Teacher Learning in Educational Systems:

Multiplicity, Entanglement, and Ontological Politics

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Introduction

Central office leaders, school administrators, and teachers face a significant challenge in their efforts to reform elementary science education in accordance with the *Framework for K-12 Science Education* (NRC, 2012) and the accompanying Next Generation Science Standards (NGSS; NGSS Lead States, 2013). Developed in 2013, the NGSS exemplifies a standards-based approach to science instruction reform (Haverly et al., 2022), that intends to shift science teaching and learning in the classrooms from *learning about* science to *figuring out* explanations for scientific phenomena through a deeper level of engagement in science practices across scientific disciplines (Schwarz et al., 2017). As many elementary teachers of science have limited preparation in both science content and pedagogy (NASEM, 2015), the majority are likely to need significant support to shift their instruction.

Scholars have shown how organizational context matters for NGSS-aligned implementation efforts (Allen & Heredia, 2021; Heredia, 2020) and include reforming organizational structures as part of infrastructuring work (Penuel, 2019). However, there has been less attention to how teacher learning is practiced in developing educational systems. As such, the context of this paper is the system-building efforts of districts and schools in response to instructional reform efforts, like the NGSS, A system-building framework positions teacher learning as a central domain of work for system actors engaged in improving instruction (Peurach et al., 2019). In particular, this domain of work intends to align teachers' instruction more closely with the educational infrastructure districts and schools provide.

While a system-building perspective situates teacher learning within the organizational demands of instructional reform in school districts, it is limited in its ability to engage with the messy and emergent practices of teacher learning. Within domains, this framework is descriptive

rather than prescriptive—it is an open question how system actors enact teacher learning in the work of system building. A system-building perspective privileges district and school leaders' ostensive design for teacher learning, but does not provide theoretical tools to examine how these designs relate to what the actors within school systems actually do. As such, we need new ways to conceptualize teacher learning as a domain of system-building that can illuminate the intersections between ostensive system-building efforts and the informal, boutique, and legacy practices for teacher learning that play out routinely within districts and schools.

As such, the purpose of this paper is to get inside teacher learning as a domain of system building and understand how system-building efforts in elementary science press on the practices of teacher learning being enacted by across three school districts. This entails both identifying the practices of teacher learning that are routinely taking place, and interrogating the ways in which district and school leaders manage these different practices as part of their system-building efforts in response to instructional reform.

The approach I take to getting inside this domain of system building is to problematize what teacher learning is, how it is enacted, and by what or whom, by engaging a multiple ontology perspective (Mol, 2002). When we understand teacher learning as something enacted within multiple practices we can see the limits of and contradictions within the ostensive designs for teacher learning. This piece unpacks how these tensions and contradictions arise for district and school leaders as they engage in system-building efforts in elementary science and the work they do to manage these. As such, this work contributes to the system-building literature by getting inside a domain of work to shed light on the approaches system actors take to teacher learning practices that sit outside their ostensive designs. But, further, taking this approach allows me to examine the implications of different approaches to system-building within this

domain in terms of (re)distributing agency and power in terms of the *ontological politics* system actors engage in.

Conceptual and Empirical Framing

This paper draws on organizational and sociomaterial perspectives to investigate how districts are developing as educational systems that support teacher learning in elementary science. First, I explore teacher learning as a domain of work within educational system-building (Peurach et al., 2019). Second, I use Mol's (1999, 2002) concept of multiplicity to explore how multiple versions of teacher learning are practiced and entangled in classrooms, schools, and districts. By analyzing system-building from a multiplicity lens, I argue that we can (re)imagine system-building as a gathering together of multiple practices that may (or may not) operate synergistically.

System-Building for Teacher Learning

System-building involves district central offices and school leaders collaborating with teachers and other actors to organize, support, and manage the core work of schooling—instruction (Peurach et al., 2019; Spillane et al., 2019). Educational system-building involves the arrangement and distribution of instructional improvement work across levels of the system (Lyle et al., 2023; Peurach, Cohen, & Spillane, 2019; Peurach & Yurkofsky, 2018; Spillane et al., 2022), such that aspects of each of the core domains of system-building work are being performed in multiple spaces and by multiple actors across the system.

Historically, districts and schools in the U.S. have focused on *building educational infrastructure*—including, most prominently, curriculum materials and assessments—to coordinate and manage instruction (Peurach, Lyle et al., 2022). However, the dissociation between this burgeoning infrastructure and the day-to-day reality of teaching and learning are

well documented (Meyer et al., 1981; Meyer, 2002; Orton & Weick, 1990), as districts and schools have had strong incentives to build structures that legitimize their work, but weak incentives to build structures that impact practice. Organizational theorists have referred to *coupling* between formal infrastructure and practice (Bidwell, 1965; Meyer & Rowan, 1978; Weick, 1976), with recent scholarship conceptualizing coupling as a dynamic practice of establishing and managing relationships between the two (Hallett, 2010; Hallett & Ventresca, 2006; Sauder & Espeland, 2009; Peurach et al., 2020). Viewed this way, coupling is an essential aspect of system-building (Peurach et al., 2020).

As districts and schools engage in system-building, they go beyond infrastructure building, such as designing curriculum planning documents for teachers to use, and also work to *support the use of infrastructure in practice* (Peurach et al., 2019). This involves implementing formal and informal teacher learning so that teachers can leverage the infrastructure provided to develop their practice. While this is one domain of system-building writ large, system-building for teacher learning can itself be refracted through the lens of system-building more broadly, as it involves engaging in various categories of system-building work. This includes *developing and distributing instructional leadership* to support teacher learning by providing formal positions of leadership to support teachers with learning and supporting teachers to become formal and informal leaders; building infrastructure that institutionalizes teacher learning by designing timetables, materials, structures, and routines for teachers' learning; *managing performance* by developing evaluation structures around teacher learning for both continuous improvement and accountability; and *managing the external environment*, including the policy context surrounding teacher learning, the local context surrounding pre-service teacher education and teacher turnover (Peurach et al., 2020). Conceptualized this way, a concern for scholars in this tradition

is understanding the nature of coupling between the structures the district is designing for teacher learning and the actual practice of teacher learning taking place within schools and classrooms.

While a systems perspective highlights the social and material infrastructure required for instructional reform, it is limited in its ability to engage with the messy, interconnected, and emergent practice of teacher learning as enacted in multiple spaces and multiple ways across classrooms, schools, and districts. In analysis a systems approach privileges ostensive designs and attempts to support the use of educational infrastructure, such as formal workshops and structures such as professional learning communities, and often positions boutique and legacy approaches to teacher learning as things to subsume, suppress, or circumvent (Forman et al., 2021). In the next section, I introduce a multiplicity perspective, and argue that this both provides a way of looking inside a domain of system-building and (re)conceptualizes system-building as a gathering together.

Teacher Learning and Multiplicity

To complement the systems framework and theorize organizational structures in use, I leverage a sociomaterial perspective to problematize what teacher learning is, how it is enacted, and by what or whom. I use Mol's (1999, 2002) work on the multiple ontologies of disease to conceptualize how human and non-human actors practice teacher learning; how they perform it into being. Following Mol (2002), I argue that teacher learning emerges in multiplicity, that different sets of practices in context give rise to different reified enactments of teacher learning, and that these enactments of teacher learning are different interconnected realities that all sit within the *support the use of infrastructure in practice* domain of system-building.

From a multiplicity lens, human and non-human actors collectively enact (multiple) realities in practice (Fenwick, et al., 2011; Latour, 2005; Law, 2004; Mol, 2002). In her

ethnography of atherosclerosis in a Dutch hospital, Mol (2002) argues that diseases, such as atherosclerosis, are performed into existence through (medical) practices, such as diagnosis at the GP, treatment in surgery, analysis in pathology, and therapy in the outpatient clinic. These distinctive reified enactments emerge from the intersecting practices and tools used to study and treat atherosclerosis. In the vascular surgery clinic, atherosclerosis requires a patient with pain in their leg when walking; but in pathology it requires a microscope slide showing a cross section of a leg artery. Mol's pathology informant explained (2002, p. 30):

> That's the lumen. There's blood cells inside it, you see. That only happens when a lumen is small. Otherwise it's washed out during the preparation. And here, around the lumen, this first layer of cells, that's the intima. It's thick. Oh, wow, isn't it thick! It goes all the way from here, to there. Look. Now there's your atherosclerosis. That's it. A thickening of the intima. That's what it really is… under a microscope.

So, the atherosclerosis practiced in pathology is not identical to the atherosclerosis practiced in vascular surgery. The tools used to construct the disease exclude each other: atherosclerosis in vascular surgery requires a living patient, but in pathology the amputated legs or dead bodies being analyzed cannot express themselves as having leg pain when walking—the clinical enactment of atherosclerosis is not possible—instead atherosclerosis is practiced under a microscope. These two atherosclerosis being enacted are two different realities enacted by different collections of human and non-human actors. Drawing on Mol's work, Fenwick and Edwards (2010) explain that "Two teachers enacting very different practices in the name of a shared science curriculum are not exhibiting different worldviews, but, in fact, inhabiting [or performing] different worlds" (p. 158). Here the science curriculum is an actor in two different practices, but as the two teachers engage differently with the materials they perform two realities.

Teacher learning performed in various organizational structures and routines can bring multiple versions (or *realities*) into being that co-exist within the system. For example, a teacher reading group based on developing teachers' knowledge of the Science and Engineering Practices (SEPs) and a lesson observation form that includes the SEPs as standards for teacher evaluation enact two realities of teacher learning. Each routinized and embodied practice has distinctive criteria for what counts as learning: teachers having deeper knowledge of the SEPs versus teachers using the SEPs more effectively in their instruction. Since these realities emerge in interdependent practices (the SEPs are an actor in both), realities are *entangled*: enacting one reality has implications for many other realities (Mol, 1999).

