

Curriculum Materials Adoption Processes: Teacher Learning in an Organizational Routine

Christa Haverly¹, Emily Seeber², Elizabeth A. Davis², James P. Spillane¹, and Angela Lyle²

¹Northwestern University

²University of Michigan

Author Note

This paper was prepared for the NARST 2022 International Conference in Vancouver, British Columbia.

This research is funded by the National Science Foundation through an ECR: Core Award grant number DRL-1761057 to Spillane, Peurach, and Davis. However, any opinions, findings, and conclusions or recommendations expressed here are those of the authors. We have no conflicts of interest to disclose.

Correspondence concerning this article should be addressed to Christa Haverly, School of Education and Social Policy at Northwestern University, 2120 Campus Drive, Room 238, Evanston IL 60208. Email: christa.haverly@northwestern.edu

Introduction

Elementary science education has the potential to pique children's natural curiosities about their world, promote scientific literacy, and foster positive science identity development for young students to help them thrive in and improve the world around them (Brown, 2017; Eshach & Fried, 2005). Yet elementary teachers may avoid teaching science or may do so in ways that emphasize exciting activities or vocabulary development over sensemaking and the development of interest and identity as science knowers, doers, and critics. One route to addressing this challenge is through professional learning experiences for elementary teachers to improve their science teaching. Unfortunately, professional learning opportunities for elementary science teachers are rare (Smith, 2020). Thus, it is all the more important to reconceptualize and reimagine when and where teacher learning takes place. This study takes a close look at an organizational routine in three districts as they embarked on a process of adopting elementary science curriculum materials. Stakeholders across the districts were included in these processes, and they occur routinely every year in different subject areas. In this paper, we argue that there may be untapped opportunities within this organizational routine to facilitate teacher learning about elementary science instruction.

Theoretical Framework: Organizational Routines as Boundary Practices to Support Teacher Learning and Development

We are particularly interested in exploring what happens when teachers are involved in instructional reform decisions, with a keen eye on their learning within this process. We explore this phenomenon through the study of three case study school districts' curriculum materials adoption processes (CMAPs). We conceptualize CMAPs as organizational structures that draw stakeholders into formal discussions about which curriculum materials will be adopted by the district in specific subject areas, with the CMAP members' advice acting as a key part of the district's final decision.

Organizational Routines as Professional Learning Opportunities

To understand the role that the CMAPs play within each of our case study districts, we use the construct of an *organizational routine*. An organizational routine is "a repetitive, recognizable pattern of interdependent actions involving multiple actors" (Feldman & Pentland, 2003, p. 95). These routines can frame and focus interactions—promoting coordinated action, routinizing practice, and storing organizational experiences—but they can also act to promote ideological conformity as a means of legitimizing and reproducing the status quo (Spillane et al., 2011). Despite this, organizational routines can shift participants' ideas about schooling or instruction, suggesting possibilities for teacher learning and shifts in instructional beliefs within these routines (Sherer & Spillane, 2011; Spillane et al., 2011). Viewed from this perspective,

organizational routines can institutionalize either de-professionalization or learning: a key question then becomes how to eschew the former and promote the latter.

Formal professional learning opportunities are traditionally characterized as being (1) designed to promote a particular change or shift for teachers, (2) multi day experiences often outside of the classroom or school building, (3) supported with ongoing learning opportunities during the school year, and (4) finite in duration (The National Academies of Sciences, Engineering, and Medicine; NASEM, 2015). However, there are opportunities for teacher learning outside of the traditional ones defined above. These opportunities are more likely to occur as teachers work collaboratively in schools (NASEM, 2015), such as in professional learning community (PLC) structures and arrangements (Bryk et al., 1999).

While PLCs can play a powerful role in teacher learning, access to science-focused PLCs is relatively rare for elementary teachers (Smith, 2020). Moreover, the kinds of unstructured learning that take place in soft spaces in schools, for example in teachers' lounges (Hammersley, 1984; Mawhinney, 2010; McNicholl et al., 2013), may be limited for informal learning about science teaching given that many elementary teachers do not think of themselves as expert or capable in science and science teaching (Haverly, 2017; Smith, 2020; Spillane, 2005). For these reasons, we focus our attention on the possibility of an organizational routine, in this case CMAPs, as a potential non-traditional opportunity for teachers' professional learning. We focus in particular on the resources brought to bear in the routine, the interactions between community members or actors, and the facilitation of the routine.

Boundary Practices

To understand the learning that may take place within our case study districts' curriculum materials adoption processes (CMAPs), we leverage the sociocultural learning theory describing boundary practices. We theorize that CMAPs are organizational routines that serve as boundary practices and, as a result, promote teachers' learning.

When individuals work in their localized groups, they develop shared repertoires of practice and histories of learning which become a source of discontinuity, or a boundary, between their community and others (Wenger, 1998). These boundaries are not impermeable: people and objects can mediate discontinuities by operating across practices. When ongoing encounters that cross boundaries—such as between teachers working in different schools or grade levels—become routine, a *boundary practice* may emerge. Social engagement in a boundary practice sustains the connections across practices and results in shared learning for the participants by “addressing conflict, reconciling perspectives, and finding resolutions” (Wenger, 1998, p. 114). In our study of CMAPs as boundary practices, we are interested in teachers' learning and development, including their growth in knowledge about science teaching as well as their growth within their professional roles.

One mechanism for teacher learning within boundary practices is engagement with boundary objects. *Boundary objects* are material or immaterial objects that import meanings, function from one context to another, and are intended to communicate key aspects of a practice

across boundaries (Wenger, 1998). Boundary objects work by allowing for coordination across multiple perspectives, with four different mechanisms supporting this coordination. The first mechanism is *modularity* whereby the content of the object is heterogeneous, allowing different individuals' perspectives to attend to different aspects of the object, such as a comprehensive course guide in which students can attend to the sections they find relevant. The second mechanism is *abstraction* in which any aspects of the object that are particular to any one perspective are removed. An example might be an index of student investigations for a topic, with the standards linked, and features like time needed, apparatus required, or pedagogical considerations removed. Wenger's third mechanism is *accommodation* in which the same boundary object is used for different activities. For example, curriculum materials themselves can both facilitate student learning in a classroom as well as support teacher learning of science content. Finally, the fourth mechanism is *standardization* wherein the information within a boundary object is constructed in a pre-specified or scaffolded format so that it can be used in various local contexts, such as a district lesson plan template used across topics and disciplines.

Boundary practices draw in individuals with different experiences and bodies of knowledge to work collectively on a task (Stein & Coburn, 2008; Wenger, 1998); in the case of a CMAP, this involves vetting and selecting curriculum materials. Those individuals may be thought of as *boundary spanners*, bringing repertoires of practice and knowing from their own teams and areas of expertise to the task, and also serving as trusted members of their own school and classroom communities.

Teacher Learning

The act of teaching is multidimensional, drawing on a wide range of “knowledge, skills, competencies, habits of mind, and beliefs” (NASEM, 2015, p. 95). If a goal of district or science education leaders is for teachers to use curriculum materials to provide ongoing, relevant, conceptually coherent learning experiences for students, teacher learning must encompass not only improving teachers' pedagogical content knowledge, content knowledge, curricular knowledge, and knowledge and skills to support diverse learners (Ball & Cohen, 1999; Ball et al., 2008; Johnson & Cotterman, 2015; Moore Mensah, 2013; Shulman, 1987), it must also include, for example, shifting teachers' beliefs about their practices (Pajares, 1992; Spillane et al., 2018).

