom practice. Labaree (1999) has described this as the shift from *rhetorical curriculum* (i.e., ideas proposed by educational leaders, researchers, and policymakers) into a *formal curriculum* (i.e., commercial and home-grown curriculum materials) and then again into the curriculum and lesson plans that teachers use in their classrooms. Where policy documents and educational reforms are operationalized at the national level (as with the NGSS and its predecessors including Science for All Americans, Benchmarks for Science Literacy, and the National Science Education Standards), part of this translation happens as state-level agencies convert the rhetorical goals of those national policies and movements into more specific state level guidelines and regulations.

That rights of states to maintain authority over and responsibility for matters of education is not simply a matter of tradition but also an authority established by the 10th Amendment to the U.S. Constitution. This authority has been a part of national debates about federal involvement in education and, as noted earlier, shaped how federal programs like NDEA and ESEA were written and operationalized. A challenge for reformers is the degree of variability that this creates from state to state. As I've already described, this results in districts in some states engaged with state

governments that legislate standards, pedagogical norms, and approved textbooks, while districts in other states engage with state governments who place fewer restrictions on their work (Carlos & Kirst, 1997; Firestone et al., 2002; Lorsch, 2008). Though organizational theorists have considered organizational fields shaped more by function than geography (Scott, 1991), the local control and local variation in matters of education might result in a greater influence of geography for educational organizations than is true in other domains.

This prioritization of more proximate influences in the environment extended beyond branches of government. While science education may have been a part of a national consciousness during this time period, the districts in the reviewed studies were more concerned with their community's feelings about science education. Examples of this were districts engaging with parents who were lobbying to state legislatures for specific pedagogical approaches (Carlos & Kirst, 1997) and concerns about how reforms in science could negatively impact their children (Rodriguez, 1999).

Public sentiments about science were complex and often tied to time, place, and community concerns. Districts had to make sense of the diversity of opinions in their community as was the case in one district where some parents expressed excitement about their students' science education while others expressed frustration (Kelly & Staver, 2005). In other cases, the districts had to navigate tensions between the desires of their agricultural and blue-collar communities and the ambitions associated with the contemporary vision for science education (e.g., Denny, 1977; Walker 1977a). While misogynistic beliefs about women's ability to teach or learn science only appeared in cases from the 1970s, as late as 1995, researchers noted that districts were working to manage the "widespread belief held by many parents, students, and educators that a perception that science is for "smart" students" (Zucker & Shields, 1995, p.16).

Other community influences that authors described districts engaging with were local businesses and religious institutions. These organizations wielded cultural influence in the community and could provide philanthropic support. For example, Zucker & Shields (1995) described how DuPont, an influential chemical company based in Delaware, had long supported science education in the state's schools, resulting in a statewide focus on science over math which in turn influenced districts' attention on science. In California, parents and members of "conservative religious groups" (Carlos & Kirst, 1997, p. 16) threatened not to participate in new state standardized assessments that were rumored to be "value-laden" (p.16).

Elaborating a Framework

To this point, I have described the organizational field for elementary science reform, the set of organizations in that field that districts engage, and some of the factors shaping why districts appear to prioritize their engagement with certain parts of their environment over others. Together, these suggest a taxonomy that provides a framework for understanding the environments that districts work with while working on elementary science. Figure 1-1 below provides a visual representation of this framework with the more proximal organizations (e.g., parents and the community) placed nearer to the district while more distal organizations (e.g., the federal government and its agencies) placed represented as farther from the district.

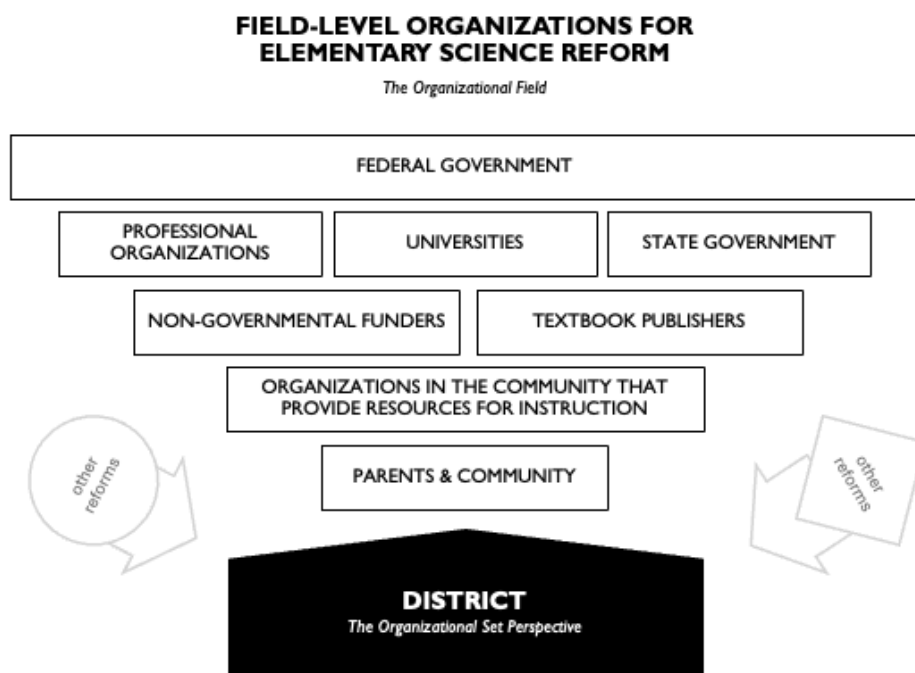


Figure 1 A Provisional Framework for Understanding the Environment of Elementary Science

Organizations that districts describe working with helps to elaborate the organizational field for elementary science as it relates to district improvement efforts. In addition to the federal government, universities and their teacher preparation programs, textbook publishers and curriculum developers, and professional organizations, districts engage with sources of funding, state and local governments, community resources for instruction, and parents and the community. But, as noted earlier, a primary concern for districts engaged in reform centers on practical, functional issues. Perhaps for this reason, districts are far more concerned with their more proximal local contexts. Together, these findings highlight the salience of parent and community groups, community resources for instruction, and sources of funding as being both proximal in their environment and important for the daily function of schools.

Considerations for Future Research

In this paper, I worked to develop a provisional taxonomy that provides a framework for supporting research that examines the ways district leaders engage their complex environments as they work to improve elementary science instruction in ways responsive to the NGSS. My analyses sought to understand first, the organizational field that has historically influenced elementary science instruction, then patterns in organizational sets with which past districts have engaged. The findings in this paper suggest the scope of organizations contemporary district leaders may be engaged with as they work to implement and support NGSS-aligned instruction in their elementary schools. While these environments remain complex and multifaceted, the taxonomy developed through this analysis provides a starting point for future research. This work also begins to identify patterns that help explain why district leaders may prioritize their engagements with certain parts of their environments over others. These findings suggest that the need to prioritize the functional needs of districts, state- and local-organizations over national or federal ones, and the need to balance concurrent and sometimes competing reforms while working on elementary science.

This analysis suggests a need for research in two critical areas. First, while these findings were drawn from accounts of reforms over the last six-decades, a crucial matter is whether these categories of organizations correctly or fully capture the ways contemporary districts understand their environment. Second, additional research is needed to explore how district leaders manage these environments as they work to improve elementary science teaching and learning in their schools where existing structures, norms, and routines may remain as legacies of past reform efforts in science and other subject areas. In the papers that follow (Foster, 2024a; Foster, 2024b), I take up these ideas by first exploring the relationships between the organizations in the

environment of districts engaged in elementary science education reform and the approaches they take to system building and then by investigating how district efforts to build educational systems for elementary science account for and manage legacy reform conditions.

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Appendix: Coding Scheme

Parent Code	Subordinate Codes	Examples
1. Textbook Publishers and Curriculum Developers	• Textbooks • teaching materials, equip, & facilities • NSF Curriculum • materials created by the state • textbook marketplace • industry created materials • science kits	<i>“It was the job of the committee to narrow the possible choices of curricula to two or three before seeking input from all teachers.” (Lorsbach, 2008)</i> <i>“Conversations with project staff members, school administrators and teachers indicates clearly that the major constraint is the quantity of equipment and materials needed. The extensive use of materials and equipment by individual children is both the major strength and weakness of programs such as ESS, SAPA, and SCIS.” (Anderson & Horn, 1970)</i> <i>“When publisher’s programs were considered, the majority of time was given to programs from textbook publishers. The fact that text companies provided materials showing correlations between their programs and state science standards appeared to play a strong role.” (Moore, 2006)</i>
2. Federal Government	• Federal legislation, mandates, and government pressures • Federal court involvement in schools • Politics • Federal funding	<i>“In ten CPS schools that were undergoing restructuring due to repeated failures to make the “adequate yearly progress” required by No Child Left Behind.” (Leslie, 2011)</i> <i>“Desegregation is an issue that is yet to be resolved in Western City. The elementary schools are under Office of Civil Rights investigation and, as a consequence, H. E.W. has stopped all new funding of federal programs. Recently, the W.C.S.D. filed a counter suit against H.E.W. and is waiting for a decision from the court.” (Serrano, 1977)</i> <i>“The MSRT wrote an Eisenhower grant so that people using Investigations have the opportunity to get together and they have formed an Investigations support group.” (Huineker et al., 1999)</i>
3. State Government	• State learning standards • Curriculum oversight • State support for science • State Legislation • Testing policies • Politics • State funding	<i>“the PR Assessment Standards state that attention must be paid to providing assessment opportunities responsive to the students’ differences in gender, ethnicity, culture, socioeconomic status, and abilities.” (Rodriguez, 1999)</i> <i>“The NCTM Standards have already had considerable impact on curricula and teaching in the state. The Department of Education has actively promoted these changes.” (Zucker & Shields, 1995)</i> <i>“‘Another thing that has helped is No Child Left Behind for science is coming, and that new state test changed the willingness of people to hear about science programs in comparison with math and reading.’ [District Science Supervisor]” (Banilower, 2007)</i>
3. Universities & Colleges	• Teacher Preparation • Research partnership & publications • Community colleges	<i>“In December, 1967, Dartmouth College was awarded an NSF Cooperative College School Science grant which will enable this project to do further teacher training in a summer institute and to</i>

Parent Code	Subordinate Codes	Examples
		<i>extend the range of its effect to several communities outside the original school districts.” (Reiser, 1968)</i> <i>“This decision was an attempt to increase our project’s impact on preservice education at the University of Chicago and to build on and strengthen existing connections between the University and CPS.” (Leslie, 2011)</i> <i>“The science program at the elementary school level in Western City is almost non-existent. This is somewhat surprising because in 1972-76, the local state university initiated an NSF Elementary Science Project for Teachers.” (Serrano, 1977)</i>
4. Professional Organizations	• Teachers Unions (locals & national) • Council of State Supervisors • AAAS, NSTA	<i>“For example, the science framework used Project 2061 Science for All Americans and NSTA’s Scope, Sequence, and Coordination’s Content Core.” (Zucker & Shields, 1995)</i> <i>“Vortex instructors struck me as being living embodiments of Ron Corwin’s (1965) “militant professionals.” Kurt, Paul and James and a junior high advocate of the feminist movement stood out, but they were not the only ones. Today’s highly-organized teachers, marked by their adherence to comprehensive bargaining agreements and demands for participation in decision-making, may not fulfill the traditional roles many administrators and parents hold for them. Nonetheless, they were working—and working very hard.” (Hoke, 1977)</i> <i>“The CRSE staff based their curriculum changes on guidelines suggested by NCTM and NRC standards, Project 2061, and the NSTA’s Scope, Sequence and Coordination educational materials project.” (Rodriguez, 1999)</i>
5. Funding	• Philanthropic Funding • Grant funding	<i>“du Pont under writes the costs for dozens of teachers to attend the National Science Teachers Association convention annually.” (Zucker & Shields, 1995)</i> <i>“Initiative funding is provided by the S. D. Bechtel, Jr. Foundation, with the Hastings/Quillin Fund supporting participation by the charter organizations.” (Cerwin, 2018)</i> <i>“The Innovative Science Training Program is judged by the Evaluation Team to have been highly successful in accomplishing the major objectives of 1 training and 2)the design of a model in-service training program. Certainly it is hoped that this program can be continued through other source of funds such as school consortium, the state education agency, private foundations, etc.” (Labahn, 1969)</i>
6. Community Resources for Education	• External Support Providers(Consultants, Eval, PR) • Regional Agencies, Centers, Collaboratives	<i>“Nearly 300 fifth-grade students and their teachers (from a number of city schools), are seated in an auditorium at the Science Museum watching a programme called “Good Vibrations,” about the wave characteristics of light and sound.” (Walker, 1977b)</i> <i>“A multi-district regional center is the principal supplier</i>

Parent Code	Subordinate Codes	Examples
	• External Teacher PD Providers • Extracurricular Science Opportunities • Field trip partners • Museums	<i>of the non-print materials used by science and math teachers.” (Denny, 1977)</i>
7. Parents & Community	• Expectations for students in & after school • Perceptions of science • Population & enrollment changes incl. private, alternative, soc, & charter school draws • Economy • Local politics • Media, Radio, TV • School Boards • Business community • Parents • Parent Teacher Organizations • Community groups like churches	<i>“they too have encountered resistance from middle and high SES parents who feel that their children will not benefit from student-centered, collaborative learning.” (Rodriguez, 1999)</i> <i>“One significant miscalculation was the backlash from certain groups of parents and the public (e.g., conservative and religious coalitions) whose perspectives were not included in the committees who developed and piloted CLAS.” (Carlos & Kirst, 1997)</i> <i>“To promote team recognition, a public information program was conducted in each team’s home area to acquaint the public with their plans for improvement of elementary science education. Because of the publicity surrounding their work, the nine teams were invited to host a special conference of the Science Association of Tennessee (SAT) at UTM and present their ideas to a statewide audience.” (Prather & Hartshorn, 1989)</i>
8. Competing, Conflicting, & Concurrent Reforms	• Ongoing projects in other subject areas • Integration & Special Education inclusion efforts	<i>“Often, the lack of a science program was attributed to a heavy focus on reading/language arts and mathematics due to high-stakes testing.” (Banilower, 2007)</i> <i>“‘In the eyes of everyone in Pecan County,’ writes the observer, ‘integration is the key issue, perhaps particularly in the schools; but much of what is focused on education pervades the community as a whole.’ (Walker, 1977a)</i>

Chapter 3

Analyzing Relationships between Approaches to System Building and Environmental Organizations in Elementary Science Education Reform

Abstract: In the majority of states, the adoption of the Next Generation Science standards calls for districts to reimagine and improve elementary science. In turn, some districts may develop educational systems to manage and organize elementary science in their schools and classrooms. Districts engage in this work in a broader context including complex environments the component parts of which are uncoordinated and variably aligned to these new standards. This paper makes the claim that districts take different approaches to system building to organize their science reform efforts. Additionally, districts engage with a wide array of organizations, regardless of the approach they take to improving elementary science. This paper explores how contemporary districts build systems to support elementary science instruction understand and engage with their environments using data from a comparative case study of system-building efforts in 13 districts across the United States. Findings from this paper show that districts coordinate across a wide array of organizations in their environment, regardless of the specifics of their system building approaches. In doing so, organizations that are more proximal and/or more directly related to districts' day-to-day functionality are more salient and may act as a filter for more distal parts of their environment.

After their publication in 2013, the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) were adopted or adapted as the science standards in a large majority of states. The new standards called for new approaches to science instruction and assessment anchored in what the standards call “three-dimensional (3D) learning” (National Research Council, 2012).

School districts striving to improve elementary science instruction in ways responsive to the new standards pursue that work in complicated environments that may simultaneously challenge, facilitate, or complicate those efforts.

Managing these environments is an important part of district efforts to improve elementary science. For example, leaders have to make sense of and coordinate government policies, determine what implications those policies have for their district, and communicate with external key stakeholders like parents about new district practices. In their review of the research on how district- and school-leaders navigate their policy environments to transform science education in the elementary grades, authors of a report from the National Academies of Sciences, Engineering, and Medicine (2022) found that “there is not a significant research base on local leadership practices that support meaningful and equitable science and engineering instruction” (p.216).

Though the ways district leaders manage their environments in specifically in relation to elementary-level science may be under explored, studies have demonstrated that leaders build relationships with partner organizations in their environment to expand capacity (Spillane et al., 2001), engage with community members (including local businesses) to foster local support for the NGSS (Iveland et al., 2017), and work to understand and implement reforms in line with new science standards (Spillane & Callahan, 2000). Other, emerging research on district/environment relationships in relation to elementary science suggests a broad array of organizations influence and support elementary science including publishers of textbooks and curriculum, government agencies, universities, and teacher training programs, professional organizations, funding sources, community resources that support instruction, and parents and community members (Foster, 2024a).

Given the expansiveness and complexity of their environments, a central problem faced by school- and district-level leadership when improving elementary science is to engage their environments strategically, in ways that align with and have potential to support district-specific approaches to improvement. Thus, there is a need for research that a) theorizes such approaches to improving elementary science and b) explores relationships between the specific approaches used by districts and the ways leaders engage their environments (i.e., the ways they bridge, buffer, and reconcile competing parts of the environment including federal and state policies, education research and resources, and community values; Honig & Hatch, 2004; Peurach et al., 2019; Spillane, 2009).

Responding to that need, the purpose of this paper is to examine district/environment relationships in a purposeful sample of 13 geographically diverse American school districts that are responding to the NGSS by endeavoring to build systems that support instructional improvement in elementary science. Specifically, this research explored how districts use of resource-forward approaches (i.e., strategies focused on the provision of more, new, and better resources as the primary focus of system building) and practice-forward approaches (i.e., strategies focused on improving instructional practice and the routines, structures, and organizational contexts in which instruction occurs) to managing and improving elementary science relate to the ways those same leaders understand and enact their environments.

In this paper, I begin by providing an analytical framework for my work. Then, I describe my study design and methodological approach. In sharing my findings, I then develop and support two claims based on my analysis: first, that districts take different approaches to system building to organize their science reform efforts; and, second, districts engage with a wide array of organizations, regardless of the approach they take to improving elementary science. My

analysis highlights the complexity of the environments in which districts operate by mapping those environments to better understand parts of the environment that are most salient to district leaders working on elementary science. Further, it suggests that leaders engage very similar parts of their environments, even when pursuing different approaches to improving elementary science.

Background: Building Systems that Bridge from Standards to Practice

Released in 2012 and 2013 respectively, *A Framework for K-12 Science Education* (published by the National Research Council) and the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) together call for ambitious and high-quality science instruction coordinated across grade levels. Since their release, the NGSS were either adopted outright or adopted with modifications (referred to as adapted) by most states between 2013 and 2019.³ The standards represent ambitious and rigorous goals for student learning and achievement across primary and secondary grades. Building on previous recommendations for state standards (i.e., Benchmarks for Science Literacy in 1993; National Science Education Standards in 1996; and Project 2061 in 1985), the NGSS call for transformational change in both the content and methods of instruction. As part of this transformation, the NGSS go beyond defining what content students should learn in science by adding in expectations that students: a) both learn and practice the skills used by scientists to build scientific knowledge, and b) begin to understand the ways ideas span across scientific disciplines and into everyday problem solving.

³ What ‘adaptation’ means varies state to state. Adapted standards often borrow verbatim language and structure from the NGSS with certain standards removed (for example, in Oklahoma’s adaptation of the NGSS, some standards relating to how humans have impacted climate systems have been modified or dropped). Perhaps because of the ambiguity around adaptation, precise metrics for this vary. The [NSTA reports](#) that all states but Florida have standards *based on* the Framework while the NGSS reports that Texas, Florida, Virginia, Pennsylvania, Ohio, & North Carolina have neither adopted nor adapted NGSS.

The NGSS were intended “to directly address and overcome” the disorganization that had been observed in K-12 science education including traditions of teaching science as a set of facts, prioritization of breadth over depth, and lack of opportunities for students to experience how scientists work (National Research Council, 2012, p.1). To achieve that goal, the new standards called for substantial changes to the content, methods, and scope of elementary science instruction. For example, in versions of the California science standards in use between 1998 and 2013, the kindergarten science standards fit on one page and included three main content standards (one each in physical, life, and earth sciences), each with three subordinate standards.⁴ A fourth “Investigation and Experimentation” standard included five subordinate activities (California Department of Education, 2000, p.2). After California adopted the NGSS in 2013, the new science standards for kindergarten spanned 12 pages and included 12 performance expectations each accompanied by up to five subordinate standards for each of the three dimensions of the NGSS (California Department of Education, 2021).

Ultimately, whether the standards achieve the goals of their authors depends entirely on how, and indeed if, they are meaningfully embraced in principle and in practice by district central offices, schools, and—most importantly—teachers. Simply adopting the new standards does nothing to address the preexisting challenges in elementary science education (such as funding challenges, teacher professional development opportunities, physical facilities, limited time, and large class sizes) (Trygstad et al., 2013). Indeed, the scale of the changes required will likely take considerable investments of additional time and resources, work that has already been complicated by both a dearth of instructional materials aligned with the NGSS (Lowell et al., 2020; Penuel & Reiser, 2017) and a relative lack of pre-service training in science (often just one

⁴ The Fordham Institute, a conservative think-tank, repeatedly scored these standards as among the country’s best.

methods course and rarely any field experience) among elementary teachers (Olson et al., 2015).

As a policy documents, the NGSS and the Framework are many degrees removed from the day-to-day experiences of students in schools. Labaree (1999) referred to reforms like the NGSS as reforms to the *rhetorical curriculum* or ideas proposed by “educational leaders, policymakers, and professors about what curriculum should be” (para. 4). As they are adopted by states and translated into commercial or home-grown curriculum materials, these ideas become reforms to the *formal curriculum* (Labaree, 1999, para. 4). But changes at either of these levels do not necessarily yield substantial change at either the level of *curriculum-in-use* (what teachers actually use in their classrooms), or what content students learn in their classroom experiences (what Labaree calls the *received curriculum*).

To bridge the NGSS from a reform at the level of rhetoric to changes at the level of curriculum-in-use or received curriculum, teachers will need support beyond the adoption of new tests, standards, or curriculum. Yet, for many years, this is how reform efforts have been pursued (Cohen & Hill, 2000; Little, 1990). Decades of reform efforts have resulted in some changes but generally fallen short of reformers ambitions (Payne, 2008; Tyack & Cuban, 1995; Tyack & Tobin, 1994). This is in part because of a persistent *loose coupling* between the technical core of schools—instruction—and other parts of the organization (Meyer & Rowan, 1978; Weick, 1976). As a result, many districts may lack established mechanisms, strategies, or infrastructure for supporting the translation of rhetorical or formal educational reforms at the district level. Instead, reimagining and improving the technical work of instruction has largely been the work of teachers, pursued in the privacy of their classrooms (Jackson, 1968; Lortie, 1975).

However, regulations and legislation like those around school accountability and teacher evaluation may make it increasingly difficult for matters of instructional practice to remain fully

decoupled from a district's administration and policies (Coburn, 2004; Diamond & Spillane, 2004; Duncan & Everitt, 2022; Kenney et al., 2024). In this context, a growing body of research has begun to describe district efforts to manage, organize, and improve classroom instruction by developing as *instructionally focused education systems* (Peurach et al., 2019). Districts engaged in this kind of system building attend to five core (and interacting) domains of work:

- *Building educational infrastructure* including developing a shared vision for instruction; selecting or creating formal resources for instruction (e.g., curriculum, benchmark assessments); and fostering social resources for instruction (e.g., common norms, teacher-leader-student relationships, support for new initiatives among educators)
- *Supporting use of infrastructure in practice* including providing professional learning opportunities, opportunities for collegial learning, mentorship or coaching,
- *Managing and Monitoring Performance* including developing strategies for continuous improvement and summative accountability
- *Distributing instructional leadership* to staff and teams beyond the administrative offices and supporting new leaders
- *Managing environmental relationships* to craft coherence from dissonant policy and contextual environments including federal funding streams, state accountability

As part of their system building work, districts distribute responsibility for managing and organizing instruction between schools and the central office (Peurach & Yurkofsky, 2018).

While instructionally focused educational system building necessitates intentional, coordinated work across these five domains, other efforts to manage and organize instructions may also be described by considering how they attend to these individual domains of work.

Analytical Framework

In this paper, I explore how district science leaders manage their environments to support their work on elementary science by focusing on the relationship between the ways they understand their environments and the strategies they draw on in their efforts to improve

elementary science teaching and learning. This work rests on the supposition that school districts are *open systems* (Scott & Davis, 2007). Open systems are characterized by interdependence between organizations and their environments and by porousness between the inside and the outside of an organization. Gareth Morgan (2006) analogized open systems to organisms that require ongoing interaction with their environment, have certain needs that must be attended to for survival, and exist in many forms. Thus understood, organizations as open systems are in an ongoing cycle of input, transformation or change, output, and feedback (Morgan, 2006). Given all of this, Scott and Davis (2007) contend that organizations are more likely to change due to factors in their environment than they are from internal planning.

The environments in which school districts exist are a particularly busy ecosystem. One way of considering that ecosystem is as an *organizational field* made up of organizations that collectively form “a recognized area of institutional life” including suppliers, consumers, regulatory agencies, and other schools (DiMaggio & Powell, 1991, p.64). The literature suggests the organizational field for elementary science includes federal, state, and local governments; organizations in the community that support elementary science like museums and middle-tier educational authorities; publishers and developers of instructional material and tools and resources to support elementary science; non-governmental funders; universities; and professional organizations including unions (Foster, 2024a).

