THE ROLE OF DISTRICT AND UNION SUPPORT IN PURSUING THREE-DIMENSIONAL SCIENCE TEACHING PROFESSIONAL COMMUNITIES

By

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ABSTRACT

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This qualitative study compares four public school districts in a state to investigate how *Next Generation Science Standards*-aligned, three-dimensional science classroom teaching and learning in biology classrooms could become normal, instead of exceptional. Interview data were collected through two rounds of interviews – one year apart – with teachers, district science coordinators, and teachers' union staff and leaders in districts using *Carbon TIME* instructional resources in high school biology. Results are shared through district-level identifying stories of current realities (actual identities) and future plans and goals (designated identities).

Each of the four school districts described similar interacting communities of practice – teachers' classrooms; teachers' course-based (biology) professional communities; and district administrators and local union leaders. The study's analytical framework addresses roles, responsibilities, and professional actions of teachers, union leaders, and administrators and district science coordinators relevant to teachers' course-based professional communities. Attention was given to professional actions that could "cross the classroom door," connecting what teachers do together in their course-based (biology) professional communities with their own classroom communities.

Two orientations of the identifying stories varied across school districts in ways that influence three-dimensional science classroom teaching and learning: collective (versus

individual) orientations and three-dimensional science (versus one-dimensional science) orientations.

Identifying stories in districts with collective and three-dimensional science orientations described teachers' professional community work as necessary to realizing classroom goals for students' three-dimensional science experiences and performances. District and union leaders endorsed teachers' professional community work as integral to classroom instruction and supported such work through mitigating transaction and conflict costs. Teachers' professional actions within their course-based (biology) professional communities included selecting, developing, and revising common three-dimensional instructional resources and making sense of their classroom science instruction using evidence of student learning.

Differently, in districts with identifying stories as individually and non-three-dimensional-science oriented professional communities, participants described teachers with individual classroom goals and teachers' professional communities with traditional norms of non-interference and egalitarian beliefs. District and union leaders endorsed teachers' independent expertise and classroom autonomy. Teachers' work with their course-based (biology) professional community was described connecting in optional ways or as not connected to teachers' individual classroom communities.

This study suggests that collectively oriented professional communities can help all classroom communities engage in three-dimensional science teaching and learning. Districts and local teachers' unions can play important roles in reducing transaction and conflict costs and endorsing identifying stories that support collective orientations.

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Chapter 1 – Introduction and Analytical Framework

Imagine walking into any biology classroom in any high school in any public school district in the state and experiencing a teacher and their students engaged in three-dimensional science teaching and learning. *The classroom lights are dimmed. Ms. Nolan is standing at a lab table near two petri dishes, each with a clear liquid that is shimmering slightly. Students watch intently as their teacher ignites a lighter and moves it near the first dish; nothing happens. Then Ms. Nolan brings the lighter to the second dish; the surface is immediately engulfed in pale, bluish flame. An enthusiastic buzz fills the room. Ms. Nolan waits before asking students to talk with each other about why they think one liquid burned while the other did not. Over the next month, Ms. Nolan and her students will carry out additional investigations and other classroom activities to figure out what happens when substances burn. Eventually, students will use an atomic-molecular scale model to explain what made one clear liquid (ethanol) ignite, but not the other (water).*

This short vignette captures a *Carbon TIME* classroom engaging in its first unit: *Systems & Scale* (*Carbon TIME*, 2019). Episodes like this represent a vision for science classroom learning provided by the National Research Council's (NRC, 2012) *Framework for K-12 Science Education*, in which students are *figuring out* natural phenomena. Students in Ms. Nolan's classroom are *figuring out* what happens when ethanol burns, not *learning about* combustion (*NGSS*, 2016).

Our *Carbon TIME* project has observed and studied classrooms and classroom video of case study teachers over the last eight years to recognize that this kind of three-dimensional classroom engagement is unusual; Ms. Nolan is a virtuoso (Covitt, Morrison Thomas, Lin, de los

Santos & Anderson, 2020). These project-specific observations are echoed in large-scale national surveys of current science teaching and K-12 classroom environments (Smith, 2020). Together, these realities set the stage for this study … What would it take to change Ms. Nolan's vignette from exemplary to ordinary; what would it take to make three-dimensional science classroom engagement *normal*?

Why Classrooms Matter: Students' Three-Dimensional Outcomes and Science Identities

Making Ms. Nolan's vignette *normal* matters because what students experience in their science classrooms affects their three-dimensional achievement and their science identity development.

We see three-dimensional classroom achievement as meaningful because of how it contributes to students' development as scientifically literate citizens, prepared to make informed choices in their personal lives and to bring science knowledge and practices to their participation in public decisions about socioscientific issues. In this way, science literacy is an essential aspect of preparing students to be effective participants in a democracy.

In our *Carbon TIME* project, we have designed assessments that measure students' three-dimensional classroom achievement (Doherty, Draney, Shin, Kim, & Anderson, 2015), so we interpret students' learning gains on these assessments as meaningful measures of progress toward larger goals for scientific literacy. In addition to students' three-dimensional achievement, classroom experiences matter in students' development of science identities (Carlone, Haun-Frank & Webb, 2011), affecting whether and how students see themselves as science people and see science as a way of knowing the world that can inform their personal

and public decisions. In this way, science identities also matter toward larger goals for scientifically literate citizens.

Our project's quantitative analysis shows that teachers were more important than students' prior knowledge and school demographic factors in explaining variation in students' learning gains (Lin, Frank, Bathia, Draney, Thomas & Anderson, 2021). Every teacher used *Carbon TIME* instructional resources differently in their individual classrooms, and those differences were consequential for students' learning gains.

Our project's study of teachers' classroom video has helped us identify aspects of classroom discourse in higher learning-gains classrooms and specific moves teachers like Ms. Nolan are making that are supporting students' three-dimensional learning. Identifying what virtuoso teachers like Ms. Nolan are doing in their classrooms to support students' three-dimensional achievement is valuable because those patterns in classroom discourse can be shared with the larger science education community and be used to inform and support teachers' professional learning.

Why Teachers' Professional Communities Matter

Our case studies helped us understand teacher-specific as well as outside-the-classroom influences on *Carbon TIME* teachers. Ms. Nolan was able to engage her students in three-dimensional classroom discourse, and we wondered what could explain why other case study teachers were not similarly engaging their students. Interviews and observations with these teachers suggested their local professional communities might be somehow hampering otherwise experienced, caring, "good" teachers in engaging in three-dimensional classroom discourse (Morrison Thomas, Covitt, Hancock, Lin, Marshall & Anderson, 2020).

We used a larger data set (interviews with about 60 *Carbon TIME* teachers) to look at how teachers talked about being a member of their local professional community. This analysis suggests that more than 80% of teachers told stories of local professional communities having little influence on their instruction behind their own classroom doors, which aligns fully with what Little (1990) has described as norms of noninterference, and which have been widely documented in schools and districts (McLaughlin & Talbert, 2006).

It seems that teachers were rarely hindered by their local professional communities, but – perhaps more importantly – they were rarely helped by their local professional communities in enacting challenging, three-dimensional science classroom engagement. Though teachers' stories of their professional communities were less strongly associated with students' learning gains than other characteristics of teachers' narratives, non-interfering professional communities did correlate negatively (and statistically significantly) with students' learning (Morrison Thomas, Covitt, Hancock, Lin, Marshall & Anderson, 2022).

Our *Carbon TIME* project was designed to provide an external (outside of the school district) professional community in which teachers could make shifts in pedagogy and related reasoning through professional learning experiences with other teachers and researchers. Our *Carbon TIME* networks in states were connected to existing local education agencies – a university-based extension center and a state teachers' association – that we hoped would further connect and support individual teachers.

Though we were successful in many ways, we realize that our external professional communities did not provide enough help for some teachers to shift classroom practice in ways

that supported their students' three-dimensional achievement, considering that most teachers had local professional communities that weren't helping.

This Study: Teacher Professional Communities within School Districts and with Local Teachers' Unions

These *Carbon TIME* research and development experiences directly informed the development of this dissertation study. We turned our attention to school districts because research suggests this is a critical level for school improvement (O'Day & Smith, 2019), and our own *Carbon TIME* experiences suggested that our external networks weren't enough for some teachers' shifts in classroom practice. We saw district science coordinators as key personnel in supporting science teachers' classroom practice, both through professional learning experiences for teachers and related work – such as curriculum selection, development, and adaptation – that happens within teachers' in-district professional communities (Whitworth & Chiu, 2015).

These local teacher professional communities can positively affect students' learning outcomes; "students do better academically in a school where their teachers take collective responsibility for the success of all students" (McLaughlin & Talbert, 2006, p. 9). These authors also noted that in schools with such collaborative teacher professional communities, "socioeconomic status had less effect" on achievement gains; "in other words, inequalities between students mattered less" (2006, p. 9).

We had relationships with teachers and district science coordinators in school districts that seemed different from each other in intriguing ways. Some seemed to fully represent Little's (1990) norms for privacy and non-interference, yet we also saw stand-out individual

teachers. Some had biology teachers that seemed to be working very closely and positively with each other, but (puzzlingly) didn't share stories of the strong professional communities we would have anticipated. Others seemed to have local professional communities that might be truly supporting teachers' three-dimensional classroom engagement – people and organizations that might be "positive deviants" (O'Day & Smith, 2019).

Further, the four study locations included local teachers' unions – another actor in public education at the school-district level – who expressed (at least generalized) support for science education reform. Though often portrayed as obstacles to educational change, teachers' unions nationally have been outspoken advocates for reforms, and locally, unions tend to accommodate – not actively oppose – reforms (McDonnell & Pascal, 1988). Teachers' unions' traditional commitments to issues of compensation and working conditions continue to be relevant and important today – with teachers feeling underpaid and overworked – and, in many ways, meeting needs around these traditional conditions seem to serve as prerequisites to teachers' active endorsement of and efforts toward reform (McDonnell & Pascal, 1988). And, of course, our *Carbon TIME* project developed a professional learning network through a state teachers' union.

Knowing that we wanted to understand more about teachers' three-dimensional science work within their local, school-district professional communities, what roles their local teachers' unions played, and how these systems could – or could not – further support teachers' shifts to three-dimensional science teaching, prompted questions about what kind of data should be collected. Here, again, our *Carbon TIME* research deeply informed decisions about this dissertation study by presenting identifying stories as a meaningful tool.

Why Teachers' Stories Matter

As mentioned, our project wondered why teachers' classroom enactment – and therefore their students' learning gains – differed. What prompted some teachers to engage students in three-dimensional sensemaking around phenomena, while others engaged classrooms in one-dimensional discourse, even though all the teachers experienced the same professional learning program?

Alongside looking at the outside-the-classroom influences (teachers' local professional communities), we looked at teacher-specific factors. Our project did this by analyzing teachers' accounts in interviews, noticing that teachers shared identifying stories through their talk – their interviews were stories of who they were and how they saw themselves as classroom teachers and professional community members (Sfard & Prusak, 2005). Their identifying stories correlated with their students' learning gains (Morrison Thomas, et al., 2022).

Teachers' stories about their *pedagogical responsibilities* – "to whom or what teachers felt beholden" – were the most correlated with student learning gains (Chen, Marshall & Horn, 2020, p. 2). Teachers' stories about their *pedagogical reasoning* – their "sensemaking" – about students and about instructional resources were also strongly correlated (Chen, Marshall & Horn, 2020, p. 3).

For example, in lower learning-gains classrooms, teachers told identifying stories as "quick-and-snappy" teachers whose successful classroom engagement meant using *Carbon TIME* activities in ways that maintained students' interest and enthusiasm (Hess & Azuma, 1991). Teachers in higher learning-gains classrooms told identifying stories in which they were facilitators or guides, supporting students' sensemaking about natural phenomena and using

Carbon TIME units to scaffold challenging three-dimensional performances. In these classrooms, teachers also cared about students' enjoyment and interest, but instead of describing students' enjoyment of fun and diverse activities, they described students valuing their own developing science identities.

These experiences and findings suggest that teachers' identifying stories are consequential for students' learning. We therefore use identifying stories as a basis for understanding more about school districts and teachers' unions in this dissertation study – using stories from teachers, district science coordinators, and local teachers' union leaders.

This Study: School District-Level Identifying Stories

In this interview-based study, teachers talked about their professional work, both inside their classrooms with their students and outside of their classrooms with their building- and district-level colleagues. District science coordinators and teachers' union leaders talked about their professional interactions with teachers, administrators, and other education leaders. As described earlier relating to *Carbon TIME* teacher interviews, we see these interviews as presenting identifying stories about each district (Sfard & Prusak, 2005). To clarify, "district" here does not imply solely the administrative entity (i.e., the district office and district office administrators, which are denoted in this study using capital letters – District X); it instead encompasses the professional teaching and leading community in the school district.

These identifying stories are powerful in how they state to individuals and others "who we are" as a district community, "how we can" interact or behave, and "what we want, should, can, or cannot" be or do in the future. Sfard and Prusak (2005) name these two kinds of narratives: *actual identities*, "consisting of stories about the actual state of affairs" and

designated identities, "consisting of narratives presenting a state of affairs which, for one reason or another, is *expected* to be the case" (p. 18).

This construct provides an important means of approaching interview-based data, supporting us in making sense of participants' talk as stories about who they are, while also elevating the idea that these identifying stories shape who we can, may, or will be. Further, these stories are available around us from different individual narrators and society; our identity may be our self-understanding, but it is created from available possibilities, potential options, existing social categories, and available stories (Nakkula, 2008; Nasir, 2012; Renn, 2012; Sfard & Prusak, 2005).

Identifying stories are reifying; they provide predictability for the future by establishing, or making concrete, qualities in the present. Combined with Bateson's (2006) description of continuous stories, we interpret some stories told about the past – not as anecdotes of a thing that has happened – but as templates that anticipate future actions in continuous narratives. This is particularly true, as Sfard & Prusak (2005) point out, of "adverbs [like] *always*, *never*, *usually* … that stress repetitiveness of actions" (p. 16). In this way, participants' interviews about how things have been shed light on their likely actions in the future.

Stories others tell about who we are as a district become available for individuals to incorporate and share. When these identifying stories are shared in a professional community, they become available to others, who can incorporate them into their own personal identities and their identifying stories of the community. In this way, stories are very powerful tools for understanding ourselves and shaping the understanding of others.

This leads us to this study's research questions.

Study Research Questions

1. What are these four district's *actual identities* as shared in stories about teachers' responsibilities; district and union roles; and what and who crosses the classroom door?
2. What are these four district's *designated identities* as shared in stories about teachers' responsibilities; district and union roles; and what and who crosses the classroom door?
3. How do participants describe the benefits and costs associated with moving from their *actual* to *designated identities*, and what limits districts' designated identities from reaching the goal *new normal*?

Study Analytical Framework Overview

My analytical framework is represented Table 1, with the same rows available in all of the subsequent, district-specific District Identity Tables shared in the results in Chapter 4.