Despite ontological multiplicity, the world we live in hangs together: we rarely feel the disjunctures between incommensurable realities (Mol, 2002; Law, 2004). Mol (2002) illuminates how medical practices enacting different atheroscleroses bridge between the multiple worlds, or buffer them from each other. The atheroscleroses of vascular surgery and pathology are held apart in different wings of the hospital that rarely need to interact, as one department deals with the living and the other with the dead or dismembered. Distributing multiple enactments across space and time works to buffer diverging realities from one another: formal teacher learning is enacted at pre-identified times in designated spaces, and informal teacher learning happens at other times, in other places. But these versions are still entangled: formal PD designed by system actors to support teachers' use of infrastructure in practice, for example, relies on teachers to engage in on-the-job sensemaking about how to enact their new learning in their teaching. Different realities can also be forcibly brought together. Different techniques for studying atherosclerosis can be made comparable: angiography measures the loss in width of the lumen, and duplex measures the change velocity of the blood. While these techniques measure (and

enact atherosclerosis as) different things, a change in blood velocity above a threshold can be translated into a percentage of lumen loss that requires surgical intervention (Mol, 2002). Similarly, when filling out an end of year teacher evaluation form for state certification, the teacher might translate a range of learning experiences into 'hours per topic.'

Mol (1999) uses the term *ontological politics* to explore questions about how enacted realities relate and their connections made visible, and what to do to bring about the good. Truth, identity, agency, and power are not prerequisites for activity from this theoretical perspective, but effects (Barad, 2007; Fenwick & Edwards, 2010; Law, 2004). What teacher learning is, what teachers should learn, how learning should happen, and who/what decides emerge within the practices of teacher learning actors engage in. As these practices are routinized truths, identities, and power relations become reified (Law, 1992). Since truth is no longer fixed or singular from a multiplicity perspective, but enacted in constellations of practices, there are a range of (political) reasons why one reality might be enacted, and made more real, rather than another (Law, 2004). When teacher learning is enacted as about improving student outcomes, for example, it creates and upholds what matters for teacher learning, along with the tools for assessing student outcomes and translating those outcomes into teacher learning outcomes.

Actors engage in ontological politics through enacting some realities of teacher learning and embedding those within wider networks operating within schools and educational systems. Further, instructional reform efforts can shape some enactments of teacher learning and exclude others. In Riveros and Viczko's (2015) study of teacher professional learning in a single school, they use ontological politics to show how some teacher learning was enacted in prescribed spaces at defined times, and other learning was performed alone in classrooms. They argue that, in contrast with teachers' individual learning, teacher learning in organized sessions and

workshops emerges in entanglement with policy goals and is institutionalized and legitimized through structures of evaluation that are interdependent with this formal infrastructure for teacher learning. As such, system-building efforts provide a rich context in which to explore multiplicity, as system-building aims to reduce variation in how practices, particularly instruction, are performed. System-building is world-building.

Research Questions

As the institutional environment of reform-oriented science standards, such as the Next Generation Science Standards, presses on districts and schools, teacher learning around reform-oriented elementary science teaching is a central domain of system-building work for system-level actors. In this paper I aim to understand the practices of teacher learning system actors enact, and the work they engage in to coordinate, and distribute multiple teacher learnings in the work of educational system-building. To this end I ask the following research question: How does the work of system-building in elementary science (re)shape the entangled enactments of teacher learning within educational systems? By understanding these entanglements, scholars of system-building could better attend to how system-building work can overlap productively with 'legacy' practices within educational systems, gathering enactments together to create better worlds: better educational systems.

Research Approach

This study is part of a five-year National Science Foundation project exploring the work of instructionally focused system-building in elementary science, in the context of a shifting policy environment as districts enact instructional reforms entangled with the NGSS. While the broader project focuses on the domains of system-building, this study brings a new analytic lens to the data within one of the domains of system building: *supporting use of infrastructure*. I

begin giving an outline of the wider study, before detailing my research approach for this embedded study in more detail.

Situating this study in the context of a wider project

This smaller project is situated within a broader collaborative study that uses a comparative case study design to explore teacher learning in 13 school districts engaged in system-building for instructional improvement in elementary science in the U.S. (Yin, 2014). I briefly describe the broader research project in this section, before going into more detail about the district and data selection and analysis for this paper in the following section.

To select the original sample of 13 districts, we[1] used snowball sampling to identify six states that had either adopted the NGSS, or developed standards based on the *Framework*/NGSS, and had (a) a policy context favorable to system-building efforts at the district level around elementary science, and (b) political and demographic variation (Haverly et al., 2022). We selected up to four districts per state by asking science education experts and state contacts to nominate districts doing system-building work in elementary science. We selected for variation in size, urbanicity, and demographics of the districts, as well as diversity in approaches to system-building in elementary science education, from these nominations, drawing on information on the districts' websites and preliminary conversations with district science leaders. At the end of the second year of data collection, we worked as a team to identify a subset of nine districts in which we would continue data collection for a third year, based on the system-building activity identified thus far.

Across the subset of three school districts presented here (selection of this subset discussed below), we conducted 49 60-minute semi-structured interviews via Zoom with 51

[1] Throughout the research approach section, I switch between 'I' and 'we' to reflect as accurately as possible the work that was done by the broader research team in collaboration, and work that I carried out individually for writing this particular paper.

people who work in the district, including science coordinators, superintendents, school principals, and classroom teachers nominated as informal science leaders by their principals. At the district-level, the interview protocol was designed to learn about actors' practices in reforming elementary science instruction. We asked questions on (1) their roles, responsibilities, and backgrounds; (2) state, district, and community context; (3) current priorities and visions for elementary science instruction; (4) infrastructure in place supporting elementary science instruction; (5) plans for continuing elementary science reform; and (6) challenges they were experiencing in this work. For non-science district leaders, such as ELA/math coordinators, Title 1 coordinators, and data managers, the interviews focused more on how their role interfaced with science system-building efforts, to contextualize our findings from the science system leader interviews. We asked school-level actors, principals and formal and informal science leaders, questions in the same broad areas as district-level actors, but focused explicitly on school context, infrastructure in use, and school-level routines for teacher learning and managing performance, as well as how the district supports science instruction within the school.

Alongside interviewing system actors in each district, we also observed eight district-level science practices, such as formal professional development, curriculum adoption meetings, and strategic planning sessions. Similarly, we observed school-level science practices, such as formal professional development and team planning. We used a low-inference protocol to capture fieldnotes throughout, capturing dialogue as closely as possible (Emerson et al., 2011). The number of interviews and observations for each district and school are shown in Tables 1 and 2 respectively. We also collected documents describing district and school achievements, goals and strategic plans, agendas and minutes for organizational routines, planning documents and resources for formal professional learning, and teacher evaluation rubrics.

Table 1
Features of the Districts and the Number of District-Level System Actors Interviewed and Routines Observed

	State	Size[2] and urbanicity	District-level actors interviewed	Observations of district-level science routines
Bartlett	MA	Small, suburban	10	1
Brookeport	MA	Large, urban	15	2
Jasper	OK	Mid-sized, suburban	13	5

Table 2
Features of the Schools and the Number of School-Level System Actors Interviewed and Routines Observed

	School	School-level actors interviewed	Observations of school-level science routines
Bartlett	Crossroads	1	1
	New Rockford	3	1
Brookeport	Clairton Elementary School	3	2
Jasper	Riverview Elementary School	3	2
	Valleyview Elementary School	3	1

We coded the interviews deductively into broad analytic categories (Miles et al., 2018) using NVivo (QSR International Pty Ltd, 2018) based on the domains of system-building described above, and also how system actors understood *dilemmas*, *coupling* between infrastructure and practice, *equity*, and *quality* in system-building for elementary science. We met

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

regularly as a coding team to ensure we were coding data reliably,[3] discussing challenging cases and building out a codebook. We used these to build out analytic memos for each district that also drew on observation and document data (Saldaña, 2016).

Design for this embedded study

This smaller project began as a space to "think with theory" (Jackson & Mazzei, 2022; Strom & Kayumova, in press) using some of the theoretical ideas that were influencing me as I engaged in my day-to-day work on the broader project. The research questions guiding this inquiry emerged from the thinking I was doing with Mol's (1999, 2002) work, as I was coding interviews, writing memos, and writing about leaders' challenges within system-building work. As such, this investigation brings a new theoretical orientation into a fully developed project to explore the tensions and opportunities of thinking system-building in multiplicity. So, while the project sits within the broad architecture of assumptions from the system-building project, such as that there is such a thing as a system, this work examines what is illuminated by reading this work through a multiplicity perspective (Barad, 2007).

I begin by describing how I selected the subset of districts for this project from the wider data-set. I then detail the data I drew on from those cases and explore the limitations of the data, and what might be left out. Finally, I detail the analytic (mis)steps I took along the way. While I have separated these into distinct categories for readability, district selection, data selection, and data analysis occurred in tandem, with decisions I made in one area, impacting decisions in others.

Selecting districts

I began district selection from the nine districts with full data sets (see above) and to identify three districts that approached work in the *supporting use of infrastructure* domain of

[3] IRR above 80% using NVivo software.

system-building differently. Of the three districts presented in this paper, two have clear designs for teacher learning. In Bartlett, the science center actors designed and managed all teacher learning practices related to elementary science. In contrast, in Jasper, responsibility for enacting different teacher learning practices was distributed over a range of actors, including the director of teaching and learning, instructional coaches in schools, and grade level teams. The third district, Brookeport, lacked a clear overall design for teacher learning as organizational fragmentation at the district level made it challenging for system actors to coordinate their activities with one another. These three districts allowed me to tell different stories about the work of system-building in this domain; they are not intended to represent an exhaustive set of approaches to this work, but their differences allow me to make some inferences about how this work presses on the practices of teacher learning.