Nurturing and sustaining teacher leadership is also key for the success of instructional reform efforts. We conceptualize teacher leaders as having knowledge, responsibility, and agency in relation to their work (Donnelly & Jenkins, 2001; Ryder, 2015). As instructional reforms arise, teachers' leadership opportunities and professionalism are sometimes diminished and their autonomy constricted (Masuda, 2010). Yet teachers' engagement in decision-making around instructional reforms may instead ensure collective commitment to, and responsibility for, enacting the reforms (Banilower et al., 2007; Enfield et al., 2008; Hewson et al., 2001).

In sum, in this paper, we investigate how the CMAPs, as an organizational routine in our case study districts, served as a boundary practice for implementing curriculum reform in three

school districts. We are particularly interested in the teacher learning that occurred among the boundary spanners involved in the CMAPs both with regards to teaching science and also their professionalization as key members and teacher leaders of a consequential decision-making process. To this end, our study attempts to answer the following research questions:

- What shifts in teachers' knowledge and beliefs about science teaching, and in their professional identities, if any, did teachers experience as a result of their interactions in the CMAPs?
- Which aspects of the CMAP organizational routines (e.g., resources, community, and facilitation) enabled and constrained teachers' interactions and how?

Methods

Study Design

This study sits within a five year National Science Foundation project investigating the ways districts and schools are developing and coordinating as instructionally-focused systems as they attempt to improve elementary science instruction. While the larger study operates across 13 school districts across the United States, for this paper we utilize comparative case study design (Yin, 2014), to focus on three school districts that serve as our cases. These districts were chosen as each had regular committee meetings for their Curriculum Materials Adoption Processes and, as such, each represented 'an instance in action' (Adelman et al., 1980) which could be richly described through (virtual) observations and interviews (Geertz, 1973; Robson, 2002). It is through attentiveness to the context, complexity, and social reality inherent in case study design that we are able to capture both (a) evidence of participants' learning *in situ* as their discourse shifts over time, and (b) how participants interpret their lived experiences as learners from, and contributors to, the CMAPs.

Context

Our three focal districts are all located in Oklahoma. Using a snowball sampling method, we first identified 18 states across the country as part of the larger study to investigate the policy contexts at the state level around elementary science and its response to the NGSS (Haverly et al., in press). We then selected three states from the 18 that we determined had a policy context that (a) could be favorable to system-building efforts at the district level around elementary science, and (b) had interesting analytic and demographic variation. We focus here on one of these states, Oklahoma, because textbook adoption committees are legislated (<https://oktextbooks.ok.gov/timeline.html>) and thus this state provides an interesting case for examining curriculum adoption as an organizational routine.

We continued our snowball sampling to select three case study districts in each state. We contacted science education experts to recommend contact people for us in Oklahoma. Those Oklahoma contacts nominated candidate districts that were doing interesting system-building work in elementary science and also put us in touch with additional state contacts. We continued contacting as many Oklahoma-based contacts as we could, and received 26 total district

recommendations. From there, we researched what we could about districts' elementary science programs from their websites, and we reached out to district science leaders to talk further about their program designs. In making school district selections, we attempted to identify variation according to the size of the district, its urbanicity, student demographics, and approaches to improving elementary science teaching. Our recruitment process carried into the start of the COVID-19 pandemic, so our selection was also determined by which districts had the bandwidth to participate in our research.

In the state of Oklahoma, legislation exists that requires school districts to cyclically engage in committee processes to update their 'textbooks'. We refer to the processes textbook adoption committees undertake as curriculum materials adoption processes, or CMAPs. Each year after updating the state standards in a given subject area, the Oklahoma Department of Education releases a list of curated curriculum materials. CMAP committees meet to review their options and make a selection for the district. When school districts select curriculum materials from the list, they are partially subsidized by the Oklahoma Department of Education.

Each district in this study organized a committee to review curriculum materials with the use of an evaluation rubric. These rubrics were similar across districts, but were co-created by committee members, thus resulting in some localized differences. The committees used those rubrics to narrow down to a selection of three or four curriculum material packages for teachers across the district to review, making use of the same rubric. At the end of each district's process, the committee made a recommendation of what curriculum materials the district should adopt. How the committees were formed and facilitated and their timelines for meeting and decision-making were different in each district.

In Jasper, a mid-sized suburban district, committees were formed across elementary, middle, and high school grades. Across the elementary schools in Jasper, principals were tasked with identifying representatives from different grade levels and specialties (e.g., English Language Development, or ELD, Specialists) to sit on the committee in addition to active parents. Thus, the elementary committee was composed of parents, teachers, administrators, and teaching and learning specialists (who are generalists), for a total of 35 individuals. The committee's first meeting was held in October 2020, with its final meeting in May 2021. All meetings were held virtually on Google Meets with the exception of the final May 2021 meeting. Jasper's teachers' reviews and recommendations were brought directly to the smaller official textbook adoption committee composed in part of select representatives from the elementary committee, and Twig was selected as the new K-4 curriculum for Jasper.

In Norhaven, another mid-sized suburban district, there is a standing Elementary Science Advisory Board composed of 33 classroom teachers from across the district. This Board turned its attention towards the curriculum adoption process in November of 2020, wrapping up with its final meeting in May 2021, all held virtually on Zoom. Similar to Jasper, Norhaven teachers' curriculum recommendations were reviewed by the smaller official textbook adoption committee. Though Twig was slightly preferred by teachers in Norhaven as well, the committee decided to adopt Amplify for K-5, a close second-place choice, to be more budget conscious.

In Chester Public Schools, a large urban district, the elementary and secondary district science coordinators hand selected teachers from the district with interest and expertise in science teaching across grade levels and specialties, as well as elementary, middle, and high school principals. The elementary committee was composed of seven individuals. The committee formed and had its first meeting in January 2021 and its final meeting in March 2021. All meetings were held virtually on Zoom. After reviewing Chester's teachers' survey results in response to the top three curriculum materials, the larger committee met to deliberate between the top two contenders. They recommended Twig to Chester's official textbook adoption committee, and Chester formally adopted Twig for PK-4. Table 1 summarizes each district's approach.