This analytical framework delineates the ideas and content of participants' identifying stories that were relevant to the research questions; different across districts; and connected in meaningful ways to my vision for a *new normal* in which walking into any biology classroom in any high school in any public school district in the state could provide an observation of a teacher and their students engaged in three-dimensional science teaching and learning.

In Research Question 1, I describe each district's *actual identity* by telling participants' stories using the rows of Table 1. When relevant in Research Question 2, I describe each districts' *designated identity* by making comparisons across columns in those tables (*actual identity* and *designated identity*), and finally in Research Question 3, I make comparisons across

columns, including the *new normal* column, as I talk about participants' perceptions of the costs and benefits of change.

Table 1. Analytical Framework and District Identity Template	
What were the patterns in participants' stories about?	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
Professional Roles and Responsibilities	
A. Teachers' Classroom Pedagogical Responsibilities	**Three-dimensional science classroom experiences and outcomes; shared across all teachers** District biology teachers hold classroom pedagogical responsibilities to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize classroom pedagogical responsibilities (A). 2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.
C: Roles of District and Union Leaders Related to Teachers' Professional Communities	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Mitigate transaction costs through time and compensation. 3. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 4. Connect to external science education communities.
Professional Actions	
1. What goes into classrooms?	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: revised 3D instructional resources, with revisions based on evidence of student learning

Table 1. (cont'd)	
2. What goes out of classrooms?	**Evidence of Students' Three-Dimensional Learning** • teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes • students' 3D outcomes (common assessment data; student work), including at the teacher-level
3. Who crosses the classroom door?	**People are connected to the professional community and the focus is on three-dimensional science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

4. What do teachers do together in their course-based (biology) professional communities?	**Actions Link "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional & consensus-seeking.**
	• select/develop 3D instructional resources
	• sensemaking around 3D instruction, using evidence
	  ○ dialogic (rehearsals and recounts)
	  ○ analysis of student learning artifacts (assessment data and student work)
	• revise instructional resources based on these two forms of evidence

5. How do teachers connect and consider the local public community?	• Teachers talk about three-dimensional science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

Analytical Framework Rows A-C, Roles and Responsibilities

In addressing my Research Questions, I use the rows in Table 1 to organize key parts of participants' stories. Rows A-C describe roles and responsibilities of different members of the district-level professional community. My analytical framework, therefore, includes stories about teachers' *pedagogical responsibilities* – reflecting to what or whom they feel beholden – in regard to their classroom work (row A) and their professional community work (row B). These responsibilities are important because they shape individual teachers' decision-making when they are with their students, behind their own classroom doors.

The framework includes the roles of district and union leaders, as they relate to teachers' professional community work (row C). These roles include the messaging and endorsement from leaders about how teachers' professional community work is (or is not) connected to teachers' classroom work alongside mitigating *transaction* and *conflict costs* (Little, 1990; Tannen, 2001).

Teachers' Classroom Pedagogical Responsibilities (row A)

Defining classroom pedagogical responsibility. Horn (2020) uses the idea of *pedagogical responsibility* to describe "teachers' engagement with their sense of their obligations" (p. 325), with these obligations representing deeply held institutional or ethical responsibilities. Chen and colleagues (2020) name "pedagogical responsibility as a driving force underlying the work of teaching" (p. 5) because of how it undergirds teachers' decision-making. In this study, I conceptualize this idea into two separate components – one related to teachers' work in their classrooms and one related to teachers' work with their professional colleagues.

So, *classroom pedagogical responsibilities* represent to-whom-or-what-teachers-feel-beholden as they work with students behind their classroom doors, making decisions about their instruction with their students.

Classroom Pedagogical Responsibilities in the New Normal. In my imagined *new normal*, teachers hold *classroom pedagogical responsibilities* to students' three-dimensional classroom experiences and outcomes. This is because these classroom experiences support students' equitable access to science identities and their development into scientifically literate citizens (NRC, 2012).

Further, students' outcomes – as measured on three-dimensional assessments – matter because they provide information about if and how classroom experiences are furthering these goals for each student and for all students (NRC, 2014). Ensuring these outcomes are aligned with external science education community standards is also important, because the science education research and development community continues to make progress around what it means for students to engage and achieve the three-dimensional performance expectations in the *Next Generation Science Standards* and our understanding of equitable engagement and achievement advances, too. Our science education world is dynamic, and part of the *new normal* includes connections to these advances.

Teachers' Professional Community Responsibilities (row B)

Defining professional community responsibility. As described above, I conceptualize Horn's (2020) idea of *pedagogical responsibility* into two separate components – one related to teachers' work in their classrooms – their *classroom pedagogical responsibilities* (A) – and one related to teachers' work with their professional colleagues – their *professional community responsibilities* (B).

Teachers' professional communities can vary widely, including within schools and districts as well as external communities outside of their specific teaching location (such as our *Carbon TIME* networks). In this study, I refer primarily to teachers' course-based (biology) professional communities, which are comprised of the other teachers in the school district who teach the same course (biology). Teachers' *professional community responsibilities* are the to-whom-or-what-teachers-feel-beholden as they work with peers in these professional

communities and as they make decisions about if and how to connect their professional community work with their classroom work, behind their classroom doors.

In this study, I use three adjectives to describe these professional community responsibilities. In *collective* professional communities, teachers work jointly as a group toward shared goals and seek consensus in decisions; in *collaborative* professional communities, some teachers regularly work together; and in *individually oriented* professional communities, teachers autonomously determine whether, and around what, they work with colleagues.

Teachers' Professional Community Responsibilities in the New Normal. In my *new normal*, teachers are members of *collective* professional communities, working together as a group and seeking consensus in decisions.

Teachers' Professional Community Work is Required (B.1). In my imagined *new normal,* teachers' professional community work is requisite for fully realizing their *classroom pedagogical responsibilities* (A). Work with their peers (described below in 4) is necessary for individual teachers to engage their students in three-dimensional science classroom experiences and secure students' three-dimensional achievement. In part, this reflects students' receiving similar experiences across teachers in a common course. Additionally, it reflects the challenges of three-dimensional science classroom instruction and assessment.

Teachers have Autonomy to Experiment Instructionally (B.2). Within these *professional community responsibilities*, teachers have autonomy to experiment instructionally in their own classrooms and respond to their own students. However, classroom success is defined through standards determined by the professional community (for example, common three-

dimensional assessments), so teachers' individual autonomy is linked to professional-community-level goals.

Peer Accountability Exists through Consensus-Seeking Decisions (B.3). As colleagues work collectively toward common goals, peer accountability emerges through consensus-seeking professional community decision-making.

Independent Improvements lead to Innovation (B.4). Alongside teachers' experimental autonomy is an expectation for innovation, meaning that teachers' independent efforts toward improvement (in their own classrooms or through connections to external communities) are shared with the local, course-based professional community.

Contrasts with individually oriented professional communities. These *new normal* professional community responsibilities contrast with teachers' independent autonomy and professional norms for noninterference and niceness (Feiman-Nemser, 2001; Little, 1990).

Roles of District and Union Leaders Related to Teachers' Professional Communities (row C)

Defining District and Union Roles. Traditionally, the major responsibility of school districts (as in, district offices/administrations) has been "sorting-resourcing-and-delegating" (Peurach, Cohen, Yurkofsky & Spillane, 2019, p. 40), while leaving the business of classroom instruction to individual teachers. Over the last several decades, roles have changed so that school districts are more involved in the work of organizing and managing classroom instruction and have become recognized as a critical level for school improvement (O'Day & Smith, 2019; Jackson, Cobb, Rigby & Smith, 2018).

Traditionally, local teachers' unions have been involved through negotiating teachers' collective bargaining agreements with school district management, particularly around issues of teachers' compensation and working conditions (Koppich, 2006).

District and Union Roles Related to Teachers' Professional Communities in the New Normal. In the *new normal*, districts are a key level in which *NGSS*-aligned visions, high-quality instructional materials, and teacher professional learning are all supported and aligned (Cobb, Jackson, Henrick & Smith, 2018; Shepard, Penuel & Pellegrino, 2018). Within school districts, district science coordinators are key personnel in supporting science teachers' classroom practice, both through professional learning experiences for teachers and related work such as curriculum selection, development, and revision (Whitworth & Chiu, 2015).

District and Union Stories Endorse Professional Community Work (C.1). One important aspect of district and union leaders' roles relates to the stories they tell – the messages they extend – about who the district is and what teachers in the district have or lack. These stories are important, because "language provides the tools for individual thinking" (Leach & Scott, 2003, p. 99). In this way, language – stories – shared by others – and therefore made available on the intermental plane – enables new ideas in our own minds (Vygostky, 1987 as cited in Leach & Scott, 2003).

In the *new normal*, leaders tell and endorse stories in which teachers' professional community work is integral to teachers' classroom instruction (in the context of this study, teachers' three-dimensional science classroom instruction). However, district and union leaders can tell other stories – egalitarian ones in which each teacher has their own valuable and

individual expertise or ones in which teachers' collaboration may waste precious time that teachers could be using to prepare for their own students.

Mitigate Transaction Costs (C.2). Teacher collaboration inherently incurs costs. *Transaction costs* reflect the time and effort required of individuals due to communication with other teachers and administrators (Little, 1990). In the *new normal*, district and union leaders work to mitigate these costs, primarily through providing time for professional communities to work together and compensating teachers for additional work.

Mitigate Conflict Costs (C.3). *Conflict costs* reflect the energy required to anticipate, encounter, and resolve potential threats to relationships that are inherent in disagreements or disputes in pursuit of consensus (Horn & Kane, 2019; Little, 1990; Tannen, 2001). In the *new normal*, district and union leaders work to mitigate conflict costs by providing training or other kinds of resources that support professional interpersonal relationships and decision-making.

Further, clear expectations provided by districts regarding how teachers are expected to connect their experiences and work with peers in their professional communities, with what they do individually "behind their classroom doors," can reduce conflict costs among colleagues.

Connect to External Science Education Communities (C.4). One of the new domains of school district work described by Peurach and colleagues (2019), is "managing environmental relationships." In the context of this study, this work includes connecting to – and also buffering against – external science education communities, including university-based research and development programs and county-, state-, and national-level science education organizations, including the state department of education and state-level three-dimensional monitoring

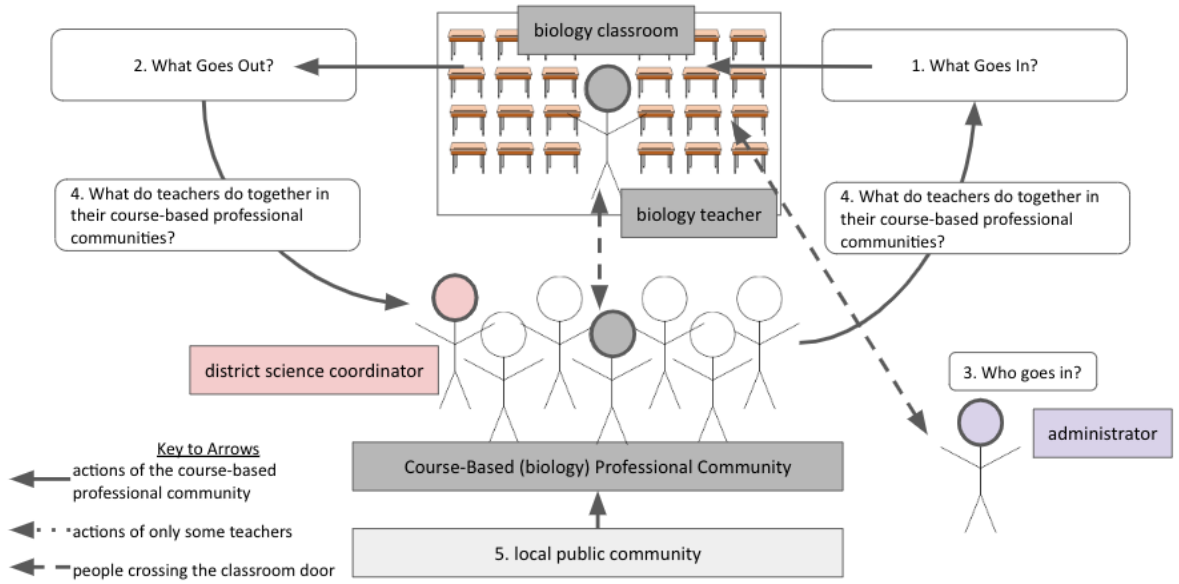
assessments. These external communities are a current source of *NGSS*-aligned information and instructional resources.

Analytical Framework Rows 1-5, Professional Actions

The analytical framework (Table 1) switches from lettered rows to numbered rows to signify that these aspects of the framework are actions of primarily teachers, but including administrators and other educators, in their local professional communities. This idea is visually represented in the model in Figure 1. Model for District Identity, corresponding to Table 1, rows 1-5, which is a template, used below in coordination with explanations for each numbered row of the analytical framework) as well as models for each district in Research Question 1.

In Table 1, rows 1-5 correspond to numbered actions in the model in Figure 1. These describe actions directly affecting curriculum, assessment, and teachers' instruction behind their classroom door. So, participants' stories – and what matters in a *new normal* – include what crosses the classroom door – what goes into the classroom with the teacher (row 1) and what goes out of the classroom with the teacher (row 2) – as well as who (besides students) crosses the classroom door (row 3). Also of importance is the work of the professional community (row 4), because what teachers do when they are together with their peers can connect with what their instruction and assessment with their students, behind their classroom doors. Finally, some participants' stories described the local public community (5) as salient to the districts' teaching and learning decisions.

Figure 1. Model for District Identity, corresponding to Table 1, rows 1-5



What Goes in the Classroom? (row 1)

Defining What Goes in the Classroom? In considering "what goes in the classroom door," I mean instructional resources, including both instructional lessons/units and coordinating, aligned assessments. Many districts officially adopt instructional resources for teachers to use in their classrooms, but many teachers modify and supplement these resources, often in ways that make them significantly different from what developers may have intended. This may be particularly true for three-dimensional instructional resources, around which teachers' goals for quick-and-snappy, one-dimensional instruction contrast with developers' goals for students' sensemaking around natural phenomena and three-dimensional engagement (Morrison Thomas, et al., 2020). Recent research confirms that most teacher-made lessons and units do not align with the learning and teaching goals of the *NGSS* (Short, 2021).

What Goes in the Classroom? in the New Normal. In the *new normal*, coherent, high-quality instructional materials aligned with *NGSS* learning and teaching goals enter the classroom with the teacher.

The benefit of having these high-quality instructional materials common across teachers is that – not only do they support teachers' three-dimensional classroom instruction – but they provide important opportunities for teacher learning within professional communities (Ball & Cohen, 1996; Horn & Little, 2010; Shepard, et al., 2018).

Instructional Resources – Three Dimensional Units/Lessons. Instructional resources are widely recognized as playing an important role in teachers' classroom instruction and students' achievement, particularly in the case of new, challenging three-dimensional classroom expectations provided in the *Framework for K-12 Science Education* (NRC, 2012) and the *NGSS* (Edelson, Reiser, McNeill, Mohan, Novak, Mohan, Affolter, McGill, Bruck Bracey, Deutch Noll, Kowalski, Novak, Lo, Landel, Krumm, Penuel, Van Horne, Gonzalez-Howard & Suarez, 2021).