Selecting data

I began by pulling all the interview data coded into the *supporting use of educational infrastructure* domain from our domains of work for system-building, as well as from two of the analytic codes: *dilemmas*, and *coupling*, as it was possible that references to teacher learning may have been coded here. A limitation of beginning with data coded into *supporting use* was that I may have missed references to teacher learning that were embedded in a chunk of text that was predominantly attending to another domain of the system-building framework. For example, minor references to teacher learning within a response about managing teachers' performance. Furthermore, the interview protocol itself likely limited participants' accounts of teacher learning enactments. While, as a team we had shifted the language away from asking participants about 'PD' or 'professional learning' to more open questions like 'how do you learn about…,' the context was around the district and school designs for supporting science instruction. As such,

while participants' responses were not limited to the ostensive designs for teacher learning in system-building, they did privilege that work.

For document data and observation data, I relied on participant's responses in interviews to understand how these documents and observations were part of how teacher learning was being constructed, conceptualized, and practiced at each site. Without these accounts from participants I did not feel I could assert that much of what was contained in the documents of observation fieldnotes was, in fact, an enactment of teacher learning, without participants explicitly performing these as teacher learning in their interviews. Instead, where I did not have performance accounts about the document and observation data, I used the observation fieldnotes as a way to enrich my understanding of the work of the districts more broadly, particularly as these were organized into the domains of system-building. This was not what I had initially hoped, as attention to documents and rich observational data is generally accepted to be important for the design of studies that take materiality seriously, as observing the movement of materials in practices is of central concern (Law, 2004; Fenwick & Edwards, 2010; see Fenwick (2014) for a study in this tradition for which observation data was not available, but where instead the interviews prompted participants to trace the movement of non-human actors across different practices as they used them and passed them along).

One important conceptual clarification is that while the participant interviews are "performance accounts" (Jackson & Mazzei, 2022), these performances are not the result singularly of participants' own agencies, but as effects of the practices they are enmeshed in. So the actors/participants are speaking from the world, *and* (re)creating it. Further, I have not used these varied performance accounts, documents, and observations to triangulate claims about teacher learning made by system actors, but instead to see how teacher learning is enacted in

multiplicity by these actors as they engage in varied constellations of practice. This reflects Law's (2004) call for social scientists to seek to explore the "vague and indefinite," rather than impose definition and stillness where none exists (p. 13).

Analyzing data

For my data analysis, I engaged in diffractive reading (Barad, 2007; Lenz Taguchi, 2012; Schrader & Juelskær, in press; Strom & Kayumova, in press), to read the data first through Mol's (1999, 2002) concepts of multiplicity and the mechanisms of constructing an appearance of singularity, and then secondly through the domains of system-building. Using this diffractive methodology I construct a "mapping of interference" (Haraway, 2004, p. 70) to produce "difference patterns" (p. 243) exploring how ideas move through these frameworks.

Using Mol's (1999, 2002) framework I began to develop analytic memos that spoke to my research questions. In particular, I wanted to capture how Mol's (2002) mechanisms for making multiple worlds hang together—layering, hierarchy, fragmentation, composition—were operating in the districts as documented in the performance accounts. In this analysis, I began to see some distinct enactments of teacher learning. I then engaged in a reorientation of my memos around these three enactments: *acquisition*, *social/collective*, and *developing personal experience*, adding *gaining accreditation* as a fourth enactment while reading Brookeport. Having these enactments, I memoed about how Mol's (2002) mechanisms were operating. I returned to my full data set and brought in direct quotes and copies of artifacts to refine and animate my memoing. I also repeatedly questioned and interrogated terms I was using in my sense-making, such as agency and power, to use these terms consistently with my theoretical framework. In this way, explicitly "plugging in" (Jackson & Mazzei, 2002) Mol's (2002) framework as I was reading and writing with the data was central to my analysis.

Secondly, I returned to the system-building domains to add another layer of memoing about each district to explore the effects of using the domains of system-building work to see teacher learning practices. I wrote about the activity happening in each domain of work within system-building, such as what infrastructure had been developed, and if/how was teacher learning being monitored for continuous improvement. This helped me to see the interferences between system-building for teacher learning, and (a) other practices creating teacher learnings, and (b) practices constraining teacher learning practices for the purpose of system-building. I pick up these threads in the findings and discussion.

Findings

From my analysis I present two main findings. First, I identify four enactments of teacher learning that can be distinguished analytically using Mol's (2002) framework. Each one emerged within specific practices, and these different realities of teacher learning created teachers differently (gave them different identities), involved different tools for working out if teacher learning was happening, and distributed agency differently. Second, having established these enactments, I present evidence that in each district system actors engaged in a range of approaches to navigate these different teacher learning realities, including layering, sequencing, distributing (buffering), and constructing composite realities. These different approaches had different connotations for system-building: some approaches embraced multiplicity and made it liveable, and other approaches eschewed multiplicity and attempted to construct a singular practice of teacher learning. As such, system actors engaged in ontological politics to enact some realities of system-building rather than others.

Enacting teacher learning for elementary science

Actors in educational systems construct and enact different teacher learnings as they engage in a range of practices for teacher learning. This gives rise to multiplicity of teacher learnings: ontologically distinct worlds of teacher learning that emerge within distinctive sets of sociomaterial practices. Drawing on my analysis, these enactments differed in five dimensions:

- the human and non-human actors involved,
- the times and places where actors engage with one another,
- the measurable outcome of teacher learning,
- how these practices construct teachers' identities,
- and how agency and power emerge within those relations.

In this section I provide an overview of four different enactments of teacher learning identified in this study. For each enactment I use an example set of practices from a single district that together enact a distinctive teacher learning reality, and unpack these practices using a Mol's (2002) framework.[4]

I construct these versions as 'ideal types' and interrogate how identity, agency, and power are constructed within each enactment. This means that, for the moment, I am silencing the interconnections between the different worlds of teacher learning. Furthermore, these enactments of teacher learning arise from the performance accounts of system leaders in science instruction, so the enactments I describe privilege the roles of these system actors and how they create them.

Teacher learning as acquisition of new knowledge

In Brookeport the science office offered 'professional development' (PD) workshops during the summer and after school for teachers in partnership with the commercial curriculum provider (FOSS), with elementary science specialists often leading the PD. The science

[4] I draw examples from Brookeport and Jasper exclusively in this section, rather than Bartlett, for reasons that will hopefully become clear in the second section of the findings

department leaders and FOSS trainer co-planned PD, or "unit trainings" (Brookeport science department director) for teachers within the district, and the FOSS trainer described participating teachers as the "audience" for PD sessions. The purpose of these workshops was transferring knowledge to teachers about the curriculum resources, including about how to use the online platform and integrate it with school intranet portals, how to access resources, and demonstrations of sample lessons from the materials (see Extract 1), and they were often differentiated based on teachers' prior knowledge.

Extract 1
Fieldnotes from Brookeport K-2 FOSS Webinar

This webinar highlighted resources available for teachers and students on FOSSweb, FOSS's online portal. First, [FOSS Rep 1] explained how to access and set up educator and student FOSSweb accounts by directing participants to video and text instructions for self-registered teachers, district-registered teachers, and families/students. [FOSS Rep 1] also introduced the FOSS Educator Success Team, which helps educators integrate FOSS activities into platforms like Canvas, Clever, Schoolology, and ClassLink. Next, [FOSS Rep 1] showed participants what the FOSSweb educator and student portals look like once logged in and pointed out a few key features for each. … The majority of the webinar focused on a tour of new FOSS resources including "Designing Your FOSS Instruction," the "Navigation Matrix," as well as resources and materials for synchronous and asynchronous instruction. … The "Navigation Matrix" is a live Google Sheet for each module that provides a "menu" of activities for teachers to engage their students in, organized by type of instruction (in-person, remote – synchronous and asynchronous) and part of the module. The "Navigation Matrix" also includes a "shopping list" of materials for each activity and optional consumable materials to be used in remote learning. [FOSS Rep 1] emphasized that the "Navigation Matrix" is not a "to-do list" but a "menu" that teachers can electively use to engage their students. … [Foss Rep 2] demonstrated a few sample lessons using some of the resources from the "Design Your FOSS Instruction" and "Navigation Matrix" for the 1st grade Air and Weather module, focusing on how to use strategies and resources to keep students engaged in a blended learning environment.

In this enactment of teacher learning, a set of actors, not directly including teachers, engage in practices of identifying knowledge teachers need and designing teacher learning opportunities. In the example above, it was through the human actors—science center leaders, the FOSS trainers, and science specialists—engaging with the non-human actors—Massachusetts Science and Technology/Engineering Standards (MSTE standards adapted from the NGSS) and

the curriculum materials—that teachers' 'knowledge gaps' were defined and enacted.

The teacher learning designed by these actors takes place at prespecified times and places, such as after school, during summer PD days, or off-timetable days. This introduces new actors into the practice, such as district schedules, principals, and district administrators that define when and where these practices can occur, and arrange for substitute teachers if required.

The intended outcome for practices that enact teacher learning as acquisition of new knowledge is for teachers to acquire the knowledge that was constructed by the actors involved in the design process as lacking. So teacher learning emerges from, and is defined within, this enactment as teachers 'successfully' acquiring this knowledge, which manifests in terms of coverage of required content (number of days offered or the comprehensiveness of "unit training") and teachers' attendance at 'sufficient' sessions to fill their identified knowledge gaps.