Table 1

CMAP Committees in Jasper, Norhaven, and Chester

	Form and formation of committee	Members of committee	Timing	Selection
Jasper	Elementary CMAP committee, principal-selected according to distributed representation	35 parents, elementary teachers, administrators, and specialists	Oct. 2020 - May 2021; mostly virtual	Twig for K-4
Norhaven	Standing Elementary Science Advisory Board repurposed as CMAP	33 elementary teachers	Nov. 2020 - May 2021; virtual	Amplify for K-5
Chester	Elementary CMAP committee, district science coordinator-selected according to expertise and engagement	4 elementary teachers, 1 principal, 1 reading interventionist, and 1 emergent multilingual specialist	Jan. 2021 - March 2021; virtual	Twig for PK-4

Data Collection

We draw on two main sources of data. Firstly, the first author virtually attended 14 committee meetings across the three case study CMAPs (representing nearly all committee meetings), observing both whole group and small breakout group sessions. While recognizing transcription is a "social, political and ideological" representational act (Jaffe, 2007, p. 831) which leverages our power as researchers and observers to shape the narrative of the event, the first author transcribed the dialogue occurring during the meetings as closely as possible. Individuals were identified by initials to maintain anonymity while allowing for tracing of individual participants' recorded contributions over time. After each meeting, the author recorded fieldnotes and added to an analytic memo on the school district. Additionally, materials shared within the meetings were collected both to contextualize the transcripts, and to broaden

the representation of the events. For the purposes of this paper, we have further anonymized committee members' initials with pseudonyms, though we can offer little other information about these committee members as we did not interview most of them.

Secondly, the first two authors recruited and interviewed two teacher participants from each CMAP committee in addition to the facilitator. For our committee member sampling, we wanted to talk to one committee member who was either identified as a strong advocate for elementary science and/or an experienced elementary science teacher. We also wanted to talk to one committee member who met neither of those criteria. We asked for recommendations from each district facilitator, and after some difficulty making contact with each recommended committee member (given how exhausted teachers were at the end of the 2020-21 school year), ended up with a group of participants who predominantly met the first set of criteria. Table 2 shows the roles of the participants within each of the three districts. The authors conducted 45-minute virtual semi-structured interviews which were transcribed and cleaned for data analysis. After each interview, the authors wrote up fieldnotes, and added to ongoing analytic memos.

Table 2

Interview Participants

District	Pseudonym	Position	Years in District
Jasper	Trinity (facilitator)	Executive Director of Teaching and Learning	30+
	Wilma	ELD Specialist, second-grade representative	14
	Mary	Fourth-grade Dual Language Teacher	11
Norhaven	Keith (facilitator)	K-12 Science Coordinator	30
	Sam	Second-grade Teacher	1
	Tori	Second-grade Teacher	17
Chester	Breanna (facilitator)	Elementary Science Curriculum Coordinator	6
	Olive	First-grade Teacher	9
	Sofia	Reading Interventionist, second-grade representative	8

Note. Other pseudonyms used in the paper are of committee members who were not interviewed but were observed in the committee meetings

The purpose of the teacher interviews was for participants to reflect on their experiences as learners, contributors, and professionals throughout the CMAP process. The facilitator was further asked about their particular role within the CMAPs, including discussing tensions they managed and lessons they learned from the process which developed both their knowledge as teacher leaders within the districts and their perceptions of the efficacy of the CMAPs as organizational routines. Furthermore, we used this opportunity to member-check emergent findings from observations of the CMAP meetings. This allowed for a revisiting, and re-rendering of the narratives when participants' recollections did not align with our inherently imperfect initial representation, aiming for responsibility where we could not attain neutrality (Bucholtz, 2000).

Data Analysis

We used an iterative process of open coding to code both the interviews and the fieldnotes (Saldaña, 2016) using NVivo (QSR International Pty Ltd, 2018). For the interviews, a set of codes was developed by the first and second author as we read a subset of the interviews, which both emerged from the data, and were shaped by our preliminary thinking around organizational routines and boundary practices. We then refined this coding scheme before coding the rest of the interviews, adding new codes as required, discussing these, and re-coding interview data.

For the fieldnotes, we open coded transcripts with a particular focus on the content participants were attending to in their interactions, and the material resources which played a role in the interactions. This process was also iterative, as we moved between fieldnotes and the coding scheme.

Findings

Through interactional analyses of 14 committee meeting observations paired with open analyses of interview transcripts with six committee participants and three CMAP facilitators, we found evidence of teacher learning that varied according to different dimensions of teaching (e.g., what to teach, how to teach, and so on) as well as dimensions of teacher leadership (e.g., how to enact change). Their learning seemed to be shaped by how the CMAP routines were organized and how boundary objects were taken up by members.

First, in the case of Jasper, disagreement among committee members about whether or not to purchase the student workbooks (a boundary object) that came with Twig triggered new learning for teacher participants about the pedagogical use of their science notebooks, as did exploring a set of carefully curated articles about science teaching. Second, in the case of Norhaven, the evaluation rubric appeared to prompt careful review of curriculum materials, with both rubric and materials serving as key boundary objects influencing teacher learning about new ways to teach science. Finally, in the case of Chester, CMAP participants—who were selected for

their comfort and expertise in science education—learned less about science teaching (in contrast to the other two cases) and more about being a teacher leader and the process of change through their engagement with curriculum materials across contexts and vendors. The curriculum materials here, too, served as key boundary objects for this learning. We organize our findings around each of our three case study districts, highlighting key learning moments in each and signaling the interactions and boundary objects that appeared to support that learning.

Jasper

In Jasper, we found multiple sources of evidence of teacher learning about how to teach science as a result of their participation on the CMAP committee. Our data shows that teacher learning was facilitated by boundary objects and occurred through discourse with other members of the committee around those boundary objects. Here we illustrate two key examples that surfaced in the data.

The first example centers on teachers' discussions in their first committee meeting around a set of readings that they were given on best practices in science teaching. The CMAP facilitator, Trinity, who is the Executive Director of Teaching and Learning for Jasper, purposely selected a set of articles about science instruction as a tool for facilitating discourse between teachers from different schools and grade levels. As Trinity selected the readings for this first committee meeting, she intentionally omitted readings on integrating science and literacy in an attempt to keep the focus on the doing of science rather than reading about science. The articles she selected largely originated from NSTA publications, including their practitioner journals and position statements. This decision impacted the discourse and decision-making with regards to the evaluation rubric in the breakout group we observed.

Each committee member selected two articles to read in advance of the first committee meeting. These articles provided a focal point for committee members to dialogue across PK-12 in small breakout groups, and identify ways in which their work was linked, building a common discourse. As an early childhood specialist, Meredith chose an NSTA early childhood science education article and shared with the group: "We talk a lot about it at this age, discovery play. That sums up what we know at this age. They're capable of a lot of things. ..." Tonya, an elementary special education teacher, followed on:

I agree with everything you just said. The little ones are always so curious. My thing was just to put out materials and let them explore. The article went along with that and was called 'What did you notice?' That talked about the teacher's role and that it's not a close-ended answer. They get a chance to explore and share what they learned. 'Tell me what you noticed'. There's no pressure on them when you use that phrase.

A high school teacher (Bobby) then contributed how this linked to the article they had read which contained recommendations for science teaching:

A 2-page list of what to do more of and what to do less of. A lot of the things to do more of, are things we've been trending towards in the last 10 years. No longer sage on the stage but interacting with students. I love what you've said about early childhood, doing some of the same in high schools. What do you see, what do you notice? It's really the same, nice to see. Separate science knowledge from science process. More of 'here's how you need to think' and not 'what you need to understand'.