Instructional Resources – Three-Dimensional Science Classroom Assessments. The National Research Council (2014) points out that "new kinds of science assessments are needed to support the new vision and understanding of students' science learning" (p. 16). In the *new normal*, assessments of students' three-dimensional science performances need to be used at the classroom level for both formative and summative purposes. In the context of this study, I focus on common *summative* assessments – assigned by teachers at the end of instructional units and/or at the end of the semester or term (end-of-course exams).

Assessing students is an important part of teachers' classroom work, and teachers use summative assessments to provide grades that are evidence of student achievement – though

not always evidence of three-dimensional achievement. Because summative assessments and related grading have consequential outcomes for students, designing equitable assessments, using equitable grading systems, and interpreting students' results in equitable ways is crucial (Shepard, et al., 2018).

What Goes Out of the Classroom? (row 2)

Defining What Goes Out? Most commonly, what leaves the classroom with teachers are anecdotes of classroom experiences, which are important stories that teachers use to both communicate with colleagues and make personal sense of experiences (Chen, Horn & Marshall, 2020; Horn & Kane, 2019). Typically, though, teachers use a kind of common-sense discourse that is concrete, monologic, and unquestionable and does not lend itself to sensemaking around students' ideas or ambitious instruction (Horn & Kane, 2019; Jackson, 1968).

What Goes Out? in the New Normal. In a *new normal*, evidence of students' three-dimensional learning leaves the classroom with teachers in a way that supports teachers' dialogic sensemaking within their professional communities.

Evidence of Student Learning through Replays & Rehearsals. Dialogic sensemaking within professional communities can occur around teachers' accounts of classroom interactions that address evidence of students' learning and/or three-dimensional science engagement. These teacher stories take the form of replays, describing events that have already happened, or rehearsals, anticipating future events (Horn, 2020). When these accounts focus on students' three-dimensional science classroom experiences and outcomes, they enable the kinds of questioning and inquiry that support teachers' sensemaking.

Evidence of Student Learning through Classroom Artifacts. Evidence of students' learning can leave the classroom door with teachers in the form of artifacts – samples of students' classroom work including formative assessments.

Evidence of Student Learning through Three-Dimensional Assessments. As mentioned above, the use of the word "assessment" here refers to common summative assessments that teachers use at the end of units and/or courses. Students' performances on three-dimensional science summative assessments can be used both for assigning grades and obtaining evidence of what students have learned (NRC, 2014). Such grades and students' responses can leave the classroom with teachers.

Who Crosses the Classroom Door? (row 3)

Defining Who Crosses the Classroom Door. Teachers are generally structurally and temporally isolated from other professionals – privately engaged with just their students behind their own classroom doors (Little, 1990; Spillane & Shirrell, 2018). Administrators do cross the classroom door to make observations for formal teacher evaluation purposes (Danielson, 2013). However, these tend to be infrequent and not connected to teachers' science-specific pedagogical practices – especially *NGSS*-aligned instructional practices – because principals, particularly at the secondary level, tend not to hold deep knowledge of science classroom discourse (Lochmiller, 2016; Stein & Nelson, 2003).

Who Crosses the Classroom Door? in the New Normal. In my *new normal*, I do not imagine building administrators becoming *NGSS* experts who can support science teachers' instructional improvement. Instead, *NGSS*-aligned instructional improvement is the work of

peers in the course-based professional community and through district- and union- programs like Peer Assistance and Review.

Peers from the Course-Based Professional Community. In a *new normal*, teaching peers from the course-based professional community engage in lesson observations (Akiba & Wilkinson, 2016) to support teachers' three-dimensional science classroom engagement and students' three-dimensional science outcomes. This kind of instructionally focused peer-to-peer work may be facilitated by a teacher-leader or instructional coach (Kane, Cobb & Gibbons, 2018).

Peer Assistance and Review Programs. In my vision for a *new normal*, peer assistance and review (PAR) programs coordinate teacher evaluation and teacher improvement systems (J. Goldstein, 2007; Papay & Johnson, 2012). Selected peer experts serve simultaneously as instructional coaches and evaluators, with district and union teams making final evaluation decisions around teachers' instructional performances.

What do Teachers do Together in their Course-based Professional Communities? (row 4)

Defining the Work of the Course-Based Professional Community. Given the time that teachers have with each other – based on District and Union factors in Row C – what do they do when they are together? For many teachers, the work they do with their peers would largely be considered "meetings;" they meet as a staff with their building administrators, meet with peers to organize and distribute shared materials, or meet with colleagues to share anecdotes (Horn & Kane, 2019).

The Work of the Course-Based Professional Community in the New Normal. In the *new normal*, teachers' work with their peers in their course-based professional community connects

integrally with their work "behind the classroom door," where they are with their students in their own classroom. In the new normal, teachers collectively select or develop three-dimensional instructional resources that go into the classroom; individual teachers use these resources behind their own classroom door; evidence of student learning leaves the classroom with the teacher when teachers meet with their professional community; and, finally, this evidence is used for sensemaking purposes that can lead to revisions in instructional resources and revisions in instruction. This time around, a more-knowledgeable teacher and improved instructional resources enter the classroom door, and the cycle repeats.

In this imagined *new normal*, the work of the professional community links what goes out of the classroom (evidence of student learning) with what goes into the classroom (three-dimensional instructional materials) through teachers' sensemaking and revisions.

Three-Dimensional Resource Selection and Development. Teachers may use rubrics, like the EQuIP (Educators Evaluating the Quality of Instructional Products Rubric for Science) or the *NGSS* Lesson Screener to engage in resource selection activities, which can also be avenues for understanding three-dimensional science instruction more deeply (WestEd, 2022).

Sensemaking around Three-Dimensional Instruction. In *new normal* professional communities, teachers spend time together making sense of classroom experiences and students' learning using evidence (McLauglin & Talbert, 2006; Horn & Little, 2010). This evidence may be dialogic (in the form of replays and rehearsals) or may be analytic, in the form of artifacts of students' learning – including student work artifacts, performances on three-dimensional assessments, and students' grades. Such analysis-of-practice endeavors that involve the use of artifacts like student work and assessment products are particularly powerful

in supporting teacher practice because they center teachers' professional thinking and discourse around their students' thinking and learning (Loucks-Horsely, Love, Stiles, & Mundry, 2003; Nelson, 2009; Roth, Garnier, Chen, Lemmens, Schwill, & Wickler, 2011).

Revisions to Instructional Resources. As teachers have classroom and student learning experiences with instructional resources and make sense of these, they may adjust – revising instructional materials and/or instructional practice – to better meet their perception of their students' needs and interests (Davis, Janssen & van Driel, 2016; Morrison Thomas, et al., 2022). These revisions may enhance or limit the three-dimensional nature of the science instructional resources and related instruction (de los Santos, 2017; Covitt et al., 2020).

In the *new normal*, teachers use evidence of student learning (Table 1, row 2) to revise instructional resources in ways that further support students' three-dimensional classroom engagement, science identity development, and successful performances.

Pull-out Professional Development (not in the analytical framework). Pull-out professional development is typically provided by a district science coordinator or experts from external science education communities, including this author as a *Carbon TIME* expert, and comprises one of the activities that teachers may engage in together with their local, course-based professional communities (Jackson, Webster & Wilson, 2018). Though an important aspect supporting teacher learning and teachers' shifts to *NGSS*-aligned classroom practice, this component was not directly included in the analytical framework.

Study interviews addressed this question only tangentially, because all teacher interview participants had already participated in *Carbon TIME* pull-out professional development. This study was seeking to explore teachers' in-district, course-based professional community

experiences. Interview-related ideas related to pull-out professional learning are addressed (when relevant) in teachers' professional community responsibilities around innovation (B.4); and in District and Union roles related to external science education communities (C.4).

Local Public Community (row 5)

Finally, some participants' stories described the local public community (5) as salient parts of their district-level community.

Defining Local Public Community. A district's local public community primarily includes parents of current and former students, who advocate for particular kinds of classroom experiences that they see linked to particular kinds of outcomes they desire (Labaree, 1997). Though local public communities influence all public school districts, only two of the districts in this study shared stories suggesting the local public community is influencing secondary science teaching.

Local Public Communities in the New Normal. In the *new normal*, teachers talk about curriculum with community members and consider local public community's goals for consistent and equitable curriculum for all students.

Two Important Dimensions in the New Normal: Collective and Three-Dimensional Science

As apparent through this introduction and my analytical framework (Table 1), my *new normal* has two core dimensions – a collective (vs. individual) dimension and a three-dimensional science (vs. one-dimensional or otherwise not-three-dimensional science) dimension. What this means is that reaching the *new normal* – in which we could experience vignettes like Ms. Nolan's in any biology classroom in any high school in any public school district in the state – will require local teacher professional communities to shift away from

egalitarian, autonomous, non-interfering communities, toward collective communities pursuing common *classroom pedagogical responsibilities*, as well as requiring individual classroom teachers to change classroom discourse away from quick-and-snappy engagement with one-dimensional student learning goals, toward phenomena-centered three-dimensional science engagement.

Collective vs. Individual

By *collective* professional communities, I mean that teachers are working together as a group, seeking consensus as they make decisions. Teachers perceive their individual work with their students as connected to their professional community through shared *classroom pedagogical responsibilities* and the joint instructional development, revision, and sensemaking supporting those responsibilities. Teachers collectively develop agreed-upon measures of student learning and can then use students' performances to identify problems, inform revisions in instructional resources, and adjust classroom instruction. In this way, evidence of student learning is formative – it informs improvements – for both the collective work of the professional community and individual classroom teachers' work behind their classroom doors.

This approach contrasts with an *individually oriented* professional community, in which individual teachers maintain autonomy to their own *classroom pedagogical responsibilities*, even if they collaborate with colleagues or spend time meeting as a professional community. Such individual orientations – with their coordinating norms for niceness and non-interference, and egalitarian beliefs – are widespread in American public schools (Little, 1990).

Three-Dimensional Science vs. Not-Three-Dimensional Science

For the second dimension, *three-dimensional science* encompasses the vision for classroom engagement provided in the NRC's *Framework* (2012), goals for student learning expressed as the *Next Generation Science Standards*, and an expectation that developments in the field of science education will continue as researchers and practitioners work together to define and pursue excellence and equity.

This contrasts with one-dimensional science (or other versions of not-three-dimensional science), which has traditionally pursued student learning goals prioritizing content memorization and stand-alone inquiry skills. Not only do these classroom approaches not represent the curiosity and endeavor of science, but they have also been historically inequitable to marginalized communities (NRC, 2012).

Collective and Three-Dimensional Science

My argument is that it takes teacher professional communities – with supports from their District and Union – pursuing both collective orientations and three-dimensional science instruction to make progress toward a *new normal*. Identifying stories from the four districts provide this data; stories from Districts N and F indicate they are pursuing both dimensions, while District A is pursuing just the three-dimensional science dimension, and District M is pursuing neither.

Summary of the Next Chapters

Next, in Chapter 2, I provide a longer literature review for topics related to my analytical framework (Table 1). This is followed by Chapter 3 – Methods – where I detail my data collection, reduction, and analysis steps. Chapters 4-6 presents my Results; Chapter 4 shares

findings for Research Question 1, describing each district's *actual identity* using my analytical framework; then Chapter 5 does for Research Question 2, describing each district's *designated identity*; followed by Chapter 6, sharing results from Research Question 3, comparing districts' *actual* and *designated identities* with the *new normal*, specifically around the benefits and costs of change toward three-dimensional science classroom summative assessments. Chapter 7 closes this study with summaries of the four Districts, a discussion of core findings, and implications for practice and research.

Chapter 2 – Literature Review

In this chapter, I provide an overview of literature related to key ideas in this dissertation study, including identifying stories; characteristics of schools and classrooms; roles of districts and unions; teachers' professional communities; and three-dimensional science teaching and learning.

Identifying Stories

"Identities may be defined as collections of stories" about people and organizations (Sfard & Prusak, 2005, p. 16). These identifying stories are powerful in how they state to individuals and others "who we are" and "how we can" interact or behave. Sfard and Prusak (2005) name these narratives *actual identities*, "consisting of stories about the actual state of affairs" (p. 18). They note that *actual identities* are shared in the present tense as factual assertions.

They also describe *designated identities,* "consisting of narratives presenting a state of affairs which, for one reason or another, is *expected* to be the case" (Sfard and Prusak, 2005, p. 18). These narratives tend to use future-facing or expectant words, "such as *should, ought, have to, must, want, can, cannot*, and so forth" (Sfard and Prusak, 2005, p. 18)

Stories about the future – *designated identities* – may also be expressed in ways that are continuous; in other words, telling about who we have been or what has happened (Bateson, 2006). In this way, we can prepare to reenact that story in the future and transfer our learning to new situations. Differently, we can designate a "fresh start" as we prepare to make different decisions in the future – telling, instead, a discontinuous story (Bateson, 2006).

Teachers' Identifying Stories and Reform

Teachers' identifying stories are meaningful because of how they affect teachers' classroom decisions and interactions with students. *Carbon TIME* research shows that teachers' identifying stories correlate with students' learning gains (Morrison Thomas, et al., 2022). In lower learning gains classrooms, teachers told identifying stories as "quick-and-snappy" teachers whose successful classroom engagement meant using *Carbon TIME* activities in ways that maintained students' enthusiasm (Hess & Azuma, 1991). Differently, teachers in higher learning-gains classrooms told identifying stories as facilitators using *Carbon TIME* instructional materials to scaffold students' three-dimensional performances and sensemaking.

Educational researchers investigating other content areas, including math, also notice patterns in teachers' identifying stories that are likely consequential to students' classroom learning. For example, Drake & Sherin (2006) share how teachers' identifying stories – including their identities as math learners – affect their use of reform-oriented curricula.

Identities

Identities, the embodiment of our self-understanding, are powerful constructs because of their roles in learning and decision-making (Nasir, 2012; Sfard & Prusak, 2005). Identity can be described as a sense of self that is constantly in the process of construction, deconstruction and/or reconstruction: fluid yet stable (Cross, 2012; Nasir, 2012; Renn, 2012). Ironically, though "identity is the embodiment of self-understanding" (Nakkula, 2008, p. 11), its development is "not an individual endeavor" (Nakkula & Toshalis, 2006, p. 6). This is because identities are constructed from available possibilities, potential options, and existing social categories

(Nakkkula, 2008; Nasir, 2012; Renn, 2012). Finally, identities are expressed – or enacted – through our choices, behaviors, and actions (Cross, 2012).

Enduring Characteristics of Classrooms and Schools.

Unlike Ms. Nolan's vignette in Chapter 1, our U.S. education system has generally provided students places to go without corresponding demands for challenging work (Lynd & Lynd, 1929). Arising under circumstances prioritizing attendance and assimilation, ours is a mass public schooling enterprise designed for enormity, not with equity or excellence in mind (Kaestle, 1983; Mirel, 2010; Peurach, et al., 2019). In fact, neither students, nor their families, nor their teachers have historically believed most students are motivated to or capable of mastering rigorous outcomes (Lynd & Lynd, 1929; Powell, Farrar & Cohen, 1985).