Within this version of teacher learning, teachers become 'limited' knowers, distinguished from the 'full' knowers among actors designing the PD. As seen in Brookeport, instructional standards and curriculum materials, as well as the FOSS trainer, science department staff, and science specialists, were enacted as locations of knowledge, and teachers were the "audience" for this knowledge. In the enactment of this teacher/teacher educator binary, agency over the content, the mechanisms of learning, and the intended outcomes is reserved for the teacher educators within the practice. As such, a power hierarchy emerges as these practices (p)reserve agency for the teacher educators engaged in the design process, in which identities are constructed, and teacher learning is defined.

Teacher learning as developing personal experience of science instruction

In Jasper, new curriculum materials had recently been adopted by the district. One of the instructional coaches at Valleyview explained that teachers were struggling to use the new kits as

they lacked experience with them: "[Teachers are saying] 'I'm just not able to get through this kit because it's new to me. I need to read more about it and know how to teach it to my students. I've gotta learn it for myself first.'" An instructional coach at Riverview emphasized the importance of time for this reality of teacher learning, expressing that "I think by the end of the year and starting next year, [the teachers will] feel more confident with it and have a better grasp of where they'll go with [the new curriculum] next year." In both Valleyview and Riverview, experienced teachers invited coaches to support them developing their teaching in areas the teachers identified as areas for improvement.

In practices that enact teacher learning as developing personal experience, the teacher is the central actor, although they engage with a range of human and non-human actors to make sense of their current teaching practice. For example, teachers might use student data and feedback, professional/local standards for practice, prior feedback from mentor teachers and administrators, comparison with their colleagues' accounts of practice, their instruction in other subjects or with different material conditions, their use of materials, instructional coaches, and their embodied reaction, to distinguish their instructional practice into areas in which they are more or less experienced. In the example from Valleyview, teachers engaged with the new materials and used them in their practice, but felt less confident than they had with the previous materials they had more experience using. They constructed teaching with these new materials as a struggle through their engagement with personal, school, and district standards for teaching.

This teacher learning reality emerges within teachers' day-to-day instruction and (any) moments for reflection: this enactment is not bounded within specific times and places, although time is constructed as a condition for learning, as described by the Riverview instructional coach.

Within this enactment, teacher learning is practiced as developing instructional expertise

over time through practicing, changing, and improving instruction in the areas in which teachers are less experienced. In this sense, teacher learning emerges from these practices as the cessation of the struggle defined by the teacher in relation with other human and non-human actors.

Teachers are constructed as the central actors in this teacher learning, connecting their individual instructional practice to wider norms and expectations for instruction distributed across actors. As such, agency flows through teachers, who define their struggles and central goals in partnership with this plethora of actors connected through the teacher. Teachers can (choose to) share this agency: instructional coaches can plug in to this enactment, redistributing agency and sharing power. They can support the teacher by making connections to, or strengthening connections between, actors to (re)construct both struggle and experience. So when Jasper teachers invited instructional coaches into areas of their teaching where they had already identified what constituted struggle or lack of experience, they shared (some) agency with the coaches by bringing them into the set of actors together defining struggle and expertise.

Teacher learning as social and collective

Jasper institutionalized district wide ‘collaboration days’ six or seven times a year, with the explicit goals of evaluating students’ performances and creating–new resources, lesson plans, instructional strategies, and assessments. An instructional coach at Riverview recalled, “this last collaboration, most of the grade levels dug into science and looked at their grade level standards, and the upcoming unit and really worked on lessons.” The Valleyview principal reflected on the terminology used in Jasper and the distinctiveness of this practice: “We have been very careful to not make that a professional learning day. It's more really about collaboration.” Collective teacher learning was also practiced within weekly school-based PLC [professional learning

community] routines scheduled throughout the school year; the principal explained that "We don't provide a lot of oversight of that. Really, we try and protect that as teachers' time."

Teacher learning enacted as social or collective both emerges from teachers' and leaders' engagements with and between each other and is held together by institutional arrangements that provide and protect temporal and spatial opportunities for peer interaction. This brings the actors that enact institutional arrangements into the practices, including administrators, school schedules, spaces for social activity. In Jasper this included collaboration days at the district level, and PLC routines in schools. Other actors are implicated in these practices too: ideas about learning in communities of practice or PLCs that teachers and leaders encounter in their reading and professional communication, for example.

In this enactment teachers become practitioners and knowers about instructional practice, including how they should use curriculum materials and the challenges or opportunities of new standards. In Jasper, the emergence of teachers as knowers within this enactment of teacher learning can be seen in the way the Valleyview principal drew a contrast between "professional learning" (PD) that enacts teachers as 'partial' knowers and this enactment of "collaboration."

As they emerge as knowledge locations, teachers are empowered to represent and deprivatize their practice with each other, although what they 'choose to' share also emerges in entanglement with (subject to) school and district administrators' expectations even as agency is practiced as emanating from teachers. So even though Jasper administrators did not "provide a lot of oversight" of teachers' collaboration, instructional norms, goals, and expectations within Jasper, and the curriculum materials and assessment results, all shaped the flow of agency around what teachers worked on in these collaborations. Finally, as they enact teacher learning as social and collective, teachers engage in the (co-)creation of new approaches and strategies, new ideas,

and new curricular resources. These emergent phenomena become measures of the success of this enactment of teacher learning. In other words, teacher learning becomes an act of creation.

Teacher learning as gaining new accreditations

In Brookeport, members of the science department in the central office were wary of teachers without the Massachusetts science endorsement teacher certification. They worked with the STEM department in the district central office and teacher educators at a local university to co-create an adult learning experience in which participating teachers gained accreditation in science content courses. The Science Department Senior Project Coordinator explained:

> [Teachers] get graduate credit for it… it can increase their salary within their lane that they're in. [Bayshore College] created this course for us for the fall. It's a 10-session earth science, and then in the winter we'll switch to physical science topics, and they'll put together the same thing. … We [the science department] don't have any money. The STEM department [will] fund it so they pay for [teachers'] registration and their credits and also, [but] they're not stipending [teachers].

This version of teacher learning emerges from the coming together of district level administrators, university-based teacher educators and administrators, and certification in elementary science. Teachers are divided into science specialists and non-specialists based on the qualifications they possess, and specialization emerges as a marker of knowledge. Consequently, within this enactment, non-specialists become identified as lacking knowledge about science instruction; and accumulating new accreditation emerges as the measurable outcome for successful teacher learning.

While this has overlaps with teacher learning enacted as acquiring new knowledge, by focusing on accreditation, this enactment is analytically distinct in two ways that are made

visible from a multiplicity perspective. First, qualifications and accreditations as symbolic actors hold the practices together. Teachers sign up because they will be recognized with graduate credits, which leads to higher pay. Second, university-based actors are integral to this enactment of teacher learning, as they, exclusively, have the power to certify a teacher as a knower—a possessor of accreditation—or not. This is in contrast to the version of teacher learning as acquiring new knowledge, in which these actors (certificates and university-based teacher educators) do not (necessarily) feature.

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Across these three districts, four different versions of teacher learning were enacted by human and non-human actors as they engaged in teacher learning practices together. These actors included system leaders, but also curriculum materials and science standards, school schedules and district calendars. It was from the engagements between these overlapping sets of actors that the knowledge teachers were constructed to need, the goals for teacher learning, routines to support teacher learning, and agency around teacher learning emerged from ontologically distinct worlds of teacher learning. However, while these four enactments of teacher learning can be seen as distinct through Mol's (2002) multiplicity perspective, empirically they were enmeshed in complex relations, as actors worked across multiple practices enacting different teacher learnings within the same districts. In the next section, I explore these entangled realities.

Table 4
Different teacher learning enactments within each school system, in which the enactments are reified constructs emerging from contextually embedded practices.

Enactment of teacher learning	Jasper		Bartlett		Brookeport	
	Central office	Schools	Central office	Schools	Central office	School
Teacher learning as acquisition	✓	✓	✓	✓	✓	✓

of new knowledge						
Teacher learning as developing personal experience of science instruction		✓			(✓)	✓
Teacher learning as social and collective	✓	✓		(✓)*	(✓)	✓
Teacher learning as gaining new accreditations					✓	

*Data not provided in this manuscript.

Entangling teacher learnings within developing educational systems

These multiple enactments of teacher learning appeared differently within each of the districts (see Table 4). However, these different enactments were deeply entangled, and in Bartlett teacher learning enacted as acquisition of new knowledge could not be distinguished from enacting teacher learning as developing experience of science instruction. In some cases, enactments of teacher learning supported or relied on each other, with multiple knowledge practices mutually legitimizing each other in terms of who teacher learning was for, what it was about, where and when it occurred, and how it worked. However, in other cases enactments remained disconnected. System actors routinized, institutionalized, and legitimized practices of teacher learning about elementary science, and in some cases they gathered together practices within different enactments into broader constellations of practice.

In this section I describe teacher learning practices by district, as they were performed by system actors in interview data, and, to a lesser extent, documents and observations. In this, I hope to illuminate some of the ways different enactments of teacher learning were entangled.

Constructing singularity in Jasper

While I found multiple enactments of teacher learning in Jasper, system actors used a number of mechanisms that gathered practices together across enactments to prevent an experience of multiplicity. First, system actors had built an infrastructure that distributed content and purposes between different enactments, while ensuring these goals were complimentary. Second, they sequenced enactments of teacher learning so that levels of support for teachers decreased over time and agency flowed from system leaders to teachers. Third, when state-mandated PD created a multiplicity that threatened the coherence of teacher learnings, it was buffered from district-based teacher learning.

Content was distributed across enactments of teacher learning. Teacher learning as acquisition focused on processes, procedures, and principles. The developing experience enactment focused on use of resources. And the collective learning enactment focused on creation and problem-solving. In the curriculum adoption process, for example, the teachers began with reading a set of articles individually, as the director for teaching and learning intended for teachers to acquire knowledge from experts about the principles of best practice in science instruction:

> I choose carefully the articles for reading for this process that talk about the ‘doing’ of science because there's so much pressure to spend so much time in reading that not everybody is committed to the power of the ‘doing’ part of science and then layering on the learning.