Sensemaking & Enacted Environments

While managing relationships with the environment is a key domain of work for districts engaged in instructionally focused educational system building (Peurach et al., 2019), no single strategy for managing environments will serve the needs of all—or most—districts. One reason for this is that districts’ environments are not objective realities, understood identically across

stakeholders, observers, or even staff members. Instead, environments are subjectively and iteratively defined through a process of ongoing interpretation, action, and reaction. This process for understanding one's environment has been referred to as *enactment* (Pfeffer & Salancik, 1978/2003; Weick, 1969) and is triggered by environmental changes including situations of ambiguity and uncertainty (Weick, 1995).

Enactment, in turn, involves an iterative *sensemaking* process that draws on individuals' biases and past experiences (Weick, 1979). The ways district science leaders enact their environment are, therefore, shaped by their individual heuristics and biases (Tversky & Kahneman, 1974). They are also shaped by a) necessarily incomplete information (Pfeffer & Salancik, 1978/2003) and b) the structures, norms, and rules in the district that control or influence how they engage with their environments (Ocasio, 1997). In school districts, sensemaking is thus influenced by the district's context and leaders' past experience, professional expertise, individual identities, and social networks (Coburn, 2001; Spillane et al., 2002; Spillane et al., 2006; Spillane, 1998, 2005).

Scholars of education often take an institutional-cognitivist perspective on enactment that focuses on what individuals attend to in their environments (Eddy-Spicer, 2019). From this perspective, a key part of a leader's sensemaking includes sorting through many organizations in the environment and deciding what to attend to and what to ignore. What leaders attend to in their environment is important because attention is a prerequisite to action. That which is not attended to—or not seen—cannot consciously affect the actions of leaders or organizations at a given moment (Pfeffer & Salancik, 1978/2003). Those parts of their environment that go unnoticed won't directly influence a leader's actions until they are observed (Ocasio, 1997; Pfeffer & Salancik, 1978/2003).

These ongoing processes of sensemaking and enactment occur as districts work to understand and implement reform efforts. In the case of elementary science standards, research has shown that leaders' sensemaking around new standards can create a misalignment between the intentions of reformers and districts' actions in ways that can appear like an implementation failure (Spillane & Callahan, 2000). Additionally, district leaders may focus on the parts of reforms that are familiar based on their past experiences and background knowledge, leading to a tendency towards more conservative implementation of reforms in science (Spillane & Callahan, 2000, p. 419).

As leaders draw on their prior knowledge and experiences, new policies supplement rather than replace prior practices and understandings (Spillane, Reiser, & Reimer, 2002). This may be exacerbated by the reality that even widely accepted policy shifts—like widespread adoption of the NGSS—do not result in an immediate or uniform shift in the organizational fields of schools. While this is most notably apparent in the delay between the publication of standards and the availability of standards-aligned instructional materials (National Academies of Sciences, Engineering, and Medicine, 2022), it is likely the case that local grant makers, community groups, or museums may lag in the degree to which their vision aligns with those of the framers of the NGSS.

Resource- & Practice-Forward Approaches to System Building

As leaders enact and make sense of their environments, they engage with and navigate multiple, sometimes conflicting *institutional logics* (Diehl & Golann, 2023). These logics are comprised of socially constructed assumptions, values, and patterns of material practices and rules individuals use to provide meaning for their social reality (Thornton & Ocasio, 2008). Logics also support lines of reasoning that connect beliefs, desired outcomes, and means of

accomplishing those outcomes and this are suggestive of theories of action (also referred to as theories of change) that organizations can take to achieve desired outcomes (Thornton & Ocasio, 2008). In the sphere of education, research has identified a diverse array of logics that provide both complementary and conflicting prescriptions for how districts should act (Diehl & Golann, 2023). For example, Golann and Jones (2021) explored the theories of action principals adopted in their approaches to maintaining school discipline. They found that principals drew on both logics of care (that emphasized the importance of understanding and respecting students and addressing the root causes of misbehavior) and logics of control (that emphasized the schools' responsibility for controlling and managing behavior through rewards and punishments), alone and in combination.

Two policy logics—*resource-forward logics* and *practice-forward logics*—have been influential and instrumental in shaping the macro-level improvement landscape and the theories of action behind efforts to manage, organize, and improve instruction (Peurach, Foster et al., 2022; Peurach & Russell, 2024). Resource-forward logics of improvement and innovation emerged in the mid-20th century alongside an increased involvement of the federal government in public education (Peurach, Foster et al., 2022). Resource-forward reforms pursue school improvement and the reduction in educational disparities through the provision of more, new, and better resources. Going beyond the distribution of extra funds, resource-forward approaches posit that giving a teacher, classroom, or school evidence-backed, high-quality, educative curriculum and tools can improve outcomes for the students in those spaces. Such approaches have a long legacy in efforts to improve schools including the NSF-funded science programs of the post-Sputnik era which included elementary and high school curriculum development projects. Resource-forward approaches to improvement and reform have also had substantial

influence on the design of federal funding strategies and an evidence infrastructure that has developed to inform macro-level policy decisions (Peurach, Foster et al., 2022).

A second, relatively newer wave of improvement has adhered to *practice-forward logics*. Improvement activities in this vein approach change by focusing on improving instructional practice and the routines, structures, and organizational contexts in which instruction occurs. Approaches to change following these logics might include efforts like one-on-one instructional coaching, teacher collaboration in professional learning communities (PLCs), lesson study, routines for co-planning or co-teaching, and some in-service teacher professional development. Practice-forward approaches to improvement have centered the use of data and evidence by school and teacher teams to measure, monitor, and understand the impacts of improvement efforts for their students. Improvement efforts in this genre also include initiatives to develop teacher leaders and develop teachers as knowledgeable, agentic professionals.

Resource-forward and practice-forward approaches are not mutually exclusive. Indeed, districts may use both approaches to different degrees (Peurach, Foster et al., 2022). For example, a district committed to fostering culturally sustaining instructional environments might hire coaches to help support teachers in building these skills and create time in the school calendar for ongoing professional learning in this area while also providing teachers with new books for their classroom libraries or adopting a new textbook that is better aligned with the school's vision. In these and other ways, districts may strategically move between these approaches.

Research Questions

Resource- and practice-forward logics structure the approaches districts take to system building by offering district leaders different theories of action for improving elementary science

instruction. As organizational gatekeepers (Diehl & Golann, 2023), district leaders may navigate and draw on these two logics in varying degrees as they reconcile and making decisions about the theories of action they will bring to bear on the work of improvement in their districts. Such local adaptations may draw more heavily on one logic over the other such that some districts primarily take a resource-forward approach to system building while others take a practice-forward approach. Still others may draw on both approaches, or on different logics entirely.

Despite the variation in local contexts, there is value in understanding the ways leaders approach the work of managing and organizing for elementary science as they make sense of their environments. Existing scholarship suggests that the ways district leaders put external policies into practice is shaped by the way they make sense of the policy pressures in their environment and their informal instructional leadership networks (Rigby, 2016; Reid, 2020; Slegers et al., 2009; Spillane & Callahan, 2002). Additionally, existing research suggests that district leaders are more likely to embrace policies and organizations that align with their own beliefs about how to improve learning (Honig & Hatch, 2004) though they may still adapt reforms to their particular contexts (Donaldson & Woulfin, 2018; Louis & Robinson, 2012).

This paper draws on qualitative case study data to explore the following research questions:

- What improvement logic are leaders in these districts primarily drawing on in their approaches to system building?
- What categories of organizations are present in the environments enacted by science leaders in these districts?
- What relationships exist between the primary approach to system building used in districts on the one hand and their environments on the other?

Study Design & Methods

This study draws on data collected as part of an NSF-funded study of school districts identified as places working to manage, organize, and support elementary science teaching and learning. That broader project had three main goals. First, to develop a practical theory of organization and management that details the key domains of work that are essential for bridging from the NGSS to classroom instruction. Second, to construct models of effective, coordinated, system- and school-level science education environments that animate that theoretical framework. Third, to explore the usefulness of both the theory and models as tools for critically analyzing efforts to bridge from academic standards to classroom instruction. The districts in our study were located in states that had adopted the NGSS or standards based on the Framework. But they were also responding to and engaging with other parts of their environment including reform efforts in other subject areas, pressures for attention on the social emotional wellbeing of children, conversations around equity and racial justice, and the onset and recovery from a global pandemic.

Sample

The sample for the broader study was composed of diverse collection of thirteen districts in six states. Districts ranged in geography from the East to West coasts, from near the Canadian border to near the Gulf of Mexico and were of different sizes ranging from fewer than two to more than 900 students per square mile. There was similarly large variability on other metrics often used to compare districts including the portion of families eligible for Free and Reduced-Price Lunch (10 to 93 percent), the portion of students with Individual Education Plans (7 to 22 percent), and the portion of students still learning English (0 to 41 percent).

The six states and thirteen districts were purposively sampled based on interviews with 136 state-level leaders. From those interviews, members of the research team solicited recommendations of districts known to state leaders to be doing innovative work in support of elementary science teaching and learning. The project team recruited districts that varied in terms of district type (i.e., urban, suburban, rural, charter) and in terms of region (i.e., West, Northeast, South, Midwest).

- Urban districts (n=3)
- Suburban districts (n=5)
- Rural districts (n=3)
- Charter districts (n=2)
- West (n=4)
- South (n=5)
- Midwest (n=2)
- Northeast (n=2)

District recruitment and subsequent research activity was challenged and reshaped by the onset of the COVID-19 pandemic, the early months of which overlapped with our district recruitment work and earliest interviews. Initial plans for travel and in person observations and interviews had to be modified for the COVID era and recruiting districts and schools had extra hurdles.

With appropriate adaptations, the team was able to conduct:

- 112 interviews with central office staff
- 55 interviews with formal & informal school leaders
- 28 observations of district-level routines in science (e.g., professional development, strategic planning meetings)
- 22 observations of school-level routines in science (e.g., professional development, team planning)
- 55 interviews with teachers
- 22 classroom observations

We also collected artifacts including district and school goal documents, curriculum materials, strategic plans, local news articles, and school-district publications. The research team, which included researchers at the University of Michigan and Northwestern University, also

interviewed teachers, observed classrooms in a subset of schools, and collected artifacts such as lesson plans and sample student work.⁵

The Current Study Sample

The data for this paper came from that larger study. Analysis for this project focused on interviews with district level staff that were mostly conducted during the 2020-2021 school year. This subsample of the data includes thirteen school districts in six states. I also used observation fieldnotes of district science routines (e.g., professional development, strategic planning meetings), artifacts collected from districts (e.g., district websites, goal documents, instructional visions, curriculum materials, strategic plans), and school-, district-, and interview-level analytic memos drafted by other members of the research team and maintained and edited throughout the research project.

For the purposes of the project and this paper, *district science leaders* were those individuals identified by district personnel and self-identified through outreach and in interviews as responsible for leading efforts around elementary science in the district. In a few instances, a person identified as the district's science leader was no longer in that position at the time of our interviews due to funding challenges or district restructuring. Leaders sometimes had formal titles associated with science (e.g., Science Coordinator, Science Specialist, STEM Director) but in some districts the role was only a part of the work of that leader. For example, some of the individuals in this sample held positions like 'Director of Teaching & Learning' or 'Assistant Superintendent of Academics' from which they lead work on elementary science either alone or

⁵ Professors Dr. Donald J. Peurach (U-M) and Dr. James P. Spillane (Northwestern) served as Principal Investigators on the project with additional leadership from Co-Principal Investigator Professor Dr. Elizabeth Davis (U-M). The research team also included a post-doctoral researcher at each university, two doctoral students/candidates at U-M (myself included), a Research Project Coordinator at Northwestern, and temporary graduate researchers also from Northwestern.

with colleagues. In the two smallest and most rural districts in the study this was particularly true and in those districts, the principal of the district's elementary school was the individual identified as the science leader. While it might seem incongruous to identify a school principal as a "district science leader," these districts both house all grades in one building with district administrative offices co-located with the school building. Further, research suggests that in districts such as these it is often the case that leaders hold multiple roles (Harmon & Smith, 2007). This was born out in our interviews.

Finally, across these districts, there was variability in the relationship between elementary science, STEM, and STEAM both in terms of central office staffing and in-classroom learning experiences. In one district, system building for elementary science was part of a STEAM (Science, Technology, Engineering, Arts, Mathematics) initiative. In another district, STEM and Computer Science initiatives were seen as distinct from science but lead by the same individuals. In a third district, there was a pronounced division between science and STEM (Science, Technology, Engineering, Mathematics) both in terms of district leadership and in-class learning experiences. There, district materials were explicit in saying "STEM/STEAM is NOT a substitute for, or replacement of, high-quality rigorous content-based instruction by licensed teachers in science, math, or the arts." Yet, there was ambiguity in how these departments collaborated and what the responsibilities for each were. For the purposes of this paper, I have included leaders of STEM and STEAM initiatives in my definition of science leaders.

Data

My analysis drew on three sources of data. The primary data for this project were 48 interviews with 27 district science leaders in 13 districts. Table 2-1 provides an overview of how these interviews were distributed among districts along with descriptive characteristics of each

district. Individuals and district names are pseudonyms and district sizes, locations, and other identifiable details like the names of district leaders have been further masked through abstraction or anonymization. Each science leader was interviewed at least once. One or more follow-up interviews were conducted with key science leaders in each district. 46 of these interviews were conducted using video conferencing and two were conducted and recorded in person. These interviews were semi-structured and most lasted for around 60 minutes.

Table 2-1: Study Sample

District Pseudonym	Region	District Type	District Enrollment	Science Leaders (N=27)	Interviews Conducted (N=48)
Bartlett	Northeast	Suburban	~ 3,000	2	3
Brookeport	Northeast	Urban	~ 50,000	5	6
Chester	South	Urban	~ 35,000	2	3
Fairby	West	Suburban	~ 30,000	3	4
Hartwell	South	Rural	< 1,000	2	5
Hillman	West	Charter, Urban	~ 3,000	1	2
Jasper	South	Suburban	~ 12,000	2	3
King Park	South	Charter, Urban	~ 5,000	1	2
Lockeford	West	Rural	~ 4,000	1	2
Norhaven	South	Suburban	~ 14,000	1	2
North Valley	Midwest	Suburban	~6,000	3	4
Rivercrest	Midwest	Rural	< 1,000	1	2
Silverbay	West	Urban	>100,000	3	6

Second, my analysis considered district artifacts like improvement plans, vision and goal statements, district websites, district social media, and curricula materials and material from district-level observations (N=30) conducted by the study team. These materials served multiple purposes. First, they supported my understanding of the district's system-building efforts,

especially as related to the approach to system building they were using to manage and organize elementary science instruction. These materials also helped evidence the role of the environment in districts' system building.

Finally, I drew on district-level analytics memos that were iteratively generated by the research team and that themselves drew on the full corpus of project data. I used these data to further inform my understandings of the work of district science leaders, district-level approaches to improving elementary science, and the organizations and interests that district leaders engaged in their environments. I also used materials published by state education agencies and the National Center for Education Statistics to verify district enrollment and demographic data. I also turned to the materials released by the organizations and parts of the environment mentioned in the data (e.g., state departments of education, publishers, local educational resources) for more detailed information about them and their work.

Analysis

My analysis in this paper occurred in three stages. In the first stage, I worked to understand the approach to system building being taken in each district. In the second, I worked to understand the environments leaders in those districts enacted, focusing on the organizations in that environment that were influential for their work on elementary science. Finally, I worked across these two ideas to understand and explore variations in how districts approaching system building in different ways enacted and, in turn, managed their environments.

Approach to System Building. A parallel analysis focused on making sense of the approaches districts were using to manage and organize elementary science. For this, I first returned to the interview transcripts of the district science leaders to understand how they described the work they were leading and the core elements of that work. A key consideration

was the ways those descriptions a) spoke of efforts to identify and provide instructional resources and b) spoke of efforts to strengthen teachers' instructional practices. I cross referenced my understandings of each districts' approach to system building with the comprehensive district-level memos that had been developed by the research team. Those memos drew on the full corpus of project data and were developed in conversation with the lead researcher/s for each site. These memos helped me to confirm or correct my understanding of the system building activities in each district and the theories of action behind that work more broadly. Reviewing field notes from district-level observations and artifacts collected from each district further supported my sensemaking and understanding of each district's work. I engaged in this work through sketching, memoing, and creating matrixes to understand the data. A core consideration was the theory of action districts were centering in this work.

I considered resource-forward districts to be those places where the district's approach to system building was motivated by a theory of action that *centered on* providing high-quality science curriculum materials as the means of improving elementary science and *did not* also center their system building on improving teachers' instructional capacity. The inverse was true in practice-forward districts, as illustrated in Figure 2-1. Districts where leaders engaged in system building activities based on both these approaches were categorized as 'both', while districts where the district central office was not engaged in system building following either of these approaches were categorized as other. As suggested by the category of schools balancing both approaches, resource- and practice-forward approaches are not mutually exclusive. Indeed, an argument could be made about the necessity of attending to both approaches. However, as will be discussed later in this paper, it was not the case that most districts in the sample were using both approaches equally.

A district's approach to system building was motivated by a theory of action that....	... did not center on improving teachers' instructional capacity as the means of improving elementary science.	... centered on improving teachers' instructional skills as the means of improving elementary science.
... did not center providing improved, coordinated, high- quality, and/or educative science curriculum materials as the means of improving elementary science.	OTHER	PRACTICE-FORWARD
... centered on providing improved, coordinated, high- quality, and/or educative science curriculum materials as the means of improving elementary science.	RESOURCE-FORWARD	BOTH

Figure 2: Resource- vs. Practice-Forward Approaches

Enacted Environments. My analysis began by reading the interview transcripts of the district science leaders and annotating those documents using deductive, categorical codes (Miles et al., 2014). This level of coding focused on understanding the component entities of the environments district science leaders described over the course of our interviews. To begin, I looked for examples of eight different categories of organization I identified in an earlier paper as having been salient parts of the environment for elementary science reform since at least the middle of the 20th century (Foster, 2024a). These were: 1) the federal government including its agencies, policies, and provisions; 2) state government including state departments of education and state testing policies; 3) professional organizations including national groups like the National Science Teachers Association and teachers unions; 4) colleges and universities including their research work and their role in pre-service teacher training; 5) non-governmental funders like philanthropies and grant-funders; 6) textbook and curriculum publishers; 7) other

resource developers like the authors and publishers of books on school improvement, developers of tools like the Danielson Framework, and creators of rubrics like the EQUIP consortium; 8) local educational resources like consultants, regional educational agencies (REAs), and area museums; and 9) parents and the community including parent groups, school boards, and local businesses. Additionally, though not a focus of this analysis, I looked for examples of district science leaders engaging with a tenth category: concurrent or conflicting initiatives within the district. While these were influences within the district rather than parts of their environment, the framework I developed in my previous work (Foster, 2024a) suggests that work on elementary science frequently experiences knock-on effects from pressures on other subject areas (e.g., districts respond to reading-retention laws in ways that impact science leaders work on elementary science).

As I coded these documents, an additional category of organization emerged that did not neatly fit into any of the a priori codes. This category comprised the developers of tools and resources that schools used to support their educational system building. Examples of these tools and resources included books written by independent authors, online software used for instruction or communication with teachers or parents, and rubrics developed by partnerships of organizations.

After coding each interview, I wrote analytic memos that aimed to capture the environment described in each interview including notes about the specific organizations in their environment. These memos were particularly helpful for further developing my understanding each district and the ways leaders experienced their environments (e.g., as supportive, as challenging). My first memos focused on individual district leaders. After reading all the leader

transcripts in a district, I created another reflection that synthesized my memo to the district-level.

Working Across These Ideas. Finally, my analysis involved drawing together my understandings of districts' enacted environments and their approach districts were taking to their system building. Part of this sensemaking involved creating spreadsheets and then tables that drew together information about the environments district leaders were observing and the approaches they were using. A simplified version of this table is included as Table 2-3 later in this paper. This allowed me to sort my coding based on district approach, district location, district typology, and environmental influence codes to look for patterns.

Limitations

A few limitations bounded this work. First among these was the fact that this research was part of a larger study, the data for which were abundant but not collected to answer the specific research questions in this paper. Though the interview protocol used by the research team included a number of prompts that captured responses about district leaders' descriptions of and interactions with their environments, project team members were not coached to specifically dig into ambiguous questions in this area. As a result, the specificity in how district science leaders describe interactions with their environment varied. The project's analytic memos (which drew on a larger sampling of district and school staff), district observation notes, and artifacts helped even out this variation, but there may still be gaps in these data.

Second, this paper investigates the relationship between how district science leaders understand their environments and the strategies they draw on as they endeavor to reform elementary science in their districts. Theories of enacted environments hold that enactment occurs through ongoing, iterative processes and observing and understanding iterative processes

through interviews, point-in-time observations, or artifacts has its limitations. The leaders we spoke to were often reflecting on past interactions with their environments and sometimes reflecting on many years of decisions in one interview. Further, leaders can only share the parts of their environments that they have bracketed and retained as noteworthy in their memories (Weick, 1979). Yet, the data still told thought-provoking stories about how science leaders see, understand, and manage their complex environments.

Ideas of the environment as not objective truths but subjectively enacted highlight another limitation of this project—individual bias. Drawing on inherently limited information, my interpretations are certainly and inescapably colored by my experience in schools as a student, teacher, and observer. As suggested by my interest in studying the context in which schools carry on their day-to-day work and their improvement projects, I likely approach these data in ways that highlight those relationships. While I aimed to cross-reference my interpretation of these districts with both district materials and analysis completed by other team members, other researchers may have still observed other patterns in these cases.

Findings

Based on my analysis, I organize my findings into two sections. In the first, I describe how the districts in the sample used resource- and practice-forward approaches in their system building for elementary science. In doing so, I highlight the pervasiveness of the resource-forward approach to system building in these districts. Then, in the second portion of the findings section, I use three illustrative cases to examine the relationships between each system building work of these districts and their approach to system building. These three districts—Silverbay, Hartwell, and King Park—varied in the approaches they took to system building, geographic location, size, rurality, and district type (e.g. conventional vs. charter). Using these

cases, I highlight the complexity of these environments, and the efforts required of districts to coordinate among their disparate parts as just one component of their system building work.

District Approaches to System Building for Elementary Science

While there are examples across each district of leaders’ attending to both instructional resources and instructional practices, in eight of the thirteen districts, the district’s prevailing theory of change was motivated by a resource-forward approach to system building for elementary science. In fact, in the eleven districts that were engaged in district-level system building during our study period, leaders in all but one drew substantially on resource-forward approaches to improve elementary science teaching and learning in their schools. The distribution of districts across four categories—resource-forward, practice-forward, both, and other—is represented in Table 2-2.

Table 2-2: Districts Sorted by their Prevailing Approach to System Building

	Resource-Forward	Practice-Forward	Both	Other
Districts	Bartlett Brookeport Chester Fairby Norhaven North Valley Rivercrest Silverbay	Hartwell	King Park Jasper	Hillman Lockeford

Districts Centering Resource-forward Approaches

The majority of the thirteen districts were using resource-forward approaches to system building for elementary science instruction. In each of these eight districts, resources—and especially curriculum materials—were the central to theory of action behind each district’s system building work.

Resource-forward districts engaged in system building for elementary science that heeded a theory of action—as described by the science leaders and reflected in the system building work investigated by our research team—that used new or better resources like new curriculum and science kits as the core means by which the district would improve elementary science teaching and learning. The eight districts that I found to be centering resource-forward approaches in their system building represent a cross section of our broader sample including urban, rural, and suburban districts and districts in the Midwest, West, Northeast, and South.

Following a resource-forward approach, these eight districts scaffolded their educational infrastructure around instructional resources they purchased or, in some instances, created. A science leader in Silverbay described the motivation behind their district’s curriculum development project by saying:

“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.”
(Yazmin)

In turn, where these districts provided support for using infrastructure in practice, those supports were anchored in how to use the resources. This included professional development sessions that largely focused on using the curriculum or that were facilitated by representatives from the curriculum companies. For example, facilitators from FOSS, Amplify, and Twig supported professional development in Brookeport, and Chester respectively.

Districts Centering Practice-Forward Approaches

Only one district in our sample, Hartwell, primarily leveraged a practice-forward approach to system building for elementary science. There, the work of improving elementary science heeded a theory of action rooted in developing teachers’ knowledge, skills, and dispositions to support teachers in improving their instructional practices in elementary science.

While Hackett adopted some instructional resources to support elementary science, the coordinated system building in the district was focused chiefly on the development of the practical knowledge, skills, and dispositions of teachers—rather than the use of those materials—as the primary lever for improving students’ learning.

Their theory of action centered on developing teachers’ skills, comfort, and capabilities with science instruction. Toward this end, leaders in Hartwell made substantial investments in developing PLCs in the district as a key part of their educational infrastructure and then worked to support those teams in working collaboratively to think about their instruction and student outcomes. Though they did adopt new science materials, these were secondary to their focus on teachers’ instructional practice.