Not only has our historic education system not defined significant student learning outcomes as goals, but it has also been loosely coupled so that organizational structures are separated from instructional activities and outcomes (Meyer & Rowan, 1978). This means that it has been organized in ways that disconnect the actual work of teaching and learning from the school and district and assign it to isolated teachers and students in individual classrooms.

Changing Patterns in Schools

Though it is the case that the previous few paragraphs outline historical and current realities that make substantive change to secondary science classrooms challenging, there is reason to be optimistic. Reforms that embrace rigorous learning goals for all students and organizational redesign that link student outcomes, classroom instruction, and professional discourse appear to be underway. In some places, schools and districts are defining and

organizing their work in new ways following a sustained, several-decades move away from mass schooling toward excellence and equity (Peurach, et al., 2019).

Roles of Districts and Unions

School Districts

From both historical and present-day perspectives, the school district is a critical scale in the educational system. As O'Day and Smith (2019) point out, "local districts have the most direct influence on what happens in schools" (p. 159). Districts are responsible for hiring and supporting staff, establishing instructional policy, and ensuring the management of individual schools. Their policies, cultures, and structure significantly shape teachers' day-to-day work environments and resources, including classroom instructional and assessment materials (Shepard, et al., 2018). Districts further control the potential for instructional change because they are the primary providers of professional development and ongoing support for teacher learning (Akiba & Wilkinson, 2016; Johnson & Fargo, 2010; Richmond & Manokore, 2011; Whitworth & Chiu, 2015).

Teachers' Unions

Alongside school districts – acting on a perceived spectrum from partner to nemesis – is the local teachers' union. These locals are affiliates of either the National Education Association (NEA) or the American Federation of Teachers (AFT). Teachers' unions – with a combined membership of 3.7 million members – are widely recognized as the most powerful organizations representing the interests of American educators (Cowen & Strunk, 2015; Moe, 2014; O'Day & Smith, 2019). This power and prowess continue, even after an onslaught of

right-to-work legislation that has nationally barred public-sector unions from collecting "agency fees" from non-members (O'Day & Smith, 2019).

The last half of the twentieth century saw collective bargaining rights granted to public employees, and this has shaped what we generally hold to be teachers' unions' traditional work and orientations (Kahlenberg, 2006). Teachers' unions historically used collective bargaining as a tool to secure "bread and butter" issues of salaries, benefits, and working conditions. This was especially necessary in a time when teachers – with college degrees – were earning less than the average factory worker.

But "professional issues" have been somewhere on teachers' unions' radars for at least the last forty years (O'Day & Smith, 2019). An early notable example is Al Shanker's response to the *A Nation at Risk* report; starting in 1985, the AFT President responded by advocating for teacher unionism based on teacher professionalism (D. Goldstein, 2014; Kahlenberg, 2006). And though it is the case that state and local affiliates – even today – have mixed feelings about Shanker's perspectives (Kahlenberg, 2006; Koppich, 2006), their actions suggest that these organizations may not be the stalwart opponents of reform for which they are notorious. As far back as the 1980's, local unions tended to respond to reforms with "accommodation and compromise [not] opposition and defense of the status quo" (McDonnell & Pascal, 1988, p. 51).

Today, teachers' union members want their organizations to pay attention to both "bread and butter" and "professional" issues (Koppich, 2006). Members want their union to be avenues for individual professional development while also wanting them to negotiate good health care and ensure they don't need to work a second job.

Some also want their unions to be vehicles for school and district instructional improvement. Though many people acknowledge that "creating effective schools may depend on the ability of the teachers' union and the district administration to work together" (Purkey & Smith, 1985, p. 371), members and leaders differ to the extent that they want their local unions engaged in serious reform, and the extent to which they want district-union partnerships (Rubinstein & McCarthy, 2011).

District-Union Partnerships. To some extent, district-union partnerships link what happens inside classrooms with what happens in teachers' professional communities (APA, 2019; Hamill, 2011; Knudson, et al., 2017; McCarthy & Rubinstein, 2017; Rubinstein & McCarthy, 2011; Rubinstein & McCarthy, 2016). Reports of district-union partnerships suggest that they foster social resources such as relational trust (Bryk & Schneider, 2002) and improve qualities of the social environment – including collaboration, open communication, and shared decision-making – that support quality teaching and student achievement (Rubenstein & McCarthy, 2011; Knudson, et al., 2017). They also appear to increase the resources available for the work of teaching and learning by aligning district and union goals and activities (Knudson, et al., 2017). There is even evidence of improved student outcomes on state science assessments due to district-union partnerships (Rubinstein & McCarthy, 2016), though these are likely traditional, skill-based assessments that are not fully aligned with new, three-dimensional science learning goals.

Peer Assistance and Review. Even more surprisingly, some district-union partnerships engage in organizational education redesign and coupling. For example, joint district-union Peer Assistance and Review programs link historically uncoupled formal teacher evaluation with

teacher improvement systems (J. Goldstein, 2007; Papay & Johnson, 2012). This is antithetical to traditional union stances which eschew peer evaluation, instructional support providers (such as mentors or coaches) as evaluators, and – truly – teacher evaluation based on rigorous student outcomes and strong connections to teachers' actual classroom practice (D. Goldstein, 2014; Moe, 2014). Yet Peer Assistance and Review programs link individual teacher's classroom discourse with professional discourses by establishing visions and goals for quality teaching that are common across teachers, schools, districts, and unions and by opening the classroom to peers' observations and critical discussions.

Teachers' Professional Communities and Teacher Learning

Within and across school districts, teacher professional communities can differ widely (McLaughlin & Talbert, 2006). Most exhibit traditional norms of non-interference (Little, 1990), while some support teachers' collective inquiry and sensemaking. Though unusual, these collective professional communities are of particular interest because their characteristics contribute to teachers' perceptions of positive working conditions, enhancing job satisfaction and keeping teachers in the profession (Johnson, Kraft & Papay, 2012). Further, collective professional communities contribute to improved academic achievement and more equitable outcomes for students (McLaughlin & Talbert, 2006).

Traditional Teacher Professional Community Norms

Traditional and current structures of classrooms and schools result in teachers' structural and temporal isolation from other professionals, which in turn allows for coordinating norms of privacy and non-interference around classroom work (Little, 1990; Spillane & Shirrell, 2018). Without collective obligations to common learning goals and with

norms for privacy, teachers (unsurprisingly) tend to communicate about professional work and success in ways that are generally accepting of other teachers' decisions, are "nice," and are disconnected from student outcomes (Feiman-Nemser, 2001; Jackson, 1990).

In professional communities in which norms of non-interference are operating, teachers (and observers) can get a sense that colleagues get along well with each other and even work together on particular tasks (Horn, 2020). This "culture of niceness" (Nelson, 2009) is widely recognized as inhibiting teachers' abilities to critically question others' beliefs or decisions. Instead, normal forms of teacher communication and storytelling use "common-sense discourse" maintain prevailing norms for privacy and noninterference and "avoid interpersonal conflict" (Horn & Kane, 2019).

Though separation between teachers' professional discourse and their classroom discourse makes sense in a loosely coupled education system, it is a barrier to widespread adoption of three-dimensional (and other rigorous and responsive) classroom discourse (Feiman-Nemser, 2001).

Science Teacher Professional Development

In practice, teacher professional development has a mixed track-record, yet the education research community is in consensus around qualities of effective professional learning experiences that impact actual science classroom discourse and student outcomes (Darling-Hammond, Hyler & Gardner, 2017; Desimone, 2009; National Academies, 2015). These consensus qualities include a focus on content, incorporating active learning, supporting collaboration, using models of effective practice, providing coaching and expert support, and offering opportunities for reflection (Darling-Hammond, et al., 2017).

Such professional learning experiences are necessary for science teachers shifting toward three-dimensional classroom discourse because this *new normal* involves ambitious goals for sophisticated, integrated student learning alongside challenging expectations for teacher practice (Anderson, et al., 2018; National Academies, 2015; Reiser, Michaels, Moon, Bell, Dyer, Edwards, McGill, Novak, & Park, 2017; Taylor, Roth, Wilson, Stuhlsatz, & Tipton, 2017).

Analysis-of-Practice Within Teacher Professional Communities

Analysis-of-practice – involving teachers' inquiry into their own (or others') classroom discourse (Roth ,Garnier, Chen, Lemmens, Schwille, & Wickler, 2011) – is one example of an effective approach to science teacher professional learning. A key feature is the use of artifacts – student work, assessment products, or lesson videos – because these allow practitioners to "slow down the teaching process to make it available for inquiry" (Roth, et al., 2011, p. 118). Analysis-of-practice approaches are powerful because they center teachers' professional learning experiences on student thinking and learning (Loucks-Horsely, et al., 2003; Nelson, 2009). In our own *Carbon TIME* project, we have noticed that teachers' sensemaking is more productive – and they are more likely to shift their teaching practices toward three-dimensional classroom discourse – when they are noticing and thinking about their students (de los Santos, 2017).

Strategies for guiding these conversations include the use of facilitators and protocols (Nelson, 2009; Richmond & Manokore, 2011; Loucks-Horsley, et al., 2003; Windschitl, Thompson, & Braaten, 2011) – though even facilitators can find it difficult to challenge teachers and ask "probing questions that could help … challenge ideas" (Nelson, 2009, p. 567).

Ultimately, protocols can guide the analysis work itself as well as guide focused conversations (Heller, Daehler, Wong, Shinohara & Miratrix, 2012; Loucks-Horsley, et al., 2003; Taylor, et al., 2017).

Three-Dimensional Science Teaching and Learning

Episodes like Ms. Nolan's vignette in Chapter 1 present a vision for science learning provided by the National Research Council's (NRC) *Framework for K-12 Science Education* (2012), in which students are *figuring out* natural phenomena: students in Ms. Nolan's classroom are *figuring out* what happens when ethanol burns, not *learning about* combustion (NGSS website, 2016). The *Framework* (NRC, 2012) describes *figuring out* as a three-dimensional process in which students engage firsthand in science and engineering practices (SEPs) while learning important disciplinary core ideas (DCIs) and applying crosscutting concepts (CCCs). In this and other three-dimensional work, students experience science in complex ways that can support their meaningful understanding of science concepts and of science as a way of knowing.

Chapter 3 – Methods

This is a qualitative study using interview data from selected teacher, district science coordinator, and teachers' union participants.

Study Context

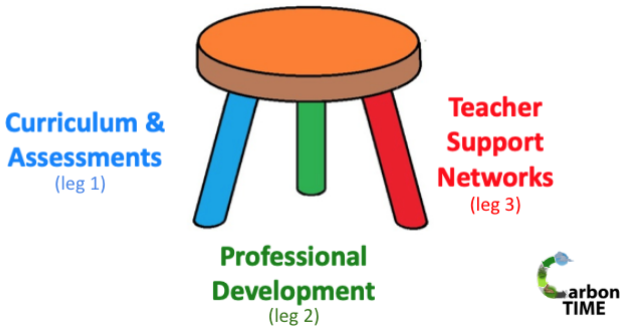
This dissertation study was developed out of *Carbon TIME* project experiences, including relationships with teachers' unions, school districts, and teachers.

Carbon TIME

Carbon TIME (Transformations In Matter and Energy) is a Design-Based Implementation Research (DBIR) project (Fishman & Penuel, 2018) funded by the National Science Foundation (NSF). *Carbon TIME* builds on the science education community's broad consensus around the *Framework for K-12 Science Education* (NRC, 2012) and the *Next Generation Science Standards* (NGSS Lead States, 2013).

Carbon TIME design efforts have been organized around a "three legs of the stool" approach, represented in Figure 2. Carbon TIME "Three legs of the stool" (Anderson, de los Santos, Bodbyl Roels, Covitt, Edwards, Hancock, Lin, Morrison Thomas, Penuel & Welch, 2018). Teachers are provided with the tools and vision for shifting classroom practice through three-dimensional science curricular units (leg 1) and coordinated professional development (leg 2), engaging in this work within a network of peers (leg 3).

Figure 2. *Carbon TIME* "Three legs of the stool"



State and Local Teachers' Unions

As mentioned in Chapter 1, one of the *Carbon TIME* teacher support networks (leg 3) was organized through a state teachers' union. *Carbon TIME*'s professional learning program is supported by the state teachers' association's professional development center, which is actively providing professional learning experiences for teacher members while also supporting members and local associations in developing, providing, and organizing around issues of professional improvement.

Two local teachers' unions – Union A and Union F – partnered with the professional development center of the state teachers' association to provide *Carbon TIME* professional learning opportunities to biology teachers in their affiliated school districts. These partnerships were facilitated with the District A and District F district science coordinators, and the *Carbon TIME* professional learning was provided by the author.

Participants

Participating school districts and teachers' union – and individual participants – were purposefully selected to provide information relevant to this project's research questions (Maxwell, 2013). Participants included high school biology teachers, their district science

coordinators, and local teachers' union leaders in locations where *Carbon TIME* units had been officially adopted or were formally available for teachers' use.

Selected School Districts and Local Teachers Unions

Table 2 provides demographic information about the state teachers' union and each of the four selected school districts and their local teachers' unions. The four school districts in this study were large enough to typically have seven or more staff teaching biology each school year, across one or more high schools.

As indicated, these districts were purposefully selected, and are not representative of all school districts of this size or larger in the state. Still, available data suggests that about 16% of public school districts in the state are large enough to likely have a course-based (biology) professional community of at least seven teachers. Further, these public school districts serve close to half – about 40% – of the state's public school students.

Table 2. Demographic Information for Participating Unions and School Districts					
Participating Location and *Carbon TIME (CTIME)* relationships	# of HS; # of HS students	District % economically disadvantaged	District % marginalized students of color[1]	State per-pupil funding SY21-22	Teachers' union members
State Teachers Union • NSF-funded *CTIME* network (SY16-18, SY17-19)					120,000
District A • 7 NSF-funded *CTIME* network teachers • Union-supported local *CTIME* Network	4 High Schools; 5,066 students	24%	23%	$9648	3,500
District F • some biology teachers piloted CTIME in SY19-20 • Union-supported local *CTIME* Network	2 High Schools; 3,245 students	29%	29%	$10,533	unavailable
District M • 4 grant-funded *CTIME* network teachers	2 High Schools; 2569 students	35%	7%	$8758	775
District N • 4 NSF-funded *CTIME* network teachers	1 High School; 2,049 students	9%	11%	$8948	1,275

Demographic data: (State of Michigan, 2022 & 2020)
Teachers' union members: (C. Williams, personal communication, May 24, 2019)
[1] percent marginalized students of color include students identifying as Native Hawaiian or other Pacific Islander; Hispanic/Latino; American Indian or Alaska Native; and African American

Selected Individual Participants

Participants were invited to participate in one or more interviews and were compensated for their time. Participants are listed by role in Table 3. Individual participants included high school biology teachers, their district science coordinators, and local teachers' union leaders in locations where *NGSS*-aligned *Carbon TIME* units have been officially adopted or were formally available for teachers' use, as well as two participants (one elected leader and one staff) from the state teachers' union affiliated with its professional development center. Appendix A includes more detailed information for each participant.