These articles were drawn into the practice as agents shaping the content of learning: the principles of science instruction. In contrast, when teachers were deliberating about how to enact these principles within curriculum design, teacher learning was enacted as collective. On the curriculum adoption committee, teachers worked together to try and identify which principles

were the most important priorities for science instruction in the district (see Excerpt 2). Teachers also used these principles to redesign the new commercial curriculum, TWIG, during collaboration days to ensure science lessons would fit into the school day. These teacher learning enactments formed layers within the system: system actors gathered different enactments together as the primary content of the learning shifted between practices.

Excerpt 2
Fieldnotes from the first curriculum materials adoption committee meetings as teachers refined the district aim statement, immediately following discussion about the articles they had read.

[TEACHER 1]: I think it captures with different words the things we expressed. I was on the committee 7 years ago, I think it's great because it captures our previous work.

[TEACHER 2]: I agree, I think the words are expressed a little differently. We talked about questioning. I think in our district, we've integrated STEM labs so well K-up, now that we're consistently doing, is there anything we need to add to guide this, or do we think this is good?

[TEACHER 3]: I think it mentions engineering practices, I think there's more focus on that now than when this was written. I think it covers everything. I… sometimes when we read these, it's more secondary. It sounds bigger than our littles. That's… the goal is to start with us and let them build on that. I think it covers just about everything we thought was important.

System actors also designed enactments of teacher learning to operate sequentially. Teacher learning was highly scaffolded in early enactments of a sequence, and most of the (human) actors were located at the central office or administrator levels. Formal district PD led by TWIG was designed to transfer knowledge to teachers about how to use the curriculum materials, such as how to access and use the website. But instructional coaches, central office leaders, and teachers identified these practices as prerequisites for teachers developing personal experience through using the new TWIG kits. The two enactments were distributed across time, and by giving each enactment different purposes that were logically sequential–developing familiarity (through acquisition) and developing expertise (through developing experience)–the two enactments were made complimentary. This sequencing also involved a flow of agency

away from system leaders and towards teachers over time; in teaching with the materials teachers were empowered to work out for themselves what they needed to learn, even as their consciousness was constrained by the practices that came before. Similarly, in supporting the PLCs in Riverview, leaders dropped into practices to model how to use essential questions to drive collective learning. The modeling enacted teachers as acquiring knowledge about collaboration, but, once they had been 'taught,' in their collaborative learning teachers were enacting 'their' collective agency in the ways school leaders intended.

Enactments of teacher learning were also distributed across different 'subjects' for the teacher learning. The central office engaged in specific teacher learning practices for 'new' teachers. The director of teaching and learning explained that the formal summer PD sessions were only available for "new teachers and any teacher changing grade levels." An instructional coach at Valleyview described 90% of her work as being with new teachers learning about 'the Jasper Way,' a form of coaching in which the instructional coach explicitly directed teachers' to conform to localized standards and expectations. Experienced teachers called in instructional coaches to support their personal goals, enacting teacher learning as developing personal experience. But, for new teachers, the instructional coaching practice was an enactment of teacher learning as acquisition of new knowledge. As such, teachers needed to have 'been through' practices of knowledge acquisition over time to become experienced within the district and create their own agency within teacher learning practices.

In Riverview, school actors experienced a multiplicity of teacher learnings around state-mandated PD. The principal performed state-mandated PD as distinct from "authentic" learning experiences, buffering teacher learning practices as about 'becoming compliant' from teacher learning focused on 'teacher growth.' The school principal shared that "I would say we

just look for those opportunities to build people without the workshop approach as much." However, when the district did design centralized workshops around how to use notebooks in science, it was rooted in a recognized problem of practice by district and school leaders and could be cogently entangled with other teacher learning practices in the district.

Across Jasper, multiple teacher learnings were taking place as part of system-building efforts in elementary science. However, system actors used a variety of mechanisms—distribution of content and actors, sequencing, and buffering—to gather these enactments together in ways that shielded actors from the destabilizing effects of multiplicity.

Teacher learning as composite in Bartlett

In Bartlett, the science center was the nexus for all science instructional learning practices: all agencies flowed through science center actors, including the director and assistant director and the materials they created in their practices. The science center itself was instigated by a district science teacher 20 years ago, and enjoyed such deep connections within the community that the superintendent acknowledged that he would lose his job if he suggested cutting funding to the science center. The science center actors had designed and implemented new curriculum materials in response to the MSTE. While the science center offered both PD around their curriculum materials and in-class support to teachers, the boundaries between the two enactments were blurred. Instead, the science center enacted a composite teacher learning in Bartlett that fused knowledge acquisition and developing experience into a singular world.

In the PD the science center enacted to support the implementation of new elementary science curriculum materials, teachers practicing with the materials was central to the design. The deputy superintendent explained:

> They brought out each group of teachers to the science center before 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. … They were … many more times comfortable with those lessons because they had been through them. That's just a great model for curriculum implementation in my eyes. I can't think of a better way to do it.

The assistant director of the science center recalled that teachers' feedback expressed "gratitude" that they were given "a day out of the school to learn this and practice this." As such, the practice of PD entailed teachers acquiring knowledge about using the curriculum materials *by* developing their experience with them.

In reciprocal relationship, the support the science center offered teachers in their classrooms, was a practice for teachers to acquire knowledge about curriculum materials and standards. The director of the science center noted that "we're very support-heavy right now." This support took a number of forms, including modeling instruction for teachers, and connecting them to other actors that emerged as locations for knowledge. The deputy superintendent explained that the science center staff were themselves resources:

> They literally get booked. They go into classrooms; they do model lessons…. Or they will go into different classrooms and help the teachers with any lessons that teachers want support for. I think that their main role is to be available to teachers if they're struggling, have questions, want to co-teach something…. It's totally a resource for teachers.

The science center also designed and provided resources for teachers to use in their teaching that

became actors from which teachers could acquire knowledge and learn about science teaching. The director of the science center described teachers' learning about teaching elementary science from using the curriculum guide in their teaching, which also included exemplar student work:

> I also feel that the curriculum guide that we have provided with exemplars in student work folders, building upon that curriculum—I was just sitting with a fifth-grade teacher yesterday. She came from second grade the year before. … This is her second full-time classroom. … I sat and observed her. She wasn't nervous about me being there. She had my guide sitting there, and she was looking at it very frequently, but the lesson was still awesome and had great science talk…. I didn't even train her on this unit… 'cause she wasn't there a few years ago when we did the full teacher training on these units, but the fact that she could still have that great level of discourse and conversation with students just by following my guide made me realize how important that support network was for her and that, before this, we didn't have that.

In these practices, the science center connected teachers to knowledge that teachers could acquire in the context of their own teaching practices.

These sets of human and non-human actors in Bartlett, connected by the science center, enacted teacher learning as intrinsically about acquiring knowledge from expert resources. As such, the science center enacted teacher learning as acquiring knowledge and through developing (im)personal expertise as a single composite reality. But while the version of teacher learning as developing personal experience was rooted in teachers' own goals for their practice in Jasper (contingent, of course, on many other agencies and actors), in this composite enactment within Bartlett the goals for teachers' learning remained centralized and determined by the science center in terms of teachers' fidelity of use of the curriculum materials. As such, this composite

teacher learning was enacted to ensure tight coupling between the curricular infrastructure being provided by the science center and teachers' individual instruction. This had implications for enacting teacher learning as social and collective. The science center assistant director explained that, while they would prefer grade level teams to onboard new teachers into using the resources, different "levels of fidelity and various levels of knowledge" among teachers made it necessary for the science center to centralize teacher learning practices, rather than institutionalize practices that enacted teacher learning as social and collective. As such, in enacting a composite, depersonalized, teacher learning, the science center actors engaged in ontological politics to create what mattered in teacher learning: that teachers used materials with fidelity.

It is worth noting here, however, that the principal at New Rockford questioned the efficacy of the teacher learning infrastructure enacted by the science center. However, the principal at New Rockford performed an alternative ontological politics as she questioned the normative value of this enactment of teacher learning, asking "what are the teachers' roles as a result of [the support from the science center]?" She went on:

> The thing is, [teachers] do [take advantage of the science center], probably to the detriment, I would have to say, of us building a more solid internal science program. We have such a talented support science program, which they take advantage of, and who wouldn't? … As a result, I'm not sure that we're building our own talent…. Teachers are talented and they're teaching science, but geez, if you didn't have to do the presentation on tide pools or whatever, solar systems, and somebody else was gonna come do that for you in your class, wouldn't you call? "Hey, do you wanna come over and teach my science lesson?" "Sure." It doesn't necessarily foster better quality teaching instruction because we have talented science shows on the road. … Aren't we fortunate? Call the

> science center. They'll come over with the animals. Call the science center. She'll bring the owl over. Call the science center. They'll be in anything.

For this principal, fidelity of implementation was not the goal of teacher learning. Instead, she viewed teachers having the skills to enact excellent science instruction on their own, without leaning on the science center in the long term, as more important. In the centralization and depersonalization of practices of teacher learning, this principal argued that an important aspect of teacher learning was being lost. In this way, the principal called out the work of the science center as engaging in an ontological politics that pushed out and sidelined other (politically) valuable ends in enacting a particular reality of teacher learning.

Distribution of teacher learnings in Brookeport

As a large and complex school district, in Brookeport many actors were enmeshed in many teacher learning practices in many spaces. As such, teacher learning was highly distributed, both horizontally between departments and across levels of the system. I begin by discussing the different sets of actors involved in teacher learning for elementary science within the Brookeport central office, before introducing and unpacking the practices these actors engaged in. Finally, I share findings about how sociomaterial conditions shaped the emergence of agency in these sets of practices.