Districts Balancing Resource- & Practice-forward Approaches

Two districts in the sample, King Park and Jasper, embraced a theory of action that pursued improvement through an approach that balanced resource- and practice-forward approaches to system building. In both of these districts, leaders adopted new resources and provided support for teachers in using that curriculum while also developing routines that focused on teachers’ instructional practice, created social norms that supported talking about those practices, and provided instructional coaching to support teachers in their work. Where the resource-forward districts focused professional development on using the materials, these districts expanded their professional development to support teachers in using student learning data and engaging in instructional coaching more broadly. Where the practice-forward district (Hartwell) focused on professional development, absent a coordinated, NGSS-aligned curriculum, these districts used core curriculum as a central component around which (but not through which) instructional capacity could be developed. For example, Jasper provided

professional development opportunities for teachers in the practice of science ‘notebooking’ (i.e. a practice of having students use a notebook for recording their thoughts, observations, data, and reasoning in relation to science activities and as a portfolio of their learning) and in-school instructional coaching while also offering professional development from Twig (the core elementary science curriculum adopted by the district) that focused on the use of those materials.

Districts Working on Elementary Science in Other Ways

In two districts, Lockeford and Hillman, work on elementary science fell outside the analytic framework used in this paper. I’ve categorized these districts as ‘other’ in Table 2-2 . While both districts had made efforts toward improving elementary science, in neither of these districts was the central office actively coordinating system building to support elementary science. In one case, Lockeford, this was because work on elementary science had come to a standstill shortly before we started our data collection and did not resume during our data collection period, nor did leaders there describe a path forward for that work. This was a result of district funding challenges coupled with the end of a grant that had previously supported the district’s work on science. Derek, who had previously led the work on elementary science in the district, told us “Funding allocated for elementary science adoption was swept away last year.” This funding shortfall resulted in the termination of Derek’s position in the central office (the only position that had been coordinating work on elementary science in the district), insufficient funds to continue lesson study projects, and insufficient funds to purchase the new curriculum that the district science leader and a team of teacher-leaders had selected through cycles of reviews and pilots.

In the second district, Hillman, the district fell outside the framework for this paper because the district’s mission for personalized, student-centered learning was facilitated at the

school-site level with scant responsibility for managing or organizing instruction placed at the district level (the unit of analysis in this paper). To the extent that Hillman was engaged in system building for elementary science, that work was decentralized and occurring at the school level, reflecting a system that had similarities with a system-design that Peurach and Yurkofsky (2018) have described as ‘market-driven’. Kaitlyn, the Chief Learning Officer at Hillman, told us that “to start from scratch seems to be really engrained in our DNA” in reference to the fact that teachers each make their own curriculum. Though district leaders in Hillman were wrestling with some of the limitations of their approach, our research found little evidence of a system building effort at the district level, further reflecting what Kaitlyn described as legacy perspective in the district that “school sites need to be doing all the things for themselves.” In the remainder of this paper, I focus my analysis on the districts that were engaged in system building using resource- and/or practice-forward approaches.

Relationships Between Approaches to System Building and Environments

Regardless of approach districts took toward system building for elementary science, district leaders engaged with multiple and disparate parts of their environments. Focusing on the 11 districts that I have described as building systems for elementary science using a resource-forward approach, a practice-forward approach, or balancing these approaches, I found evidence of leaders engaging with multiple and disparate categories of organization in their environments, from government agencies to commercial publishers to parent groups. In the appendix, I provide an overview of nine categories of organization that I observed in these data including: the federal government and its agencies; state governments and their agencies; professional organizations; colleges and universities; non-governmental funders; curriculum and instructional materials publishers; developers and suppliers of other resources like evaluation rubrics, assessments, and

classroom supplies; community-based educational organizations like REAs; and parents and community groups.

As shown in Table 2-3, in seven of these eleven districts, leaders engaged with organizations in their environment from eight or more of these categories. Further, within any one of these categories, they dealt with a diverse array of discrete organizations. For example, in Chester, an urban district in the south, science leaders described coordinating with four non-governmental funders to support their elementary science program including a grant from a retired athlete's charitable foundation, a corporate grant from a computer company, and support from the district's booster fund, and a grant from a state university. This was in addition to working with organizations in all eight remaining categories including supplemental federal funding from the Department of Defense and funding from the Elementary and Secondary School Emergency Relief Fund (ESSER).

Table 2-3: District Science Leaders' Enacted Environments

	Resource-Forward								Practice-Forward	Both	
	Brookeport	North Valley	Chester	Silverbay	Bartlett	Fairby	Norhaven	Rivercrest	Hartwell	Jasper	King Park
Total Count	9	9	9	9	8	7	7	5	9	8	6
Federal Government (n=3)	x	x	x	x					x		
State Government (n=11)	x	x	x	x	x	x	x	x	x	x	x
Professional Orgs. (n=8)	x	x	x	x	x	x			x	x	
Universities (n=8)	x	x	x	x	x		x		x	x	
Funders (n=11)	x	x	x	x	x	x	x	x	x	x	x
Materials Publishers (n=11)	x	x	x	x	x	x	x	x	x	x	x
Resource Developers (n=10)	x	x	x	x	x	x	x		x	x	x

Community Ed. Orgs.(n=11)	x	x	x	x	x	x	x	x	x		x		x	x
Community (n=11)	x	x	x	x	x	x	x	x	x		x		x	x
Concurrent Initiatives (n=9)	o		o	o	o	o		o			o		o	

Though the categories of agencies and actors that district leaders engaged with were common across all eleven districts, the specifics of those agencies and organizations varied between districts. In some districts, clear connections can be observed between the approach leaders used in their system building for elementary science and the ways they understood their environment. In the following sections, I focus on three illustrative cases. In Silverbay, science leaders centered their system building work on the development of a bespoke, comprehensive elementary science curriculum for the district while recognizing and leveraging practical and financial resources in the community to support that work. In Hartwell, leaders focused on practice-forward system building both in response to the limitations in their environment and in ways that shaped the relationships they fostered in their environment. Finally, in King Park, leaders drew on both resource- and practice-forward approaches to system building, shifting their work and the partners they turned to for support as they did so.

Silverbay, its Environment, and a Resource-Forward Approach to System Building

Silverbay provides an example of the ways in which districts leveraging a resource-forward theory of action might engage with and manage relationships with their environments. There, system-building to support science was centered on the development of a pilot STEAM curriculum. In building an educational system around this resource, district leaders in Silverbay attended to many parts of their environment. As reflected in Table 2-3, science leaders in Silverbay attended to organizations in their environment that spanned all nine categories. Examples of this included engaging with federal grants to pay for staff and paid teacher professional development, using materials developed by their state department of education to

guide their curriculum development work, sought to minimize conflict with the union contract by having teachers opt-in in advance to the extra PD time, and worked with local and regional universities to support the development of different components of the curriculum. They also worked with non-governmental funders like corporate philanthropy to support their project; used resources like learning software, books on school improvement, and externally sourced tools and protocols to support and guide their work; partnered with educational organizations in their community like their REA for additional support and trainings; and were responsive to community concerns and needs in their curriculum development process. Finally, while the STEAM team's work focused on creating its own instructional materials, they leveraged some commercial materials like videos from Mystery Science within their lessons.

As these examples demonstrate, the STEAM team often engaged organizations in their environment with an eye toward expanding their team's size and therefore capacity, enriching the materials they were creating, generating teacher buy-in for the program, and fostering interest in the program in the district's elementary schools. In the sections that follow, I first give a brief introduction to the pilot work in Silverbay and the science leadership team behind it. Then, I describe the environment the STEAM team engaged with and the ways they managed relationships with their environment as part of their system building work.

Background. Silverbay is a very large urban district in the West serving more than 100,000 students at more than 100 schools. The focus of our research in the district was a STEAM pilot program that started in a few dozen schools in 2018 and was the core science curriculum in about half of the district's elementary schools at the time of our data collection. Starting in the 2025-26 school year, the pilot aims to be the science curriculum for all pre-Kindergarten through grade five classrooms in the district.

The central feature and priority of the STEAM pilot was an expansive curriculum created by the STEAM team over the course of 6 years. For each grade level, the pilot team developed four or five units of 80 to 100 lessons each. The lessons were designed to last anywhere from 35 to 100 minutes and included direct tie-ins to the district’s visual and performing arts, computer studies, math, and ethnic studies curricula. The materials included educational resources from the community (e.g., local citizen science projects), commercial sources (e.g., Mystery Science), and other resources (e.g., related children’s books, YouTube videos) as reflected in Table 2-3. The curricular materials were also made available in Spanish with support from the English Language Development team.

These resources were designed to be both robust and flexible. Each unit included supplemental materials for teachers to use in other parts of their instruction. Yazmin, one of the curriculum writers, told us the curriculum “is integrated so that if a teacher wanted to do this across an entire day, they could. There's enough in there, extensions, literacy, math, you name it. Maybe one day it will be that.” Yazmin added that her vision for the program was that teachers would “feel like they have a base, they have a foundation, and they can lift off from” (Yazmin).

Nicholas was the director of the STEAM pilot project during our data collection. He had taken over leadership of the project a year after it was launched when the founding director moved on from the district. It was unclear how much the design of the pilot had been established before he assumed control he under his leadership, the program the partnership needed to support the pilot.

Silverbay’s Environments. While the team in Silverbay engaged with organizations across many different categories in their environment, a central focus of that engagement was with resources that they used to support their curriculum-development work. This included

support from local, regional, and federal funding opportunities that financially supported their work; regional education agencies that shared tools and resources they'd developed; national professional organizations that contributed to the team's professional learning; tools and resources from the broader science education landscape the team leveraged in their work; and partnerships with public and private universities in the state that provided in kind support and guidance for their curriculum development work. The environment also challenged the pilot team's work including content concerns from parents, contractual considerations with the union, and delays in state-level accountability measures.

Before Nicholas was the STEAM director, he worked in the district's office of innovation, coordinating partnerships between the district's high schools and local organizations. "The vast majority of my responsibilities were working with industry partners to do work-based learning experiences to bring input from the STEM community into our school district" (Nicholas). Moving from that position to his current role, Nicholas continued working to find resources in the community that could support the STEAM pilot including those that could provide supplemental funding for the project. And he was successful. As represented in Table 2-3, Nicholas leaned on federal and non-governmental funders to support the pilot.

Shortly after Nicholas took over as director of the program, he was able to hire two curriculum writers, Yazmin and Mindy, both of whom had been teachers in a local project-based charter network. A few years later, Libby, who had also been a teacher in that charter network, joined the team in a grant-supported role to develop computer science lessons within the pilot curriculum in collaboration with a local university. All three curriculum writers drew on their experience at that charter in their work including adapting protocols and tools like a "project tuning protocol" from their work as classroom teacher in that network school to their new roles.

In addition to the grant that supported Libby’s role—a nearly \$4 million, five-year, federal Education Innovation Research Grant—Nicholas had secured grant and philanthropic funding from a state-level philanthropy, a million-dollar donation from a local biotech firm, partnered with a university on an NSF grant, and a federal Magnet Schools’ Assistance Program grant. Together, these funding sources were crucial for pilot and allowed the team to provide professional learning opportunities as they rolled out of the new curriculum materials. Without these grants, it’s unclear if those trainings would have been possible. “Just speaking very plainly,” Nicholas told us, “The district hasn’t contributed a dollar to professional learning for the STEAM initiative.” The funding he’d gathered from the state-level philanthropy and the biotech firm were “going to pay for all of my training in TK-2 next year” (Nicholas).

Members of the pilot team also turned to their environment for non-financial assistance. Locally, the county-level educational authority had developed resources for principals to use during walk-throughs of science classrooms that the Silverbay team incorporated into their work. They also collaborated with other districts nearby that had received funding to support work on implementing the NGSS and used professional development opportunities from that experience to guide the design of their units and, where possible, extend invitations for teachers to participate in trainings.

The district’s partnerships with universities (noted in Table 2-3) supported their practical work developing curriculum. For example, Libby’s work creating computer science units for the STEAM curriculum was supported by a public university in Silverbay. Another partnership with the same university supported work on lesson study with teachers in the early grades while a partnership with a different university in the state helped the team develop assessments that were aligned with their curriculum materials and the NGSS.

In addition to supports in the environment, the STEAM team also identified some hurdles in their environment which the team had managed in different ways. Parent feedback and concerns around a grade two unit that aimed to help students “connect their history to the landscape of the Earth and study the natural processes that make it change” lead the team to refine and edit content that had asked students to talk to their parents about their stories of immigration. Working with the district’s ethnic studies department, the team revised the language and framing of the lesson to better account for the indigenous communities in the area and histories of enslavement that brought some families to North America. Mindy told us, “We got a lot of feedback on that, which is something—is also really a part of what we do. We ask for feedback and seek feedback to improve. We have really an improvement mindset with what we’re creating, and we feel like it’s iterative.” This iteration was partially made possible by the all-digital format of the STEAM curriculum that the team could edit easily (compared to printed texts), and which was built using the Google Suite, Seesaw, and other online resources.

The design of the STEAM pilot also attended to some challenges they anticipated in their environment including pressures from the local teachers union and delays in state science assessment data dashboards. While other districts in our sample described how teachers’ contracts and state laws—which each predetermined some aspects around required PD—proscribed some of their ambitions for professional development, Silverbay anticipated this challenge by developing the project as a pilot and by having teachers vote to participate, an assent that included an agreement to engage in extra PD. Whether the program would have otherwise met substantial union resistance is unclear as the program had the support of the former union president. Nevertheless, the team was able to get teachers to join additional PDs and didn’t describe the challenges in that that leaders in other districts described.

The other issue that the team worked around was the suspension of state plans to incorporate science test performance into school- and district data dashboards. As Nicholas explained:

“The science test being suspended last year was also I feel like a step back for science in general. There was a lot of momentum. A lot of people were leveraging the [state] science test as ‘Hey, look. This is going to show up on the dashboard. This is how your—this is how schools will be viewed,’ because it’s like—let’s not mince words. School districts care about test scores, right. They care about what—the way that they are perceived.” (Nicholas)

Nicholas had been hopeful that state-level plans to add science to the school and district public-facing ‘dashboards’ would help him garner buy-in from other district leaders and school principals. Though the COVID-19 pandemic delayed the state’s work updating those dashboards, the district was still successful in attracting new schools to the pilot year after year.

Resource-Forward System Building. Drawing on his past experience to gather financial and practical backing for the project, Nicholas was able to support his team in developing resources that made it “as easy as possible for principals and teachers to [make a change]” (Nicholas). Though Nicholas understood the importance of shifting teacher practice, the district approached that goal as something to be achieved (at least initially) through the creating of new, better instructional resources.

“We’ve taken the approach that if we provide a foundational curriculum, that we can train into what it should look like in the classroom. Then we can also support the philosophical shifts or the instructional shifts that we want to see in next-gen science.” (Nicholas).

In Silverbay, the material resources of the STEAM program were seen as “foundational” for improving elementary science. The program also used material resources as an incentive offered to schools that joined the pilot during its first years.

“When we started it, in order to come onboard, everyone in the grade level had to be trained. The whole site had to be onboard through conversations. You had to add a site

governance-team agreement that you were going to take on this effort because we didn't want to train—in addition to curriculum and materials, sites were getting paint, and furniture and different things, and 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.” (Nicholas)

As Nicholas describes above, the program provided the early pilot sites with new STEAM facility improvements including desks, libraries, other furniture, and material kits and to ensure parity between classrooms, the pilot required that a majority of teachers agree to the program.

To support the use of these resources in classrooms, the district lead PD sessions for teachers throughout the school year. During the roll-out, these sessions focused on supporting a) teachers in the grade-level of the materials being launched that year and b) teachers new to their grade level. These PDs were paid for with external grants (from both federal and non-governmental sources as noted in Table 2-3) and lead by the four-person STEAM team (supporting thousands of elementary grade teachers). Budget and staffing challenges required that the district shift PDs from full-day, in-person trainings to synchronous online trainings after school hours. Still, these opportunities were described by a former union president as being unusually extensive compared to the launch of other curriculum in the district.

Though this work was anchored in a resource-forward theory of action, the members of the pilot team shared visions of this curriculum as a springboard from which they could work on instructional practice. The size of their team relative to the district and the challenges of the pandemic appeared to have narrowed the scope of work of the project and largely curtailed practice-forward ambitions including lesson-study, targeted training for school-site based science leaders, and classroom observations and coaching. Prior to the pandemic, the STEAM team had also collaborated with a member of the superintendent's team to support professional development opportunities for principals including familiarizing those leaders with what an

elementary science classroom might look and sound like. The need to coordinate the many pivots during the first years of the pandemic ended this program. Later, Nicholas told us:

“I really wish that we had also involved principals more closely and superintendents more closely in the process because anything that we want to see happen quickly in our district you need to have the executive leadership buy-in on that.” (Nicholas)

Still, even after the engagement with principals waned, the program continued to expand across the district, adding more school sites (and more classrooms) each year.

Summary. The case of the STEAM Pilot in Silverbay illustrates an approach to system-building rooted in a resource-forward theory of action. In that system building work, the district engaged deeply and broadly with its environment to support its work and to develop these resources. This included working multiple funding partners (e.g., grants from local philanthropies, a donation from local bio-tech corporation), community partners (e.g., local citizen science projects, supports their REA), and even commercial curriculum and resource developers (e.g., embedded Mystery Science videos, books on school improvement). Where practice-forward logics appear in the design, they seem to have been among the program elements that were cut during the pandemic. The work in Silverbay raises questions about how resource-forward approaches like this carry forward or if there is space for them to evolve and adapt more practice-forward routines once the resources themselves are developed.

Hartwell, its Environment, and a Practice-Forward Approach to System Building

Hartwell is small, rural district that has taken a practice-forward approach to system building for elementary science. As in Silverbay, science leaders in Hartwell recognized and engaged with actors in their environment from all nine categories of organization (Table 2-3). This included using federal Title II funds to support their partnership with their REA, attending to changing state level policies and struggling to secure competitive state-level grants, sending

teachers to NSTA conferences and navigating union contracts around PD, and partnering with area universities and college both for access to equipment and materials and as sources for teachers' professional learning. Though the district didn't secure million-dollar donations to support their work, local businesses provided financial assistance for their robotics programs and an area university financed their acquisition of some curricular materials. Though the district engaged with the commercial materials market to purchase a host of science materials (e.g., *Picture Perfect*, *Engineering is Elementary*, *Mystery Science*, *Study Island*, *Exact Path*, *Gizmos*, and *BrainPop*), their main investment was in a contract with Solution Tree, a company that provides support and resources for leading PLCs. The community of Hartwell was supportive of these efforts and trusted the schools and, where they could, offered their support (e.g., a local manufacturer sending engineers to coach the robotics team).

The district's system building is illustrative of the relationship between leaders' enacted environments and the theories of action they use as they build systems to manage, organize, and support elementary science. Specifically, leaders in Hartwell recognized that they faced practical limitations on how much they could rely on resources—either external supports or internal finances—to support long-term improvement given their geography, economy, and rurality. Instead, they turned to practice-forward approaches to improvement that they understood as developing the capacity, skills, and expertise of the core resource they already had—teachers.

Background. Categorized as rural-distant by the National Center for Education Statistics (NCES), Hartwell Public Schools (Hartwell) is located in a southern city with a population of around 800.⁶ In recent years, Hartwell merged with a neighboring district that had been

⁶ NCES defines rural-distant as an area that is 5 to 25 miles from an Urbanized Area or 2.5 to 10 miles from an Urban Cluster. Rural-remote is the only designation farther from an urban area. In 2019 the NCES found that about 1 in 10 districts were in rural-distant areas.

experiencing untenably low enrollment, bringing students and some teachers from that district to Hartwell. The district now enrolls about 800 students from the city and surrounding area on a single campus that serves kindergarten through grade 12 in a K-6 elementary school and a 7-12 high school. Like many high-poverty, small, and rural districts (Belsha, 2024), Hartwell spent much of its federal ESSER funding (reflected in Table 2-3) on HVAC upgrades in their building but were also able to use some of the money for student Chromebooks.

The elementary principal, Ursa, was one of the main leaders of the district's work on elementary science.⁷ Ursa had been with the district since the mid-1990s and spent more than two decades as a classroom teacher. Winona, whose formal title was Curriculum Coordinator but whose responsibilities included coordinating federal funding, special education programs, English learner programs, testing, and parent involvement supported Ursa in that work. Ursa, Winona, and other district staff wore many hats and leaders couldn't always depend on outside support for science or any other part of the school day. For example, Hartwell annually trained a group of school staff act as armed school security officers because "if there doesn't happen to be a county officer just driving through Hartwell at that moment, it could take upwards of 30 minutes to respond to an emergency" (Ursa).

As described in the previous section, the central focus of system building Hartwell's work on elementary science was training, building, and supporting their teachers' instructional practices. This work was anchored in a theory of action that centered the development of teachers' skills, comfort, and capabilities broadly and inclusive of science. Much of that work occurred within the structure and norms developed in the district's PLC program and was

⁷ Ursa retired at the end of the 2023-2024 school year after almost three decades with the district.

supported by routines and a school culture that was supportive of teacher collaboration. Ursa told us:

“My staff is so committed to this. [...] As I come down the hallways in the afternoon [when] school’s over, they’re there together, working again almost every single day after school, and lots of my teams do that. They have time after school, before school that they set aside to meet.”

Though teachers were bought in to this work and, as Ursa describes in the quote above, created time for collaboration even outside their contracted hours, the district was considerate of teachers schedules and strove to make sure teachers had time to work together. This could be a challenge in the small district. Still, for grades three and up, Ursa was able to align prep-periods so that teachers could collaborate every day and grades one and two had two and three co-planning times each week.

Hartwell’s Environment. In contrast to the resource-forward districts where leaders’ engagement with their environments included working with curriculum publishers or community resources that could support the use or development of their science curriculum materials, leaders in Hartwell largely focused on partnerships in their environment that supported teachers’ instructional practices including external organizations that could provide professional development, contracted coaches that could support their meetings internally, and funding sources that could support their work.

In part, Ursa and Winona’s enacted environment (as represented in Table 2-3) appeared to be responsive to the fact that finding new resources—including new teachers—could be challenging for a small, rural districts like theirs. For example, after one of their special education teachers retired, Ursa was struggling to hire a replacement. She told us, “I’ve been trying to do [push-in] with one special education teacher, because I absolutely could not find one last semester. There was not one to be had in this area” (Ursa).

The community features that leaders in Hartwell described had some similarities with other districts in our sample. Like Rivercrest, another small, rural district, leaders in Hartwell recognized that the socioeconomics of their community including connections with prisons in the area had practical implications for their schools and the needs of their students and their families. “The community in Hartwell—probably the best way to describe it—there are no stoplights in Hartwell. We have a Dollar General, a gas station, a bank, and a post office,” said Winona. Public utilities in the area were also poor, especially in terms of internet and cell service. The NCES estimates suggest that about a fifth of households in the community lack reliable internet or cell access. Leaders in the district described this problem as being particularly challenging during the COVID-19 pandemic when even state-provided hot spots were unreliable.

Even though Hartwell didn’t have as many companies to partner with as did the districts in large, urban tech-hubs like Brookeport and Silverbay, the district still developed relationships with those businesses they did have—a food processing factory and a conveyor belt factory—to support the districts work in areas like coding and robotics through in-kind support. Because the school district is one of the largest employers in town and because of the size of the population, there were often multiple family ties between students, teachers, and parents.

Further owing to its size, the district didn’t have central office staff that were subject area specialists. Winona told us, “We do not have the funds where we could hire a specialist for those things. I’m not sure the size of our school always warrants us having one.” For these and other supports, as represented in Table 2-3, the district turned to its local Regional Education Agency (REA). In Hartwell’s state, membership in REAs is voluntary (with membership paid for from federal Title II funds) but is designed to support schools in ways similar to other REA structures (e.g., Hughes et al., 1972). In addition to content specialist support, the REA (which includes

nearly two-dozen districts) also provides other practical supports like a novice teacher mentoring program, finger printing services, professional development programs, and other technical support. In the case of Hartwell, their local REA had a lending library of tools teachers could borrow and a science specialist who “our teachers work closely with. You’ll see him on campus several times a year—more than that. He’ll come out and do little experiments for the students and stuff like that” (Winona). The REA also offers trainings on practical issues that elementary science teachers face, like how to integrate science, math, and ELA. Like the REA, the closest public university campuses also housed a materials and equipment lending library and offered professional learning opportunities for the district.

Where some districts turned to their community for funding, leaders in Hartwell recognized that their community was neither an affluent one, nor were there many businesses nearby that could support their work. A local conveyor belt company supported the district’s robotics team by making sure they had the funds to cover the competition entry costs (\$750) and by sending company staff in to help coach. “They support us with engineers that come in and help our kids and learn to code the robots for the competitions. Overall, I would say we have tremendous community support; support if they are able” (Ursa).

In addition to looking beyond their immediate community for practical support, the district looked beyond their immediate boundaries for supplemental financial support. The district received some grant support from a local university to purchase *Picture Perfect*, a book series that combines science and reading. But the main grant the district hoped to get was a state-level grant to support the expansion of their PLC work. The district had applied for that grant three times without being selected, a fact that Winona attributed to the size of her district and the

prioritization of districts with more students.⁸ However, they were selected in the fourth year they applied. The grant funded three years of work supported by a larger team of external specialists. Ursa was part of a ceremony that summer hosted by the state board of education.