Table 3. Interview Participants by Role

	Round 1 *May-June 2020*	Round 2 *May-June 2021*
State teachers' union – governance & staff	2	0
Teachers' union staff	4	1 (w/ local president)
Local teachers' union presidents	4	4
School district science coordinators	4	4
Carbon TIME classroom biology teachers	11	--
Total Interview Participants	25	9 (8 interviews)

District Science Coordinators. District science coordinators varied in their position descriptions and designs. In Districts A and F, district science coordinators are full-time release, district-office staff who are members of the teachers' collective bargaining unit (not administrators). District A's district science coordinator is responsible for secondary science instruction, while District F's district science coordinator is responsible for K-12 math and science instruction.

District N's district science coordinator is a full-time high school biology teacher with an extra-duty stipend; she had one hour of release time for five years during the district's *NGSS* rollout.

District M's district science coordinator has a broader role than her study counterparts, overseeing all secondary curricular areas. She is the only one classified as an administrator, and therefore not eligible for membership in Union M.

Interview Data Collection

Both Round 1 and Round 2 interviews employed a semi-structured protocol with several main questions and coordinated probes for each. Participants in Round 1 and Round 2 interviews are listed in Table 3.

Round 1 Interviews

Round 1 interviews were completed in May and June, 2020. There were 25 interviews, with teachers, district science coordinators, and teachers' union leaders. Interview protocols were modified for each of these participant roles. Interviews were approximately 60-90 minutes, were conducted and recorded via a virtual meeting platform, and were then transcribed.

Round 1 interviews asked participants questions about the *Next Generation Science Standards* and related classroom implementation in their context; how teachers spend (and should spend) their non-instructional time; how curriculum, assessment, and teacher professional development connect with teacher accountability and evaluation; and district and union roles in the aforementioned areas. The Round 1 interview protocol (compiled for all participant roles) is available in Appendix C.

Round 2 Interviews

Follow-up, Round 2 interviews occurred a year later, in May and June, 2021. There were eight interviews, with nine participants. In District A, the local union president and the local union executive director (staff) participated together.

Round 2 interviews asked participants to share their perspectives and then respond to specific scenarios around four aspects of the *new normal*: common curriculum; common assessments; evidence of students' learning (through common assessment data); and teachers' time with colleagues reviewing student work samples. A sample Round 2 interview protocol is available in Appendix D.

Data Reduction and Analysis

In this study, initial data analyses supported the development of the second interview protocol and were also used in support of overall findings. In total, this study produced more than 850 pages of interview data, so data reduction and analysis were important.

Initial Analysis

Initial analysis of interview data included a review of notes taken during the interview sessions and writing of post-interview memos. These steps supported noticing potentially important or otherwise surprising aspects of interviews as well as connections across interviews (Maxwell, 2013).

After the completion of Round 1 data collection, I listened to each recorded interview while reading the transcript, making notes reflecting important ideas and questions using comments. This process was then repeated, supporting an in-depth understanding of the content of the interviews.

During this time, transcript quotes were copied and organized into tables around district-specific issues that seemed different across districts and prompted exploration. These often related to teacher accountability and participant-described situations presenting obstacles to local three-dimensional science classroom instruction. These initial analysis steps led to the development of the Round 2 interview protocol.

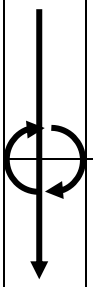
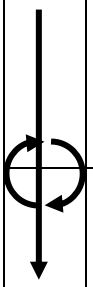
Formal Data Reduction and Analysis

Following Round 2 interviews, I began a formal data reduction and analysis process, represented in Table 4. This work was both linear and iterative, as represented by both straight and looped arrows in Table 4. For example, narrative-writing and concurrent sensemaking discussions prompted revisiting summary tables and overviews, sometimes returning to quote tables to reaffirm conclusions or pursue new ideas and hypotheses.

Table 4. Ongoing Data Reduction and Analysis Process

qualitative codes used in interviews ↓	*Codes related to Table 1 Analytical Framework Rows A & B, Responsibilities:* vison (*NGSS*); colleagues
	Codes related to Table 1 Analytical Framework Row C, Roles: union; district
	Codes related to Table 1 Analytical Framework Rows 1-4, Professional Actions: curriculum; assessments; teachers' time; evidence of students' learning
quote tables compiled by theme around Professional Actions	*Quote tables corresponding to Table 1 Analytical Framework Rows 1-4, Professional Actions:* 1a. common curriculum (included *NGSS*-vision) 1b. common assessments 2. evidence of student learning 3. people crossing the classroom door 4. teacher's time (what do Ts do during non-instructional time?)

Table 4 (cont'd)

		Research Question 1 Actual Identity	Research Question 2 Designated Identity	Research Question 3 Costs & Benefits
Data Source(s) for coded quotes copied to thematic quote tables		Round 1 interviews, with excerpts from Round 2 interviews	Round 2 interviews, with excerpts from Round 1 interviews	Round 2 interviews, with excerpts from Round 1 interviews
	**Summary Tables & Overviews** *Purpose: notice small grain size (trees) and look for patterns*	*for each Professional Action* • summary tables by district	*for each Professional Action* • overviews by district • overviews by role • summary tables of two dimensions	*for each Professional Action* • overviews by district • overviews by role • summary tables of two dimensions
	**Outlines, Key Sentences & Models** *Purpose: notice larger grain size (see the forest)*	• district models, with focus on crossing the classroom door • outlines of district & union roles • key sentences around district identities and *new normal* characteristics	• district models, with focus on crossing the classroom door • key sentences around district identities and *new normal* characteristics	
	Narratives *Purpose: sensemaking*	• narrative summaries by teacher action • narrative stories of district *actual identity*	• narrative stories of district *designated identity*	• narrative stories of comparing district identities and *new normal*
	Quantitative Analysis *Purpose: confirming two dimensions*			Analysis of costs and benefits by District along two dimensions: • individual vs. collective • 3D science vs. not-3D-science

Qualitative Coding. Interviews were read and qualitatively coded using codes relevant the study's analytical framework (Table 1). These codes and their connections to the analytical framework are listed in Table 4. Qualitative codes were related to teachers' responsibilities; district and union roles; and aspects of teachers' professional work including curriculum, assessment, and time with colleagues. The "local public community" (Table 1, row 5) component of the study's analytical framework was not included in the qualitative codes; the salience of that characteristic emerged later, across quotes in some districts.

Thematic Quote Tables. Quotes (in the form of individual interview responses or larger chunks of conversation) with the same code were copied into thematic quote tables. Each quote was reviewed and briefly summarized as part of these thematic quote table.

Summary Tables and Overviews. Separately, quotes were organized into summary tables by noting just participants' district and role. In later work focused on Research Question 2 and Research Question 3, quotes were rearranged into like-groups and titled, with titles recorded in separate overview tables. These efforts focused on concisely representing characteristics of districts, supporting fine-grain (tree-level) interaction with and understanding of the data, while affording opportunities for pattern-finding (moving to the forest).

Outlines and Models. Next, these summary tables and overviews were used alongside this study's literature-based analytical framework to create models (drawings), written outlines, and key sentences. The purpose of these efforts was to make connections among patterns in the data and larger concepts and purposes in the analytical framework.

Narratives. Outlines, models, and key sentences, in turn, were used to draft narratives around each research question. These supported personal sensemaking and collaborative

discussion and sensemaking with my advisor. Over time, significantly longer narratives were shortened to focus on key points. In this process, multiple quotes from participants in a district were reduced to one key representative quote or summarized without quoting.

Quantitative Data Analysis around Costs and Benefits. As shown in Table 4, participants' quotes about costs and benefits of district and union roles and teachers' actions in the *new normal* were quantitatively analyzed around two dimensions – individual versus collective and three-dimensional science versus not-three-dimensional science.

For the first dimension, costs and benefits were analyzed as an individual teacher benefit or a collective benefit to the larger, course-based teacher professional community. For the second dimension, a list of key words and phrases related to three-dimensional science were used to consider the cost or benefit as three-dimensional (ex: *phenomena, argumentation, storyline, students' sensemaking*, etc.).

The quantitative data was used to produce district-specific matrixes showing the percent of costs and benefits along each dimension – for example, the percent collective costs and benefits listed by district participants, as compared to individual costs and benefits. These efforts were an important part of the sensemaking process and contributed to my confidence that these two dimensions were, indeed, valuable to the results presented in Chapters 4-6. However, in-and-of-themselves, these quantitative data were less informative than originally anticipated. Therefore, these data are provided as Appendix D, but not included in the results for Research Question 3.

This decision also reflects constraints around validly and reliably interpreting the quantitative data. There were sampling limitations, in the sense that the semi-structured

interview protocols did not afford opportunities for participants to consistently discuss the same kinds of costs and benefits. There was also an interpretation issue; first, around what counted as a cost or a benefit and second, around whether it was collective or individual (or both) and whether it was relevant to three-dimensional science or not-three-dimensional science (or both). Finally, there were perspective constraints. Specifically, the questions were asked in an attempt to elicit participants' perceived costs and benefits of changing to the *new normal*, but review of the data suggests participants were responding based on costs and benefits of their *designated identity*.

Chapter 4 – Results for Research Question 1: Districts' Actual Identities

In Research Question 1, I use this study's analytical framework to identify patterns in participants' interviews addressing this question: *What is each district's actual identity as shared in stories about teachers' responsibilities; district and union roles; and what and who crosses the classroom door*?

As described in Chapter 1, *actual identities* are identifying stories about "the actual state of affairs" (Sfard & Prusak, 2005, p. 18). These stories express important qualities, such as *who we ar*e; *what we value*; and *how things work* in each district. Though each participant's interview was uniquely their own, stories representing aspects of my analytical framework (and thus relevant in my *new normal*) were quite consistent across interviews from the same district, portraying district-specific identities that are shared here.

In what follows, results are organized by district and correspond with Table 5, Districts' Actual Identities. An overview of the district's *actual identity* is shared first, and then each characteristic from the study's analytical framework is described, coordinating with lettered rows (roles and responsibilities) and numbered rows (professional actions) in Table 5.

Table 5. Districts' Actual Identities (Research Question 1)					
What were the patterns in participants' stories about?	**District N Actual Identity** A collective professional community with three-dimensional (3D) science goals for all students.	**District F Actual Identity** A collaborative professional community with three-dimensional (3D) science classroom experiences as goals for students.	**District A Actual Identity** An individually oriented professional community with three-dimensional (3D) science goals for students.	**District M Actual Identity** An individually oriented professional community maintaining the *status quo* for science teaching and learning.	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
A. Teachers' Classroom Pedagogical Responsibilities	**3D classroom experiences and outcomes; shared across all teachers** District biology teachers were described as holding *classroom pedagogical responsibilities* to students' 3D science classroom experiences and outcomes.	**3D classroom experiences (many teachers)** Many district biology teachers were described as holding *classroom pedagogical responsibilities* to students' 3D science classroom experiences.	**Teacher-valued classroom experiences and outcomes (many 3D)** District biology teachers were described as holding individual *classroom pedagogical responsibilities* to students' science classroom experiences and outcomes valued by the individual teacher.	**Quick-and-snappy & 1D** District biology teachers were described as holding *classroom pedagogical responsibilities* to students' quick-and-snappy experiences and 1D outcomes. One teacher was described as the exception, holding 3D goals for students.	**Three-dimensional science classroom experiences and outcomes; shared across all teachers** District biology teachers hold classroom pedagogical responsibilities to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A).	**Collaboration supports classroom work (for some teachers).** 1. Teacher collaboration with colleagues helps some teachers realize *classroom pedagogical responsibilities* (A).	**Individual Autonomy** 1. Teachers' selective collaboration helps individual teachers realize *classroom pedagogical responsibilities* (A).	**Individual Autonomy** 1. There are no connections between teachers' professional community work and their individual *classroom pedagogical responsibilities* (A).	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A).

Table 5 (cont'd)					
	2. Teachers have autonomy to experiment instructionally in their classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.	2. Teachers have autonomy within shared common curriculum. 3. Peer accountability exists through shared decision-making and peer-to-peer conversations. 4. Teachers share independent experiences with external science education communities with the professional community.	2. Teachers have autonomy in their classroom decisions. 3. Professional norms for non-interference and egalitarian beliefs maintain positive professional relationships. 4. Teachers may have independent experiences with external science education communities.	2. Teachers have autonomy in their classroom decisions. 3. Professional norms for niceness and non-interference maintain positive professional relationships. 4. Teachers may have independent experiences with external science education communities.	2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.

Table 5 (cont'd)

C: Roles of District and Union Leaders Related to Teachers' Professional Communities	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Transaction costs addressed through time and compensation (contractual; substitutes; extra pay). 3. Conflict costs addressed through district systems of accountability and support for the professional community. 4. Connections to external science education communities through the district science coordinator and teachers.	**Collective Support with some Individual Accountability** 1. District and union stories endorse collaboration; union stories limit peer accountability. 2. Transaction costs somewhat addressed through contractual collegial (PLT) time. 3. Building administrators play a role in accountability to professional community decisions. 4. Connections to external science education communities exist through the district science coordinator and the union in CTIME professional learning network.	**Enable individual teachers** 1. District and union stories endorse collaboration and autonomy. 2. Transaction costs not addressed, despite contractually required after-school meeting time. 3. Conflict costs minimized through accountability to generalized "good teaching." 4. Connections to external science education communities through the district science coordinator and teachers.	**Enable individual teachers** 1. District and union stories endorse individual teachers as autonomous experts. 2. Transaction costs not incurred. 3. Conflict costs minimized through accountability to generalized "good teaching." 4. Connections to external science education communities are limited.	**Collective Support with Collective Accountability** 3. District and union stories endorse professional community work as integral to 3D classroom instruction. 4. Mitigate transaction costs through time and compensation. 5. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 6. Connect to external science education communities.