Even though the boundary object—that is, the set of articles to select from—was experienced differently by those who selected different articles, it still facilitated productive cross talk between teachers as they learned about how science is taught at different levels within the district. This discourse was then leveraged in the revision of the district's science instructional vision statement and the construction of the CMAP evaluation rubric. One group member suggested removing the “need[s] to integrate literacy and have explicit strategies for reading” from the provisional curriculum material evaluation rubric because they did not want literacy resources to be a “driving factor” (Meredith) in curriculum materials selection. The group facilitator, a teaching and learning specialist, agreed to remove it “since that's not something that came out in our research [the set of articles]”.

Our second example of pedagogical learning in Jasper came from our interviews, as both teachers reported learning new things about their use of science notebooks as a result of their participation on the CMAP committee. For example, Mary shared:

I will say that the committee added value to the way that I did my science notebooking. I have taught fourth grade for a number of years, but it's always been in our teachers' guide, “Here's the question that you have them put in their science notebook. Here's the answer.” That's what I've always done even though that's not necessarily how I teach my science.... Through this process and even just listening to other teachers, a lot of it was having students do their science notebook how they wanted to do their science notebooks. You still give 'em that guiding question, but it's not that open-ended, black-and-white question and letting them walk you through what they did and letting them decide what exactly they wanna put in their science notebook from the experiment that we did, which I thought was mind blowing, but it totally made sense 'cause I'm here.

We see evidence of this learning emerging from teachers' engagement in debate about whether or not to adopt the student workbook as part of the Twig adoption. Jasper has for over a decade supplied students with science notebooks with the expectation that these are a central feature of their science curriculum. The only common assessment in Jasper for science has for some time been a rubric for assessing student work and progress in their science notebooks. As such, the decision to consider adopting the Twig student workbook to replace the Jasper science notebook triggered much discussion and deliberation in the final committee meeting. We were

not invited to this meeting so that committee members could deliberate without concern of being observed for research. However, we did hear about these deliberations in our interviews.

As long as I have been teaching there, I think we've never had a workbook. Science notebooking has always been something that the district has really encouraged. We found that it was a very split decision on whether or not to purchase the workbooks. We decided after a long meeting and lots of back and forth thing, no yelling, but just like, "Yeah. Did you think about this? But did you think about that?" and how different it looked at each grade level, it was nice. There were some grade levels that were like, "Absolutely. We need the work book." There were some grade levels that were like, "No. We don't know." We discovered at the end of the meeting, that one, we would not go with the workbook and two, we, as a district, particularly at the elementary level, discovered that we have not done enough training in that grade. (Wilma)

These deliberations, of course, centered around a key boundary object - the Twig student workbook. The following is more from Wilma about how the workbook supported learning in the Jasper CMAP:

The [Twig] workbook is beautiful and the workbook has passages that you can have the kids read. That's supplemental reading pieces and it has beautiful charts to fill out. ... we've never had a workbook. Science notebooking has always been something that the district has really encouraged. We found that it was a very split decision on whether or not to purchase the workbooks. ... I went in with all of my teachers going, 'Yeah, that workbook is incredible. We want that workbook. That's a huge important piece to this [curriculum]'.... Then I left thinking, 'You're right. You're right. We don't need the workbook. We need more training in how to science notebook,' because once everyone started talking about it, what we discovered was that when you have the workbooks, sometimes it just squashes a lot of that thinking that [students are] having. It boxes them in rather than allowing them to think freely and observe freely and document their thing... We decided we're, 'Workbook out, science notebook in,' but we really need a lot more [professional development] in that area in how to do it and how to get the most out of science notebooking, so huge discovery there.

In this example, the group used the Twig Student Workbook as a boundary object to clarify their collective vision for science instruction and identify their continued learning needs with more specificity.

Norhaven

In Norhaven, both teacher participants reported new learning about elementary science teaching, including how they want to organize their science teaching moving forward and how to

teach science. This learning appeared to be influenced by both the curriculum materials they were reviewing as well as the evaluation rubric they used in their review.

At the beginning of the CMAP process in Norhaven, as second-grade teachers were reviewing the evaluation rubric for science curriculum materials in a small breakout group, it was clear that they lacked confidence using the 3D science standards from the NGSS.

Sam: So what's the disciplinary core idea?

Tori: That's the content. Kathryn, what would be a good example in second grade?

Crosscutting is cause and effect. OK, I'm pulling it up. I can't remember. See, I should know this.

These teachers recognized that if they could not readily explain the 3D standards, their colleagues who are not on the CMAP committee would struggle as well when it was their turn to use this rubric. One participant, Tori, who had contributed to writing the district's current curriculum materials 6 years prior when the adoption committee had determined that there were no adequate materials available on the market for purchase, returned to her current lesson plans as a boundary object to (re-)learn about the standards. She provisionally defined disciplinary core ideas, crosscutting concepts, and science and engineering practices.

Ok, disciplinary core ideas, 'Earth events, the history of planet earth' is one of the ones that comes up. And, the crosscutting concepts is 'stability and change', and science and engineering practices is 'construct explanations'. So, each lesson plan has it at the very end of the paper copy that kind of explains it, but I guarantee you no one is looking at that part.

In this way the lesson plans as boundary objects facilitated teacher learning about the standards. This is something Keith, the district science coordinator, hoped teachers would learn as part of the CMAP process, recognizing that elementary teachers' familiarity with standards across all the content areas was an ongoing challenge, as he shared in his interview:

My hope always is that [teachers] become more familiar with their standards because when you talk with an elementary teacher, they are responsible for the ELA standards and social studies standards, the math standards, the science standards. All of those look a little different, and in my mind, the science standards are probably the most complex of any of the standards. The understanding of, what content am I teaching? How do I incorporate the crosscutting concepts? What am I looking for when I'm looking for a curriculum that incorporates the crosscutting concepts and the science and engineering practices?

As previously stated, learning occurred as Tori and her second-grade colleagues were reviewing and offering feedback on the evaluation rubric for curriculum materials. They then asked Keith to include links to the standards on the next iteration of the rubric which teachers in schools would use. As such, the evaluation rubric, as another boundary object, was both created within the organizational routine and for it. Keith, the district science coordinator, described the rubric, sharing, “I think that we have really identified the important pieces of a science curriculum to us. ... the critical pieces of a guaranteed and viable curriculum. I think we really defined what that means.”

This shared set of criteria then supported the committee members in their appraisal of the curriculum materials, as Tori noted in her interview: “We had a set of things that we were looking for the district, which was way beyond I think what I have ever had to look at for any curriculum. It made me think beyond that, typically when I'm looking at a curriculum. ” This careful review of materials, with the help of the rubric as a boundary object, seems to have impacted Tori and Sam’s learning about elementary science teaching.

Sam’s learning was around instruction, and her time on this committee got her thinking about new ways she wants to teach science moving forward. Her learning was rooted in deficit beliefs about her students, an indicator that neither her participation in the CMAP nor her review of curriculum materials had helped her identify more asset-based perspectives on her students. That being said, she shared that one of the curricula that she reviewed had a “big focus on careers in the science field.”

I love that because I feel, definitely, our students, specifically, at my site are so—they don’t have a world view. They don’t go on vacations outta town, really. It’s so limited, and I just want to expose them to more of what are the career options out there. That was something that, through the process of the adoption and seeing other ideas out there made me—stick these things away and say, “Well, next year, well, I’m gonna do this, and next year I’m gonna do that.” Whether or not it’s included, I think that I’m going to look for things like that.