Within Brookeport central office two departments performed teacher learning: the science department and the STEM department. The STEM department was created relatively recently, in Fall 2020—the new director was explicitly told to use the funding to improve elementary science—and the science department was slimmed down to only three members of staff. This fragmentation of responsibility for elementary science was a science-specific structural arrangement that the STEM director argued was related to the district managing an external

environment in which STEM was a “hot topic” nationally and a local corporation had gifted the district with 24 million dollars specifically for STEM. Given the organizational shifts, it was not initially clear to these actors what was the responsibility of the science department or the STEM department in terms of supporting elementary science, including around teacher learning.

These organizational changes were linked to wider changes the superintendent made in how teacher learning was practiced in the district, as the STEM director explained:

> the superintendent wanted to have more … professional learning to be owned by schools and for more teachers to be leading professional development versus [central office] departments really owning it and being the sole provider of it. I think that that was also part of the decision-making around [the reorganization]

The science department, historically tasked with teachers’ learning around the curriculum materials, were concerned that this learning would not be practiced in schools, as the science director explained:

> if you're told no longer are you gonna have district-wide professional development, it's gonna be school-embedded, but you ask the questions, what about our district-wide curricula, how are we supposed to provide professional development for that, and then they can't answer those questions because they didn't think of those questions because they didn't talk to any of the directors and assistant directors prior—those conversations didn't happen prior to the decisions being made.

Consequently, while “in theory” science PD was decentralized, the science director resolved that “we’re still going to have centralized PD [in practice].” The director further explained that the science department was still able to incentivize teachers to attend centralized PD by providing them with “professional development points” and further instructional materials that contained

knowledge for teachers to acquire. In this case, non-human actors acted as repositories of knowledge that teachers could acquire as they engaged with them.

These practices of teacher learning that the science department led differed according to teachers' roles. Science specialists were the target demographic for much of the centralized PD, with the science department director explaining that "when we do see the classroom teachers, [they] come to the full district-based PDs of like, here's the unit training," whereas the science specialists were more likely to contact the science department for personalized support. Science specialists were also able to join a cadre of science teacher leaders and lead PD on the curriculum materials for other teachers. This science teacher leader group was established over 20 years ago and went on annual retreats to engage in "adult learning around how to facilitate professional learning" and design teacher learning opportunities, including "unit training" for teachers. The former K-12 STE director elaborated:

> That kind of thing goes a long way with teachers because you had teachers who were in Brookeport teaching you how to use the curriculum materials. It's not like you're someone from a company, and you're like, 'You don't know my kids. You don't know what I do every day.'

The FOSS trainer explained that "basically, teachers were trained to teach the FOSS modules to their peers. We called them peer-led workshops. Those were really well received by teachers. I think they're thinking about sustainability and how to keep the trainings going." So while science specialists were able to join the set of actors, led by the science department, taking part in designing and performing these practices, non-specialist classroom teachers were excluded.

In sharp contrast to the practices involving science department actors, the STEM department used grant funding to develop a coaching initiative to place STEM instructional coaches in schools for two-year cycles. The Clairton instructional coach explained her role:

> I'm here full-time at [Clairton] and the idea of the initiative is that each coach stays at their placement school for two years and then we move on to another school in the district as well and continue the work. That's the overarching what the—where my position belongs to. The mission of my team is essentially to build teacher capacity for delivering high-quality science instruction that is culturally responsive, that meets the science and engineering practices, that creates an inclusive culture and so on.

She further described this work as about meeting teachers "where they are" in terms of comfort with science pedagogy, supporting teachers through observation and questioning, and ensuring teachers themselves made suggestions for their practice. So this coaching practice enacted teacher learning as developing teachers' personal experience of science instruction, rather than about teachers acquiring knowledge from experts (as seen in Bartlett). The STEM director noted that "the goal of the initiative is to have whole-school ownership in implementation of science" which was why coaches were employed by the district but embedded full-time in schools.

Enacting coaching as a teacher learning practice drew in actors like school schedules, and put two teacher learning realities in competition. A common in-school planning period was instantiated across the district, and the elementary superintendent argued that "you could and should consider [this period] as professional development that's about 45 minutes," institutionalizing that time as for teachers to engage in collective teacher learning. The school principal described this as "sacred" for teachers' work and learning. He explained:

> Part of my theory of action is really building this into making space for teachers and teams to do the intellectual work together with a focus or lenses on science with our science specialists, so that it's not something that's peripheral done in the evenings. That it is the core work of the school.

However, the STEM coach struggled to identify times to work with teachers to support them in developing their personal practice. Neither the school nor district had institutionalized time for coaching, and she worried about displacing teachers' collaboration times for her to work with teachers individually around their personal practice.

The teacher learning realities being performed by actors centered in the science department and in the STEM department differed significantly, with the science department focusing on teachers' acquisition of knowledge about how to use district-wide curriculum materials, and the STEM department enacting an instructional coaching model focused on developing teachers' personal experience of science instruction. As these enactments were distributed across the two offices, it was not clear that these were designed to be mutually supportive or legitimizing, although both shared a goal of supporting teachers' use of educational infrastructure. For example, the Clairton principal explained that the STEM instructional coach worked to support teachers with "critical consumption" of curriculum materials through adapting the materials provided by the district for their own classrooms, including integrating across subject areas in unit redesign of a literacy and a science unit. This work intersected with the centralized PD being offered by the science department in partnership with FOSS and teacher leaders on using the curriculum materials. Where there is evidence of science and the STEM departments explicitly working together with a local university to design and fund graduate

education credits in science content courses, these actors–science department, STEM department, local university–layered over yet another world of teacher learning.

These layered and distributed practices emerged from different sets of actors which had specific goals and social and material constraints over their agency. For example, while the science department was focused on providing PD for teachers around how to use the district-wide curriculum materials, the former science department director shared that they were unable to design and create this PD in the ways they wanted to:

> In our district, I hate to say it, but the past couple years, [professional learning has] been the one and dones. We're lucky if we get people in the room for the full day. It is so hard to get teachers to come for at least 18 hours, which is what we know changes practice.

As described by this leader, constraints over time for teacher learning and budget in the science department provided limitations to the kind of PD the science department offered. In contrast, the Brookeport STEM department had a substantial budget from an external grant, so were able to invest in more expensive teacher learning practices. They were accountable for these material investments, however. The Deputy Chief of Academics explained:

> Coaching is really expensive. It's an expensive model of professional learning. If there isn't impact or evidence of impact, then I don't—why are we here? Why am I paying you? *[Laughter]* 'Cause they charge me *[laughter]* over $90,000 per coach.

The STEM department was able to practice teacher learning differently, but in leveraging significant material resources, new agencies shaped the practices as the goals and purposes became constrained by performance metrics. This also constrained instructional coaches' and teachers' actions in identifying goals for coaching. For example, the Clairton science specialist's goal to improve fifth-grade students' scores in the Massachusetts Comprehensive Assessment

System (MCAS) was rooted in his professional success and evaluations, as the instructional coach explained:

> [The MCAS is] just the reality of this is something we need to take a look at. I believe in [the science specialist's] case, his goal is on [the MCAS] and it impacts—like for fifth grade teachers and himself, they're the ones who impact statewide data for the school, so there is an emphasis for them professionally, based on their evaluations and so on.

As such, specific elements of the science specialist's teaching were explicitly sanctioned as legitimate goals for teacher learning.

Across Brookeport different ontological politics were operating, but they mutually pushed on and constrained one another, and actors needed to manage these alternative realities. The superintendent drew on political reasoning for shifting responsibility for teacher learning to schools based on school-ownership, but the science department also had political reasons to continue enacting centralized PD based on their understanding that teachers needed support using the materials. These two ontological politics defined doing 'the good' in incommensurable ways. However, the STEM instructional coach and principal enacted another ontological politics as they focused on 'critical consumption' of the FOSS curriculum materials in their work with teachers. This practice of teacher learning managed the two competing political realities of the superintendent, and the science department, as it involved a constellation of practices across actors at different levels of the system in learning through co-constructing new, localized materials from district-wide ones. In this way, within educational systems, managing ever shifting tensions in ontological politics is part of the work of system-building.

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Multiple realities of elementary science teacher learning were practiced and entangled across the three districts, but this entanglement took different forms and both emerged from and shaped agency around teacher learning. In Bartlett, the science center actors entangled two versions of teacher learning—acquisition of new knowledge and developing experience—into a single composite reality, and limited enactments of teacher learning as social and collective to ensure teachers used materials with fidelity. In contrast, multiple realities of teacher learning in Jasper were entangled through layering them on top of each other and sequencing them to ensure these multiple realities hung together. In Brookeport, different teacher learnings were distributed across different sets of actors at the central office level, but school-level actors, including the STEM coach, made efforts to bring these realities together in productive tension.

Discussion

The instructional demands of the NGSS are ambitious, and empirical research suggests that all but the most highly-performing teachers are likely to need significant support to meet these standards in their instruction (Peurach, Foster et al., 2022; Cohen, 1990). One approach to this challenge is through engaging in instructionally-focused system-building that (re)distributes responsibility for organizing and managing instruction so that other system actors are engaged in this work alongside and in partnership with teachers, including through teacher capacity-building efforts (Bryk, 2010; Peurach et al., 2019; Smith & O'Day, 2008). However, while a system-building perspective offered *supporting use of infrastructure* as a broad domain of work, the findings above, drawing on Mol's (2002) ontological multiplicity as a theoretical lens, tell a story of system-building as as ontological work: work that creates new realities or ways of being. And this allows us to distinguish the alternative approaches to system-building that system actors are engaged in and the ontological politics that they enact in the process.