Table 5 (cont'd)

1. What goes in?	**Common 3D Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments and end-of-course exams – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning	**Some common 3D units** • Initial: Some regular biology teachers piloted 3D instructional resources, selected by the professional community.	**Individually determined curriculum; common 3D course-level assessments** • Initial: 3D curricular units made available; 3D course-level assessments developed by science leadership team • Ongoing: Revised 3D course-level assessments	**Individually determined; mostly pick-and-pull, 1D resources** • Teachers used individual 'pick-and-pull' approaches to available 3D instructional resources, selecting classroom activities that prioritized quick-and-snappy engagement and 1D rigor. • One teacher was described as the exception.	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning
2. What goes out?	**Evidence of students' 3D learning** • teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes	**Limited evidence of students' learning** • some teachers' recounts focus on students' experiences • students' 2D/3D outcomes shared through student work artifacts	**Evidence of students' 3D learning** • students' 3D outcomes (common assessment data at building/district level and item level; student work)	**Recounts; some with evidence of students' 1D learning** • Teachers' recounts may include evidence of students' 1D learning. • Teachers share content-coverage information.	**Evidence of Students' 3D Learning** • teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes

Table 5 (cont'd)					
	• students' 3D outcomes (common assessment data), including at the teacher-level				• students' 3D outcomes (common assessment data; student work), including at the teacher-level
3. Who crosses the classroom door?	**3D & Connected to the Professional Community** • Building administrators complete observations for formal teacher evaluations and are aware of common 3D instructional resources. • Peers from course-based professional community use observations to support 3D instructional growth.	**3D & Disconnected from the Professional Community** • Building administrators complete observations for formal teacher evaluations and are aware of common 3D instructional resources.	**Disconnected from the Professional Community** • Building administrators enter during formal teacher evaluations. • Non-critical peers from outside the course-based professional community enter during Instructional Rounds (one high school).	**Disconnected from the Professional Community** • Building administrators enter during formal teacher evaluations. • Non-critical peers from outside the course-based professional community enter during Instructional Rounds.	**People are connected to the professional community and the focus is on 3D science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

Table 5 (cont'd)

4. What do teachers do together in their course-based (biology) professional communities?	**Linked "in" and "out"; 3D & Consensus-Seeking**
	• selection/ development of 3D instructional resources
	• sensemaking around 3D instruction, using evidence
	  ○ analysis of student learning artifacts (common assessment data)
	• revisions of instructional resources based on evidence
		Limited linking of "in" and "out"; 3D & Collaborative
		• selection of 3D instructional resources
		• sensemaking around 3D instruction, using (limited) evidence [*primarily building-based PLTs*]
		  ○ dialogic (rehearsals & recounts)
		  ○ analysis of student learning artifacts (student work)
			Limited linking of "in" and "out"; 3D
			• selection/ development of 3D assessment items [*science leadership team only*]
			• sensemaking around 3D instruction, using evidence
			  ○ analysis of student learning artifacts (common assessment data; student work)
			• revisions to common 3D assessments; unclear if based on evidence
				Minimal Actions
				• Participants shared only one story of consensus decisions, around students' credit-recovery materials.
					Actions link "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional and consensus-seeking.
					• selection/ development of 3D instructional resources
					• sensemaking around 3D instruction, using evidence
					  ○ dialogic (rehearsals and recounts)
					  ○ analysis of student learning artifacts (assessment data and student work)
					• revisions of instructional resources based on these two forms of evidence

5. Local Public community	**Common Instructional Resources for Equitable Outcomes** • Local public community supports shift to common instructional resources.			**Affirm *status quo*** • Local public community supports *status quo*.	• Teachers talk about 3D science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

District N: A Collective Professional Community with Three-Dimensional Science Goals for All Students

District N participants' stories portray District N's *actual identity* as a collective professional community with three-dimensional science goals for all students. Participants described all teachers holding *classroom pedagogical responsibilities* to all students' three-dimensional science classroom experiences and outcomes. Teachers' joint work within their professional communities was regarded as integral to individual teachers fulfilling their *classroom pedagogical responsibilities*. District and union leaders were described as providing collective support with collective accountability, as well as employing strategies that reduced transaction and conflict costs.

In District N, teachers described common, three-dimensional instructional resources crossing into the classroom and multiple forms of evidence of students' three-dimensional learning leaving the classroom. Participants described building administrators and members of the course-based professional community crossing the classroom door to make instructional observations. The course-based (biology) professional community selected and developed three-dimensional instructional resources; engaged in sensemaking around three-dimensional instruction, using evidence; and engaged in revisions of instructional resources based on evidence, linking what goes into the classroom with what goes out of the classroom.

Finally, the local public community supported district-wide use of common instructional resources to support equitable student outcomes.

Row A. District N Teachers' Classroom Pedagogical Responsibilities

District N participants shared stories of an actual state of affairs in which all biology teachers held *classroom pedagogical responsibilities* (Table 5, row A) toward all students' three-dimensional science classroom experiences and achievement, meaning their instruction behind their own classroom doors provided their students with sensemaking opportunities around natural phenomena and assessment opportunities measuring students' three-dimensional performances.

District N participants described the shift to the *Next Generation Science Standards* as students "figuring out" out natural phenomena, "instead of [teachers] giving away the answer," generally using a shared language that drew on the *NGSS*. This was true of the local union president (who was not herself a secondary science teacher), suggesting that teachers across grades and content areas were aware of important aspects of *NGSS*-aligned classrooms.

District N participants described every biology teacher agreeing that "all the kids are going to experience" the same key phenomena-centered classroom experiences, regardless of the specific teacher. This commitment to students' common experiences preceded *NGSS* and was described as enduring.

Participants noted that, "early on," *classroom pedagogical responsibilities* were not shared across all science teachers. Participants said that one of "the initial response[s] [to *NGSS*] was that we were actually 'dumbing down' the science … because we were removing some of the content." The district science coordinator said that District N took its "time with [the *NGSS*] rollout;" in fact, the rollout took five full years. She perceived this extended timeline

as valuable because it allowed skeptical teachers to try three-dimensional instructional resources with their students and review students' outcomes over time.

It took several years, according to participants, but eventually, "the AP biology teacher … [gave *NGSS*] the stamp of approval," reassuring other teachers that students "[we]re understanding things" successfully. In this way, teachers who had held *classroom pedagogical responsibilities* to students' content-memorization had time to engage in their own experiences, notice students' outcomes, and consider perspectives and evidence from other teachers in the professional community.

Row B. District N Teachers' Professional Community Responsibilities

District N participants' stories reflected their perceptions that working with their course-based colleagues was integral to their work behind their own classroom doors (Table 5, row B). Teachers' autonomy was described as experimentally linked to students' outcomes and peer-accountability arose from a consensus-seeking approach to decision-making.

Professional Community Work is Required (B.1). In District N, teacher participants explained that fulfilling their *classroom pedagogical responsibilities* (Table 5, row A) required collective work with their colleagues (Table 5, row 4). This was because *NGSS*-aligned science classroom engagement was challenging, requiring new instructional resources and new instructional approaches, and because teachers were committed to all students achieving three-dimensional outcomes.

The district science coordinator said District N's leadership set "high expectations for teachers … paired with high levels of support." Patterns across participants' stories suggested that this district-provided support came through the course-based professional community (see

examples below in C). This design helped reinforce the professional community as integral to teachers' classroom work, because instructional resources, digital tools, and expertise that supported individual teachers' work behind their own classroom doors were accessed through the course-based (biology) professional community.

Further, the course-based (biology) professional community was integral to teachers' classroom work because it was responsible for all teachers' success. As one teacher explained, "essentially, we've been told, 'Hey, if you have a certain … percentage of kids failing, then you as a teacher pretty much are failing … and we can't have that.'" When too many students were failing in some biology teachers' classes, the entire course-based professional community worked together to make changes (see example below in 4).

Teacher Autonomy to Experiment (B.2). District N participants said teachers perceived holding a "good bit of autonomy" around their classroom instructional decisions. Despite the district's expectations for students' common classroom experiences, there were no stories from participants suggesting that teachers' autonomy was diminished.

Instead, District N participants described autonomy in experimental terms: "If a teacher were to say, 'Well, I don't want to do it that way.' Well, that's fine. Put your own twist on things and … let's talk about it afterwards and see how it went." This experimental perspective – linking teachers' instructional autonomy to students' outcomes – was common across District N interviews. It suggests a shared belief that what teachers do in their classrooms affects students' outcomes. In this way, teachers could consider differences in their instruction from an "experimental" stance: Whose approach worked better?

Peer Accountability (B.3). Participants described a sense of being beholden to the decisions of the course-based professional community. As the district science coordinator put it, an educator "can't do [their] job" as a classroom teacher, until the professional community "select[s] the things that we're going to teach … What's it going to be? … No one … can move forward [individually] until we have at least a loose plan [collectively]." In District N, these decision-making plans sought consensus, where "everyone agrees."

Peer Accountability through Consensus-Seeking. Participants described a responsibility to others in the course-based professional community for enacting and upholding the group's decisions; they described peer accountability. This professional responsibility was described as widespread throughout District N. The local union president, for example, said that teachers "are expected to be part of [the course-based professional community] and they're … expected to [do the work]" with their peers, so that – behind each teacher's classroom door, everyone is doing "what we do."

Innovation (B.4). District N participants described an expectation for innovation – teachers would share their independent experiences or classroom improvements with the course-based (biology) professional community. The district science coordinator recognized the challenges with this expectation. Teachers might bring experiences or ideas back from external professional development, "but we don't really understand it well enough" to evaluate its utility within the course. She continued, "if everybody does … a different thing … how do you know which one is the useful one?"

For this reason, the district science coordinator tried to ensure that new, three-dimensional science curricula were piloted by multiple teachers. Stories from District N

participants indicated that piloted units originated from university-based research and development programs, which was beneficial in that "most of the teachers … were willing to do the pilot[s] … for the [additional, external] money" attached to their participation.

Row C. Roles of District N and Union N Leaders related to Teachers' Professional Communities

At least ten years before this study, District N initiated a "school improvement monument" that was described as a key source for District N's and Union N's roles (Table 5, Row C). This included supporting stories endorsing teachers' professional community work as integral to teachers' three-dimensional science classroom instruction. District N and Union N addressed transaction costs related to teachers' professional community work through time and compensation, and the district provided clear systems of accountability for teachers and each course-based professional community.

District and Union Stories Endorse Professional Communities as Integral (C.1). District N's school improvement monument was described as providing a district-wide message: "This is what we believe in, and this is how we're going to make decisions," that was rooted in "equity for kids."

District N Stories. Participants explained that the school improvement monument included "an expectation that everybody is using the same curriculum … [and] common assessments," because shared instructional resources were described as supporting equitable experiences and outcomes for students. This story positioned what teachers do together in their course-based professional community (selecting, developing, and revising common curriculum and assessments) as integral to what they do individually behind their classroom doors.

During District N's 5-year *NGSS*-rollout plan (2014-2019), the *NGSS*' "all standards for all students" stance was perceived as aligning with District N's messages and actions around "equity for kids." The district "prioritize[ed] science [so] ... during the five years of that rollout … everything else got put on hold." In this way, District N communicated "that science was important" and reserved resources to support shifts in science teachers' instruction. The rollout period provided valued time for teachers to make changes, but it did not imply that changes were not important. Participants shared that the message from District N was clear: "'This is not optional. *NGSS* is not optional'."

Union N Stories. Participants' stories indicated Union N "protects their teachers." In this case, that meant ensuring that if the district "wanted [teachers] to do something that's outside of our normal workday, the union says it needs to be compensated." From Union N's perspective, expectations for developing all new common curriculum and assessments incurred additional work for teachers, and Union N ensured this work was compensated.

The district science coordinator said, "because [the work] was compensated, teachers did it." As the local union president pointed out, this led to "teachers [becoming] the owners of [the common instructional resources] and then as things changed, teachers made the changes. So, it wasn't seen as something that the administrators were pushing on teachers. … Having teachers … doing the work was huge."

Union N is perceived as critical in establishing a system that has been longstanding and viewed as successful as well as in broadcasting messages about teachers owning these accomplishments. Additionally, Union N is perceived as an organization that doesn't "stop innovation from happening." Some union members initially tried to grieve the District N

expectations for common instruction, saying "'We don't have to be the same … [the district] is taking away my professional creativity'." However, Union N determined that these concerns "didn't violate the contract [and] they fizzled out there." Union N's "attention to their contract" supported the district's move to common – and more equitable – experiences and outcomes for students.

Mitigating Transaction Costs through Time and Compensation (C.3). The district science coordinator – one of the two teacher-leaders leading the *NGSS* rollout – described "high levels of support" during the *NGSS* rollout, including District N's financial support of teachers' time together and compensation for additional work.

Time. With District N and Union N already having expectations in place that ensured teachers were provided time with their course-based professional community to focus on instructional resources, District N's *NGSS* rollout followed suit. District N funds supported substitutes for both pull-out professional development days and school-day course-based (biology) professional community collaboration time. Additionally, teachers regularly had two contractual after-school course-based professional community meetings each month.

District N's *NGSS* rollout included a release period for two science teacher-leaders over the five years. This time was provided for the teacher-leaders to work with teachers, leading new curriculum and assessment selection and development, as well as coordinating and facilitating pull-out professional development.

Compensation. District N and Union N ensured teachers were paid for their outside-of-school time related to the additional work of developing new *NGSS*-aligned common instructional resources. District N and Union N also ensured that teachers were compensated

for the related updates in the district's digital curriculum platform, including adding *NGSS*-specific details and standard-based-tags.

Mitigating Conflict Costs through Systems of Accountability and Support (C.3). One avenue that District N and Union N used to decrease conflict costs was through the revamping of a traditional grade- and department-chair teacher-leader position. In the updated positions, these individuals became responsible for ensuring each course-based professional community had "something that goes into [the district's digital curriculum platform] that [teachers] agree to." This position provided the teacher-leader with "a tiny bit of authority … enough to say 'Hey, it is my job to make sure that [our course-based professional community] ha[s] produced something, and it goes into this system'." Further, teacher-leaders were provided training on how to facilitate difficult, consensus-seeking conversations among peers.

In District N, teacher-leaders were selected through a joint union-district process. Because of this process, teachers knew that their teacher-leaders "were selected by peers." This system and related union-based messaging supported the narrative that teacher-leaders "stood out," not just to the administrators, but to "peers, as well."

Finally, District N and Union N supported facilitated "restorative circles" for situations in which professional communities – sometimes with administrators – needed to engage in difficult listening and reparative relational work.

District N Systems of Accountability. Participants described District N having a series of monitoring systems that both supported students' outcomes and ensured accountability to the course-based professional communities' decisions. The district science coordinator said, "There has to be a mechanism for monitoring. Because if no monitoring occurs, then people are not

going to follow through. They don't want to … [because] it takes time. Sometimes … you're busy doing other things that you find more valuable for kids." This was representative of most stories from District N participants – a belief that (at least most of the time), if a teacher isn't following through on an expectation, it's because they are supporting their students in other ways. Accountability was described, not punitively, but as a support for enacting course-based professional-community decisions that were good for kids.

Accountability mechanisms included common student grading policies and categories; student performances from common assessments tagged by standard and entered into the district's digital data system; the professional community's review of students' assessment performances; and the school's support team's review of students' grades (see examples below in 2 and 4).

The district science coordinator shared a specific example illustrating her role in such accountability mechanisms. She said that a District N administrator in charge of student data notified her that some biology teachers' data for the course-level common exam were missing from the district's data system. She described walking from classroom to classroom, first checking her colleagues' system settings and then telling her peers, "'hey, we need your scores in the system' … you['ll] have to rescan [the tests] and check [this box to] get your scores [to] feed into the data in the district."

The district science coordinator explained that she had an additional release period to support District N's K-12 *NGSS* roll-out, so she "had that extra [time to] … walk around," and she had that "tiny bit of authority" related to her position as both a science content teacher-leader and a teaching member of the course-based professional community. She perceived that

some teachers simply needed to know that monitoring occurred, saying that the teachers "were like, 'oh, shoot, people are checking'."