Tori similarly learned new things about teaching science. In particular, the background knowledge sections of the curriculum materials she reviewed seemed to impact her thinking.

I really did learn other ways to teach the standards. To stretch and have a different thought process, because it also did provide background knowledge; even while I'm going through and looking at what would they do for teachers, I was learning even just from some of those background knowledges on some of the curriculums.

For both Tori and Sam, the process of reviewing the curriculum materials from multiple vendors exposed them to new ideas about and strategies for teaching science; the curriculum materials served as a boundary object for this learning. As well, their design and use of the

evaluation rubric as a boundary object prompted them to dive deeper into the standards and the curriculum materials themselves.

Chester

In contrast with Jasper and Norhaven, we found no evidence of teacher learning with regards to science teaching from the teachers we interviewed in Chester—that is, these teachers did not seem to develop new knowledge for teaching science. Rather, both reported new learning related to their charge of being teacher leaders and the process of supporting curriculum change. First, we offer a possible explanation for why the Chester teachers diverged from those in Jasper and Norhaven when it came to their knowledge for science teaching. Second, we present evidence of their learning related to teacher leadership.

With regards to their science teaching, both teachers reported that their participation on the committee validated their previously held ideas about how best to teach elementary science. This may be explained by teachers' positioning on the committee—having been hand-selected by Breanna, the district science coordinator, according to who she knew she could work well with and the varying expertise that folks would bring to the table. This selection process was made explicit by Breanna in committee meetings.

For example, as the committee members engaged with the curriculum materials, they drew on their different perspectives and areas of expertise as they attended to different aspects of the curriculum materials (e.g., the teacher's guides, supports for emergent multilingual learners, student-facing videos, and so on) as boundary objects. During one of the committee meetings, Kendall noticed inconsistencies in vocabulary around scientific investigations:

that was something I was looking for. Theirs seemed too much, and they don't seem to use the same words all the time. No 'wonder', 'investigate,' 'activity'. It seemed flexible and not consistent.

Breanna, the district elementary science coordinator, responded that the committee was set up to exploit these differences in perspective and support the learning of less experienced teachers: "That's why we chose who was on this committee. For what you're looking for, but also to mentor the new teachers coming on who don't have those tricks." Sofia internalized this positioning by recognizing the expertise that she brought to the group, as she shared in her interview: "I was the one representative of second grade. To get picked for that position, it made me realize I gotta be knowledgeable in some area to be that representation."

Because committee members who were selected to serve on Chester's committee were more likely to already have instructional visions more closely in line with the Framework and NGSS, they may have been less likely to notice significant shifts in their thinking about science teaching and learning. However, both teachers in this district did report learning more about the process of curriculum adoption itself, which we are describing as learning about teacher

leadership and the process of change in an educational system. For example, Olive reported learning how different and how similar various elementary science curricula can be.

Oh, well, this is how this one is set up, and this is how this one is set up. They're basically the same, but I like the placement of this one slightly better because it makes more sense for a newbie teacher.

She also shared that she learned about differences both between what districts might be looking for in curriculum products based on their size and budget constraints, as well as what teachers might be looking for in curriculum materials, saying: "It's hard to adopt a curriculum when you have so many teachers who are looking for different things."

For Sofia, her learning from the process was rooted in recognizing that curriculum vendors are looking to make a profit. Chester's evaluation rubric helped Sofia to get beyond the 'sales pitches' from the curriculum vendors to learn about the materials:

I learned that it's not an easy task being a textbook committee. Their job [the vendors] is to make a profit, to get their stuff sold. It's a sale, you've got to really dissect it. I like having tools like a rubric and knowing your end in mind really helps you objectively look at things and not just be like, 'I like this because it's pretty.' It's because it has what we're looking for and this and having that before we went in, was very helpful.

As an example of how the rubric was utilized, in the final CMAP meeting, Sofia and her colleagues drew on the rubric to interrogate the curriculum materials, taking part in coding the feedback from district teachers on the two top-ranked sets of curriculum materials. In this way, the rubric served as yet another boundary object—one that was used to gather together and analyze evidence provided from multiple teachers' perspectives.

A key challenge experienced by the committee in Chester surfaced when one set of curriculum materials was selected by middle school science teachers as a clear top choice (Inspire Science), and another set surfaced as top choice for elementary (Twig) with Inspire Science as a close runner up. Committee members were left needing to determine the relative importance of having the same curriculum for elementary and middle grades to allow for continuity, or to pursue the curriculum that was the top choice of elementary teachers across the district. Breanna posed the following question to committee members after they had finished their coding:

Is it worth picking Twig when we can have K-8 be the same? Let's look at the highlights of Twig. Gather your thoughts, getting Twig, would it be worth getting Twig for elementary? Is it worth that to not have the K-8 experience?

With Breanna in the breakout room, the teachers responded with a discussion about the proportion of students who leave the district after elementary. Olive suggested “a lot of Chester parents are okay with them going to elementary school, but then when they get to middle school, they go to charters,” and Taylor resolved, “if you look at the statistics, you do see big drop off moving from 5th to 6th, but higher percentage stays with us than don’t.” Breanna encouraged the group to use the rubric to look again at Twig, but was then required to leave the breakout room, and the tone of the conversation shifted dramatically.

Okay, I’m saying it. The standards have the built-in progressions. The curriculum is how we’re teaching it. How we’re teaching it in Pre-K and K matters. If we have a curriculum that we know is good, that’s how we should go. How we teach it in PK-4 is important for them going to middle school. And we buy a new curriculum every 4 years. (Tess)

The teachers stopped using the rubric for evaluating Twig, and instead had a wide-ranging discussion, pointing out the many things they felt were better about Twig, particularly its academic vocabulary development, that it was “more interesting, engaging” (Nancy), “easier for teachers to use” (Fernanda), and met the standards more comprehensively than the other curriculum materials for elementary. On Breanna’s return Carey summarized the group’s resolution, “it was very, very, very pro Twig”. When Breanna asked why, Olive responded

[Twig is] better geared toward littles. If we set that foundation of this is how you teach science, this is how you learn science, teach academic vocabulary at the very beginning of science. When they go on, they’re better prepared for middle school curriculum.

In the moment, without Breanna present, the group was able to step beyond the limitations of the evaluation rubric and discourse about why consistency in curriculum materials might or might not matter for learning science, and then, having built solidarity about the best choice for the district, were able to share their collective learning.

For Sofia and Olive, there were important learning outcomes from this process for their professionalization in the district. They were positioned as experts with valuable perspectives to share, and their engagement with multiple boundary objects serving multiple purposes triggered learning for them about the otherwise perhaps abstracted routine of selecting curriculum materials.