Though Hartwell's work was focused on improvement through teachers' practice, the district still engaged with textbook and curriculum publishers. However, these resources were not central to the ways they described their work on elementary science. In fact, leaders talked about the importance of curricular materials more in relation to their work on literacy than on science. The district used an assortment of materials in their elementary science instruction. Units written by district teachers drew on *Picture Perfect* (a book series that combines science and reading), *Engineering is Elementary*, *Mystery Science*, *Study Island* and *Exact Path* by edmentum, *Gizmos*, *BrainPop*, and resources from Teachers Pay Teachers.

The main external resource Hartwell paid for was a contract with Solution Tree, a national professional development company that supports PLCs. Ursa learned about the company (and the state's grant program) during a training and wanted to bring the program to her school. Despite not winning state funding to support that work, the district was able to purchase what their Solution Tree consultant referred to as the 'economy model.' This allowed them to work with one coach who, though formally was a math specialist, they asked to support them in their PLC work for all subject areas. Even at this more limited model, contracting Solution Tree was a substantial cost for the small district—"I mean, it's very, very expensive" said Winona—but was still seen as having "been a very positive thing for our elementary" (Winona). Through their work with Solution Tree, elementary teachers developed science units and assessments based on the state standards, were reviewing student data, and discussing their instructional practices.

⁸ Recently, funding for Solution Tree contracts and the PLC program becoming a hotly contested issue in the state legislature and state funding was discontinued.

Practice-Forward System Building. The science leaders in Hartwell focused on practice-forward approaches to manage, organize, and improve elementary science. Specifically, they focused their work on the PLCs system. Through that work, the district focused on improving instructional practices as informed by student classroom data and using metrics like the NWEA's Measures of Academic Progress formative assessment data that students take at multiple points during the school year starting in grade three. The district also uses Google Surveys for science assessments in grades four through six, data from which is also used in PLC meetings. In creating and protecting common planning periods and shared spaces for collaboration, the district cultivated the social support for groups of teachers to discuss their teaching, problem solve, share feedback, and work toward improvement.

Solution Tree guided these PLCs by helping with data analysis, supporting teachers in designing formative assessments and unit plans, running PLC meetings, and guiding reflection on classroom observations. There was buy-in for this work from teachers in Hartwell in part because Solution Tree consultants "still currently work in classrooms" which meant that "everything that they do they know works because they're using it directly in the school that they work for" (Ursa).

Among the strategies Solution Tree uses is a triage of the NGSS standards and to prioritize some over others. This was guidance they provided Hartwell across all subject areas.

"If you taught every single standard the way they expect you to, you would need 22 years of school, not 12. [...] We have to focus on what is essential, you know, what are those essential Standards, per subject, per grade level. Those are what we focus on. That is what they build their units from, those essential Standards." (Ursa)

The Solution Tree coach helped teachers identify which standards were essential as they developed each unit, and which were the "nice to know" (Ursa) standards that they can weave into their teaching if time allows. This practice carried across subject areas and focused teachers'

work on developing lessons that were motivated by their students' needs and the "essential" science standards, and that looked for materials to support that work. Where some of this work was new for classroom teachers or teachers in other subject areas, Ursa felt that the districts science teachers (in departmentalized grade levels) had "already kind of been doing this anyway, just pulling in, knowing what their essential standards were, putting those into units, and then pulling in those resources if they needed to help kids, teach those standards" (Ursa).

Summary. Hartwell stands out in our sample for its commitment to change through practices not resources. In fact, no single textbook or curriculum anchored their work on elementary science. Though the theory of action and practice-forward approach to system building adopted in Hartwell was, on its surface, unusual, it also reflected the necessity for practical, pragmatic designs in public schooling. Ursa and Winona's engagement with the environment included interactions with organizations representative of all nine categories I identified in Table 2-3 including everything federal and state grants; local in-kind support; contracted services with a resource provider; and local universities and REAs. Across these organizations, the leaders in Hartwell saw opportunities in the PLC structure and other teacher development programs that could maximize the resources they already had and develop district resiliency. Not only did this practice-forward approach expand to subjects beyond science, but it also expanded to other areas of schooling including school safety and special education.

King Park, its Environment, and a Hybrid Approach to System Building

King Park is an urban charter district that took a hybrid approach to system building. There, work on elementary science was sparked by the state's adoption of new, NGSS-aligned standards in 2017. As reflected in Table 2-3, the district's science program attended to figures in its environment from six of the nine categories of organization. Examples from across these six

included state assessment and accountability policies, donations that allowed for the acquisition of new materials. Farrah, the Primary Science Manager in King Park, used resources like the EQUIP rubrics to review the commercially available curriculum and engaged with the charter's national offices in the ways other public charters might engage with their REA office. Farrah centered resource- or practice-forward approaches at different stages of the system building process. In this, the district provides an example not only of this hybrid approach but of ways districts centering their work on one of these approaches might shift their work overtime.

Background. King Park runs a portfolio of public-charter schools in a southern city. The district's mission has shifted from a focus on preparing students for college to incorporate a commitment to anti-racist teaching, a shift that is discussed explicitly in their instructional work, including in elementary science. Collectively, the schools serve about 5,000 students from pre-kindergarten through grade 12 in PreK-4, PreK-8, 5-8, and 9-12 schools. The district is one of the larger charter networks in its area and has run schools in the community for nearly two decades. In addition to the other public schooling options, families in the area enroll their students in private schools at much higher rates than the national average, supported in part by the state's voucher program.

Historically, the elementary schools in the network have had flexibility around assigning teaching responsibilities and some schools in the district created science teacher/specialist roles while followed the generalist model with one teacher in charge of multiple subjects. During our data collection, these structures were in flux as the district navigated a safe return to in person learning during the COVID-19 pandemic. The district has also gradually expanded its central office staff to provide increased supports for instructional coaching.

This may partially have been related to a changing landscape for hiring and retaining teachers. Where the district had historically hired many new teachers from programs like Teach for America, they were finding fewer qualified candidates to fill vacancies in the district. One of the district directors outside of science program felt that this may have a result of the lack of colleges of education in the city (though at least five universities and colleges in the city offered undergraduate degrees in education).

King Park’s Environment. In comparison to Hartwell and Silverbay, the environment described by Farrah from her perspective as the district’s science leader was somewhat narrower in scope, including connections with organizations in only six of the nine categories of organizations. Its structure as a charter district also shifted its relationship with the community from the other eleven districts in that it was neither the default school for any community member nor did it have a local, elected school board. Despite these differences, there were still pressures to be responsive to community needs and preferences (in order to secure student enrollment) and state accountability standards (in order to maintain their authorization).

As represented in Table 2-3, the district incorporated what they were hearing from the community to direct their own work on elementary science. For example, though the academic teams in the district had already been in conversation about more explicit value statements around equity and anti-racism, they expedited that work in the summer of 2020 when “racial justice came to the forefront for everyone, but especially for our kids” (Farrah). Sparked by this, Farrah began working with a consultant to develop a rubric for auditing the district’s curriculum around issues of equity and anti-racism.

In science, those curriculum materials were internally revised units from the Amplify curriculum. King Park made the decision to purchase those materials after reviewing the

commercially available science curriculum. “At that time,” Farrah told us “There wasn’t a ton of [curricula] out there, especially that aligned to the rigors and needs of the new standards. We looked at a couple. Also on the table was creating our own.” As part of their decision-making process, a team of “key stakeholders who both cared a lot about science and [knew] a lot about science” who could “evaluate accurately” different curriculums that would be “most aligned” to the standards reviewed available curricula (Farrah). As denoted in Table 2-3, the district referred to state-created guidelines for assessing the quality of available curriculum and then filtering those guidelines “through the lens of our vision and guiding principles—what we decide that we believe is true about science” (Farrah). The district also reached out to the national network that supports King Park and other charter schools around the country. In that network were districts that were a few years ahead in adopting the NGSS. Those districts had settled on Amplify and the network “supported” its use (Farrah). That national network recommended Amplify based on their experience with the curriculum in places that had adopted the NGSS earlier. Ultimately, King Park agreed Amplify would “would align the best with [their state] standards, of course, with our little asterisk of, we’ll have to adjust some things and add some things and do our own thing because” their state had adapted (rather than adopted) the NGSS (Farrah).

King Park was particularly sensitive to state policies and requirements. Leaders in the district attributed this to their reality that, as previously described, their ability remain operational as a charter district was closely tied to standardized testing. In addition to formal consequences from the charter authorizers for low performance, school report cards also shaped parents’ enrollment choices in the district. As a result, the state’s standardized tests were important to district leaders and had strong implications on how science was taught there. For example, the district did not dedicate time for science instruction until grade three, the first year

that the state tests in science. The district also worked to make sure they were familiar with the ways the state's test assessed science when sample items were released.

Resource- & Practice-Forward System Building. The district's purchase of Amplify curriculum materials marked what the science leader there believed to be the district's first investment in elementary science. "That was the big first investment in elementary science, I think, in the history of King Park" (Farrah). Though the materials would need to be adapted for both their state their district's specific vision for science, the perception was that they would be in a better place starting with Amplify—a curriculum that Farrah understood as having been in development for about 10 years—and that the curriculum would help establish a baseline "that was just so much higher" than developing a curriculum from scratch in one year.

In this first stage of system building, Farrah and teacher leaders began work adjusting the Amplify materials to better serve teachers in the district.

"I don't know if you're familiar with the Amplify curriculum. It's really hard for teachers to use. Basically, my summer was pulling the units and putting them into actual lessons for teachers to use because it's just hours of prep, especially in elementary school where teachers have multiple jobs as teachers. That was just a huge barrier that we could get in front of. King Park also invests in something call Curriculum Fellows, so building leadership through teachers that want to get on to the curriculum side over the summer. It was a small group. It's one person per grade, basically, to do that work. I think, the first summer, we focused on making the existing Amplify—not adding or taking away too much but making existing curriculum accessible so that a teacher could just open up a document that's just a couple of pages because, if you print from Amplify, it's 11 to 15 pages. Just simplifying the existing curriculum, that was year one." (Farrah)

In this excerpt, Farrah is describing a resource-forward approach to system building focused on achieving improvement in elementary science through the provision of new, high quality curriculum materials. Further, the intention is to give teachers with complete lesson plans—removing the need for teachers to engage with the broader curriculum and translate those resources into discrete lessons. At the same time, the engagement of teacher leaders in this work

develops and distributes teacher leaders and expands their expertise beyond being a focus on the materials as written. Instead, these teacher leaders are working with Farrah to interpret and revise the materials for their local context and thinking through the supports and guidance both teachers and students will need while interacting with these materials.

Once the curriculum was selected and revised, the district’s work with teachers on elementary science primarily occurred through coaching and through some professional development. The district’s instructional coaches worked with teachers regularly (weekly in school buildings that had departmentalized their teaching assignments and nearly weekly in the remaining schools) and supported the practice-forward elements of King Park’s system building. Meanwhile, Farrah continued to refine and revise the curricular materials.

“Year Two was then refining that curriculum based on where the gaps were in the standards, so digging more into those standards, and refining the assessments because the assessments [in Amplify were] terrible, so creating new assessments that were aligned. Also, at that point, we had gotten more information—because [the state] changed the standards, but then [they] didn’t release any information on the assessment side for another year.” (Farrah)

Farrah’s work addressing the gaps between the curriculum materials, the state standards, and—once they were released in 2019—the state assessments kept her work focused on resource-forward parts of system building.

In the third year of implementation, Farrah’s work shifted again but was still focused on refining the district’s curriculum and lesson plans. This work was sparked by the social justice activism of 2020. Though the academic teams “had been talking about our values and [...] explicitly calling out anti-racism [and] equity throughout the previous year” the district decided that they needed move from conversation to action that summer.

“We just need to do it—stop with the editing, and the like—I don’t know—handwriting. Just do it, because it’s better to do something than not. Everyone became more vocal about it as a result, and more. [...] It was also really helpful to have shared

language and shared commitments as well. It accelerated quite rapidly, which was really great and—in making it a priority and—making it something that we all share as a part of our vision [was] spurred by the summer of 2020 for sure.” (Farrah)

For elementary science, this meant Farrah began “refining and focusing on the cultural relevance piece” of the district’s lesson plans by asking questions like “Where can we make deeper connections, and where can we add counternarratives to the science?” (Farrah). It was during this stage of system building that Farrah engaged a consulting firm to support anti-racism professional development and to create a curriculum audit rubric for evaluating whether their instructional materials “accurately [build] kids’ identity of self,” whether students could “see themselves in the subject,” and whether the curriculum included:

“Exposure to other cultures diversity of opinion, and is it accessible to all learners? Is it building equity in that way too? [...] Our phenomenon should both connect to kids lived experience because that’s what science is but also provide windows into stuff that’s happening in the world and in history and all of that stuff too. It’s really exciting to see a tool that is across contents that reflects those things that we’ve been talking about in science.” (Farrah)

In this excerpt, we hear Farrah describe what she sees as the promise of this auditing rubric to help support expanding the district’s vision for culturally sustaining practices and a suggestion that this rubric could be used in routines for auditing the curriculum materials in other content areas.

While Farrah’s day-to-day included curriculum selection, refinement, and revisions, she was also supporting the site-based coaches and leading professional development for teachers. During professional development days for teachers, sessions focus on preparing teachers for the upcoming units in science and on developing particular instructional skills.

“We’re spending the day together, internalizing the upcoming unit, and then focusing on a skill that we’re going to prioritize and practice in our sessions so that we can then apply it. Historically, it’s been—we’re going to focus on giving kids feedback in the moment or, maybe, a part of the block or something like that. We’re going to focus on the synthesis of the lesson or something like that. That’s usually the structure of those day-

long PDs. It's unit internalization and then the skill piece. Those happen across grade levels and across contents. Every person that has a job like me will have their group of teachers." (Farrah)

Aside from working with Farrah, these sessions also provided time for teachers from across the district to collaborate and help each to locate and understand resources, for teachers to exchange supplemental materials or ideas about how to lead each lesson, and to share strategies they use to support student learning. In the excerpt above, Farrah illustrates how the district's professional development expanded beyond training teachers in using the curriculum materials to include supporting teachers instructional practices around particular skills. The examples she offers include providing students "feedback in the moment" and "synthesis of the lesson", both skills that are anchored in a vision for instructional practice rather in the use of a particular resource.

Summary. King Park's system building balanced resource- and practice-forward approaches to improvement. In support of the former, as reflected in Table 2-3, the district engaged with educational organizations in their community to help in choosing a curriculum from the materials available from commercial publishers while also weighing developing their own. Part of their motivation to work on elementary science and investment in the Amplify curriculum was connected to the state's accountability policies which made them particularly attentive to their performance on the state's standardized tests. However, this matter of accountability also influenced their use of practice-forward approaches which centered on instructional coaching and internal strategies for monitoring and managing both teacher and student performance. Though the district attended to somewhat fewer organizations in its environment than did some other districts, this hybrid approach still allowed the district to develop and leverage its internal capacity in ways that supported all five domains of system building.

Discussion

My analysis explored the relationship between leaders' enacted environments and the approaches they drew on to build systems to organize, manage, and improve elementary science instruction. In my findings, I first shared how the different approaches districts took to this work as defined by the core theory of action motivating their work. I then used three example cases to illustrate how districts taking different approaches—resource-forward, practice-forward, and a mix of the two—engaged with different parts of the environment. Looking across these three cases, two interceding parts of the environment emerged as at least partially explaining some of these observations. In the first section, the persistent influence of resource-forward logics of improvement resulted in all but three districts in the thirteen sampled relying heavily on a theory of action that supposed that improved outcomes can be achieved through improved resources. The second section illustrated these efforts in context and highlighted the necessity for leaders to be pragmatic and responsive to local political contexts in their system building work. As a result, those more proximal environments occasionally filtered or mediated more distal organizations and actors.

Entrenched Resource-Forward Logics

Many school districts in this country have experienced, engaged in, or endured decades of school reform initiatives that have been anchored in resource-forward logics (Peurach, Foster et al., 2022). Reforms based in practice-forward logics emerged later and less embedded in the policy landscape. It is therefore not surprising to find that districts in our sample drew most heavily on resource-forward approaches to improvement as these approaches to reform may have been more familiar (Spillane & Callahan, 2000). Even when leaders were willing to work in new ways toward innovative visions for teaching and learning, they may still draw on these familiar

ideas of improvement. This was reflected in Silverbay where Nicholas and his team—including a staff recruited from a charter school widely celebrated for its innovative, non-traditional approach to education—drew heavily on resource-forward approaches to improvement as they launch their pilot STEAM program.

It might also be the case that, like their emergence in the policy landscape, districts see resource-forward approaches to improvement as a foundation on which practice-forward logics might build. Though coaches and professional development in King Park attended to matters of practice throughout their work on elementary science, Farrah’s initial focus as the science leader was on selecting and adapting an appropriate curriculum for the district and in training teachers in using those materials. Looking across the data in King Park, it appeared that these resource-forward approaches made up a proverbial bedrock on which practice-forward approaches could develop (Peurach, Foster et al., 2022). This is echoed in Silverbay where district leaders appeared to have practice-forward ambitions (e.g., supporting teachers in being comfortable developing their own units) but, as the curriculum was being written and released, were focused on developing and distributing those resources.

Hartwell was alone in our sample for the degree to which their theory of action privileged practice-forward approaches to system building. This approach did not appear to be motivated by a *disinterest* in new, better, or more abundant resources as a way to improve. Rather, the environments enacted by leaders in the district appeared to motivate attention inward to developing what was already there. Future research might explore whether other small, rural districts like Hartwell take the same approach to system building and whether their social and informal professional networks (Rigby, 2016) privilege this focus on developing existing skills as the preferred starting point for improvement over acquiring new resources.

Pragmatism & Local Politics

What Hartwell had in common with other districts was the ways pragmatic and political considerations influenced how district leaders moved from what they understood of their environment toward how they worked to manage and organize elementary science. The recognition that improvement might best be pursued through developing the capacities of the teachers in Hartwell was pragmatic as there was—almost literally—no cavalry that could reliably be called in for support. Financial resources were limited for both the school and its community. In a town with no stoplights, local businesses offered what they could, but most area businesses were in the next school district over. As they are in many rural districts (Ingersoll & Tran, 2023), human resources could not be taken for granted and were, as Ursa described, difficult to replace.

In Silverbay, Nicholas and his colleagues had ambitions that exceeded what was possible through the usual curriculum roll out but without the day-to-day, in-school staffing that existed for other subjects like literacy. To balance this vision and the available resources—including his team’s capacity—Nicholas extracted from his environment the resources he needed to support the STEAM pilot with specific attention on the things his team might not be able to make internally like the financial compensation for teachers to participate in the extra PD and assessment systems that could capture data from nearly 50,000 elementary students. And in King Park, Farrah and her team moved between the pragmatic realities of their state and community’s accountability systems, charter authorization process, school report cards, and school enrollment mechanisms on the one hand and the racial and cultural history of that same community on the other. For Farrah, this was especially true during the summer of 2020 when communities like King Park’s were a cacophony of public tumult over racial justice, police brutality, confederate monuments, and related issues.

Further, in each of these districts, more distal parts of their environment like those at the federal- and state-levels were often filtered through local, proximal organizations. In Hartwell, this was exemplified by the use of Title II funds to received instructional support from their REA. In Silverbay, the district's federal funding streams also involved universities in their community and state as co-investigators. In King Park, the local context around charter schools and school choice reshaped how the district responded to state level policies like the report cards the state published on school performance. In a communities where these report cards were not so closely tied to enrollment decisions (e.g., communities where enrollment was based on address rather than a lottery), districts may have experienced these state-level actors in their environment differently.

The filtering effect of pragmatism and political concerns extended across these three districts despite their different approaches to managing and organizing for science and their notably different environments—both as observed by their leaders and across common metrics. Perhaps this should come as no surprise. A 2017 paper by David Cohen and Jal Mehta argued that five attributes explained the success of some reforms. These were: a belief among educators that the reform solved a problem they had, a perception that reforms were aligned with the mainstream perspective on the purpose of public schools and understanding of how schools are organized, that the reforms are practicable and offer educators with support needed to achieve them, and that the reform is responsive to the political and socioeconomical circumstances of schooling (Cohen & Mehta, 2017). Decades before, Tyack and Tobin (1994) argued that that reforms succeed or fizzle based on the ways they intersected with the functional work of schools, cultural expectations communities have of their schools, and the political realities of schools as a

quasi-governmental agency. Together, these findings raise questions about how to achieve reforms that are both ambitious and require substantial change to instructional practice.

Writing about reforms that have tried to change instruction in ways that were unfamiliar and counter to popular ideas about education, Cohen and Mehta (2017) wrote: “Successful implementation of such reforms requires more and more unusual educational knowledge and know-how. If such reforms also had no large, broad, and powerful constituency outside of public education, they encountered additional problems. If they were designed for system-wide change, they found little success” (p.676). In these three cases, we see leaders who seem to be instinctively aware of this reality and who draw that awareness into their efforts to improve elementary science. But they may also be aware of one of the core challenges facing elementary science teaching and learning—its persistent status as a lower priority than math, writing, and reading in the elementary school curriculum.

Conclusion

Regardless of the approach taken by district science leaders to system building, they attended to a remarkably expansive array of organizations in their environments. From local booster clubs and to federal grants, from responding to individual parent concerns to nation-wide social unrest, from partnering with one curriculum provider to assembling the resources to develop a curriculum from scratch, in each of these eleven districts, the work of managing relationships with the environment—just one of the five domains of system building—involved engaging with dozens of external organizations. From their environments, these leaders gathered material resources, professional guidance, and financial support in relationships that in some instances were used to support one curriculum adoption process or professional development session and in others entailed multi-year contracts and partnerships. And, while leaders may have

relied on these organizations for support, they were variably aligned with either the district's vision or with the NGSS.

Since their publication, some advocates for elementary science have been clear-eyed on the scale of change that the NGSS will require. Among the reasons they found districts to be “woefully unprepared for the NGSS” (Trygstad et al, 2013, p.21) were issues of instructional time, the availability and provision of NGSS-aligned materials, and teacher background. Findings from this paper shows that leaders building systems that are attentive to these challenges are, in addition to more internally focused work, managing relationships with a multitude of external organizations in their environment—even in communities with fewer partners to turn to and regardless of the approach they take to their system building work.

But even still, this may not capture the full complexity of the work of district level science leadership. The framing for this paper draws on my prior work on the environment of elementary science reform (Foster, 2024a). In that framework, nine categories of organizations in the environment are described as being influential for districts' work on elementary science. However, there is also a tenth category: concurrent—and sometimes competing—reforms elsewhere in the district that science leaders describe as influencing their system-building work. Because the focus of this paper was on the relationships between districts' approaches to system building and their environments, I did not focus on this component of the framework in this analysis. Yet, as noted in Table 2-3 and described in the appendix, these parts of the environment *did* appear in many of these districts as relevant for leaders' work on science. How might one unpack the ways that work on science is impacted by these concurrent reform projects? One way might be to consider how district efforts to build educational systems for elementary science

account for and manage legacy reform conditions. Indeed, this is the work I take up in my next paper (Foster, 2024b).