District N Systems of Support. These same systems of accountability also provided support. For example, a school-wide review of students' grades triggered the course-based (biology) professional community to investigate one of its units and assessments, while being provided release time and instructional coaching support to do so.

As mentioned, participants' stories suggested that support came through the course-based professional community, which helped secure the professional community as integral in individual teachers' classroom success. District N provided resources and tools, including a digital curriculum platform for organizing and storing common instructional resources, to support teachers' professional community work.

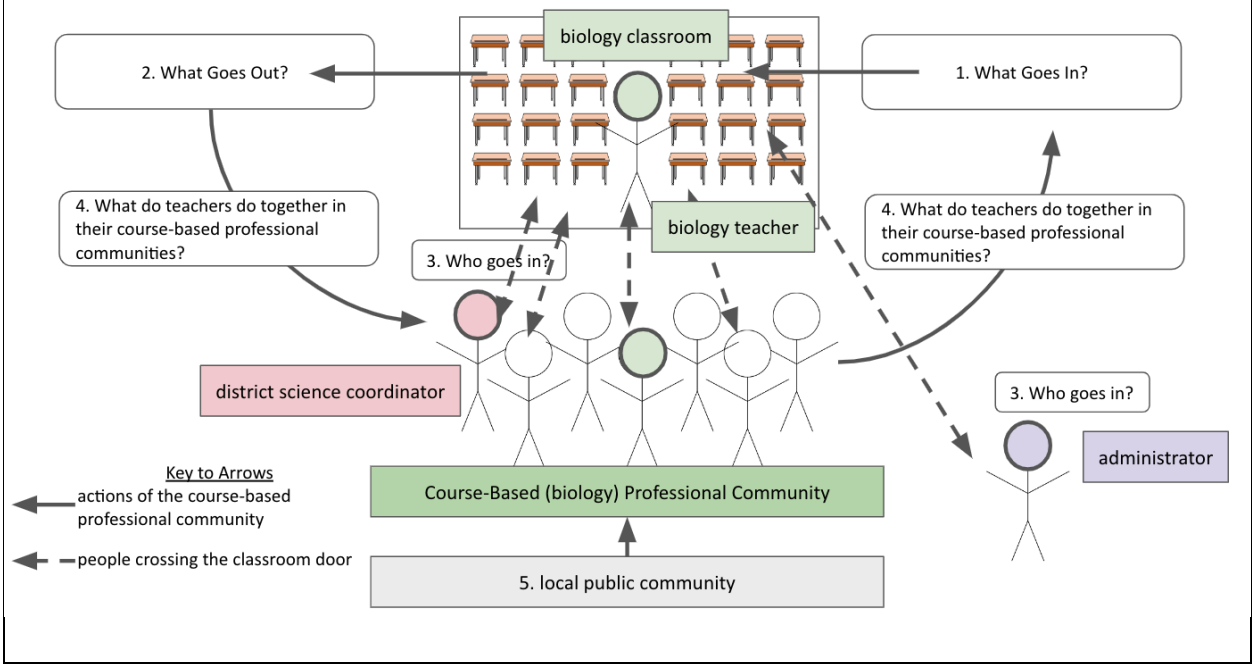
Connecting to External Science Education Communities (B.4). In District N, stories suggest that the district science coordinator played an important role in connecting the district's science-specific decisions with the external science education research and development community. For example, she located potential instructional resources through her connections to universities and the county's regional school district office. She was not, however, the only science teacher with these kinds of connections, which likely helped *NGSS*-aligned information and resources to move into District N.

For example, several District N teachers (including the district science coordinator) participated in three-dimensional item-writing for a new state-level science assessment. As the district science coordinator explained, "that meant we brought back this knowledge-set about what good item development looked like." Then, two additional teachers went through training

at the county's regional school district office. In this way, the district science coordinator ensured that the course-based professional community knew "how to write good quality assessments" and there were enough knowledgeable people – through connections outside of the district – to support in-district assessment development.

As described above, expectations for innovation (sharing independent experiences) are challenging for teachers around entirely new curricular programs. This was one reason that the district science coordinator felt *Carbon TIME* was the "most successful pilot." She explained that the *Carbon TIME* project "wasn't a one-shot deal. It happened over multiple years, there were opportunities later on for people … to join in and learn." These "multiple onramps over a period of time" gave teachers opportunities to provide a voice during the course-based (biology) professional community's curricular decision-making, while still not requiring everyone to continuously try and change new approaches.

Figure 3. Model for District N Actual Identity, corresponding to Table 5, rows 1-5



District N, Row 1 and Model 1. What goes in?

As shown in Table 5, row 1, and in Figure 3. Model for District N Actual Identity – corresponding to Table 5, rows 1-5, District N participants described common, three-dimensional instructional resources – including curricular units, unit-level assessments, and course-level exams – crossing the classroom doors of all biology teachers.

Initial Curriculum. District N participants described common curriculum as in-use across grades and content areas; teachers within a course-based professional community were all teaching "the exact same units," including "85-90% of the same lesson plans" from *NGSS*-aligned instructional materials including *Carbon TIME,* teacher-developed units, and *Next Generation Science Storyline* units. These units provided a common set of storylines and common activities that teachers were using: "We all had the mealworm investigation. We all had the plants investigation. We all had these labs that we knew we were going to do, and then we had the *Explanations* [*Tools*]."

Initial Assessments. Biology teachers described using common, three-dimensional summative assessments for their end-of-unit tests and end-of-semester course exams. Some common assessments were described as selected from aligned resources, like *Carbon TIME*. Others were written by the biology professional community, modeled off the item-cluster design of the state's three-dimensional science assessment. In these assessments, students were presented with a novel phenomenon and each item-cluster addressed all three *NGSS* dimensions.

Ongoing Revisions. Participants described common units and assessments as revised iteratively based on evidence of student learning, with updated versions available to all teachers in the course-based professional community through shared digital folders.

District N, Row 2 and Model 2. What goes out?

As shown in Table 5, row 2, and in Figure 3, District N participants indicated that a variety of evidence of students' three-dimensional learning left the classroom door to be shared with the course-based professional community.

Teachers' Recounts. District N participants described recounting their instruction with their course-based professional community in ways that focused on students' three-dimensional experiences. For example, one teacher said that the professional community "talk[ed] about the activities that we're doing and how long it took kids to set up [the mealworm] lab or how … kids [did] their *Expressing Ideas Tool*. And we talk about these similar activities all the time."

Students' Grades. Participants described how District N high school courses had common grading categories within the teachers' digital grading platform; teachers "all have … the exact same [categories] that utilize [common] unit titles." Teachers also used "common grading practices" so that students' grades were similarly calculated, primarily reflecting scores from the common unit tests. In this way, students' grades reflected similar achievement, regardless of teacher. Further, because the unit tests and final exams assessed students' three-dimensional performances, students' course grades provided information about their *NGSS* achievement.

Students' Outcomes on Three-Dimensional Assessments. Students' performances on the course-level common assessments also left the classroom door to be used by the professional community. Teachers described accessing students' performances in multiple ways through the district's data system. They could view their own students' performances and they could also view that data aggregated by class averages and by item-level analyses. Further, teachers could view course-related versions of the data showing the performances of all biology students in the school/district. Teachers said that they could not view other teachers' data through this digital platform, though they said that administrators and the district's secondary-level instructional coach could.

Patterns across interviews suggested that participants perceived what goes out of the classroom – their recounts, students' grades, and students' assessment performances – influenced what goes into the classroom through revisions to instructional resources (see example in 4).

District N, Row 3 and Model 3. Who crosses the classroom door?

As shown in Table 5, row 3, and in Figure 3, building administrators – aware of common, three-dimensional instructional resources – crossed the classroom door when making observations for formal teacher evaluations. Though infrequent, members of the course-based (biology) professional community crossed the classroom doors of some District N biology teachers.

Building Administrators. Participants shared stories of building administrators crossing the classroom door to complete observations for biology teachers' formal evaluations. Teachers' stories were of supportive experiences in which observations usually led to

"productive conversations around … teaching" during post-observation meetings. Administrators were able to review *NGSS* expectations and biology-specific common instructional resources for observed lessons through the district's digital curricular platform. However, teachers agreed that the administrators' science-specific understanding was not enough to provide meaningful feedback in terms of their *NGSS*-aligned instruction.

Course-based Professional Community Peers. "In order … to move forward and grow," in their three-dimensional science classroom instruction, the district science coordinator felt that the professional community needed feedback from knowledgeable peers. Though not frequent, peer observations did happen in District N, with participants sharing stories of science teacher peers crossing into others' classrooms through teacher-initiated visits as well as experienced science teachers observing newer science teachers as part of District N's mentoring program.

Participants shared one example of the entire course-based professional community observing a peer's instruction. This event was organized and led by a district instructional coach and involved a pre-observation meeting; the classroom observation itself; and then a post-observation reflection using "a clear discussion protocol" that supported teachers in making sense of their common experiences. This design enabled the entire course-based professional community "to see [the teacher] … help kids unpack [science] ideas." Multiple participants shared that it was "one of the most powerful things we did" as a professional community.

Participants noted the significant resources invested in just this one experience. The instructional coach, for example, made plans during the preceding school year to secure "district-allocated … professional PD days … which means she got subs." The coach organized

the experience and communicated it with teachers and building administrators, who then ensured the professional community's participation by "say[ing], 'This is not optional. You have to go'," even though teachers felt, "sometimes … it's a lot of work to be out of your classroom."

District N, Row 4 and Model 4. What do teachers do together in their course-based (biology) professional community?

As shown in Table 5, row 4, and in Figure 3, District N's participants described the professional community's work as connecting what goes out of the classroom with what goes into the classroom, and therefore as integral to their classroom work.

Selection and Development of Three-Dimensional Curricular Units. The district science coordinator described the science professional communities' initial experiences developing common curriculum as leading to limited, and "ugly, compromise units." For biology teachers, the new *NGSS* provided an opportunity to "start fresh."

The district science coordinator shared that the *NGSS*-oriented curriculum piloting and selection process "felt like it took forever," as teachers tried different options. After selecting *Carbon TIME,* the district science coordinator said, "we moved into this phase where, 'This isn't a choice anymore.' We've now looked at all these options [and] we've collaboratively made some decisions about what does and does not work." Patterns across interviews support this idea; the course-based professional community was engaged together in shared piloting experiences that led to consensus-seeking decisions about common curricular resources.

Teachers then described using *Carbon TIME* units as a template, "saying, 'Okay, this worked [first semester]; How can we do the same kind of thing with the rest of the course?'" They organized their units into a "shared summary table where [every teacher] has [links and

information for] all the tasks," that teachers could update. In this way, work of individual teachers around common units became usable by the entire professional community.

Selection and Development of Three-Dimensional Assessments. Participants described an assessment-development process in which draft assessment items were shared and co-edited, and – because of the internal sharing settings – teachers could see "who's trying to make them more three-dimensional and who's trying to work out the kinks in them." District N teachers described how the approval or input of every member of the professional community was actively sought through charts in which each teacher "mark[ed] 'Okay' or [added] ideas for changing," which allowed the group to review collective input when making consensus-oriented decisions about three-dimensional assessments.

Sensemaking About Three-Dimensional Instruction Using Evidence. Participants' descriptions of sensemaking with the course-based (biology) professional community were primarily connected to student learning evidence from common three-dimensional assessments. This sensemaking was closely tied to inferences about classroom instruction, with the professional community "trying to figure out, 'All right, how can we change what we're doing in class to get … more desired results … on our assessments?'."

In this case, comparisons of students' performances at the item-level, across teachers, was described as helpful. The district science coordinator explained that this approach was supportive and framed positively; "Largely, 'We're all doing a good job, but on this one question, [so-and-so] did a great job … [so-and-so], can you tell us how you teach this particular thing?'."

District N participants described one experience of comparing students' performances on common assessments across teachers, not at the item-level, but at the (de-identified) teacher-level. A district instructional coach facilitated the experience, in which teachers reviewed their own students' performances on a common exam and then saw de-identified teacher reports with student averages. One participant said, "[the coach] removed [teacher] names from across the top, so when we looked at the data together no one could see [whose was whose], but you knew where you fell."

District N interviewees who participated in this experience said they "didn't really like" it. Knowing "where you fell in the grand spectrum of things … that was tough." But it was also described as productive. The district science coordinator explained, being confronted "by the fact that this assessment that you were part of developing, and that your kids aren't doing as well as other peoples' are, then all of a sudden you have to really wrestle with something inside of you, this deep-seeded belief that 'What I'm doing is right and best for kids'."

The district science coordinator said that "teachers who were using the curriculum closely were scoring higher on that [midterm] assessment. And … since then, one of the [lower performing] teachers has shifted" to using the unit-suggested phenomenon. Using student performance data – including comparing data across teachers – led to individual teachers adjusting instruction in ways that further supported students' three-dimensional achievement on the course-based professional community's shared measures of success.

Revisions to Three-Dimensional Instructional Resources. Teachers described using student learning evidence from common assessments to improve instructional resources,

including the assessments themselves: “If it’s not a great assessment, if kids are struggling, at least this tells us we’ve got to go back [and] we’ve got to fix this.”

In District N, participants shared stories of the professional community being alerted to revisions they needed to make through the high school’s student support team. This team regularly reviewed student grades by course, identifying units where many students were performing poorly, particularly students identified as “striving learners” who benefited from additional supports due to language, learning, or other needs. This team “identified [biology] as one of the top courses where students [were] failing” and raised the question, “’What’s going on? … Why are [these students] struggling in biology’” on this one assessment?

In this case, the entire biology professional community was brought together. The district science coordinator shared, “We were provided time to work … [and support from] the coach,” to address what was needed to improve students’ outcomes in the biology course. The district science coordinator felt it made sense to involve the entire professional community – not just the teachers with the most failing students – because, from her perspective, “the teachers that [have] more problematic [student grades] need [the professional community’s] help to” improve. Further, any changes made to common instructional resources would affect all biology teachers.

District N, Row 5. And Model 5. Local Public Community

District N’s move to common instructional resources was aligned with the local public community’s longstanding commitment to providing students with similar experiences. The district science coordinator shared that families would go to administrators saying, “How come, if [students] have Miss so-and-so, they get this, and if they have Mister so-and-so, they get

this?" Initially, administrators had largely responded to these inquiries by defending teachers' individual autonomy, but that "wasn't working anymore with our families."

As part of District N's move toward common instructional resources, "the unit order and certain details about [common] units [were made] public and available on [the district's curriculum platform] to our families." The district science coordinator believed that – initially – the "public visibility of our curriculum [was] the thing that … really got people – when they shut their doors – to actually follow along, because while the other teachers might not see them … the students see them and their students have parents and the parents know the curriculum." In this way, the district's use of its digital curriculum platform may have been one early step that paved the way to District N's *actual identity* as a collective biology professional community with three-dimensional goals for all students.