Discussion and Conclusion

Teaching is not a monolithic practice, and as such, neither is teacher learning. Teachers’ professional learning must cover quite a bit of ground in order to aid in the development of their professional practice: pedagogical content knowledge, content knowledge, knowledge of students, beliefs about science, beliefs about students, and identities as science teachers (and/or

as science leaders) to name a few. Given the lack of formal opportunities for elementary teachers to learn about science teaching in their professional practice, we became interested in the opportunities for teacher learning within the organizational routine of selecting new curriculum materials. In this paper, we analyzed data from three case study districts' curriculum materials adoption processes in order to uncover (a) what teachers learned as a result of participating on these committees, and (b) what aspects of the CMAPs as organizational routines appeared to facilitate their learning. Across our cases, we see evidence of teachers learning about how to teach science and what to teach in science class, as well as evidence of increased understandings of science content and the process of enacting change. This learning appeared to be mediated by a few key events and mechanisms: (a) points of contention that arose within the committee that members needed to resolve, (b) the boundary objects that were utilized on each committee and their effects on committee members' interactions, (c) facilitation techniques—both planned and unplanned—that impacted committee members' interactions, and (d) the manner in which committee members were selected for the committees in the first place. We organize our discussion section according to these themes that surfaced in the data.

CMAP Committee Members' Sense-Making During Points of Contention

Two points of contention surfaced in our case studies that appeared to give rise to important moments of sense-making and learning for teacher participants. The first occurred in Jasper at the end of the CMAP when committee members debated whether or not to purchase the student workbook that comes along with the Twig curriculum. The committee decided to continue using and improving their use of science notebooks with students in elementary science. Both teachers that we interviewed identified learning new things about how to use their science notebooks with students that appeared to be precipitated by the conversations from this debate. The second point of contention occurred in Chester, also at the end of the CMAP, when elementary committee members were tasked with deciding whether to adopt their first-choice curriculum, Twig, or to adopt their second-choice curriculum that was from the same vendor as the top choice for middle school. The committee decided to go with Twig and offered rich justifications that elaborated on the purposes of standards, curriculum materials, and elementary science including references to young students' experiences as science learners and reticent elementary teachers' use of science curriculum materials. The development of ideas through this conversation in the final meeting showcased collective sense-making on the part of the elementary committee members around these central issues.

That these two instances of learning and sense-making were sparked by debates is well supported in sense-making literature that describes points of uncertainty, ambiguity, and incoherence as key moments for teachers and teacher educators to lean into for the promotion of teacher learning (Allen & Heredia, 2021; Allen & Penuel, 2015; Heredia, 2020; Weick, 1995). Furthermore, a central purpose of boundary practices writ large is indeed to resolve such points of contention (Wenger, 1998). Thus, our data illustrates the utility of CMAP committees, particularly when there are points of contention, as fertile ground for coming to resolution

through negotiation—and through that negotiation, participants will likely come away having learned something new.

Forms of Boundary Objects and their Effects on Interactions and Teacher Learning

Across our three districts, we can see boundary objects functioning to support teacher learning, with the four different mechanisms—*modulation*, *abstraction*, *accommodation*, and *standardization* (Wenger, 1998)—featuring at different moments. For the purposes of this discussion, we focus on how boundary objects were repurposed or redesigned and functioned differently to support teacher learning as they were used within the CMAP boundary practices, by tracing interlinked boundary objects in their various forms in Jasper and Norhaven.

In Jasper, a set of articles around science instruction, selected by Trinity, became an important boundary object which shaped the CMAP process. This worked through *modulation*, as different committee members were able to select articles from the boundary object as a whole to attend to. While different committee members working with different grade levels experienced this boundary object differently through their choices, the members engaged in productive cross-talk as they noted similarities in approach across grade levels, deepening their knowledge of the broader science curriculum and the purposes of science instruction (Lee & Luft, 2008). The committee then drew on this knowledge in constructing a district ‘Aim Statement’ for science and repurposing an earlier curriculum material evaluation rubric. In this practice, the group transformed the set of articles into new forms of boundary objects, which *abstracted* features from the articles, deleting detail and context from specific articles to construct a shared vision for science instruction and curriculum materials. In deliberating over terminology, and orders of priority for different pieces, this practice further developed their collective understanding of the ends and purposes of science instruction (Darling-Hammond et al., 2005; Shulman, 1987).

A lesson plan available to the teachers became a critical boundary object for committee members in Norhaven, as they initially struggled to recall the NGSS standards when they were looking at the draft evaluation rubric. In this way, the lesson plan facilitated learning through *accommodation*, as it both supported the teaching of science content, but also learning about science teaching through knowledge of the curriculum (Gess-Newsome, 2015; Magnusson et al., 1999). As the teachers on the committee deepened their knowledge of the standards, they also recognized that teachers in schools would need access to the language of the NGSS so that they could use the evaluation rubric when they analyzed the curriculum materials, and so they linked the NGSS standards to the rubric, which both *standardized* the evaluation rubric so that it could be used locally, and appropriated the NGSS standards themselves into the practice as a new boundary object. Reflecting on the CMAP, Sam and Tori credited their learning to the curriculum materials themselves, but Tori identified the central role that the evaluation rubric played in being able to learn from the curriculum materials, as it allowed her to go deeper in her analysis than previously. In this way, the rubric as an *abstraction* (containing only the core features of an ‘ideal’ elementary science curriculum), played a key role in transforming the

curriculum materials themselves into boundary objects from which the committee members could learn.

In these ways, the curriculum materials, the evaluation rubrics, practitioner-oriented articles, and other artifacts served as boundary objects that worked across a range of mechanisms and connected with each other to support teachers' learning. Given the limited opportunities and strong need for professional learning in elementary science (NASEM, 2021), it is promising that the organizational routine of the CMAP could serve as a learning space in this way.

Facilitation

Facilitation is a key aspect of teacher learning. As might be expected, each district's facilitator brought a different style of facilitation and different facilitation techniques to bear on their CMAPs. We highlight two key moves that our data suggests had particular impacts on committee members' interactions and learning, moving the CMAPs forward in productive ways. We see these moves as examples of how leaders can actively shape CMAP committee members' learning in an otherwise often untapped opportunity for teacher learning, helping these committees become spaces for teacher learning akin to PLCs (Vanblaere & Devos, 2018). One of these moves was made intentionally by the facilitator, and one was incidental.

Firstly, in Jasper, we found evidence that Trinity's decision to select articles for the first CMAP committee meeting that omitted the integration of literacy and science had a direct influence on the observed small group's revisions to the evaluation rubric, wherein they suggested removing a focus on literacy resources in the science curriculum materials as a key indicator of quality. In her facilitator role, Trinity strategically made use of a boundary object—the set of articles—to create a shared vision of science teaching and learning without directly dictating that vision. In other words, her selection of articles shaped the discussion among committee members while still allowing them choice of which articles they preferred to read. Just as teachers need to select resources for children to use with care (Stein et al., 2007), so too do leaders who are facilitating learning opportunities for teachers.

Secondly, in Chester's final CMAP committee meeting, as the elementary committee members were discussing whether or not to adopt Twig given some committee members' desire for a consistent curriculum PK-8, Breanna unexpectedly needed to step away from the breakout room. Before leaving, she directed committee members to continue working through this issue. Upon leaving, committee members found space to talk more openly about Twig, moving beyond the limitations of the boundary object and having a normative discussion about the relative importance of continuity in curriculum materials across grade levels. They spoke at length about what they preferred about Twig and what they understood to be the purpose of elementary science and curriculum adoption, as well the sorts of science experiences they wanted young children to have and the sorts of teaching experiences they wanted novice teachers to have. Breanna's facilitation in this case was important to set up the conversation, but equally important was not having her there in order to make space for ongoing teacher deliberation. Again, just as

teachers need to make space for children's ideas (Haverly et al., 2018), so too do facilitators need to make space for participants' ideas to surface and coalesce.