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Appendix: Organizations in the Environment

Category	Description	Examples
<i>Federal Government (n=3)</i>	Federal governments appeared in these cases primarily in relation to federal funding packages and their provisions and requirements (e.g., Title I funding, progress metrics in NCLB). In some districts, federal safety regulations like OSHA accountability and forklift licensing were mentioned in relation to the equipment and material supplies for science lessons. Sub-codes included: Title I, II, III funding & regulations, NSF Funding, IES Grants, Regulations (e.g., OSHA)	<i>“Yes, every school gets—I think we get—it’s roughly \$30- to \$40,000. They’re called Eisenhower funds, and so that’s what you do, is you dedicate those funds to your [REA]. Then all of your professional development, that is free.” (Ursa, Hartwell)</i> <i>“We did create some curricular enhancements and do some curricular revisions with another NSF ITEST grant that we had with Bayshore College where we were directly able to connect one of our third-grade units to the [local corporation], so the engineering challenges are set in the context of Brookeport. That’s another curriculum example.” (Heather, Brookeport)</i>
<i>State Government (n=11)</i>	As these districts work on elementary science, they all anchored their work in one thing—new standards. But new standards were not the only artifact of state educational agencies that districts described as influencing their work on elementary science. Policies around PD credits, funding for particular kinds of programs, rules around curriculum adoption, state-run science networks, state-provided supplementary funding, and support documents from state agencies all featured in districts’ environments. Leaders were also responsive state testing and accountability policies around science including when science is or is not tested, state-run data dashboards, and whether science was included in measures of Annual Yearly Progress. Sub-codes included: Legislation, Department of Education Policies, State-provided supports	<i>The science test being suspended last year was also I feel like a step back for science in general. There was a lot of momentum. A lot of people were leveraging the [state] science test as ‘Hey, look. This is going to show up on the dashboard. This is how your—this is how schools will be viewed,’ because it’s like—let’s not mince words. School districts care about test scores, right. They care about what—the way that they are perceived.” (Nicholas, Silverbay)</i> <i>“Bartlett’s not a district that focuses on the state assessment. Now, we know it’s important, but we come—I feel very fortunate that we’re in a district that does not hold [state test] scores over our head as the ultimate know-all, tell-all of what’s going on in the classrooms.” (Yvette, Bartlett)</i> <i>“From the ‘60’s to 2002, we used SCIS. That was not on our state textbook adoption list with the last adoption, so we moved to a combination of STC from Carolina, the Science Technology in Children, and we moved to some Delta science modules.” (Keith, Norhaven)</i>
<i>Professional Orgs. (n=8)</i>	The professional organizations mentioned fell into two main categories: National or state level professional groups like the NSTA, its state chapters, and state Science Educational Leadership Associations. Science leaders described these groups as providing them with professional learning experiences, connections with other leaders, and supports for their work. The second type of professional organization were the teachers’ labor unions. While the science-focused professional networks were consistently a source of support for district leaders, their interactions with	<i>“We also then just had to make the decision—and this is where our relationship with our teachers’ union is so fantastic. They have given a ton of grace for us to add positions or purchase things that, yes, it may negatively impact their bottom line on their paycheck, if you’re going to go there with that.” (Sergio, North Valley)</i> <i>“Then I noticed we used a lot of the position statements from NSTA for this next week’s work because they have, ‘Here’s what elementary science should look like and sound like middle school.’ It’s a nice affirmation position. They call them declarations.” (Trinity, Jasper)</i>

Category	Description	Examples
	unions were more complicated. A challenge in multiple districts was around planning PD since PD hours were often negotiated as part of the teachers' contract and funds to incentivize extra PD were limited. Sub-codes included: NSTA, Unions, Associations of Superintendents and Administrators	<i>"The only reason we were even willing to go about trying to do this internally was the fact that I had been on a curation team, a resource curation team for NSTA for a few years leading up to it, maybe two years." (Travis, Bartlett)</i>
Universities (n=8)	Colleges and universities served as collaborators, sources of support, and sources of material and financial support. In most instances, districts were engaged with colleges and universities that were nearby. Occasionally, they worked with universities farther away but in the same state. Universities helped districts to develop parts of their curriculum including performance assessments, create NGSS aligned field trips, and to developed lesson plans. Universities were also tapped to help develop teachers' content knowledge or lead teacher trainings. Some districts also used material and equipment lending libraries based on universities or partnered with universities to offer teachers graduate credit for their PD (and in turn earn steps on their pay ladder). Sub-codes included: As research partners, As PD providers, As collaborators	<i>"The K20 Center out of [the state university], they have come in and done some training with us as well. We are trying to get Engineering is Elementary in our fifth grade." (Breanna, Chester)</i> <i>"To supplement some of the lack of engineering, we've contracted out with [a local college], and so we've been able to build out at least two of the units. Motion and design with magnetism is one of them, and soils, rocks, and landforms." (Opal, Brookeport)</i> <i>"We've been working with [a college] to really transform our assessment practice and create performance assessments that are three dimensional that students are learning through rather than just assessing what they have learned. That was a bit ah-ha for us in these assessments in that they're being introduced to new phenomena that are real world as well." (Mindy, Silverbay)</i>
Funders (n=11)	These funding organizations included the donations from corporations, non-profits, philanthropies, and the community (including booster foundations for the schools). Districts' engagement with these funding streams came with concerns about relying on grants or donations and the experience of failing to get a grant despite repeat applications. Sub-codes included: Grant foundations, corporate philanthropy, booster groups, other non-profit donations	<i>"Now our Fairby Education Foundation— last year their focus was on Maker Ed. And so, they went to every single elementary school and did a little presentation on it." (Tessa, Fairby)</i> <i>"The caveat we have here is we have what's called a school farm where they do a lot of deforestation and cutting down trees or whatever that is, and selling the trees, so we've built quite a nice little nest egg, and it's called our Forestry Money" (Whitney, Rivercrest)</i>
Materials Publishers (n=11)	All of the districts that were building systems to support elementary science engaged with purveyors and producers of teaching materials in their environments. Some districts engaged in external resources markets but then decided to create their own teaching materials. Even in these districts, the in-house created curriculum was supplemented with resources like instructional videos (both made and found),	<i>"We pick up and deliver over 10,000 boxes a year. We have a warehouse. They rotate of the Foss and the Smithsonian K8 units." (Heather, Brookeport)</i> <i>"Another thing they use Engineering is Elementary. There are a couple of websites. One little website they really like it's called Mystery Science. They want that. I think that is third through fifth grade. Or it might be kindergarten through—I can't think right now.[...] They can do science</i>

Category	Description	Examples
	and children’s books that provided ELA tie-ins to their curriculum. Sub-codes included: Commercial curriculum providers, instructional kit developers,	<i>through that. Study Island has science they can do. Also, BrainPOP.” (Winona, Hartwell)</i>
Resource Developers (n=10)	District leaders in all but one of these districts reached for many different tools and resources when working on elementary science. These were practitioner-facing resources developed by different organizations including commercial developers and educational organizations like WestEd and EdReports. Examples of these resources included books and publications (e.g., the 90/90/90 case study by Douglas Reeves, materials from Marzano), rubrics and guides (e.g., EQUIP, Danielson), software (e.g., Seesaw, Book Creator, and Peardeck), commercial assessment systems and contracted consultants (e.g., Solution Tree). Other tools and resources included the physical infrastructure districts needed for this work including refills for science kits, suppliers of lab equipment, and classroom furnishings (e.g., desks, smartboards).	In Jasper teachers worked together to “<i>dig into current literature</i>” and study chapters of books to motivate collective understanding of “<i>where we are,</i>” how “<i>we need to be growing or changing,</i>” or “<i>what we need to be doing in whatever the subject area is that we’re studying.</i>” (Trinity, Jasper) “<i>We’ve done a couple, especially as we’ve been adopting the next-generation ones. Earth and Sun is a new—relatively new module for us, and that was piloted and then went through an EQUIP process, and it got high marks, so we pulled it in.</i>” (Opal, Brookeport) “<i>ECA was going to then afford us the opportunity to just have materials prepped, ready, and delivered. We had to work through the different cost options and that came up with the best solution cost-wise for us.</i>” (Fiona, North Valley)
Community Ed. Orgs.(n=10)	Local educational resources were those partners in the community that supported districts through programs like teacher professional development, research partnerships, student field trips, and technical assistance. Examples included REAs, museums, conservancy groups, regional science education networks (e.g., STEM Ecosystems), and science-focused organizations. A standalone case in this category was King Park where their parent organization provided guidance and support in a relationship that approximated those between districts and their REAs. Sub-codes included: Museums, nature centers & other public institutions; REAs; libraries; neighboring districts	“<i>We’ve got a lot of help. We have also, and I haven’t partnered too much with them yet, but we have the [Regional STEM Ecosystem].</i>” (Carson, Chester) “<i>Not as much, recently, I’ve had in the past connections with a number of the non-formal providers in Fairby. So, whether it’s The Science Hub, there’s an organization called LEAF, we’ve got a county organization [...] that does a lot of environmental ed. and recycling work..</i>” (Oliver, Fairby) “<i>I also attended a yearlong course through [the REA] about Next Generation and how to deliver professional development to other teachers around those standards.</i>” (Fiona, North Valley)

Category	Description	Examples
Community (n=11)	Science leaders described the parents and community of their schools including the ways students' home-lives, local politics, the school board, and local businesses supported, complicated, or were not able to support their work on elementary science. Their descriptions also included more general details about the cultural backgrounds of their local community, the economic security or precarity of families, and connections between families and local employers—or in one case, prisons. The local community was salient for leaders in districts regardless of the approach they took to system building. While there were many discrete parts of the community that district leaders noticed, these largely aligned with two ideas. First, leaders described individuals in their community the support or lack of support they provided to schools. Most often this meant parents, volunteers, and school board members. Sub-codes included: Parents & Parent Groups, Local businesses & employers, School Boards	<i>"We also have a district where a lot of parents are engineers, and different scientists, and doctors, so science is important in the community."</i> (Cecelia, North Valley) <i>"When Common Core happened, that was a whole shift in how math was taught, with more for conceptual understanding. And some of the resources—the textbooks that were adopted, were not very good initially. [...] And so, parents really felt that their kids were, were—I'd say they just—it wasn't fair. [...] So then, when NGSS came, and we didn't have curriculum, and curriculum didn't become available for I think five years, in [our state]. [...] So, those are some reasons why I think there was a lot of, 'Don't do any more experiments on my child.'"</i> (Tessa, Fairby) <i>"Our local [television] station here just asked us to start doing little science shorts for their—for the Bartlett TV show, so that's another great way to show [...] the community, 'what are we doing in schools?'. We'll go on and talk a little bit about something that we're passionate, but then we also say, 'Here's an example of how we teach this concept to your kids.'"</i> (Yvette, Bartlett)
Concurrent Initiatives (n=9)	District efforts to manage, organize, and improve elementary science were often just one of multiple ongoing initiatives in districts. Science leaders in nine districts described this tension in their work. Though these initiatives were internal to the district, they were, like work on elementary science, initiatives that were responsive to districts in their environment. In this way. Thus, science leaders whose work was influenced by a reading-initiative within the district were, by extension, attending to the policy environments for ELA in their work on science. Sub-codes included: reading laws, new curriculum in other subject areas, ELA & Math recovery programs, professional development allotments, Social-Emotional learning initiatives, remote learning programs, special education changes, expanding pre-K	<i>"ELA really tends to drive the bus, and so, it's been interesting to advocate for science and use research to show how science supports ELA and mathematics. ELA has always been the driver, mathematics second to that. Math, you can imagine, has much more staffing. For science, we've traditionally in the—I guess when I say, 'Traditionally,' I mean in the last five years, have only had one particular individual that supposed to support science TK through 12."</i> (Nicholas, Silverbay) <i>"In math you have Math Recovery or math intervention where we help the students identified that we give support in math. Same thing with ELA. We have reading interventions, Reading Recovery where we provide extra support, [...] what school can afford a [...] science intervention specialist? We can't. We're already down one ELA intervention, and the only reason why we're able to have those intervention teachers to provide support for is because we're a Title I school."</i> (Whitney, Rivercrest)

Chapter 4

Improving Elementary Science Instruction: Analyzing District-Level Efforts to Build Systems Alongside Legacy Reform Conditions

Abstract: Many major reforms underway in districts' elementary science programs are the result of the release and adoption of the Next Generation Science Standards (NGSS) in 2013. More than a decade later, districts are still working to put the vision of those standards into practice. The changes these standards call for are ambitious and have implications for instruction, instructional materials, assessments, and how teachers are prepared. Yet, the NGSS are being introduced into elementary schools in which existing structures, norms, and routines developed as part of past reform initiatives may complicate efforts to positively respond to these challenges. Drawing on case-study data (including interviews, observations, and artifacts) from 13 districts across the United States, I make the claim that there are at least three distinct approaches (integrating, retooling, and skirting) that districts use—alone and in combination—to manage relationships between new efforts to improve science instruction in line with the NGSS and these pre-existing structures, norms, and routines. These approaches help districts to mitigate enduring challenges and complications of instructional improvement in part by leveraging internal strengths. District leaders may draw on these ideas in weighing possible approaches to respond to their environments, given legacy conditions in their districts.

Generations of scholars have documented how challenging it can be to reform, improve, reimagine, or simply change schools and schooling. And yet, remarkably undaunted, educators continue to try. These reforms have focused on improvement in many corners of the schooling experience from how to teach reading (Pearson, 2004) to the physical design of classrooms

(Rabinowitz, 1974). In the world of science education, waves of reform movements have endeavored to reimagine the teaching and learning of science in elementary schools since the turn of the century, gaining traction and substantial federal attention with the NSF curriculum projects of the 1960s. Most recently, the release of the Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) has been used to catalyze systemic change in curriculum, pre-service teacher training, and means of assessment. Since their release, most states have either adopted outright or adapted with modifications the standards.⁹ More than a decade on from their release, these standards remain a—and perhaps *the*—major force in elementary science education and continue to motivate creation of new curricula and assessments, revisions to existing curricula and assessments, updates to teacher preparation programs, and new strands of research.

A problem, however, is that the NGSS are not being introduced into a reform vacuum. To the contrary, decades of efforts to improve elementary science have created legacy conditions that have potential to challenge and to complicate efforts to improve elementary science instruction in ways responsive to the NGSS. Thus, there is a need for research that examines strategies used by districts to manage the relationship between new efforts to improve elementary science instruction and the legacy of past reform initiatives.

The purpose of this paper is to explore how school districts go about the work of building systems to implement the NGSS and improve elementary science teaching and learning in their elementary schools. In doing so, I focus specifically on the strategies used by three focal districts

⁹ Precise metrics for this vary. The [NSTA reports](#) that all states but Florida have standards based on the Framework and the NGSS lists Texas, Florida, Virginia, Pennsylvania, Ohio, and North Carolina as states that have neither adopted nor adapted the NGSS. What ‘adaptation’ means also varies by state, but adapted standards often borrow the language and structure of the NGSS with certain elements removed (e.g., Oklahoma’s adaptation of the NGSS drops or modifies some standards relating to how humans have impacted climate systems).

that allowed them to overcome some of the persistent challenges of instructional reforms, including managing relationships with legacy reform initiatives. Each of these districts employed a different strategy for how they approached system building within the context of their districts. Those strategies—integration, retooling, and skirting—allowed districts to manage some of the challenges commonly faced when drawing new logics and ideas into established organizational structures. These cases provide models for ways other districts might begin thinking about their own system building efforts in science or other areas of schooling.

Challenges of Improving Elementary Science

By design, the NGSS challenge the status quo in elementary science instruction by (among other things) orienting it around new conceptions of three-dimensional learning (National Resource Council, 2012) coordinated across grade levels. The changes these standards call for are ambitious and have implications for instruction, instructional materials, assessments, and how teachers are prepared. Yet, the NGSS are being introduced into elementary schools in which existing structures, norms, and routines developed as part of past reform initiatives are likely to complicate efforts to respond to positively respond to these challenges. These could include legacies of past science standards (e.g., old curriculum material, lesson plans aligned to old standards), or other, broader reforms (e.g., multi-grade classrooms, magnet program). In some cases, these reform efforts may be ongoing, district initiatives.

Since being published in 2013, the NGSS have become the cornerstone of contemporary reform efforts around elementary science. The standards heeded the recommendations put forward the year before in *A Framework for K-12 Science Education* (The Framework), a report published by the National Research Council (2012). That report detailed the ambitions and goals of the new standards, outlined the key ideas and practices that the new standards would cover,

and suggested future avenues of reform including the development of new curricula, changes to teacher preparation programs, and the development of new science assessments and assessment technologies. As a first step toward that vision, the NGSS aimed to resolve what the authors described as a disorganized status quo in content of K-12 science. By setting ambitious, rigorous goals for science learning across grade levels, the Framework and the standards aimed to disrupt embedded traditions of teaching science as a set of facts, prioritization of breadth over depth, and few opportunities for students to experience how scientists work (National Research Council, 2012, p.1).

Like the NGSS, many curriculum and educational reform projects start with a change to the *rhetorical curriculum*, or the ideas about curriculum proposed by policymakers, professors, and leaders in education (Labaree, 1999). While reforms at this level can give the appearance of major transformation, policies set at this macro-level often have little connection with what happens in day-to day classrooms. To achieve change at that level, reforms must infiltrate to the *formal curriculum* including written state and district policies and the curriculum materials adopted by those schools and districts (Labaree, 1999). Still, without impacting the *curriculum-in-use*, that is, what teachers actually teach in their classrooms, it is hard to see how the NGSS could achieve its expansive goals of ensuring that:

...by the end of 12th grade, all students have some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not

limited to) careers in science, engineering, and technology. (National Research Council, 2012, p.1).

That task—the work of translating a formal curriculum into a practicable, curriculum-in-use—has often fallen to teachers.

A problem, however, is that many, if not most, elementary school teachers are likely underprepared for such a task, having had minimal opportunities for training in either science content or the methods of science instruction. While the National Science Teaching Association (NSTA) has long recommended that future teachers receive practical training in science instruction and take at least one college course each in a life science, Earth science, and physical science (NSTA, 2012), few teachers have had this content training. In the most recent national survey of Science and Mathematics Education (a survey that has been conducted regularly since 1977), less than one third of teachers had had such preparation (Banilower et al., 2018), a small decline from the preceding national survey (Banilower et al., 2013). Other studies have found that 47 percent of the 907 elementary teacher training programs reviewed failed to adequately prepare elementary teachers for teaching STEM content (Greenberg et al., 2014). When preservice teachers are provided field experiences in teaching science, they frequently experience a misalignment between what they are taught in their courses and what they observe in the classroom (Kruse et al., 2021).

The deficiency of preparation goes beyond teachers' preservice training. In 2018, 43 percent of teachers reported having had no professional development (PD) in science in the preceding four years, and 30 percent of elementary teachers reported either *never* having received professional development (PD) in science or having not had a science PD in more than 10 years (Banilower et al., 2018). This is somewhat startling given that, at the time of the survey,

19 states and the District of Columbia had adopted standards based on the Framework and/or the NGSS in the preceding five-years. What’s more, between 2015 and 2018, one in five teachers had had less than six hours of PD in science and more than two in five teachers had had none at all (Banilower et al., 2018). Given this, it’s no surprise that teachers report having less confidence in their readiness to teach science compared to other subject areas (Banilower et al., 2018).

More than a decade since their release, it’s unclear how far the NGSS has progressed from a rhetorical change to a change in the daily teaching and learning of science. One landscaping study on the status of K–12 science education found that NGSS-aligned professional learning opportunities and preservice teacher preparation were still in early stages of field building and lacked a knowledge base, actors, a field-level agenda, infrastructure, and resources (Smith & Plumley, 2022). Administrations of the National Survey of Science and Mathematics Education (NSSME) in 2012 and 2018 found that instructional time for science had fallen in all elementary grades between those surveys. This was especially true among teachers in grades four through six who reported spending 27 minutes per day on science in 2018, down from 47 minutes five years before (Banilower et al., 2013; Banilower et al., 2018). Additionally, there was a nearly three-fold increase in the portion of teachers who heavily emphasized “learning science vocabulary and/or facts” and a decrease in the portion of teachers who heavily emphasized “understanding science concepts,” “learning about real-life applications of science”, and “learning science processes” (Banilower et al., 2018).¹⁰ The study authors described their

¹⁰ Specific phrasing changed over time for certain items. In 2018, the survey used the phrase “learning science vocabulary and/or facts” while the 2012 survey used the phrase “*Memorizing* science vocabulary and/or facts”. “Learning science process skills (e.g., observing, measuring)” was used in 2012 but changed to “Learning how to do science (develop scientific questions; design and conduct investigations; analyze data; develop models, explanations, and scientific arguments)” in 2018.

findings as “somewhat surprising” given that many states had already adopted the NGSS or similar standards at the time of their survey and thus would have expected higher emphasis on “learning to do science” (Banilower et al., 2018, p. 108).

If the NGSS follows in the path of previous reform efforts, we can predict a number of the challenges those aiming to implement the reform might face. Among those challenges may be the legacy effects of those previous reform efforts. A considerable body of scholarship has investigated why, despite decades of reform efforts, there has been ‘so much reform, and so little change’ (Payne, 2008). Among the challenges instructional reformers face are a number of core features of the institutional norms and organizational character of school districts. These include the normative institutional pressures that help maintain the longstanding grammar of schooling (Tyack & Cuban, 1995; Tyack & Tobin, 1994), a legacy of loose coupling between the technical core of schools (instruction) and other parts of the organization (Meyer & Rowan, 1978; Weick, 1976), and traditions of instructional autonomy and privacy (Little, 1990; Lortie, 1975).

Against this background, while some uniquely capable and motivated teachers may be able to independently transform their practices to bring life the learning ideals of the NGSS, most teachers will need considerable support (Blumenfeld et al., 2000; Cohen & Ball, 2007; Cohen & Hill, 2001; Duke, 2000). Research in other subject areas has found that, even after the adoption of new materials and visions, teachers may make only small or surface-level changes to their practice or may make changes that appear to align with the new visions in some ways but contradict it in others (Cohen, 1990). Teachers making these ambitious changes to their instructional practices are likely to need systemic support through an educational infrastructure including formal structures and resources that support teachers’ instructional practice including

both instructional materials and increased school-level capacity for structuring the work of improvement (Cohen et al., 2018; Spillane et al., 2018; Spillane et al., 2016).

System Building for Elementary Science

Though the literature on the history of instructional reforms provides us with a sense of the challenges that reformers face, it also provides a framework for how districts have worked to overcome those challenges. For purposes of this paper, I draw on a theory of *instructionally focused educational system building* as initially detailed by Peurach and colleagues (2019) and developed and expanded by Yurkofsky and Peurach (2023), Datnow and colleagues (2022), Spillane and colleagues (2019), and others.

I begin this section by describing in more detail educational system building as a strategy for supporting elementary science teaching and learning. Using that framework, I first describe a representative ideal-type that outlines the kinds of activities one might expect to see—in principle—in a fully-developed educational system to support elementary science as an analytical tool for thinking about such endeavors in practice. An ideal-type is not an example of how such a system would ideally be designed but a “construction of a simplified model that focuses attention on the most salient or distinctive features of some phenomenon” (Scott & Davis, 2007, p. 50).¹¹ With this construct as a reference point, I then describe how educational system building requires navigating the challenges discussed in the previous section and, at the same time, increases the possibility of friction with existing norms, structures, and routines for managing and organizing instruction.

¹¹ The ideal-type or *Idealtypus* is commonly associated with the social theorist Max Weber (Kim, 2022; Weber, 1904/1949)

The Work of System Building

In principle, districts that are developing or have developed as educational systems have intentionally built their organizational capacity to support, manage, organize, and improve instruction and student outcomes. Education system building of this sort represents a shift from a legacy of districts as *schooling systems* in which administrators focus chiefly on organizing and managing access to instruction but leave decisions about instruction to teachers. By contrast, one line of theoretical and empirical research frames the work of building instructionally focused education systems in terms of five core, interwoven domains of work distributed among district central offices and schools (Peurach et al., 2019; Peurach & Yurkofsky, 2018). Those are:

- *Building educational infrastructure*, including developing a shared vision for instruction among educators; selecting or creating formal resources for instruction (e.g., curriculum, benchmark assessments); and fostering social resources for instruction (e.g., common norms, teacher-leader-student relationships, support for new initiatives among educators)
- *Supporting use of infrastructure in practice*, including providing workshops, opportunities for collegial learning, mentorship, or coaching
- *Managing and monitoring practice and performance*, including developing strategies for continuous improvement and summative accountability like routines for classroom observations or using benchmark, assessment data to track progress or test new strategies
- *Developing and distributing instructional leadership* to teachers, staff, and teams beyond the administrative offices and supporting new leaders in these same domains of work, and
- *Managing environmental relationships* to craft coherence from dissonant policy and contextual environments including federal funding streams, state accountability requirements, and the local ambitions of families and communities.

System building is not a one-size-fits-all formula. Across each of the five domains of work, districts can develop plans specific to their local contexts, delegating work in different ways between schools and district central offices, in accord with different theories of action (Peurach & Yurkofsky, 2018).

Educational system building is characterized by the intentional coordination of work across these five domains. By developing internal capacities and working strategically, districts aim to manage, organize, and improve instruction in ways that work toward ambitious new visions for student learning in science or other subject areas. While many districts may work on some or all of these domains in isolation, it is the coordination and organization across these domains toward particular goals and ambitions that distinguishes a district as an educational system rather than a more conventionally organized *schooling system* (Peurach et al., 2019).

An Ideal-Type

What might such a system—designed to support and advance new ambitions for elementary science—look like in practice? While there are at least as many ways to approach this work as there are districts, I continue by constructing an ideal-type to model a district engaged in the work of education system building. I do so by drawing on a comparative case study of system building in four contexts (each anchored in a distinct theory of action) and by integrating across those cases to develop an ideal-type (Peurach et al., 2019). This construction is useful as an analytical device for examining the work of education system building in practice, as enacted in actual districts.

In a district that is developed as an educational system supporting elementary science, one would expect to see districts *building an educational infrastructure* for elementary science by purchasing or creating instructional materials that align with the district's vision for

elementary science. We might expect this process to include strategies for fostering teacher buy-in, excitement for the infrastructure and responsiveness in its design to both teachers' concerns and existing norms, structures, and routines for managing and organizing instruction. For example, a district leader might draft a vision for science teaching and learning in collaboration with classroom teachers, meaningfully include teachers in the decision-making process around new instructional materials, and coordinate with other subject-area teams to align the scope-and-sequence for science with other subject areas.

Since many elementary teachers have not previously had substantial training in either science or teaching science, one would expect such a district to have a design for and invest in *supporting the use of educational infrastructure* for elementary science. This would include strategies for providing teachers with training before, during, and after the adoption of new instructional materials. Professional development would nurture familiarity with and buy-in to the district's vision for science and the principles of the NGSS, allow teachers to preview the materials ahead of using them, provide opportunities to observe science classrooms, and develop both content- and pedagogical content knowledge. Subsequent PD would support teachers in translating the formal curriculum into daily practice, refining and strengthening those capacities over time. Where districts have established PLC structures, mentor teacher programs, or instructional coaches, one would expect to see districts providing guidance and support for how to bring science into those meetings.

A challenge of achieving change in schools is learning about, first, what is happening and classrooms and then monitoring how new strategies are implemented by classroom teachers. A district developed as an educational system supporting elementary science would have strategies in place for *monitoring and managing practice and performance*. This might include routines for

classroom observation, the use of internally crafted district-wide benchmark assessments, or the incorporation of commercial assessments like those developed by NWEA (formerly the Northwest Evaluation Association) and included in their Measures of Academic Progress (MAP) suite of formative assessments. In addition to these assessments, one would expect to see routines that facilitate ongoing school- and district-level conversations about progress toward the districts goals and planning tied to the results of internal measures.