While Mol's (2002) framework has been taken up by some scholars working in education to analyze educational policy discourse (Carusi & Niwa, 2020; Carusi, et al., 2018; Singh, et al., 2014), how policies become entangled in teacher learning practice (Riveros & Viczko. 2014) and critical approaches to pedagogy (Postma, 2012; Kaplan, 2019), to my knowledge, this is the first application of this lens to system-building. By plugging into this framework to interrogate system-building efforts around teacher learning, this study has shown that, while system actors were engaged in practices to support teachers' learning around using the district educational infrastructure, this work was more than just establishing ostensive designs for practice but also involved ensuring their efforts worked across, co-opted, and circumvented alternate realities of teacher learning within the district. Furthermore, we have seen that this work is highly political, as some enactments of teacher learning distribute agency across actors and make space for alternative enactments, and other enactments, as we saw in Bartlett, preclude alternative realities of teacher learning, and practice agency in ways that construct specific hierarchies of power.

From a system-building perspective, *supporting use of educational infrastructure* is a departure from the status quo (Peurach, Foster et al., 2022). Instructional reform efforts in the U.S. have historically emphasized providing teachers with more and better resources, but left them on their own in terms of organizing and managing their own instruction, despite evidence that without coherent and coordinated support teachers differ significantly in how they use the resources they have available (Cohen & Ball, 2001; Cohen et al., 2003). However, in each of these three districts, system actors institutionalized and routinized practices to support teachers' use of educational infrastructure as a means of ensuring tighter organizational coupling between the formal infrastructure provided by the district and teachers' instruction (Peurach et al., 2019). These practices included ostensive designs for teacher learning practices anticipated from a

system-building perspective: teacher PD workshops and practice-based coaching. But, taking an ontological multiplicity approach allows us to get inside system-building efforts around teacher learning and see some of the work system actors are engaged in that is usually hidden.

By diffracting teacher learning practices through Mol's (2002) framework, the processes system actors used to couple formal infrastructure and instruction can be seen as meaningfully different across districts. Instructional coaching, for example, was practiced differently in Bartlett and Brookeport, and this enacted two different realities of teacher learning: as developing personal experience in Brookeport, and as a hybrid of acquisition of new knowledge and developing (im)personal experience in Bartlett. These two alternative teacher learning realities also enacted coupling differently. The Bartlett science center actors engaged in in-class support so that teachers would use the materials with fidelity: to move the teachers' instructional practices closer to the materials as designed. In contrast, instructional coaching in Brookeport was intended to support teachers learning with and through moving the designs of the materials closer to their instructional needs through a practice of "critical consumption." This diversity of ongoing efforts to ensure tighter coupling between formal infrastructure and instruction reflects earlier findings about organizational coupling as a dynamic process in which system actors are not just responding to teachers' needs in terms of using infrastructure, but (re)constructing those needs as they engage with each other (Hallett, 2010; Hallett & Ventresca, 2006; Sauder & Espeland, 2009; Spillane et al., 2019). These different approaches to coupling evident in the practices for *supporting use of infrastructure* found in Bartlett and Brookeport reflect the ways different collections of system actors in each district made sense of what teachers might need to do in relation to formal infrastructure to improve instruction in line with the MSTE.

Furthermore, these findings suggest that system actors aiming to couple infrastructure and practice through system-building need to face the alternative realities that precede or overlap with their efforts (e.g. preexisting structures that are not domain specific, like PLCs) and engage in complex, political work as they create teacher learning realities that couple infrastructure and practice more closely. Across these three districts, I observed two broad ontological politics of system-building within the *supporting use of infrastructure* domain. The first approach consisted of constructing and enacting a comprehensive design for teacher learning practice to bring one, singular teacher learning reality into being, as seen in Bartlett,. The second approach involved gathering together a range of practices for teacher learning in Jasper, and to a lesser extent Brookeport, and constructing bridges between the multiple realities these practices performed.

In Bartlett, the science center actors enacted a singular reality of teacher learning by hybridizing teacher learning as acquiring new knowledge and as developing (im)personal experience, with practices including unit training in which teachers practiced using the materials for the unit, and in-class modeling of instruction. While teachers may have engaged in collegial learning practices about science instruction in their schools, or talked about science in their limited planning times, there is no evidence that these alternative realities of teacher learning were brought into productive contact with the science center's world-building: indeed, the science center actors were concerned about teams of teachers supporting new colleagues in case there was a loss of fidelity. System-building efforts in Bartlett viewed alternate practices of teacher learning as something to be designed around, or smothered by the science center's ostensive design. This reflects an "internal coherence" approach to system-building for teacher learning (Forman et al., 2021). This ontological politics buffers the disorienting effects of multiplicity (Law, 2004) within this domain of system-building by constructing a tacit hierarchy

of teacher learnings for elementary science and positioning teacher learning enacted by the science center actors as at the top as sanctioned and legitimized practices.

In contrast, system actors in Jasper described a number of ways in which they brought together a plurality of teacher learning realities. This included appropriating district-wide collaboration days specifically for teacher learning in science to support teachers when a new set of curriculum materials were implemented in the district, making space for teacher learning within organizational routines like the curriculum adoption committee through including readings and adapting materials (see Haverly et al., under review, for further details), and institutionalizing various teacher learning practices in a designed sequence so that the multiple versions would hang together. In this way, *supporting use of infrastructure* as a part of system-building around elementary science in Jasper involved gathering together legacy practices within the district, such as collaboration days, and introducing new practices, including the workshop on science notebooking. This ontological politics of gathering represents an alternative approach to system-building. In Brookeport there was also some evidence of this pluralist approach, such as the science and STEM departments working together with other actors to enact local university-based science content courses linked to the topics of instruction featured in the "unit trainings" the science department, FOSS trainer and cadre of science specialists offered. However, the STEM instructional coach's uncertainty about when to work with teachers so as not to compete with their collaborative planning time, for example, suggests that opportunities remained for system actors to continue gathering these distinct teacher learning realities, so that they buttressed, rather than sabotaged, each other.

So, while a system-building perspective prescribes the domains of work for system-building for instructional improvement, it merely describes potential activities within

those domains (Peurach et al., 2019). It is not committed to a process of coupling that moves infrastructure towards instruction or a process that moves instruction towards infrastructure. Neither does the system-building framework make claims about whether system actors should design comprehensive systems for teacher learning, as in Bartlett, or gather together multiple practices, as in Jasper. By using Mol's (2002) framework, this study sheds light on the political implications of system-actors' world-building around teacher learning, in particular the way an ontological politics of plurality tolerates multiplicity and distributes agency, in contrast to an ontological politics of singularity that enacts agency as the preserve of actors involved in the ostensive design practice. In system-building that puts serious attention on teacher learning, system actors necessarily perform a previously invisible ontological politics as they routinize, institutionalize, and legitimize practices for teacher learning in elementary science that bring some realities of teacher learning into being rather than others.

Conclusion

In this paper, I have tried to bring a theoretically rich sensibility to bear on a concrete challenge for system actors working with and around science in U.S. elementary schools. Reformed science standards, such as the NGSS and MSTE, pose significant challenges to the status quo of elementary science teaching, and teachers' learning is a central mechanism for system actors concerned with teachers being able to perform reform-oriented instruction. While the system-building literature situates teacher learning as but one domain of work for supporting improved instruction that includes both social and material resources, a multiplicity-perspective drills down into the many ways teacher learning is being practiced sociomaterially within educational systems as system actors work to improve elementary science instruction. In engaging with teacher learning as it emerges and is (re)defined within practices, I have been able

to show how system actors enact teacher learning in their engagements with non-human actors, such as curriculum materials and science standards, and how they are implicated in multiple realities of teacher learning. I have also been able to explore how system actors ensure these different realities hang together as part of their system-building work: from privileging one reality as legitimized teacher learning and ignoring and invisibilizing divergent realities, to gathering them together and layering them productively: from mandating singularity to finding ways to live with multiplicity. Finally, I have used Mol's (1999) idea of ontological politics to explore the ways an ontological politics of plurality and an ontological politics of singularity enact different versions of the good in terms of what matters for teacher learning about elementary science.

So, why do these theoretical forays matter for the concrete problem of improving instruction in elementary science? They matter because they highlight distinctive ontological politics of system-building that, at their extremes, have radically different connotations for the work of system actors. Both ontological politics deal with the fragmentation and incoherence around teacher learning that has inhibited the development of instructionally-focused education systems in U.S. public schools (Peurach et al., 2019). An ontological politics of singularity privileges comprehensive, coherent and ostensive designs for teacher learning (an approach which is surely an improvement on the status quo). But an ontological politics of plurality shows the potential of an alternative approach: an approach that makes space for a wide array of actors, an approach that makes space for productive tensions between different worlds of teacher learning, an approach with a more democratic ontological politics.

References

Barad, K. M. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press.

Bidwell, C. E. (1965). The school as a formal organization. *Handbook of Organizations*, *972*(8), 1019.

Bozelak, V. &

Bryk, A. S. (2010). Organizing Schools for Improvement. *Phi Delta Kappan*, *91*(7), 23–30. https://doi.org/10.1177/003172171009100705

Carusi, F. T., & Niwa, T. (2020). Learning not to be poor: The impossible position of teachers in Aotearoa New Zealand education policy discourse. *Asia-Pacific Journal of Teacher Education*, *48*(1), 30–44. https://doi.org/10.1080/1359866X.2019.1684434

Carusi, F. T., Rawlins, P., & Ashton, K. (2018). The Ontological Politics of Evidence and Policy Enablement. *Journal of Education Policy*, *33*(3), 343–360. https://doi.org/10.1080/02680939.2017.1376118

Cohen, D. K. (1990). A Revolution in One Classroom: The Case of Mrs. Oublier. *Educational Evaluation and Policy Analysis*, *12*(3), 311–329. https://doi.org/10.2307/1164355

Cohen, D. K., & Ball, D. L. (2001). Making change: Instruction and its improvement. *Phi Delta Kappan*, *83*(1), 73–77.