CMAP Membership Selection

CMAP committee membership was designed differently across districts according to who was selected, by whom, and for what reasons. Our evidence suggests that this CMAP design feature mattered because it influenced the sort of boundary spanning that took place among members of each committee. That said, we also identify trade-offs of the different designs, noting that there may not be one ideal design depending on the goals and interests of CMAP facilitators.

Horizontal versus vertical boundary spanning. The work of vetting and selecting curriculum materials requires developing alignment between members of different schools, specialisms and grade levels through boundary spanning (Stein & Coburn, 2008; Wenger, 1998). Individual members of a boundary practice can act as boundary spanners by brokering between perspectives. In all three districts, boundary spanning was a feature of the practice; however, the different structures of the CMAPs facilitated particular sorts of boundary spanning, with Norhaven predominantly vertical, and Chester predominantly horizontal.

In Norhaven, the standing Elementary Science Advisory Board was repurposed for the work of the CMAP across the school year. While the Advisory Board does bring together teachers from different schools and grade levels, the primary purpose of the routine is to provide a vertical connection between the district office and teachers in schools, with Keith disseminating information 'down' to teachers via the Board, and teachers passing questions and concerns 'up'. In contrast, members of the CMAP in Chester were hand-selected by Breanna to bring specialized knowledge of teaching elementary science, with additional expertise from a principal, reading interventionist, and emergent multilingual specialist. In other words, the boundaries between their own sets of expertise were central to the boundary practice, and boundary spanning worked horizontally across these discontinuities. As such, the committee in Chester was specifically positioned to reconcile their divergent (but expert) perspectives, address internal conflict, and find resolutions with each other. The two districts differed, then, in their boundary spanning structures; these differences led to trade-offs in how they operated.

Trade-offs of different designs. Organizational routines are composed of both ostensive and performative aspects (Feldman & Pentland, 2003; Spillane et al., 2011). Ostensive aspects of organizational routines are the ideal, abstract, and generalized ideas that organize the routines. For example, in our case study districts' CMAPs, the general scope and sequence of the meetings, the meeting agendas, and the intended participatory and democratic structures of the CMAPs are all ostensive features of the organizational routine. Performative aspects of organizational routines are the actions taken by people, in specific places, at specific times. For example, in the data we have presented, the discussions that took place among teachers during committee meetings and the moves facilitators made in orchestrating those discussions are performative aspects of the organizational routine. In considering the affordances and constraints

of different designs for CMAP committee membership selection, we zoom in on an ostensive aspect of the CMAP routine and consider its effects on performative aspects of the routine.

In Chester, where teachers were hand-selected according to their expertise and interest in elementary science, there was unsurprisingly less evidence of teacher learning with regard to their knowledge related to science teaching. Breanna undoubtedly made this ostensive design decision because she wanted individuals on her committee who were seasoned and experts in science and elementary education. Furthermore, it is not as though these teachers learned nothing in the routine as performed—they had important takeaways from the process about teacher leadership and effecting change in school systems (Spillane, 2006). A possible trade-off of this approach is that the selected teachers are likely not representative of the general elementary teacher population across the school district, despite their earnest attempts at boundary spanning. Thus, achieving buy-in from district teachers may prove more challenging during Chester's early implementation phase.

On the contrary, in Jasper and Norhaven, the teacher CMAP committee members more systematically represented schools and grade levels across the districts. As a result, they were less likely to come with the same level of knowledge and expertise in elementary science as would be expected in Chester. Again, these ostensive aspects of the CMAPs were likely intentional for Trinity and Keith—that is, greater representation could very well increase the likelihood of teacher buy-in across the district through the early implementation phases of the new curriculum materials. As well, these teacher participants reported more learning about science teaching than their peers in Chester, a welcomed outcome from the CMAP as performed. A possible trade-off of this approach could be that the committee members making consequential curricular decisions for the district started with less knowledge of the *Framework* and NGSS, in both cases beginning by trying to understand the three dimensions of the science standards (National Research Council, 2012; NGSS Lead States, 2013).

These identified trade-offs illustrate an important consideration for district leaders facilitating CMAPs. To what degree does one hope that a CMAP might shift some teachers' knowledge and beliefs about elementary science teaching while also potentially increasing buy-in from teachers across the district? And to what degree does one hope that a CMAP will engage in decision-making guided by professionals who have more expertise in elementary science? It may be difficult to accomplish both without more time for teacher learning within the CMAP given the many challenges elementary teachers face in science teaching and learning (NASEM, 2021; Smith, 2020). Furthermore, of course, the primary goal of an organizational routine like a CMAP, from the standpoint of many system leaders, is to accomplish an operational goal—here, to adopt a new set of curriculum materials.

Our study of teacher learning within their CMAP participation offers an image of the possible: it is possible to get the job of selecting curriculum materials done *and* to promote teacher learning at the same time. This study illustrates a few of the many ways in which these CMAPs functioned as learning and sense-making spaces for elementary teachers, through working with boundary objects (such as readings or rubrics), engaging in horizontal or vertical

boundary spanning, and through both carefully designed and incidental facilitation. Through such mechanisms, CMAPs may serve as crucial organizational routines that support teacher learning.

References

- Adelman, C., Jenkins, D., & Kemmis, S. (1980). Rethinking case study: Notes from the second Cambridge conference. In H. Simons (Ed.), *Towards a science of the singular*. Center for Applied Research in Education, University of East Anglia.
- Allen, C. D., & Heredia, S. C. (2021). Reframing organizational contexts from barriers to levers for teacher learning in science education reform. *Journal of Science Teacher Education*, 32(2), 148-166. <https://doi.org/10.1080/1046560X.2020.1794292>
- Allen, C. D., & Penuel, W. R. (2015). Studying teachers' sensemaking to investigate teachers' responses to professional development focused on new standards. *Journal of Teacher Education*, 66(2), 136-149. <https://doi.org/10.1177/0022487114560646>
- Ball, D. L., & Cohen, D. K. (1999). Developing practice, developing practitioners. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3-32). Jossey-Bass Publishers.
- Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education*, 59(5), 389-407.
- Banilower, E. R., Heck, D. J., & Weiss, I. R. (2007). Can professional development make the vision of the standards a reality? The impact of the National Science Foundation's local systemic change through teacher enhancement initiative. *Journal of Research in Science Teaching*, 44(3), 375-395.
- Brown, J. C. (2017). A metasynthesis of the complementarity of culturally responsive and inquiry-based science education in K-12 settings: Implications for advancing equitable science teaching and learning. *Journal of Research in Science Teaching*, 54(9), 1143-1173. <https://doi.org/10.1002/tea.21401>
- Bryk, A., Camburn, E., & Louis, K. S. (1999). Professional community in Chicago elementary schools: Facilitating factors and organizational consequences. *Educational Administration Quarterly*, 35(5), 751-781.
- Bucholtz, M. (2000). The politics of transcription. *Journal of pragmatics*, 32(10), 1439-1465.
- Darling-Hammond, L., Banks, J., Zumwalt, K., Gomez, L., Sherin, M. G., Griesdorn, J., & Finn, L.-E. (2005). Educational goals and purposes: Developing a curricular vision for teaching. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do* (pp. 169-200). John Wiley & Sons.
- Donnelly, J., & Jenkins, E. (2001). *Science education: Policy, professionalism and change*. Sage.