All of the preceding activities require that districts *develop and distribute instructional leadership* for elementary school science by activating and empowering leaders across the district, both within formal leadership roles and beyond (including formal and informal teacher leadership). This could include train-the-trainer activities to prepare teacher-leaders to lead science PD, coach their peers, coordinate classroom observations, and foster continued commitment to work toward the district vision for science among their colleagues. It could also include opportunities for teachers to share their work with other schools and districts. Since principals often set a school's agenda, a district leader might work with principals and teacher-leaders to ensure science be included in daily schedules. Districts might also train and support principals so that they understand and support the district's vision for science; are familiar with the standards, curriculum, and pacing guides; provide them with tools for- and practice in observing science lessons.

While attending to these parts of system building that are largely internally focused, districts that are developed as educational systems *manage environmental relationships for elementary science*. This might include relationships between the district and its organizational landscape including regional education agencies, local museums and universities, and vendors of instructional supplies and equipment. Though this might entail managing relationships with grant

fundings, an educational system for science would have designs to guarantee the long-term fiscal support for work on science. This work might, therefore, involve managing internal organizational dynamics about funding priorities but could also include strategies for developing community support for elementary science programs that in turn fix science as a district priority. That could involve communicating information about the science program to the community (e.g., highlighting exciting new programs) and strategies for attending to community interests and concerns around science. One might also see plans for aligning existing extracurricular opportunities (i.e., field trips, afterschool programming) with the new district vision and curriculum for elementary science, procedures for managing the provision and maintenance of science kits, live specimens, and other materials for elementary classrooms. Table 3-1 summarizes the preceding description of activities in an ideal-type educational system for elementary science.

Table 3-1: Activities in an Ideal-Type Educational System for Elementary Science

Domain	Activities in an Ideal-Type
<i>Building an educational infrastructure for elementary science</i>	• Develop a district vision for elementary science • Purchase or create NGSS-aligned curriculum and instructional materials aligned with that vision (including assessment tools) • Implement strategies for fostering teacher buy-in • Ensure responsiveness to teachers' concerns and existing routines in refining and implementing the vision & curriculum
<i>Supporting the use of educational infrastructure in practice for elementary science</i>	• Provide teachers with training before, during, and after the adoption of new instructional materials on the science content, the curriculum, and the NGSS • Reinforce familiarity with and buy-in to the district's vision for science and the principles of the NGSS • Provide opportunities for teachers and leaders to observe science classrooms • Provide opportunities to develop both content- and pedagogical content knowledge • Include science in established PLC structures, mentor teacher programs, or instructional coaching structures or develop instructional coaching structures to support ongoing development of teachers' elementary science practices

<i>Monitoring and managing practice and performance for elementary science</i>	• Build routines for classroom observation by coaches, principals, and/or teacher leaders of elementary science lessons • Use internally crafted district-wide benchmark assessments, or the incorporation of commercial assessments like the NWEA-MAP • Build routines that facilitate ongoing school- and district-level conversations about progress toward the district's goals • Include science in ongoing, regular school- and district-level conversations about progress toward goals • Develop school- and district improvement plans that include measures and goals for elementary science
<i>Develop and distribute instructional leadership for elementary science</i>	• Activate and empower science leaders in formal and informal roles across the district • Train-the-trainer activities or other strategies to support teacher-leaders to lead science PD, coach their peers, coordinate classroom observations, and foster continued commitment to work toward the district vision for science • Develop opportunities for teachers to share their work with other teachers, schools, and districts • Support principals in understanding the district's vision for science; with training in the district's standards, curriculum, and pacing guides; with tools for- and practice in observing science lessons; and with guidance for making sure science has protected time in school schedules
<i>Manage environmental relationships for elementary science</i>	• Manage relationships with regional education agencies, local museums and universities, and vendors of instructional supplies and equipment and make sure those partnerships are aligned (or become aligned) with the district's vision for elementary science • Coordinate with grant funders while developing support with school boards for long-term, internal budgeting for elementary science • Foster and strengthen community support for elementary science programs through outreach and through drawing in community input around elementary science • Align existing extracurricular opportunities (i.e., field trips, afterschool programming) with the district vision and curriculum for elementary science • Develop plans and procedures for managing the provision and maintenance of science kits, live specimens, and other materials for elementary classrooms

The Challenges of Educational System Building

The work required for districts to progress toward an instructionally focused education system of this kind is complex. While educational system building heeds lessons learned from decades of reform efforts, such work is not without challenges of its own. Though it is possible to describe the five domains of work and to describe an imagined district as an ideal-type of education system, the work of system building itself is challenging, time and resource

consuming, and rife with dilemmas (Seeber et al., 2024; Yurkofsky & Peurach, 2023). Moreover, in many school districts, this work runs counter to the norms and expectations for how schools operate—again, many of which are artifacts of past reform efforts. For many districts, system building may, metaphorically, require a combination of building, remodeling, renovation, and retrofitting.

Consider, for example, the legacy of loose coupling. Describing schools as loosely coupled highlights the separation between the technical core of schools—classroom instruction—and other parts of the organization and its environment historically observed in the American schooling enterprise (Meyer & Rowan, 1978; Weick, 1976). In loosely coupled districts, central offices have traditionally focused on administrative functions like staffing, human resources, payroll, building contracts, and relationships with vendors, leaving responsibility for this bridging work to teachers (Peurach et al., 2019; Spillane et al. 2019). Central offices might filter and buffer pressures from the environment for the district broadly, while school leaders may also buffer their schools from central office pressures (Honig & Hatch, 2004). As a result, policies, reforms, and legislation have historically had a relatively weak influence on classroom instruction.

Contemporary regulations and legislation have made it increasingly difficult for districts to fully decouple the technical core of their work (daily instruction) from their external environment or from other internal units. Accountability policies, for example, have been shown to have shifted instructional practices (e.g., Diamond, 2012; Hayes & Trexler, 2016) but those effects have been experienced unevenly (Diamond & Spillane, 2004). Some scholars have borrowed the term “recoupling” from sociological work beyond schools (Espeland, 1998) to describe this process of “creating tight couplings where loose couplings were once in place”

(Hallett, 2010, p. 54). Yet, even in systems where there has been some degree of recoupling, educational system building may still face challenges around what recoupling requires and its implications on things like teacher autonomy and relational trust.

Planned Change and Recoupling

Instructionally focused educational system building functions to couple instruction with other district and school functions. Where districts are developing these systems for the first time, they must develop new ways of working. Yet, given the contemporary policy pressures on schools, it is likely that districts have developed norms, structures, and routines around managing and organizing teaching and learning, even if they haven't begun to coordinate those efforts as part of an educational system.

Existing organizational routines potentially act as recoupling mechanisms between particular reform efforts and classroom instruction (Hallett, 2010; Spillane et al., 2011; Woulfin, 2015;). In one study, researchers observed that school leaders developed routines for regular student testing and common learning benchmarks in response to changing district-level policies, low scores on the standardized tests, and feedback from their school board (Spillane et al., 2011). However, leaders can also be selective in how extensively they couple reforms with instruction through routines. In the same study, leaders at another school established routines that required teachers to plan lessons anchored in the standard school curriculum but also allowed teachers to decide on their own content for up to 40 percent of their lessons.

Changes that endeavor to support recoupling can be disruptive and have unintended consequences. Planned change efforts can damage relational trust and erode improvement efforts in schools (Hargreaves, 2002). Hallett (2010) described the struggles experienced in K-8 school recoupling in response to accountability measures. There, after many years of loose coupling and

buffering by school leadership, teachers felt a loss of autonomy, increased stress, and broader turmoil when a new leader was tasked with implementing accountability policies in the school. Many veteran teachers left, teachers who remained closed their doors tighter, and reading scores dropped after years of upward movement. Diamond (2012) found evidence of partial recoupling in response to accountability pressures but observed that it often resulted in changes that were the opposite of some of the policy makers' intentions. For example, such changes included allocating resources not to students struggling the most but instead to students closest to the cut-point for proficiency on the tests scoring system.

Where districts are expanding existing educational systems to incorporate new areas of instruction—like science—they may face similar challenges as districts that are developing new routines. This is because past efforts may have been developed around specific subjects in ways responsive to environmental influences specific to that subject (Burch & Spillane, 2003, 2005). As a result, while districts may have grown internal capacities as an educational system for a subject like ELA, that work may draw in infrastructure, support networks, social resources, assessment systems, and external partners that are not transferable to elementary science, are incompatible with elementary science, or that do not have parallels in elementary science.

This would suggest that many districts working to manage and organize elementary science teaching and learning must necessarily reconcile the district's existing norms, structures, and routines (e.g., repeated, recognizable processes that involve multiple actors and are embedded in context; Becker, 2004; Feldman & Pentland, 2003) with their new approach to elementary science. These include norms like age-graded classrooms, generalist teachers in elementary schools, bell schedules, and the use of textbooks (Cuban, 1990; Elmore, 1995); and school routines like procedures for curriculum adoption, new-teacher mentoring, teacher

evaluation structures, patterns of PLC meetings, or lesson study activities (Diehl & Golann, 2023).

Autonomy

Districts building systems to manage and organize elementary science instruction may also need to reconcile that work with existing norms and routines that maintain both teacher and school autonomy over instruction (Elmore, 1995; Little, 1990; Lortie, 1975). Where teachers feel they lack a say in some of the structural decisions in schools, there may be increased conflict between and among teachers and administrators (Ingersoll, 1996).

Indeed, some reform movements have aimed to expand teacher and school autonomy. For example, the provision and expansion of autonomy has been a key construct behind reform efforts like charter schools which received by partisan support when first proposed in the early 1990s (Chubb & Moe, 1988; Wohlstetter et al., 1995;). By giving schools and teachers the power to self-manage and by removing some of the policy burdens placed on them by higher levels of government, the belief was that charter schools could be innovative spaces for teachers and others to try new models of teaching (Shanker, 1988). Increasing school-level autonomy has not been a project solely pursued by establishing charter schools outside the authority of conventional districts. Public school districts including large districts like Los Angeles, Chicago, Boston, and New York City have also experimented with giving school sites more autonomy to develop new approaches to teaching and learning *within* the district (Honig & Rainey, 2012).

While these and other initiatives have aimed to improve schools through expanding school- or teacher autonomy, other initiatives have functioned—or been seen as functioning—to limit teacher autonomy. Indeed, a key opposition to standards-based reforms was an argument that standardization would limit teacher autonomy (e.g., Frymier, 1987). Yet, researchers have

found that even in circumstances where they believed teachers autonomy was restricted by reforms, there was no clear evidence that teachers themselves experienced perceived these limitations (Archibald & Porter, 1994). And, even teachers who do self-report reduced autonomy from a reform initiative have been observed to remain supportive of those reforms (Rowan & Miller, 2005). Together, this suggests that rather than focusing on whether their system building efforts are restricting teachers' autonomy, district science leaders might instead consider the degree to which their work is experienced by teachers as enabling or coercive (Adler & Borys, 1996).

In districts building instructionally focused systems for elementary science, the introduction of new educational infrastructure aimed at implementing the NGSS may be experienced as a shift from more autonomous curricula to more prescriptive curricula. This might be especially true for more than 28 percent of elementary level teachers that report working in districts where their district does not designate the instructional materials to be used in science (Banilower et al., 2018). Where those districts move to adopt district-wide curriculum, teacher may experience a decreased efficiency or efficacy in their instruction (OECD, 2024).

Relational Trust

When structures and functions that are taken for granted by members of an organization are altered, it may decrease the *institutional trust* (i.e., an individual's trust in an organization) which in turn can impact *relational trust* (i.e., the trust between individuals) (Bryk & Schneider, 2002; Louis, 2007). Research has found that many schools have low levels of relational trust though smaller subsets of teachers may have high relational trust (Goddard et al., 2001). Low

levels of trust have been associated with depressed student achievement (Hoy & Tschannen-Moran, 1998) and teacher burnout (Friedman, 1991).

Planned change efforts in schools can disrupt relational trust and erode improvement efforts (Hargreaves, 2002). This suggests that system building efforts that are perceived by teachers as a violation of their trust may face larger hurdles in achieving their goals. On the other hand, trust has also been observed to support schools in achieving reforms (Louis, 2007; Spillane & Thompson, 1997) suggesting that some of the challenges of educational system building may be lessened where districts are able to maintain the trust of teachers. Research on the perspectives of elementary teachers engaged in reform-based professional learning for elementary science found that supporting relational trust among teachers and those leading the training reduces the perceptions of risk and uncertainty that teachers may have in implementing new methods of instruction (Radloff et al., 2019).

While research has found that schools with higher levels of trust use more collective decision-making processes, there is no clear prescription for how to build trust where it is absent (Louis, 2007). Some scholarship has suggested that trust may be enhanced where teachers have an influence in decision making; where they feel that their interests are being considered by other decision makers; and where there is a clear understanding of the intended outcomes of a change (Louis, 2007).

Research Question

In this paper, I aim to develop richer understandings of the ways school districts build systems to improve elementary science teaching and learning in their elementary schools. Thus situated, my research set out to answer the question:

How do districts attend to the intersection between system building efforts for elementary science and existing norms, structures, and routines for managing and organizing instruction in ways that mediate challenges and conflicts?

Study Design

Sample

This paper draws findings from a comparative case study of school districts across the country with data collection spanning from 2019 through to 2023.¹² As detailed in Table 3-2, the study included thirteen districts in six states located across the United States and were of different sizes ranging from fewer than two to more than 900 students per square mile. Individuals and districts are referred to by pseudonyms in this paper. Additionally, precise district sizes, locations, and other identifiable details have been masked through abstraction or anonymization. As detailed in Table 3-3, the districts were varied in terms of type (i.e., urban, suburban, rural, charter) and community demographics but were purposively sampled based on interviews with 136 state-level science leaders as places engaged in substantial work on elementary science.

Table 3-2: Study Sample

District Pseudonym	Region	District Type	District Enrollment	Science Leaders (N=27)	Interviews Conducted (N=48)
Bartlett	Northeast	Suburban	~ 3,000	2	3
Brookeport	Northeast	Urban	~ 50,000	5	6

¹² Professors Dr. Donald J. Peurach (U-M) and Dr. James P. Spillane (Northwestern) served as Principal Investigators on the project with additional leadership from Co-Principal Investigator Professor Dr. Elizabeth Davis (U-M). The research team also included a post-doctoral researcher at each university, two doctoral students/candidates at U-M (myself included), a Research Project Coordinator at Northwestern, and temporary graduate researchers also from Northwestern.

Chester	South	Urban	~ 35,000	2	3
Fairby	West	Suburban	~ 30,000	3	4
Hartwell	South	Rural	< 1,000	2	5
Hillman	West	Charter, Urban	~ 3,000	1	2
Jasper	South	Suburban	~ 12,000	2	3
King Park	South	Charter, Urban	~ 5,000	1	2
Lockeford	West	Rural	~ 4,000	1	2
Norhaven	South	Suburban	~ 14,000	1	2
North Valley	Midwest	Suburban	~6,000	3	4
Rivercrest	Midwest	Rural	< 1,000	1	2
Silverbay	West	Urban	>100,000	3	6

Table 3-3: Overview of District Characteristics

Urban districts (n=3)	West (n=4)	Low Income*: 10 to 93%
Suburban districts (n=5)	South (n=5)	Special Education*: 6 to 25%
Rural districts (n=3)	Midwest (n=2)	English Learner*: 0 to 41%
Charter districts (n=2)	Northeast (n=2)	

* These numbers draw on state data and thus include some state-to-state variation in terminology and population.

At the district level, the research team was able to gather data through:

- 112 interviews with central office staff
- 55 interviews with formal & informal school leaders
- 28 observations of district-level routines in science (e.g., professional development, strategic planning meetings)
- 22 observations of school-level routines in science (e.g., professional development, team planning)
- 55 interviews with teachers
- 22 classroom observations in nine schools

Field data collection was divided among the post-doctoral researchers, the doctoral students, and the principal investigators. The doctoral students and post-doctoral researchers were also responsible for cleaning and coding the interview transcripts for project analyses. The team also

collected artifacts in each district including district and school goal documents, curriculum materials, strategic plans, websites, flyers, social media and blog posts, and local news articles.

Data

This paper focused on the interviews with district science leaders that were largely conducted during the 2020-2021 school year. That subsample of the data includes 48 interviews with 27 district science leaders across 13 school districts. Table 1 shows how these interviews were distributed across the districts. The onset of the COVID-19 pandemic coincided with our efforts to recruit districts for the project and subsequent research activity was reshaped over the course of the pandemic. As a result, initial plans for travel and in-person observations and interviews were modified and research activities were conducted remotely until the final year of data collection when we visited schools and conducted classroom-level observations.

The interviews conducted for the project were semi-structured interviews that were almost all conducted using video-conferencing software. In most cases, interviews were conducted by one research team member with one participant, though occasionally two researchers were present, or district participants preferred to do a joint interview with a colleague. In each district, the research team conducted follow-up interviews with at least one science leader. In some districts, for example in districts where the district science leader was also the elementary school principal, the science leader was interviewed three or more times.

For the purposes of this paper, science leaders are those individuals identified by district personnel and self-identified through outreach as responsible for leading efforts around elementary science in the district. These leaders sometimes had formal titles associated with science (e.g., Science Coordinator, Science Specialist, STEM Director) but in some districts the role was only a part of the work of that leader. For example, some of the individuals in this

sample held positions like ‘Director of Teaching & Learning’ or ‘Assistant Superintendent of Academics’ from which they lead work on elementary science either alone or with colleagues. In the two smallest and most rural districts in the study this was particularly true and in those districts, the principal of the district’s elementary school was the individual identified as the science leader. While it might seem incongruous to identify a school principal as a “district science leader,” these districts both house all grades in one building with district administrative offices co-located with the school building. Further, research suggests that in districts such as these it is often the case that leaders hold multiple roles (Harmon & Smith, 2007). This was born out in our interviews. In a few instances, a person identified as the district’s science leader was no longer in that position at the time of our interviews due to funding challenges or district restructuring.

The interview data were supplemented with district artifacts (e.g., district websites, goal documents, instructional visions, curriculum materials, strategic plans), observation fieldnotes of district science routines (e.g., PD, strategic planning meetings), interviews with teachers, and analytic memos maintained by the research team throughout the research project.

Analysis

Analysis for this paper was anchored in analytic memos and thematically analyzing the interview transcripts with district leaders (Miles et al., 2014). The first level of analysis involved understanding the big picture of system building in each district. To do this, I began by reviewing system-level analytic memos that had been developed by the project team. Then, I began reading and re-analyzing the interview transcripts of the district science leaders to specifically focus on this paper’s research question. While working through these transcripts I annotated the documents with my own sense making. I also used inductive codes from the

framework for instructionally focused system building to understand what system-building for elementary science looked like in the district. These inductive codes included: building educational infrastructure, supporting the use of infrastructure in practice, developing and distributing leadership, monitoring and managing performance, and managing the environment. I worked through these transcripts, leader by leader, writing synthesizing memos after reading each transcript. Unless there was only one science leader in the district, I next read across these leaders and memos to develop an understanding of the district-level work and added this synthesis to those memos.

The next matter was to identify the places where the new attempts at system building to support elementary science were intersecting with established approaches to managing and organizing instruction. For this, I returned to the transcripts to highlight and flag the places where leaders described these intersections including tensions, limitations, work-arounds, and facilitating factors. These annotations helped me to collect quotes from the transcripts that appeared particularly illustrative or data-rich. These syntheses focused on understanding what science leaders were saying about their contexts, their approach to supporting elementary science, what enabled their work, the challenges they faced, and the solutions they came up with. I supplemented my review of the transcripts by returning to an emergent code applied to the data by the project team that identified places science leaders were ‘managing the internal environment’. I also drew on analytic memos developed by the project team that described and made sense of the system building work in each district. These memos allowed me to confirm my understandings of the approach to system building from the science leader transcripts aligned with the understandings developed by the project team from the full corpus of data.

While reading, coding, and annotating the data, I used memoing for my own sensemaking of the cases. I worked to identify like-cases by considering smaller groupings of cases from the broader sample to find shared and dissimilar characteristics in the approaches district leaders took to their work. I also regularly referenced online materials shared by districts and state governments including district curriculum materials posted online, union contracts, district improvement plans, state policies and timelines, outreach materials about elementary science, and descriptions of curriculum adoption routines. These materials helped to further check that my understanding of district activities and state contexts were both accurate.

Limitations

While this research was conducted using the broader project data described above, this work was not a part of the research design at its outset. As a result, the data draws on interviews conducted with protocols designed to answer a different set of research questions. Those protocols did not include specific questions designed to answer this paper's motivating question nor were those ideas a subject for which interviewers always probed for more details. Further, while interviews were conducted following set protocols, individual respondents and interviewers engaged with the protocol in different ways, drawing on their individual expertise.

The analysis also is limited in that the larger study focused on districts identified by outsiders as places already engaged in efforts to improve elementary science instruction in ways responsive to the NGSS. These data cannot speak to the degree to which what we've observed in these districts is relevant for other districts.

Finally, the system building framework I draw on in this paper is predicated on a coordination of activities between district central offices and schools. For many reasons, educational system building may delegate substantial responsibility for science instruction to

individual schools. Because my analysis focused on the district-level as a whole and used interviews with district-level (which is to say: central office) staff as the primary data source, this paper is limited in its abilities to describe the components of system-building that occurred at individual schools.

Findings: Approaches to Managing Challenges of System Building

The analysis for this paper investigated how districts pursued instructionally focused educational system building for elementary science in ways that addressed or mitigated legacy challenges associated with past instructional reform efforts, including attending to existing norms, structures, and routines for managing and organizing instruction. Across the districts we studied, districts faced certain challenges related to existing district routines and structures. These included challenges that seemed to have persisted over a longer term (e.g., professional development routines, district fragmentation, tensions between the union and the district, staffing challenges) and challenges emerging from or dramatically exacerbated by the COVID-19 pandemic (e.g., shifts around remote learning; supply-chain interruptions; safety protocols; staff, substitute teacher, and budget shortages; and accountability pressures). Yet, the districts that we studied also exemplified approaches to system building that were mindful of these challenges in ways that appeared to avoid the potential for conflict including by leverage internal strengths.

In the following sections, I present three case studies that are each illustrative of positive and distinct approaches to system building that were attentive to existing district designs for managing and organizing instruction. I frame these approaches as *integrating* with, *retooling*, and *skirting* existing norms, structures, and routines. For each approach, I use a focal case to show how district efforts to improve science interacted with different domains of system building. Though these approaches could be used in combination or with other approaches

beyond those I identified in this sample, the three districts I focus on here relied heavily on a single approach and therefore are useful illustrative cases.

As expected, each of these districts deviates from the ideal-type of an educational system built for elementary science. The system-building projects in these districts were imperfect and in-progress at the time of our data collection. The districts we studied, including Jasper, Bartlett, and Silverbay, were variably engaged in the five core domains of work that characterize education system building, as well as in the coordination of these domains of work. In describing these districts, I refrain from evaluating whether or not the districts are meeting a particular benchmark of educational system building and, instead, recognize each district as a work in progress.

Approach 1: Integrating Science within Existing Norms, Structures, and Routines

One approach districts took to instructionally focused educational system building was to *integrate* elementary science within existing district norms, structures, and routines. This approach included a variety of activities that took advantage of existing capacity in support of the district's efforts to improve elementary science instruction in ways responsive to the NGSS. In my wide-angle analysis of the data, integration surfaced as a category of approaches in districts that had already been engaged in educational system building and, hence, where that had established routines that science leaders recognized as places into which elementary science could be incorporated. This occurred in districts where some degree of educational system building had already occurred and where science leaders recognized opportunities in those capabilities for supporting elementary science.

In general, integration strategies used existing norms, structures, and routines without making substantial changes to them. Examples of this included leveraging existing norms around

collaboration, adding science to the agendas of existing professional meetings, and following predetermined schedules or processes for reviewing curriculum. These characteristics meant that, in contrast to *retooling* or *skirting*, integration was the closest to a business-as-usual approach to implementing new standards in science. However, simply calling this business-as-usual obscures the fact that some of these districts were leveraging their past efforts to develop new strategies for managing and organizing instruction in elementary science. It is possible that the existing norms, structures, and routines that integration leverages may have created friction when they were first introduced in the district. Yet, by integrating into these routines (rather than creating new ones), districts using this strategy may still be minimizing the friction their current initiatives create.

In this section, I focus on Jasper Public Schools (Jasper), a district that integrated its work on elementary science into existing district norms, structures, and routines. Using this approach, Jasper was able to use existing routines to build and revise its educational infrastructure for science, draw on existing social resources for collaboration and improvement to support elementary science, use existing system capabilities for Continuous Improvement to support the use of that infrastructure in practice, and monitor and manage performance. Integration allowed Jasper to take advantage of their past investments in dismantling conventional expectations of privacy, autonomy, and loose coupling. Instead, the work on science integrated into a system where instruction had been at least partially recoupled and where a culture of collaboration and continuous improvement had been established.