Cohen, D. K., Raudenbush, S. W., & Ball, D. L. (2003). Resources, Instruction, and Research. *Educational Evaluation and Policy Analysis*, *25*(2), 119–142. https://doi.org/10.3102/01623737025002119

Emerson, R. M., Fretz, R. I., & Shaw, L. L. (2011). *Writing ethnographic fieldnotes*. University of Chicago press.

Fenwick, T. (2014). Knowledge circulations in inter-para/professional practice: A sociomaterial enquiry. *Journal of Vocational Education & Training*, *66*(3), 264–280. https://doi.org/10.1080/13636820.2014.917695

Fenwick, T. (2015). Sociomateriality and learning: A critical approach. *The SAGE Handbook of Learning*, 83–93.

Fenwick, T., & Edwards, R. (2010). *Actor-Network Theory in Education*. Routledge. https://doi.org/10.4324/9780203849088

Fenwick, T., Edwards, R., & Sawchuk, P. (2011). *Emerging Approaches to Educational Research: Tracing the Socio-Material*. Routledge. https://doi.org/10.4324/9780203817582

Forman, M. L., Stosich, E. L., & Bocala, C. (2021). *The Internal Coherence Framework: Creating the Conditions for Continuous Improvement in Schools*. Harvard Education Press.

Hallett, T. (2010). The Myth Incarnate: Recoupling Processes, Turmoil, and Inhabited Institutions in an Urban Elementary School. *American Sociological Review*, *75*(1), 52–74. https://doi.org/10.1177/0003122409357044

Hallett, T., & Ventresca, M. J. (2006). How Institutions Form: Loose Coupling as Mechanism in Gouldner's Patterns of Industrial Bureaucracy. *American Behavioral Scientist*, *49*(7), 908–924. https://doi.org/10.1177/0002764205285171

Haraway, D. (2004). *The Haraway Reader*. New York: Routledge.

Haverly, C., Lyle, A., Spillane, J. P., Davis, E. A., & Peurach, D. J. (2022). Leading instructional improvement in elementary science: State science coordinators' sense-making about the Next Generation Science Standards. *Journal of Research in Science Teaching*.

Haverly, C., Seeber, E., Davis, E. A., Spillane, J. P., Lyle, A., (under review). Teachers Learning on-the-Job Through Participation in an Organizational Routine: A Comparative Case Study of Three Curriculum Materials Adoption Processes for Elementary Science

Jackson, A. Y., & Mazzei, L. A. (2023). *Thinking with theory in qualitative research* (Second Edition.). Routledge.

Kaplan, H. (2019). Border Materials, Early Childhood Art Education, and the Ontological Persistence of American Flexibility. *Studies in Art Education*, *60*(2), 120–131. https://doi.org/10.1080/00393541.2019.1600220

Latour, B. (2005). *Reassembling the social: an introduction to actor-network theory*. Oxford: Oxford University Press.

Law, J. (1992). Notes on the theory of the actor-network: Ordering, strategy, and heterogeneity. *Systems Practice*, *5*(4), 379–393. https://doi.org/10.1007/BF01059830

Law, J. (2004). *After Method: Mess in Social Science Research*. Routledge. https://doi.org/10.4324/9780203481141

Law, J. (2011). Knowledge Places: Or Putting STS in its Place. *Plenary Paper Prepared for Delivery at National Yang Ming University: Taipei, Taiwan*, *4*.

Lenz Taguchi, H. (2012). A diffractive and Deleuzian approach to analyzing interview data. *Feminist Theory*, 13, 265–282.

Lyle, A., Spillane, J. P., & Haverly, C. (2023). Leading Within and Beyond the Schoolhouse: Taking a Multilevel Distributed Perspective to Analyze the Practice of Leadership for Elementary Science. AERA Presentation.

Meyer, H. (2002). From “loose coupling” to “tight management”? Making sense of the changing landscape in management and organization theory. *Journal of Educational Administration*.

Meyer, J. W., Rowan, B., & Meyer, M. (1978). The structure of educational organizations. *Schools and Society: A Sociological Approach to Education*, 217–225.

Miles, M. B., Huberman, A. M., & Saldaña, J. (2018). *Qualitative data analysis: A methods sourcebook*. Sage publications.

Mol, A. (1999). Ontological Politics. A Word and Some Questions. *The Sociological Review*, *47*(1_suppl), 74–89. https://doi.org/10.1111/j.1467-954X.1999.tb03483.x

Mol, A. (2002). The body multiple ontology in medical practice. In *The body multiple ontology in medical practice*. Duke University Press; U-M Catalog Search.

National Academies of Sciences, Engineering, and Medicine. (2016). *Science Teachers' Learning: Enhancing Opportunities, Creating Supportive Contexts*. https://doi.org/10.17226/21836

National Academies of Sciences, Engineering, and Medicine. (2021). *Science and Engineering in Preschool Through Elementary Grades: The Brilliance of Children and the Strengths of Educators*. https://doi.org/10.17226/26215

National Research Council. (2011). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. https://doi.org/10.17226/13165

National Research Council. (2013). *Next Generation Science Standards: For States, By States*. https://doi.org/10.17226/18290

Orton, J. D., & Weick, K. E. (1990). Loosely Coupled Systems: A Reconceptualization. *Academy of Management Review*, *15*(2), 203–223. https://doi.org/10.5465/amr.1990.4308154

Peurach, D. J., Cohen, D. K., & Spillane, J. P. (2019). Governments, markets, and instruction: Considerations for cross-national research. *Journal of Educational Administration*, *57*(4), 393–410. https://doi.org/10.1108/JEA-09-2018-0172

Peurach, D. J., Cohen, D. K., Yurkofsky, M. M., & Spillane, J. P. (2019). From Mass Schooling to Education Systems: Changing Patterns in the Organization and Management of Instruction. *Review of Research in Education*, *43*(1), 32–67. https://doi.org/10.3102/0091732X18821131

Peurach, D. J., Foster, A. T., Lyle, A. M., & Seeber, E. R. (2022). Democratizing Educational Innovation and Improvement. *The Foundational Handbook on Improvement Research in Education*, 211.

Peurach, D. J., Lyle, A., Haverly, C., & Foster, A. (2022). Introduction: The Study of System Building for Elementary Science Instruction. *Annual Meeting Program American Educational Research Association*. https://par.nsf.gov/biblio/10327110-introduction-study-system-building-elementary-science-instruction

Peurach, D. J., & Yurkofsky, M. (2018). Organizing and Managing Instruction in US Public School Districts: Considerations for Families, Communities, and States. In *National Education Policy Center*. National Education Policy Center. https://eric.ed.gov/?id=ED591996

Peurach, D. J., Yurkofsky, M. M., Blaushild, N., Sutherland, D. H., & Spillane, J. P. (2020). Analyzing Instructionally Focused Education Systems: Exploring the Coordinated Use of Complementary Frameworks. *Peabody Journal of Education*, *95*(4), 336–355. https://doi.org/10.1080/0161956X.2020.1800172

Postma, D. (2012). Education as Sociomaterial Critique. *Pedagogy, Culture and Society*, *20*, 137–156. https://doi.org/10.1080/14681366.2012.649419

QSR International Pty Ltd. (2018). *NVivo.* In (Version 12) https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home

Riveros, A., & Viczko, M. (2014). The enactment of professional learning policies: Performativity and multiple ontologies. *Discourse: Studies in the Cultural Politics of Education*, *36*, 533–547. https://doi.org/10.1080/01596306.2015.980492

Saldana, J. (2021). The Coding Manual for Qualitative Researchers. *The Coding Manual for Qualitative Researchers*, 1–440.

Sauder, M., & Espeland, W. N. (2009). The Discipline of Rankings: Tight Coupling and Organizational Change. *American Sociological Review*, *74*(1), 63–82. https://doi.org/10.1177/000312240907400104

Schrader, A. & Juelskær, M. (in press). Diffraction.

Schwarz, C., Passmore, C., & Reiser, B. (2017). *Helping Students make Sense of the World through Next Generation Science and Engineering Practices*. NSTA Press.

Singh, P., Heimans, S., & Glasswell, K. (2014). Policy enactment, context and performativity: Ontological politics and researching Australian National Partnership policies. *Journal of Education Policy*, *29*(6), 826–844. https://doi.org/10.1080/02680939.2014.891763

Smith, M. S., & O'Day, J. (1990). Systemic school reform. *Journal of Education Policy*, *5*(5), 233–267. https://doi.org/10.1080/02680939008549074

Spillane, J. P., Blaushild, N. L., Neumerski, C. M., Seelig, J. L., & Peurach, D. J. (2022). Striving for Coherence, Struggling With Incoherence: A Comparative Study of Six Educational Systems Organizing for Instruction. *Educational Evaluation and Policy Analysis*, 01623737221093382. https://doi.org/10.3102/01623737221093382

Spillane, J. P., Seelig, J. L., Blaushild, N. L., Cohen, D. K., & Peurach, D. J. (2019). Educational System Building in a Changing Educational Sector: Environment, Organization, and the Technical Core. *Educational Policy*, *33*(6), 846–881. https://doi.org/10.1177/0895904819866269

Strom, K., & Kayumova, S. (in press). Diffractive Analysis.

Weick, K. E. (1976). Educational Organizations as Loosely Coupled Systems. *Administrative Science Quarterly*, *21*(1), 1–19. https://doi.org/10.2307/2391875

Yin, R. K. (2014). *Case study research: Design and methods* (Fifth edition.). SAGE.