- Enfield, M., Smith, E. L., & Grueber, D. J. (2008). "A sketch is like a sentence": Curriculum structures that support teaching epistemic practices of science. *Science Education*, 92(4), 608-630.
- Eshach, H., & Fried, M. N. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology*, 14(3), 315-336. <https://doi.org/10.1007/s10956-005-7198-9>
- Feldman, M. S., & Pentland, B. T. (2003). Reconceptualizing organizational routines as a source of flexibility and change. *Administrative science quarterly*, 48(1), 94-118. <https://doi.org/10.2307/3556620>
- Geertz, C. (1973). Thick description: Toward an interpretive theory of culture. In C. Geertz (Ed.), *The interpretation of cultures* (pp. 3-30). Basic Books.
- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 28-42). Routledge, Taylor & Francis.
- Hammersley, M. (1984). Staffroom news. In A. Hargreaves & P. Woods (Eds.), *The sociology of teachers and teaching* (pp. 203-214). Open University Press.
- Haverly, C. (2017). *Many elementary teachers have anxiety about teaching STEM* (Grand Challenges White Papers, Issue. https://grandchallenges.100kin10.org/assets/downloads/many-elementary-teachers-have-anxiety-about-teaching-stem-subjects/GrandChallengesWhitePapers_Haverly.pdf
- Haverly, C., Calabrese Barton, A., Schwarz, C., & Braaten, M. (2018). "Making space": How two beginning teachers create opportunities for equitable sense-making in elementary science. *Journal of Teacher Education*. <https://doi.org/10.1177/0022487118800706>
- Haverly, C., Lyle, A., Spillane, J. P., Davis, E. A., & Peurach, D. J. (in press). Leading instructional improvement in elementary science: State science coordinators' sense-making about the Next Generation Science Standards. *Journal of Research in Science Teaching*.
- Heredia, S. C. (2020). Exploring the role of coherence in science teachers' sensemaking of science-specific formative assessment in professional development. *Science Education*, 104(3), 581-604. <https://doi.org/10.1002/sce.21561>
- Hewson, P. W., Kahle, J. B., Scantlebury, K., & Davies, D. (2001). Equitable science education in urban middle schools: Do reform efforts make a difference? *Journal of Research in Science Teaching*, 38(10), 1130-1144.

- Jaffe, A. (2007). Variability in transcription and the complexities of representation, authority and voice. *Discourse Studies*, 9(6), 831-836. <https://doi.org/10.1177/1461445607082584>
- Johnson, H. J., & Cotterman, M. E. (2015). Developing preservice teachers' knowledge of science teaching through video clubs. *Journal of Science Teacher Education*, 26(4), 393-417.
- Lee, E., & Luft, J. A. (2008). Experienced secondary science teachers' representation of pedagogical content knowledge. *International Journal of Science Education*, 30(10), 1343-1363. <https://doi.org/10.1080/09500690802187058>
- Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp. 95-132). Kluwer Academic Publishers.
- Masuda, A. M. (2010). The teacher study group as a space for agency in an era of accountability and compliance. *Teacher Development*, 14(4), 467-481.
- Mawhinney, L. (2010). Let's lunch and learn: Professional knowledge sharing in teachers' lounges and other congregational spaces. *Teaching and Teacher Education*, 26(4), 972-978.
- McNicholl, J., Childs, A., & Burn, K. (2013). School subject departments as sites for science teachers learning pedagogical content knowledge. *Teacher Development*, 17(2), 155-175.
- Moore Mensah, F. (2013). Retrospective accounts in the formation of an agenda for diversity, equity, and social justice for science education. In J. A. Bianchini, V. L. Akerson, A. Calabrese Barton, O. Lee, & A. J. Rodriguez (Eds.), *Moving the Equity Agenda Forward: Equity Research, Practice, and Policy in Science Education* (pp. 317-335). Springer.
- NASEM. (2015). *Science teachers' learning: Enhancing opportunities, creating supportive contexts* [Committee on Strengthening Science Education through a Teacher Learning Continuum Board on Science Education and Teacher Advisory Council Division of Behavioral and Social Science and Education Ed.]. The National Academies Press.
- NASEM. (2021). *Science and engineering in preschool through elementary grades: The brilliance of children and the strengths of educators*. The National Academies Press. <https://doi.org/doi:10.17226/26215>
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. The National Academies Press.
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press.

- Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of educational research*, 62(3), 307-332.
- QSR International Pty Ltd. (2018). *NVivo*. In (Version 12)
<https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home>
- Robson, C. (2002). *Real world research: A resource for social scientists and practitioner-researchers* (second ed.). Blackwell.
- Ryder, J. (2015). Being professional: accountability and authority in teachers' responses to science curriculum reform. *Studies in Science Education*, 51(1), 87-120.
- Saldaña, J. (2016). *The coding manual for qualitative researchers*. Sage.
- Sherer, J. Z., & Spillane, J. P. (2011). Constancy and change in work practice in schools: The role of organizational routines. *Teachers College Record*, 113(3), 611-657.
- Shulman, L. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review*, 57(1), 1-23.
- Smith, P. S. (2020). *2018 NSSME+: Trends in U.S. science education from 2012 to 2018*. Horizon Research Inc.
- Spillane, J. P. (2005). Primary school leadership practice: How the subject matters. *School Leadership & Management*, 25(4), 383-397.
- Spillane, J. P. (2006). *Distributed leadership*. Jossey-Bass, A Wiley Imprint.
- Spillane, J. P., Hopkins, M., & Sweet, T. M. (2018). School district educational infrastructure and change at scale: Teacher peer interactions and their beliefs about mathematics instruction. *American Educational Research Journal*, 55(3), 532-571.
<https://doi.org/10.3102/0002831217743928>
- Spillane, J. P., Parise, L. M., & Sherer, J. Z. (2011). Organizational routines as coupling mechanisms: Policy, school administration, and the technical core. *American Educational Research Journal*, 48(3), 586-619. <https://doi.org/10.3102/0002831210385102>
- Stein, M. K., & Coburn, C. E. (2008). Architectures for learning: A comparative analysis of two urban school districts. *American Journal of Education*, 114(4), 583-626.
- Stein, M. K., Remillard, J., & Smith, M. (2007). How curriculum influences student learning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 319-369). Information Age Publishing.

- Vanblaere, B., & Devos, G. (2018). The role of departmental leadership for professional learning communities. *Educational Administration Quarterly*, 54(1), 85-114.
<https://doi.org/10.1177/0013161X17718023>
- Weick, K. E. (1995). *Sensemaking in organizations*. Sage.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge University Press.
- Yin, R. K. (2014). *Case study research: Design and methods* (fifth ed.). Sage Publications.