Jasper Public Schools – Context

A large suburban district in a southern state, Jasper Public Schools are located in an active state policy context. The state department of education and government to which Jasper

reports have a number of policies that directly and indirectly influence the district's work on science and bear on the work of building educational infrastructure. Among these factors is a timeline set by the state that requires districts to review curricular materials on an established schedule. As part of that schedule, the state reviews its educational standards every six years and every district in the state is required to review and adopt science materials at the same cadence. The state department of education largely requires that curriculum be selected from an approved list. It is also one of many states that have recently passed laws or announced mandates around the science of reading, critical race theory, and religion.

State level policies also shape Jasper's efforts to support the use of educational infrastructure. As in many districts, state-level policies pre-determine the content of many of the annual professional development hours required of teachers—of the 15 professional development hours teachers must earn in a year, nine are predetermined and must be completed by the end of September each school year. The state first adopted new science standards that were based on the NGSS and the Framework in 2014 and updated them in 2020.

Jasper had been iteratively working to build its educational systems since the 1990s when the district adopted a focus on supporting continuous improvement based on a total quality framework—in effect, developing capabilities for monitoring and managing practice and performance, though as a general capability agnostic of content area. In an article published in 2006, the district superintendent at the time described the districts work as rooted in “W. Edwards Deming's quality principles of strong leadership, continuous improvement, customer focus and a systems/process focus.” More than two decades later, Trinity, the district's Executive Director of Teaching and Learning, told us that her work on continuous improvement focuses on effectiveness including effective communication and engagement with families and providing

“opportunities that allow students to really grow toward their lives beyond K-12. It just means you never rest on your laurels.” These efforts continue to be a very visible cornerstone of the district’s vision and are explicitly included in the district’s vision, goals statements, and elsewhere.

In the first year of our district-level data collection, Jasper was engaged in a curriculum review and adoption process (in effect, building educational infrastructure) led by the district’s office of Teaching and Learning (in effect, part of its distributed leadership structure). “We have all kinds of subject areas cooking [...] along here. Each year, we have a focus area. This past year has been social studies. The year before was mathematics. This year is science,” said Trinity. The district uses one year as a curriculum review and adoption year, followed by a second year focused on implementation. The district planned on using “the implementation year to really solidify our assessment practices” (Trinity).

The district’s Office of Teaching and Learning was organized as a generalist department rather than subject area specialists. At each elementary school site, instructional specialists, who reported to the central office team, “help our teachers become better teachers” (Natalie, Secondary Science Teaching & Learning Specialist). The district’s Associate Superintendent for Educational Services told us that the district had been encouraged to cut these positions but had decided not to because “the value of having the instructional coaching right there on site is really significant, especially for newer teachers who are coming into the district” (Mallory). The instructional specialists help bridge between district led initiatives and policies and classrooms. One school-based specialist told us: “A lot of decisions are made [...] that people don’t really put faces to, but then we’re the faces they can put to it. We are the ones that are onsite, meeting with

teachers through their PLCs, [...] talking data with them and talking collaboration, talking curriculum, all those good things” (Viola).

The district had also developed a social infrastructure that supported improvement and collaboration. People we spoke to in the district mentioned “the Jasper Way,” a phrase that was used to refer to both the district’s vision for instruction and norms around instructional coaching. This shared commitment was fostered in a number of venues including in the relationships between school-based instructional specialists and teachers. One specialist told us that the Jasper Way was:

“Something that makes you eye-roll at the beginning, but then when you really get familiar with the Jasper philosophy of teaching—which is very much ‘we will guide you in what to teach, but the art of teaching is yours’—it is amazing for some of those well-educated, very well-prepared teachers to take on. For those teachers that aren’t, whether you’re emergency certified or whether you’re coming back into the classroom after staying home for a while, that’s where it can get a little tricky in the support for those teachers. That’s where we step in. (Viola)

Thus, the Jasper Way was shorthand for a normative expectation in the district that educators develop a willingness to work with colleagues and coaches about instructional practices and strategies for improving, that coaching was available, and that, ultimately, teachers were professionals in charge of their own classrooms.

To further support Jasper’s vision for instruction and continuous improvement, the district had invested in an online infrastructure. The central office had developed a Canvas page for teachers that outlined the district’s core values and documented the basic expectations for instruction and classroom climate including the key instructional practices the district expected teachers to practice or work toward. The site also shared teaching strategies the district recommended but didn’t require. The district was working to pair each of these resources with video examples of Jasper classrooms demonstrating an instructional strategy in action.. Trinity

told us, “We’re trying to grow that so teachers really see this isn’t something we just grabbed from Teacher’s College, [...] that we really have living, breathing people in our district who are doing this practice.” The videos, she said, might be accompanied by articles that justify the featured instructional practice and provide some “how-to” guidance for other teachers.

Integrating with Existing Norms, Structures, and Routines

District leaders in Jasper pursued their work on elementary science as part of this larger system building project. This had leaders leveraging extant parts of the education system in Jasper including existing cycles for new curriculum adoptions, social resources for collaboration between teachers, instructional coaching routines, and expectations around using student data. Table 3-4 provides an overview of how Jasper integrated their system building to support NGSS aligned science into these existing policies and improvement routines. Their work included using existing procedures for reviewing and adopting new curriculum, leveraging shared norms around continuous improvement and collaboration, using existing instructional coaching routines and professional learning communities to support the use of infrastructure in practice, and carrying forward existing strategies for reviewing student data to monitor and manage performance. To support her understanding of the subject, Trinity and her colleagues did their own professional learning of science education and the new standards. Among the resources they tapped were commercial books on improvement and school leadership, articles on science education, and webinars on topics like cross-cutting concepts.¹³ The central office team also described learning from science education professionals in their environment including their state science coordinator and representatives from the local STEM Ecosystem hub.

¹³ One of the three prongs of the NGSS standards that has been the subject of some debate (Osborne et al., 2018; Saleh et al., 2019, Osborne & Rafanelli, 2019)

Table 3-4: Integrating in Jasper Public Schools

	Extant parts of the system	Integrated with system building to support NGSS science
Build Ed. Infrastructure	Existing cycles for reviewing and adopting new curriculum; existing social resources for instruction & collaboration; online resources	Used existing practices to adopt standards-aligned materials and refine them for district performance management strategies; used existing social resources for collaboration and improvement in the context of elementary science
Support Use of Infrastructure	Existing school-based coaching and teacher teams	Used existing coaching structures to support the implementation of the curriculum
Monitor & Manage Performance	Existing practices and culture around looking at student data	Used existing practices and culture around looking at student data to monitor and manage performance in the new vision for elementary science

The work of building the educational infrastructure was integrated with existing practices for adopting new curriculum materials and established social resources for instruction. As Jasper moved to adopt new curriculum materials, they did so with the guidance of educators and community members using existing routines for curriculum adoption. Though recognizing the need to support the new state standards for science, their decisions took into account existing instructional routines and considered whether some should be carried forward. One such routine was the use of science notebooks. At the end of the curriculum review process, Jasper adopted a new curriculum package—Twig. Through conversation with teachers in the review process, the district decided to keep the district’s previous science ‘notebooking’ routines for their lower elementary grades, rather than adopt the Twig workbook component. Though the upper elementary sites decided they wanted the Twig workbooks, the conversation about whether to keep the district’s existing notebooks surfaced a number of issues teachers had observed in those existing structures and routines. As a result, though the lower grades kept the district notebooks, a few changes were made to their format like switching from traditional composition notebooks

to more tailored formats for kindergarteners to provide more space to draw for the first half of the year and add more lines later in the school year as students' writing proficiency develops.

The school-based instructional specialists supported the use of the new curriculum in practice and helped teachers use the adopted materials in ways that aligned with the district's vision and values. Like the central office, those specialists were generalists and "really fabulous educators. They've risen through teaching and learning, teaching in classrooms to that role. They are, in a sense, leading science from what we do at the district level at their sites" (Trinity). The district's online learning webpage provided additional supports for teachers.

Jasper was also able to integrate routines for monitoring and managing performance into the district's existing structures for continuous improvement. This included setting and communicating expectations around the rubrics teachers use for looking at science notebooks and other student work. While the new curriculum materials from Twig included many assessments, they were not all aligned with the vision for assessments and science held by the district. Trinity told us:

"I want this year to truly be a learning year of what is effective and provides that opportunity for students to share their understanding, to share their growing insights, and yet gives teachers understanding of how they're growing as scientists. That's kind of why we took off the benchmark and the multiple choice [assessments from Twig]. [...] We'll explore them together at the district level [...] I think that's really going to be an important exploration this year for us in sorting through what we carry through with for the next year." (Trinity)

Though Jasper uses commercial benchmark assessments for other subject areas (e.g., Renaissance Learning STAR Reading assessments to monitor student progress in ELA), the district recognizes a misalignment between its vision for science teaching and learning and Twig's assessments and instead opted to explore the possibilities.

System building in Jasper reflected many of the characteristics described in the ideal-type. After reviewing the available curricular materials, they purchased a curriculum series that a

team of teachers and other stakeholders felt to be aligned with their vision for elementary science. They responded to teacher concerns about implementation in building that infrastructure and revised some of their plans in ways that maintained their vision but addressed teachers' concerns and requests. They included science in existing routines for site-based coaching and meetings where teachers looked at learning data to manage and monitor improvement. In contrast to the ideal type, issues of funding were resolved not by generating strong community support for science but by including science within a subject-neutral approach to coordinating teaching and learning in the district.

Integration as Mitigating Challenges of System Building

While the legacy of past reform efforts can challenge system building, Jasper's past reform efforts created conditions that supported its efforts to improve elementary science and that favored the use of an "integration" approach. One of the challenges districts face when engaged in educational system building is that such work runs counter to normative expectations of privacy, autonomy, and loose coupling in many districts. While the work of recoupling can cause turmoil and disruption (Hallett, 2010), Jasper's previous and continued investments in its educational system appeared to have mitigated such challenges by generating a school community that is familiar with and supportive of the routines and recoupling in the district.

By embedding their work on elementary science within exiting norms, structures, and routines, Jasper was able to build its educational infrastructure for science, support the use of that infrastructure in practice, and monitor and manage performance largely by leveraging structures and practices already familiar to educators, administrators, and the community. This starting point seems to have focused the district's efforts to improve elementary science on questions of 'what' rather than questions of 'how'. Further, the district's standing commitment and

accompanying investment in building shared buy-in for continuous improvement seems to have alleviated some questions about whether improvement was even necessary.

The design in Jasper was suggestive of some of the possible opportunities afforded by a generalist central office approach to system building. Based on the progress made in system building for science, one conjecture is that, as generalists, the Teaching and Learning team had a keener perception of how science fit into the broader context of teachers' daily work, allowing them to coordinate instructional reform projects and minimize the number of concurrent initiatives. Another conjecture is that working as a generalist team is an enabling factor in being able to leverage systems for multiple subject areas.

By incorporating science into existing frameworks for improvement, the district's work on elementary science may have created less disruption for teachers by following established routines and patterns in the district to which teachers have become accustomed. While, in many districts, efforts to recouple organizational practices and the collective activities of educational system building would represent a substantial change in the taken-for-granted parts, this was not necessarily true of Jasper.

The district worked to create consistency across schools as well as classrooms. It did so in ways that maintained boundaries on autonomy rather than provide openings to foster it. In comparison to the science teams in the other districts explored in this paper, the complete integration of science within the core administrative function is about as far from autonomy as is possible. Yet, this integration of subjects in one central team may have afforded the district a degree of flexibility for managing science in school and classroom contexts that the other two districts achieved by acting as separate from the core central office.

Approach 2: Retooling Existing Norms, Structures, and Routines

Another approach districts used in their instructionally focused educational system building work was *retooling*. Retooling was characterized by maintaining some aspects of norms, structures, and routines but revising some of their core features or using them in new ways. Retooling also described district work that made considerable changes to the internal characteristics of district norms, structures, and routines while leaving its surface-level characteristics intact. This approach leveraged existing roles, relationships, and ways of working but refocused their purpose. In contrast to integration, retooling involved marked changes to norms, structures, and routines in districts while maintaining enough of their past forms as to be recognizable and familiar. In contrast to skirting, retooling worked within the existing configurations for managing and organizing instruction.

In this section, I focus on Bartlett Public Schools (Bartlett), a district that retooled its existing district norms, structures, and routines as part of its system building for elementary science. In doing so, they were able to support their work building educational infrastructure, support the use of that infrastructure in practice, and manage relationships with their environment by repurposing existing structures and routines for collaboration. Working in this way allowed the district to mitigate some of the challenges that can accompany planned change by leverage internal strengths including the relational trust between science leaders and teachers.

Bartlett Public Schools – Context

Bartlett is a suburban district located in a Northeastern state that adapted the NGSS standards in 2014. Despite having been one of the 26 lead states involved in the development of the standards, the state's adaption of the standards included a number of notable changes. The most substantial of these for the elementary science standards were the exclusion of cross-cutting

concepts and the development of standards specific to prekindergarten. Though the state kept the same numbering system from the NGSS to the state's standards to support the use of materials developed to support the NGSS as written, the state did edit and omit two to six standards per grade level. In the state's documentation, where standards have been edited or omitted are noted for educators.

As in Jasper, a core piece of Bartlett's system building work rested on a foundation developed over decades. However, the resources Bartlett developed over those years were rooted in museum education and enrichment programs like presentations and fieldtrips rather than in routines for continuous improvement. This work had been led by the Bartlett Science Learning Center (BSLC) which was established in the 1980s by a science teacher in the district and inspired by a similar center elsewhere in the state. The BSLC is a well-known and popular resource in the district that manages science equipment, professional development, live animals, teaching resources, field trips and more for the district and especially for the district's elementary schools. The BSLC is now run by Travis and Yvette who jointly manage the district's work on science. Both have backgrounds in science though only Travis has classroom teaching experience—Yvette previously worked in museum education.

Prior to the present efforts to reimagine science in line with the NGSS, Bartlett's educational infrastructure for elementary science was provided by the BSLC. The main instructional materials were science kits that included various, thematic resources. Teachers told us these kits had been quite unstructured, and individual teachers had substantial autonomy over and responsibility for creating lesson plans from their contents. Veteran teachers in Bartlett told us that these kits, though full of resources, were not organized into lessons or units but instead allowed teachers to use their discretion to use the component parts.

“The BSLC wasn't quite what it is today. You'd get a kit, but the kit was mainly posters and signs to hang up, and very whole language-y, if you remember that terminology. It was very different, but we had BSLC people [...] who would come in and do shows and programs.” (Abigail)

“You would get a kit, and you would kind of sort through it and figure out what you wanted to do with it. You had your standards and you just kind of figured it out. Okay, this is how I want to incorporate this. What I was doing may have been different than what another teacher was doing.” (Sadie)

Though perhaps thoughtfully curated by the BSLC team, these kits reflected ambitions of the BSLC to emphasize and support “non-text”, “project-”, and “museum-based curriculum” (Floyd, District Superintendent) for teachers to implement in classrooms.

Beyond these kits, BSLC leaders would support elementary science by visiting classrooms and schools to give special presentations on different topics in science or to display the live animals housed in the BSLC. They also led most, if not all of the district's science professional development for elementary school teachers. One teacher recalled:

“I don't remember any kind of science PD that wasn't put on by the BSLC. All of their PD was fabulous. We would go to the BSLC, and they would do a whole thing. We would be doing stuff, making things, and then I was doing this other stuff on my own time, but if the BSLC had not run those things, I hate to think what our PD would've been. I really do.” (Abigail)

Classroom visits and demonstrations might have been matched with the theme of the kits currently being used by teachers, but they were not integrated into the curriculum by the BSLC.

The strong positive relationship between the BSLC and the district's environment was intentionally cultivated. As early as 2008, the BSLC was using blog posts as a means of public outreach around their work. The center's website shared information about the BSLC with the community and in 2011, they added a Facebook page to further that outreach. The blog, Facebook, and later Instagram and Twitter accounts shared information, showed students engaged in science activities, and documented field trips. From our interviews, there was

community support for the BSLC well before these pages were created which would suggest that these pages do more to maintain support than to build it. The district superintendent told us that “even if I were to want to cut the [BSLC], I wouldn’t survive in my job doing that. That’s the following that they’ve built and earned.”

Retooling Norms, Structures, and Routines to Support a New Vision

Though the BSLC was a well-established unit within the Bartlett school district, it was not one that had built systems to manage and organize instruction in elementary science. Its extant system provided kits and demonstrations for classroom teachers, ran generalize science professional development in science, and maintained strong, positive connections with the school’s community. Table 3-5 provides an overview of how Bartlett pursued system building for NGSS science by retooling these extant features in their district. Where leaders in Jasper could integrate system building for science into an existing system, leaders in Bartlett did not have that option. Instead, Travis and Yvette retooled the educational infrastructure provided by the BSLC by redeveloping the curriculum kits and shifted the focus of their professional development to supported teachers in using those materials in practice. Like a retooled assembly line, the surface level characteristics of the BSLC stayed relatively unchanged though they were able to share details of the changes behind the science through continued outreach to their community.

Table 3-5: Retooling in Bartlett Public Schools

	Extant parts of the system	Retooled as part of system building for NGSS science
Build Ed. Infrastructure	Science Center provided thematic kits, demonstrations, and classroom visits	Redeveloped kits to align with new science standards, remade demonstrations and visiting as part of this infrastructure

Support Use of Infrastructure	General, themed science PD	Science PD anchored in new standards & revised kits, used classroom visits as an opportunity for coaching & teaching demonstrations
Manage the Environment	Community support for science, outreach mechanisms	Used existing mechanisms to continue to generate support for science, make changes visible and transparent

Travis “had been getting signals” around 2015 the State would be adopting new science standards based on the NGSS. Around then, he and Yvette started “gathering curriculum resources, informing ourselves around how to go about this approach in a thoughtful manner that wasn’t just going to leave us with a terrible curriculum or frustrated” (Travis). Instead of buying new materials which would replace the existing science kits, Travis and Yvette decided to retool the existing kits to support a new vision for science instruction with materials specific for their district. Though they were the leaders on this work, they collaborated with teachers during summer curriculum development sessions with teachers from across the district including some who were part of the district’s curriculum council for science.

Ultimately, the materials they developed included lesson-by-lesson resources and instructions for teachers including supplementary reading and all the materials they needed for each unit. “We’re just handing our teachers like, ‘These are the materials in the box that you need. Here’s how you start. Here are some talking points as you go. You want to wrap up with this to set the stage for the next lesson’” said Travis. Teachers’ interactions with the kits themselves followed familiar routines. As before, science shared instructional time with social studies and science kits were delivered to classrooms by district staff—but the contents were entirely changed. New units and lessons were developed with teacher input and with attention to the specific needs of Bartlett teachers. For example, they developed the lessons to fit into the 35-minute block the district scheduled for science, and they collaborated with other departments including individuals responsible for ELA and for supporting English Learners to make sure that

the materials they were developing aligned with existing practices and priorities in those departments.

By retooling their resources into a new, more coordinated educational infrastructure (rather than adopting a new, commercial curriculum), Travis and Yvette were able to intentionally retain resources from the BSLC that were adored by teachers, students, and families into the new science lessons. For example, I observed a classroom shortly after Yvette had brought the district's great horned owl to a first-grade classroom to support their unit on the external parts and functions of animals.¹⁴ Travis and Yvette were also able to shift and expand relationships with community partners to dovetail field trips into the new district curriculum. "It's not a simply, let's go to the [museum] and just kind of run around for a few hours, but how can we connect informal science education to formal science education in a meaningful way?" said Yvette. The result of their work included trips to farms as part of units on pollinators, work with a conservation group around ecosystems and water treatment, and trips to the coast to explore tidepools after learning about earth and moon cycles and to explore the body parts and functions of the animals students found in the tidepools with learning resources designed for the classroom that would bookend these experiences. Though the routines around teachers receiving the kits stayed the same, the contents of the kits had changed dramatically. The transition from old to new units happened "in a rolling way where we were taking units off and then bringing the new ones on. That was a long process" (Travis).

To support teachers in using these new materials, the BSLC tapped into existing structures for providing professional development in science and retooled those offerings to align not only with the themes of the kits but with the specific lesson sequence for which they were

¹⁴ How cool is that!

designed. When the new kits were developed but before teachers were expected to use them, they brought teachers to the BSLC where they:

“They undertook one of these new units, and the teachers went through it together. They went through the units together as they were students. When they did it in their classroom, it wasn’t their first time running through it. They were much more comfortable. They had been in the students’ shoes literally and saw how things are supposed to work.” (Quentin, Assistant Superintendent)

This training experience gave teachers “the opportunity to be a part of the revision process” (Quentin) as Travis and Yvette took in teachers feedback and made revisions over the course of the curriculum development. In the final year of implementation, Travis reflected that the BSLC’s work was still:

“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.”

To which Yvette added, “Then we change and revise it, and then they have to learn those changes and revisions. It’s a never-ending wheel.”

By retooling the supports Travis and Yvette had been providing to schools to more specifically connect with the new elementary science program, Bartlett was able to reorient special presentations and lead field trips as part of a coordinated and organized elementary science infrastructure. In this retooling, existing (and popular) supports like live animals were now a feature of a centrally coordinated curriculum, not just an offering on a menu.

With everyone in the district working from a shared curriculum, Travis and Yvette were better able to support teachers in their use of the curriculum. They were also better situated monitor and manage performance as lessons were common across classrooms and they could offer pointers based on successes other teachers were having or provide occasional co-teaching support to help teachers gain confidence in the new lessons. Though they are available as on-call

support when teachers ask, one teacher shared that she doesn't find herself using that resource because "they've trained us, we have the resources, we're capable." (Tessa). Instead, teachers we spoke to described sharing their materials between teachers like digitized worksheets or templates for science notetaking in a shared drive. And by maintaining some of the hallmarks of the BSLC, they were able to preserve the strong community support for elementary science in the district.

Bartlett most closely reflected the work in the ideal-type detailed above regarding the ways that the district established and maintained community support for elementary science and in the district's work building an educational infrastructure for science. Additionally, Travis and Yvette were committed to supporting teachers both in using the curriculum they had developed and in supporting teachers' confidence in science more broadly. The systems for developing and distributing leadership for science appeared less developed, perhaps in part because of the active and capable involvement of Travis and Yvette as leaders across school sites. Additionally, there were few strategies for monitoring and managing performance in the district.

Retooling as Mitigating Challenges of System Building

Bartlett's strategy of retooling leveraged existing system strengths to mitigate the challenges of system building which can disrupt relational trust between district personnel (Hargreaves, 2002). System building that recouples classroom instruction with other parts of the organization can result in teachers feeling a loss of autonomy and increased stress (Hallett, 2010). By retooling popular, existing structures to manage and organize elementary science instruction, leaders in Bartlett were able to retain the relational trust between the BSLC and teachers while recoupling instruction into a more coordinated educational infrastructure. In contrast to integration, retooling involved notable changes to the function of existing structures

and routines. In contrast to skirting, which is discussed in the next section, retooling reworked those structures and routines instead of creating wholly separate structures and routines.

Bartlett's design for system building took advantage of the relationship the science department already had with teachers and attended to existing traditions in the district including field trips in the community and drop-ins from the science specialists to support classroom teachers.

Based on the progress made in system building for science, one conjecture is that the relational trust between teachers and the BSLC enabled the districts work on science and, as a result, retooling (rather than another approach) allowed them to leverage that trust in support of their efforts to manage and organize for elementary science. There is evidence that the district recognized that the nature of the relationship between Travis and Yvette and teachers was important. The district superintendent felt that teachers were more likely to collaborate and explore the work of science with Travis and Yvette if their roles were not ones where they could evaluate teachers. If relational trust was an enabling factor, as posited, to the success of Bartlett's system building, this role definition may have been a contributing factor to teachers' willingness to collaborate and experiment with Travis and Yvette. That teachers trusted them was clear in the data, indeed, both Yvette and Travis were part of the same union as the teachers and, toward the end of our data collection, Travis became the Union president.

Bartlett's strategy to retool existing district routines may have allowed the science team to maintain the existing relational trust they had developed with schools. It was clear that Travis and Yvette were trusted and valued by teachers and administrators alike. Indeed, in the later years of our data collection, Travis was elected to a leadership role in the district's union. Their work, which was done gradually using familiar features, may have helped ease teachers into the project. Furthermore, their involvement of teachers in the development process and their efforts

to refine the curriculum based on feedback and observations may have helped nurture teacher trust thus mediating the potential disruptions the change might cause.

It was not the case that Bartlett's approach to elementary science reflected the district's broader approach to managing elementary teaching and learning. But that may have been changing. In describing Bartlett's approach to system building for elementary science, Yvette told us their work was "a little different from the other curriculum areas" but that other teams were beginning to take inspiration from the BSLC's work.

"The ELL specialist is now following our lead where they are developing their own units [...] with teachers and actually doing it in collaboration with our science units, which is so exciting to me that's happening. They're developing their own science units but are still using pieces and parts of ours and blending them. The social studies coordinator—or whatever her title is right now—she's also kind of on this journey and trying to build it with teachers." (Yvette)

That Travis and Yvette's work retooling existing structures and routines was successfully able to manage possible frictions with existing structures, norms, and routines may be reflected in the fact that these other teams were starting to model their work on the elementary science program.

Approach 3: Skirting Existing Norms, Structures, and Routines

A third approach districts took to instructionally focused educational system building was to build systems to support NGSS aligned elementary science by *skirting* existing district norms, structures, and routines. In contrast to retooling or integrating, skirting entailed establishing new norms, creating new structures, and developing new routines that were detached from existing district practices. If integration was moving into an existing house and retooling was renovating a house, skirting was building a detached in-law suite. Skirting allowed district leaders to intentionally avoid the established district practices they believed could complicate their work on elementary science while leveraging the strengths of their team.

One district that relied on this approach was Silverbay Public Schools (Silverbay). There, leaders skirted existing district norms, structures, and routines by working on elementary science as a stand-alone pilot program. Though the long-term goal of the project was to develop a districtwide curriculum, skirting insulated their work from the established practices for instructional reform in the broader district. The approach also allowed the central office team to work in ways that were countercultural to typical organizational norms. Skirting allowed the pilot team to gradually build an educational infrastructure in partnership with schools that had voluntarily opted in to the program, support the use of that infrastructure in practice, and manage direct relationships with their environment. It also allowed them to cultivate trust in their program across the district by developing a proof of concept and program recognition in the large district.

Silverbay Public Schools – Context

Silverbay, a large urban district, is located in a Western state that adopted the NGSS more than five years before our data collection began. However, the state educational leaders had suggested an adoption timeline for districts that accounted for a delay between the release of the standards and the availability of aligned curriculum. The State’s timeline for adoption included a few years to build understanding of the standards with the expectation that districts begin implementing the standards within five years. During that time, elementary schools in Silverbay continued to use the FOSS instructional materials that had been adopted prior to the release of the NGSS.

Our project focused on the STEAM pilot project underway in Silverbay. Though STEAM is commonly an acronym of Science Technology Engineering Arts and Math, Silverbay also includes ‘Equity and Ethnic Studies’ and ‘Agency’ in their design framework. The STEAM pilot

was launched in 2018, five years after the state had adopted the NGSS. Though the program was launched in only a subset of the district’s 120 elementary schools, the size of the pilot group at the time of our data collection was still larger than Jasper, Bartlett, and all but one other district in our study sample.

Prior to the start of the pilot, the district had only one central-office staff person to support science across all grade levels. That role worked “without a lot of resources” according to the STEAM Director. “It’s a pretty daunting, heavy job to roll out new standards, new trainings without a lot of resources as one person to represent [thousands of] teachers” (Nicholas).

District documents showed that curriculum adoption is typically done by a committee of teachers and other stakeholders who review materials solicited from publishers, receive presentations from publishers, and create a rubric for scoring the materials. The last elementary science curriculum adoption in the district had occurred before the adoption of the NGSS—those FOSS materials were still in use in schools that were not part of the pilot.

The district appeared to have no significant role in supporting the use of those materials in practice, monitoring and managing performance, or developing leadership. The leadership in Silverbay was described by the science team as being quite hierarchical and it was uncommon for science leaders to be included in meetings with executive leadership or superintendents. As part of this hierarchy, it was also necessary to secure support from area superintendents (who oversaw portfolios of schools across the district) in order to collaborate with schools.

Skirting Existing Norms, Structures, and Routines

By developing their STEAM program as a pilot, Silverbay’s science leaders were able to skirt a number of norms, structures, and routines in the district. Table 3-6 provides an overview

of the ways the STEAM pilot skirted existing routines and structures in Silverbay. The foundational piece of the pilot that skirted district routines and for reviewing and adopting new curriculum internally developing a new STEAM curriculum for the grades PreK-5 instead of purchasing a commercial curriculum. From our interviews with the STEAM team and other district personnel, the STEAM project appears to have been unique in the district both in its vision and design. Nicholas was able to break the convention in the district’s “very hierarchal leadership structure” to establish lines of communication between offices where it was typically “hard to get access.” Nicholas told us that, for someone in his role in the district “meeting with the chief of staff and area superintendents was something that didn’t happen.”

Table 3-6: Skirting in Silverbay Public Schools

	Extant parts of the system	Skirted as with systems to support NGSS science
Build Ed. Infrastructure	Very large school district with competing initiatives; existing science infrastructure are pre-NGSS instructional materials	Developed a curriculum from scratch that was district-specific and designed for flexibility for use and revision; developed units to release one grade level at a time
Support Use of Infrastructure	Professional development negotiated in teacher contracts	Required whole-school buy in to participate in pilot; started small and added new schools each year; required teachers participate in extra professional development provided by the pilot team
Manage the Environment	Large, diverse community with many science-related resources available	Secured grant funding to support this work

Working as a pilot program afforded the program with independence to pursue its own plan for system building. In the pilot’s first year, the STEAM curriculum launched in kindergarten classrooms in over 30 schools. Year after year (and despite the pandemic) the STEAM team built this core piece of their educational infrastructure by adding new grade levels. The pilot also expanded each year to include more schools. In its sixth year, the pilot STEAM curriculum was being used up in grades pre-kindergarten through five in more than 80 schools

(75 percent of district schools). The STEAM curriculum was intended to align with the NGSS standards and the district's vision for integrated and project-based learning.

The materials were designed to be responsive to the district calendar with scope and sequence documents available on the district website that suggested how many days and hours teachers should plan for each unit. Hosted online through the district's Google platform, these curricular materials were expansive but also able to be edited by the central office team as issues were flagged by educators. By growing from a science team of one to a team of four, the pilot was able to develop 80 to 100 lessons across four or five units for each grade level. Lessons were designed to last anywhere from 35 to 100 minutes and included direct tie-ins to the district's visual and performing arts, computer studies, math, and ethnic studies curricula. Lessons were supported by the district's instructional technology team and made available in Spanish with support from the English Language Development team. The curriculum was designed so that "if a teacher wanted to do [the STEAM curriculum] across an entire day, they could. There's enough in there, extensions, literacy, math, you name it" (Yazmin) but teachers could also use the materials just within the context of their science blocks.

The pilot aimed to foster social resources for instruction through shared buy-in to the district's goals. To do this, schools in the pilot had to voluntarily opt into the program at both the administration and teacher levels. Nicholas, the director of the project, told us:

When we started it, in order to come onboard, everyone in the grade level had to be trained. The whole site had to be onboard through conversations. You had to add a site governance-team agreement that you were going to take on this effort because we didn't want to train—in addition to curriculum and materials, sites were getting paint, and furniture and different things, and 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." (Nicholas)

Opting into the program required positive assent of the teachers working in those schools. In the first stages of the pilot, Area Superintendents also had to agree to let schools under their authority join the pilot, which required some internal diplomacy and outreach at the project's start. In the years before the COVID-19 pandemic, Nicholas was in regular communication with the area superintendents who, in turn, facilitated professional development with school principals.

In addition to the written curriculum materials, the pilot's educational infrastructure included the expendable science materials and new classroom equipment:

"It was voluntary sign-up. It's not like you were picked. It was a voluntary sign up. The schools that did sign up get classrooms that are painted. The classrooms are outfitted with all of this amazing things, new furniture, all with the STEAM. You would be like, 'Why didn't all the schools sign up for it?'" (Damian)

These resources included new and updated STEAM facilities including furniture, equipment, and a STEAM library of science-based books that "get kids thinking and ideating, introducing phenomena just through the literacy as well" (Nicholas).

Skirting existing norms, structures, and routines gave the pilot program flexibility in how it supported teachers in using the new educational infrastructure. As a pilot program, the team skirted existing limitations around PD time by making clear before teachers opted-in that participation in the program would require additional professional development time. During the pandemic, these agreements also allowed the STEAM team to work directly with teachers separate from the ongoing cycles of negotiation between the union and the district over remote learning and other temporal issues. This was true of principals, too.

"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." (Nicholas)

For both principals and teachers, participation in the pilot meant agreeing to participate in extra PD time than would otherwise have been offered or required for elementary science.

The pilot skirted district budget limitations by turning to its environment for financial support. While Silverbay invested in some of the additional personnel needed to create the curriculum, grants secured by the program director funded some of the development teach and all of the professional development programming. This included grants from local philanthropic organizations, regional bio-tech companies, and the federal government that the director estimated would, together, cover the cost of professional learning through to the fifth-grade professional development. The team also partnered with colleges and universities both in the city and around their state for support on parts of the curriculum including assessments and computer science.

The work in Silverbay most closely reflected the work in the ideal-type in the ways that it was building its educational infrastructure and supporting the use of that infrastructure in practice. In contrast to the ideal-type, Silverbay had few strategies for developing and distributing leadership, monitoring and managing performance, or establishing long-term funding for elementary science in the district. Like each of the three focal districts in this paper, Silverbay system building was a work in progress. Yet, it was a project run by four people to build curriculum from scratch and support its use by thousands of teachers. In the vision described by the team members for what they hoped to develop in the future, there was a clear vision for more expansive system-building even if their work during our data collection had not yet reached those goals or had been stymied in some of its efforts (like science walk throughs with principals) by the circumstances of the COVID pandemic.

Skirting as Mitigating Challenges of System Building

Where the broader schooling enterprise in Silverbay was sprawling, variably coordinated, and had restricted options for professional development, the Silverbay STEAM pilot was able to skirt existing norms, structures, and routines, and work creatively on building educational infrastructure, supporting use of infrastructure in practice, and managing relationships with the environment to support elementary science. A particular strength of this approach was in mitigating a challenge related to the particular demands of system building to support elementary science. As suggested by the literature, efforts to support new, NGSS aligned teaching in elementary school will require substantial investment in training teachers. This perspective was shared by science leaders in Silverbay and across our sample who were aware that many elementary teachers in their districts didn't have strong content awareness in science, were uncomfortable with science, or had spent their careers working under different standards. Yet, existing district structures for PD often created substantial limitations to the ways districts could schedule supports for teachers.

In unionized districts, the negotiated contracts between teachers' unions and the school board can substantially shape how much PD is required and scheduled within the district. Though I wasn't able to identify the specific guidelines around PD in Silverbay from district documents or our interviews, leaders in other districts in our sample detailed the limitations they faced around PD. For example, in a suburban district in the same state as Silverbay, the Math & Science Coordinator told us that, under the terms of the negotiated contract in that district, teachers were required to attend 12 hours of Staff Development annually of which only three were required to be coordinated by the district. As a result, leaders in the district could provide PD opportunities but they could not require attendance and competed with all other district

priorities for inclusion both in the required PD hours and during other PD time made available to teachers. State departments of education and state legislatures also created limitations on how districts could design PD; in three of our southern districts, more than half of the required PD content was pre-defined by the state legislature.

By working as a pilot in schools where teachers had opted in, the pilot in Silverbay could skirt these kinds of limitations by making agreements with teachers directly about the extra professional development the work on science would require. Drawing on the support of their grant funders, these professional development sessions were well attended. Though these site agreements helped engage teachers in extra professional development time, they didn't fully insulate the program from the effects of the pandemic, but professional development continued to be offered online even while schools had pivoted to remote learning. At the start of the 2021 school year, professional development remained an online program. That fall, the director told us that over 120 teachers had attended three days of professional development for the STEAM curriculum.

While the STEAM team was able to pivot their PD offerings to online sessions, COVID had a more deleterious effect on their ability to observe classrooms. Owing in part to first remote learning and then concerns around minimizing the spread of COVID on the one hand and the need for their small team to quickly repackage learning materials for a largely remote school year, the STEAM team stopped visiting classrooms in person. The district does house exemplar materials on the curriculum website but there are still questions around monitoring how the resources are being used. One curriculum writer told us:

“It's also hard for us, honestly, to know the scope in which our teachers, because we have so many, and we can't get into everyone's classroom. We haven't, even before all of this, we haven't been able to get into everybody's classrooms, so to know the level at

which they are taking our curriculum and facilitating it with fidelity is still unknown as a whole.”

Though the district had partnered with a university to develop assessments, those were not launched at the time of our data collection. Furthermore, it was the district’s policy is to allow school sites to develop their own assessment routines leaving open the question of how schools would be expected to use the STEAM assessments, if at all.

In Silverbay, skirting district routines meant that the science team would work with teachers on elementary science in ways that were substantially different than they would have experienced in previous years in the district. The lack of concerted district wide attention on supporting science in the past combined with the fact that the entire STEAM curriculum development team were new hires meant that there was likely little relational trust between teachers and the science team. On the other hand, this may have meant there was also less established *distrust*. And by starting and growing the pilot program with schools that opted-in with teacher support and by establishing the clear intention that the curriculum would be revised based on teacher feedback, the program may have planted the seeds for a more trusting relationship that what otherwise existed between the central office and teachers.

Silverbay’s work on elementary science was set apart from normal operations in the district, giving the STEAM team substantial autonomy over what elementary science could look like in their elementary schools. While the team was formally a part of the central office, the pilot program allowed them to collaborate with schools in ways that were different from business-as-usual conditions in the district, including working around union contracts (with teacher buy-in) and, for a time, working in more direct communication with area superintendents. As in Bartlett, the program also had a degree of financial autonomy with the Silverbay STEAM pilot securing substantial external grants and philanthropy to support its work.

Discussion

Despite the challenges districts may face while system building for elementary science, Jasper, Bartlett, and Silverbay provide evidence of ways that districts might navigate those difficulties. By integrating with, retooling, and skirting existing norms, structures, and routines, those districts were able to play to their strengths and manage for potential conflict in their work. These approaches offer a starting point for understanding how districts attend to the intersections between their system building efforts for elementary science and the existing norms, structures, and routines for managing and organizing instruction that districts have developed. While they didn't negate all challenges or yield fully developed educational systems, these approaches did appear to support progress toward those goals. To discuss the broader implications of these findings, I return to the framework for educational system building. Focusing on each of the five domains in turn, I describe how districts' use of integration, retooling, or skirting helped them advance their system building work while attending to existing norms, structures, and routines for managing and organizing instruction.

Building Educational Infrastructure

In all three districts, the approaches used to manage existing norms, structures, and routines had implications for the educational infrastructure that they built. Jasper adopted—with modifications—a new, commercial science curriculum by integrating their work on science within their established approaches to manage and organize instruction through continuous improvement. Their approach further demonstrates the possibility that leaders, working under a generalist mantle, can successfully bridge between subject-specific environmental influences (Burch & Spillane, 2003, 2005) and broader district goals for student learning. In Bartlett, leaders retooled the existing infrastructure in ways that took advantage of the existing norms,

structures, and routines developed around the BSLC. In doing so, they created alignment between those norms, structures, and routines; their vision for elementary science; and the NGSS. In Silverbay, skirting existing norms, structures, and routines around adopting and disseminating curriculum allowed the STEAM team to create and grow a bespoke curriculum.

Integration, retooling, and skirting also had notable impact on the social resources for instruction that are part of a district's educational infrastructure. By attending to existing norms, structures, and routines in their system building, districts appeared to be accounting for a number of social challenges including the turmoil recoupling can generate (Hallett, 2010). The findings in this study are illustrative of the ways districts may be sensitive to these issues and are working to minimize violating teachers trust and maximize teacher support for their reforms (Bryk & Schneider, 2002; Louis, 2007; Spillane & Thompson, 1997). In Bartlett and Jasper, the use of familiar approaches for science or curricular change seemed calibrated to minimize disruption while pursuing the changes needed to achieve new visions for science. Both districts work built on decades-old initiatives which raises the question of how replicable those approaches might be in other districts.

Rather than leverage existing norms, structures, and routines, Silverbay's approach worked outside these established patterns to develop social resources for instruction by cultivating interest, excitement, and buy-in. This approach was similar to one past improvement programs have used to minimize teachers' experience of a program as one imposed by the administration and investing the district's limited resources for the projects in schools where teachers would resist or refuse to use the materials (e.g., Peurach, 2011). This approach to skirt exiting routines also echoed research-based recommendations that collective decision-making processes may support higher levels of trust (Louis, 2007).

Supporting the Use Infrastructure in Practice

Many of the existing norms, structures, and routines that districts attended to in their system building work were those related to supporting the use of their infrastructure in practice. In particular, integration, retooling, and skirting each had implications for districts' plans for professional development for elementary science. In Bartlett, retooling the existing routines meant that the BSLC team could draw on their relationships with both their external partners and district teachers to support the professional learning necessary to achieve their ambitions for science. Externally, the original founder of the BSLC—now a college professor—continued to support professional learning opportunities by partnering with Travis and Yvette so that teachers could earn college-credits from some of their PDs (in turn contributing to higher pay). Internally, existing relationships between the BSLC and teachers may have fostered a willingness among teachers to participate in professional learning opportunities. Meanwhile, Jasper's approach of integrating science improvement into existing improvement routines meant that it was incorporated into professional coaching routines and (albeit limited) professional development time.

Given what we know about the average elementary school teacher's readiness to teach science and the limited time teachers say is devoted to that preparation in professional development (Banilower et al., 2018), the amount of professional development teachers likely need to achieve new ambitions in elementary science exceeds the zero to six hours the majority of teachers report receiving. Our study did not ask districts about the number of hours allocated for science PD, but these findings would suggest that, even against the backdrop of a global pandemic, these districts were able to provide enough professional development to exceed the experiences of more than 40 percent of teachers in Banilower and colleagues 2018 study.

Monitoring and Managing Performance

Across our larger sample, it was often the case that districts were the least developed in their efforts around monitoring and managing performance compared to other areas of system building. Two extrinsic factors may have contributed to this. First, our data collection occurred during the COVID-19 pandemic. As a result, schools may have limited classroom visits, districts may have paused formative assessment routines, and state governments may have waived teacher evaluation requirements. Second, it was unclear how well aligned available assessment tools were to the NGSS, even nine years after their release. A Carnegie Corporation report found that “in many states, perhaps most, assessments are still catching up” in terms of their alignment with the NGSS standards (Smith & Plumley, 2022, p.36). Though monitoring and managing is not solely a matter of testing and data collection, science educators still highlight that developing three-dimensional assessment “remains a thorny challenge for those trying to gauge students’ progress” (Severance et al., 2024).

This weaker development of strategies for monitoring and managing performance held true in Jasper, Bartlett, and Silverbay. Of these three districts, Jasper had the most developed capacity for monitoring and managing performance—an organizational capacity developed through their decades of development as a district focused on continuous improvement. As a result, the district had norms about looking at and talking about student data, using common materials to make cross-classroom comparisons, and routines for instructional coaching. There were also existing routines for reviewing and updating curricular materials, and the leadership team was beginning to focus on assessments as our data-collection turned to the school-level. Integrating science improvement efforts with these existing norms, structures, and routines made

Jasper one of the few districts in our larger sample that had developed and was using clear strategies for managing and monitoring performance.

Developing and Distributing Leadership

None of these strategies created substantial changes to existing routines for developing and distributing leadership around elementary science. Bartlett used existing teacher teams and networks to support the work without substantial changes to their function or purpose beyond the changes to the materials being used in the district. Similarly, Jasper's strategy of integration made use of the conventional patterns of curriculum review and adoption in the district. In Silverbay, the pilot program had planned to directly engage building principals and include them in their professional development sessions. However, these plans were largely thwarted during the pandemic as classroom observations became impossible and as the district worked to manage the needs of its student body. Had circumstances been different, however, the explicit inclusion of PD time for principals as part of the pilot program agreement may have supported more progress on developing school leaders as science leaders—an activity made possible by the choice to skirt existing organizational routines by launching the STEAM program as a pilot. Because school-level leaders may bridge and buffer district initiatives to create school level coherence (Honig & Hatch, 2004) and are key actors in school reform and improving learning outcomes (Leithwood et al., 2004), investing in professional development for principals is a worthwhile approach to distributing science leadership.

Managing Environments

The analysis in this paper largely focused on the internal parts of system building and their interaction with the norms, structures, and routines already used by districts to manage and

organize instruction. However, educational system building also entails managing relationships between districts and their environments including by crafting coherence from their environment by selectively buffering and bridging external influences (Honig & Hatch, 2004). In Silverbay and Bartlett, the approaches used to negotiate the relationship between system building for elementary science and existing norms, structures, and routines were also attentive to the district's environment.

Silverbay's decision to develop the new STEAM curriculum as a pilot allowed them to skirt existing norms, structures, and routines in part because making agreements directly with participating schools saved them from needing to negotiate their project with the teachers' union. It also gave them the flexibility to a) pursue research grants for experimental curriculum work in partnership with universities, b) leverage philanthropic grants to support wall-to-wall professional development in pilot schools over 6 years, and c) ensure a continuity of learning experience across classrooms for students and their families at the school level. In Bartlett, retooling existing routines around curriculum and the role of the BSLC allowed existing relationships with community partners to be incorporated into the new science curriculum in ways that might have been impossible in the context of commercially created curriculum. Furthermore, retooling the existing structures in the district was responsive to a community desire not only to keep the BSLC but to protect it.

Conclusion

In this paper I explored the strategies districts use in their system building to support the implementation of the new NGSS standards and to advance new, ambitious visions for elementary science teaching and learning. The NGSS call for substantial changes to science education generally and represent a particularly large challenge for many elementary schools

where many teachers are underprepared in the methods and content of science education and few principals are prepared to support their teachers in that work. If such a change is to occur, it is likely, then, that districts will need to work more intentionally across school and district levels to develop systems to support elementary science teaching and learning. But that work, too, is challenging and runs counter to many existing routines including those that emerge from and reinforce traditions of loose coupling that isolate the work of instruction from other parts of the organization.

The findings presented in this paper show that, despite these challenges, districts are able to work resourcefully to navigate and avoid potential frictions between new ambitions and old routines. By skirting, retooling, or integrating with existing routines, district science teams were able to work around challenges that were substantial barriers in other districts including limitations in funding and professional development time. Despite using these strategies to mitigate friction, none of these districts closely mirrored the ideal-type across all domains of work. Instead, each district prioritized or focused their work on a few of these domains during the course of our data collection.

While these approaches appeared to help science teams in managing and mediating possible friction between their system building for elementary science and existing routines, structures, and norms, another issue stands out as being an important consideration: time. Time is a complicated thing. Others members of my research team have previously explored how dilemmas related to time were experienced by the districts in this sample, in addition to how those districts understand time (see: Davis et al., 2024). Time is as a salient variable for considering how these districts approached system building (on the one hand) and managed for potential friction between that system building and exiting routines (on the other).

In Bartlett and Jasper, integration and retooling allowed the science teams to make use of time spent in the past on developing structures, norms, and routines. Doing so saved them from spending significant time in managing frictions resulting from their work on elementary science in the present. These districts suggest the value of long-term commitments to reforms.

Additionally, where Bartlett retooled its system for elementary science in the present, the very nature of the BSLC as a stand-alone, museum-like learning center established in the 1980s may itself have been an act of skirting by pulling elementary science apart from past routines and structures for elementary science. In skirting existing strategies for curriculum and instructional improvement in Silverbay, the STEAM team may have sacrificed its ability to leverage past efforts in exchange for greater autonomy and freedom in building a system for elementary science from scratch.

That elementary science standards have changed is demonstrably true. Whether a reciprocal change has occurred in elementary classrooms remains to be seen and whether such changes persist where they have occurred will require continued and concerted attention and effort to manage, organize, and support elementary science in ways most districts have not previously attempted.

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Conclusion

Together, the three papers in this dissertation provide rich insights into both district approaches to system building and the contexts in which districts engage in that work. The first paper develops an organizational taxonomy that helps map the environment for elementary science and that illustrates the relative salience of different categories of organization for districts. Drawing on this taxonomy to understand districts' efforts to improve elementary science, the second paper provides insight into the remarkably expansive array of organizations with which contemporary districts engage. A key contribution of this paper was the recognition that, regardless of the approach district science leaders took to their system building, leaders interacted with a wide variety of organizations in their environment that were themselves variably aligned to either the vision for elementary science of either the district or the NGSS. Finally, a key takeaway of the third paper was a recognition that districts work in different ways to navigate potential frictions between new ambitions and existing structures, norms, and routines. The paper highlights three such approaches—skirting, retooling, and integrating—as ways district science leaders build systems for elementary science that leverage district strengths and manage conflicts

For policy makers, these findings are a reminder that work on elementary science plays out in complex environments that district science leaders draw into their work and rely on for support but that also require coordination. Efforts to strengthen or expand existing programs like STEM Ecosystems might consider the ways those networks could alleviate some of those

burdens. Reforms that focus on creating alignment outside of schools might, in turn, allow district leaders to focus more attention on instruction. For practitioners interested or engaged in system building for elementary science, these papers may engender reflection about their approach to system building including the strategies that might best help them navigate potential conflicts with existing structures, norms, and routines, and the balance between resource- and practice-forward approaches in their system building efforts and plans.

Findings from these papers also point toward new directions for future research. In relation to system building, these papers suggest additional research is warranted on whether a threshold exists that more clearly delineates the work of system building from other improvement efforts. As system building is, for every district we studied, a complicated and ongoing project, this also raises the question of how systems, once built, are maintained and how the systems we observed fare over time.

In consideration of the environments in which elementary science reforms are enacted, future scholarship might consider how the environments of districts engaged in elementary science improvement efforts vary from the environments of other districts. As districts build and strengthen educational systems for elementary science, future research might also explore how this work weathers changes in the environment (e.g., future reforms to state standards) and whether substantial changes to organizations in the environment that are more distal for districts (e.g., the federal Department of Education) impact their work on elementary science.

Future scholarship of this sort would extend the contributions of this dissertation by providing even richer perspective on the complex relationships among environments, organizations, and leadership in efforts to advance new ambitions for elementary science instruction.