District F: A Collaborative Professional Community with Three-Dimensional Science Classroom Experiences as Goals for Students

District F participants' stories portray District F's *actual identity* as a collaborative professional community with three-dimensional science classroom experiences as goals for students. Participants described many teachers holding *classroom pedagogical responsibilities* to students' three-dimensional science classroom experiences (not outcomes). Teachers' joint work with colleagues supported some teachers in fulfilling their *classroom pedagogical responsibilities*. District and union leaders were described as providing collaborative support with some individual accountability, as well as employing some strategies that reduced transaction and conflict costs.

In District F, teachers described common, three-dimensional instructional resources crossing into the classrooms of some regular biology teachers, with some forms of student learning evidence leaving the classroom. Participants described building administrators crossing the classroom door to make classroom observations. The course-based (biology) professional community engaged in some work related to what goes out of the classroom door and some work related to what goes in the classroom door, though revisions did not complete that cycle.

Row A. District F Teachers' Classroom Pedagogical Responsibilities

District F participants described a widespread recognition for the significance of science teachers' shifts from the previous state standards to the *Next Generation Science Standards* (*NGSS*). This was generally described as science classrooms moving away from a focus on content-memorization and toward supporting students in "think[ing] like scientists." This was even true of the local union leaders, who were not science teachers. One described the changes science teachers needed to make "from 'I can stand and deliver this stuff and I'm good at it,' to, 'I've got to now have kids make their learning visible … How do I lecture about that? I can't'."

Patterns across interviews suggested that many – though not all – teachers held *classroom pedagogical responsibilities* to students' *NGSS*-aligned classroom experiences (Table 5, row A). Many participants talked about this responsibility as different from their previous goals for students' experiences. For example, teachers described how students used to complete a "lab at the end … but now [students do it to] see what they already knew and [to] figure things out."

District F's participants described their *classroom pedagogical responsibilities* to students' *NGSS*-aligned experiences as also including common student experiences across

classes. This was connected to scheduling conditions in which "kids switch classes [and teachers] between semesters" and was heightened by teachers' realization that students' classroom experiences would be "a lot different than what was taught before" the shift to *NGSS*. To ensure that some students weren't "at a disadvantage second semester," participants described a responsibility for students to receive three-dimensional, common experiences across teachers. "If everyone's not on the same page, it's not going to be good for kids."

However, participants described some biology teachers as "not on the same page," resisting the shift to *NGSS.* Participants' stories suggest that this resistance was not due to competing *classroom pedagogical responsibilities*. Instead, participants described it as likely related to the cumulative workload accompanying multiple and frequently changing preps in the district. It was described as common for teachers to "change their subjects every year … all bio one semester … bio and earth science next. Or … bio and chem first year, and now … all [different] physics." Participants imagined that teachers resisting the new standards likely felt "taken advantage of" by District F, potentially thinking, "'Why on earth would I change what I'm doing … if I don't even know that I'll teach it next year?'."

Row B. District F Teachers' Professional Community Responsibilities

District F participants' stories reflected their perceptions that collaborating with course-based colleagues was valuable to their instructional work behind their own classroom doors, but recognized that not all biology teachers felt that way. Teachers experienced autonomy within the parameters of a common curriculum. Peer-based accountability was described as existing through shared decision-making, leading to fulfillment of course-based professional community decisions. However, as revisited throughout the next sections, participants

described agreeing as a full course-based (biology) professional community that teachers would pilot the *Carbon TIME* curriculum with their regular biology classes, but two teachers did not follow through on this agreement.

Collaboration Supports Classroom Work for Some Teachers (B.1). In District F, collaboration among colleagues helped some teachers realize their *classroom pedagogical responsibilities* (Table 5, row A), both because shifts to *NGSS*-aligned science classroom engagement were perceived as challenging and because teacher participants were committed to all students having common experiences across teachers. Time with colleagues was described as so valuable by participants that they made additional meeting times outside of their contractually required weekly Professional Learning Team (PLT) meeting. Since participants taught more than one course, additional meetings were required to ensure defined time with each course-based group.

Stories conveyed that not all biology teachers perceived professional community work to be this valuable. For example, one participant described some of her science colleagues as only superficially engaged, with "a history of saying they're PLT-ing when they're not PLT-ing … And we have had multiple members that [will] walk in and they'll hand you a worksheet and say, 'Here, try this. Look, we PLTed! I'll mark it down an hour,' and walk out. That's not PLT."

Teacher Autonomy within Shared Curriculum (B.2). Teachers described a common curriculum as providing "guidelines," yet individual teachers could exercise their autonomy and be "creative, even within those guidelines." As the district science coordinator explained, "you can still be the teacher you want to be, while trying to do what, as a district, we've determined is best for kids."

No participants expressed concerns that using a common curriculum infringed on teachers' perceptions of autonomy, even in their discussions of the few regular biology teachers who were not piloting the agreed-upon *Carbon TIME* units.

Peer Accountability through Decision-Making and Conversations (B.3). Participants described the course-based (biology) professional community as one in which teachers "hold each other accountable" to shared decisions like using a common curriculum, "just because we know it's what we're supposed to be doing." This peer accountability was identifiable in stories participants shared about the joint work accomplished as a professional community; teachers used almost identical language to explain that group decisions felt like "a responsibility that we need to live up to."

However, participants acknowledged that there were "one or two, in particular" biology teachers who did not perceive this same kind of peer accountability. One teacher participant used a private conversation to directly engage a colleague she suspected would not enact the professional community's decision to pilot *Carbon TIME*. She described saying "'This is really important … we're making the commitment between [high] schools right now … Are you willing to follow through and do these things?'" Though the teacher said, "'Yes'," he was not described as actually piloting the units. In this case, the peer-to-peer intervention was not successful.

The participant explained that she had "no problem going to [a] colleague" directly with a disagreement. In a different example, another participant was encouraged to talk to the administrator to secure support when the two teachers weren't enacting the pilot units. Colleagues reminded the participant about the course-based professional community's decision

to pilot the curriculum and said to her, those two teachers "'should do this with you'." These stories suggest some norms for interference.

Stories did not suggest that disagreements about science instruction jeopardized otherwise friendly interpersonal relationships. The teacher who confronted her colleague said, "in a social setting … we're great" – even though the two disagreed about "the meat and potatoes of science teaching." Another teacher said that biology teachers were "pretty close and we can talk to each other," even about instructional issues around which they disagreed.

Sharing without Innovation (B.4). Participants described learning about *NGSS* through external science education communities like the state's science teachers' association. These experiences were shared with the course-based professional community, but participants felt that the group had "really dragged our feet" in transitioning to *NGSS*. Several teachers had attempted to redesign existing units and found it to be difficult and time-consuming work: "We spent two days just trying to bring in some of the *NGSS* core things into an ecology unit." Together, these examples suggest that teachers' independent experiences with external science education communities were shared with the full professional community but did not lead to community-level uptake.

Row C. Roles of District F and Union F Leaders Related to Teachers' Professional Communities

District F participants shared stories in which District F and Union F both endorsed professional community work and saw teacher accountability as existing within the guidelines of a common curriculum. Union F's stories limited peer accountability. Transaction costs were somewhat addressed through teachers' time with smaller (building-based) Professional

Learning Teams (PLTs). Individual building administrators supported individual teachers' accountability to course-based professional community decisions.

District F and Union F Stories Endorse Collaboration (C.1). District F and Union F stories tended to describe working toward highly functioning professional communities as a goal in-and-of-itself, not necessarily as an avenue to specific student or instructional goals. Even shared instructional resources were described as valuable because they would allow a professional community to work better together: "In order to be a functioning [Professional Learning Team], we have to have some common tasks in order to talk about the data and where our kids are headed." Still, both organizations endorsed teachers' time with their professional communities as valuable.

District F and Union F were described as endorsing a view of teacher autonomy existing within the confines of a shared, common curriculum. For example, a participant endorsed teachers' use of common curriculum using contractual language: "All [biology teachers] are supposed to be on the same page … We do have contractual requirements; [there is] a piece in our contract that says that administrators can collect lesson plans."

The local union president confirmed that "academic freedom is a section of the contract," while noting that nothing in that contractual language precluded expectations for teachers adhering to a shared curriculum.

Union F Stories. Union F stories placed firm limits on acceptable peer-based accountability. Participants said they had "been told very clearly [by state union staff] we are not to ever … get a colleague in trouble. We are not tattletale[s] … we are there for protection."

Because of this, one teacher shared that she would not "go to an administrator" with concerns about a colleague.

Union F played a role in supporting biology teachers' *Carbon TIME* professional learning, which teachers described as "incredibly helpful." They noted their teachers' unions' role as unusual – "the only time I've ever seen [the union] have any interaction with curriculum." However, they were understanding and appreciative – the union's "job is to support teachers in all facets … [this] absolutely fall[s] under that realm." Participants described the union's role in providing time with the *Carbon TIME* professional learning provider (this author), providing substitutes, lunches, and teachers' continuing education hours through the state department of education.

Mitigating Transaction Costs through Time (C.2). District F participants described limited time as a full course-based (biology) professional community, and less time than they had together in the past. Participants met more regularly with smaller Professional Learning Teams (PLTs).

Time. In District F, participants described working together in Professional Learning Teams (PLTs) during contractually required, weekly after-school meetings. PLT membership was not the same as membership in the full course-based (biology) professional community; PLTs were smaller because they were building-based (not district-based) and because some biology teachers were instead part of PLTs for other courses they taught.

Teachers had some ability to select with whom they met, since most teachers were eligible to join multiple PLTs due to teaching multiple versions of a class (regular and honors biology) or multiple classes (physics and biology). It's noteworthy that teachers' decisions about

their PLT participation led to different biology-related outcomes at different high schools. At the high school where two of the three biology teachers did not initially pilot the *Carbon TIME* units, biology teachers did not meet as a PLT. Their counterparts at the other high school, where both regular biology teachers were piloting the *Carbon TIME* units, did meet as a PLT.

Participants described their opportunities to meet with the full course-based (biology) professional community as limited and decreasing over time. Teachers said they met so infrequently "that we spend half the time catching ourselves up." Two years before, participants described having a "half-day every month" with the district science coordinator to focus on aspects of the new *NGSS*. But in subsequent school years, building-level data-digs had taken over time previously available to the district science coordinator.

Participants did share that they felt they had enough time in pull-out professional development through several "full days with [*Carbon TIME*] … and with each other to just dedicate to" learning the new curriculum during pilot-related professional learning sessions. One teacher said, "It was so helpful that we could have those days just for that. And then we [could] still have our … regular" district professional community meetings.

Accountability through Building Administrators (C.3). Stories from participants described no district-based monitoring systems in District F. Instead, stories described individual building administrators playing roles in supporting teachers' fulfillment of professional community decisions.

At one District F high school, a building administrator was described as attending course-based (biology) professional community meetings and was aware of the decision to pilot *Carbon TIME* units in regular biology. Stories described this administrator talking to individual

teachers and eventually meeting with all three regular biology teachers. One teacher participant said the conversation led "to a bit of a compromise … 'You said you would do this. So, … what's manageable for you? Like, can you at least do a unit? Or try to do … this activity … at the very least?'." Still, it was unclear – in the end – to what extent the two other teachers implemented parts of the pilot curriculum with their students.

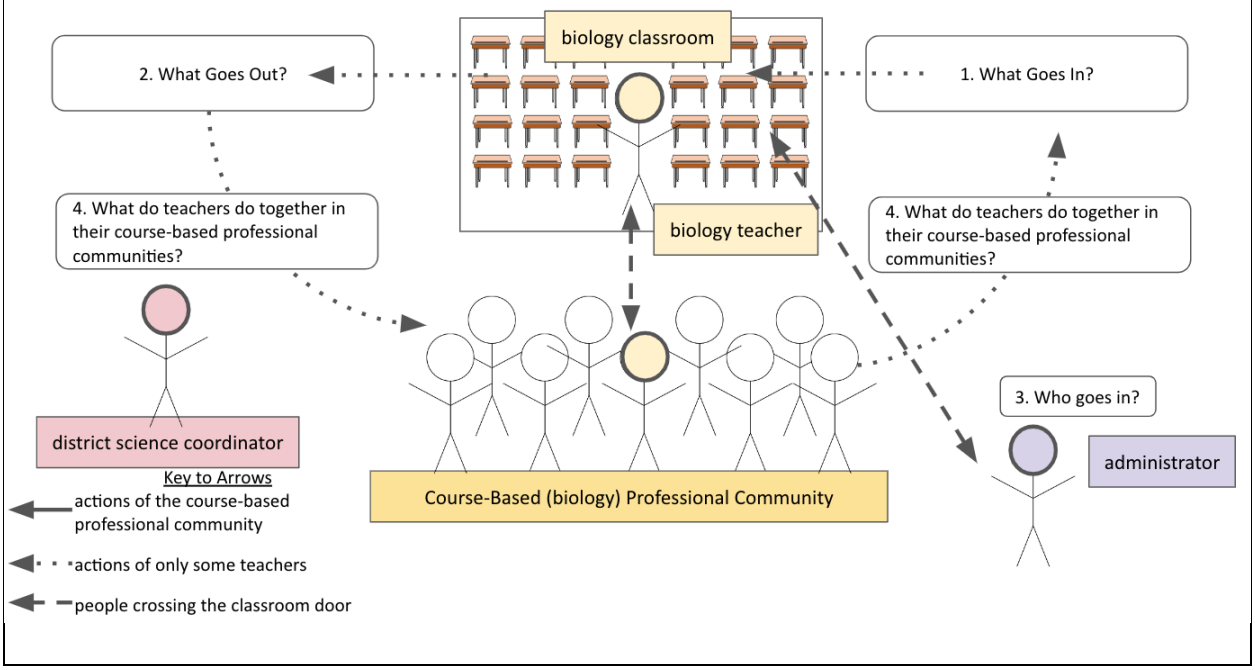
This administrator was described as unique in that she "pa[id] enough attention and … would actually … follow-through" in ways that supported individual teachers in fulfilling decisions made by the course-based professional community. This was described as different than a longstanding "lack of accountability" from building administrators, who had tended to "just let things go." Regarding the science professional community's work, a previous administrator "was [like], 'You guys got this. No worries, whatever you say.' And so things ha[d] a tendency to fall by the wayside [because there was] not some type of check-in."

Connecting to External Science Education Communities (C.4). The district science coordinator served as a connection to county-level science resources. She ensured that all the District F science teachers went through the Next Generation Science Exemplar Program (NGSX) professional learning sessions through the county. Also, she arranged for a science consultant from the county's regional school district office to organize a series of presentations from a variety of *NGSS*-aligned curriculum developers, including *Carbon TIME*. Other participants also described connections to external science education communities, like the state science teachers' association.

The district science coordinator – in her position as a district-level curriculum coordinator and as a local teachers' union member and leader – also supported connections

across District F, Union F, the state teachers' union, and *Carbon TIME*. This opportunity was made available through district- and union-support, with District F providing coordination, permission, and substitutes for released teachers and the State Union and Union F primarily providing for the external science education (*Carbon TIME*) professional learning provider (this author). This partnership provided several days of pull-out professional development. The district science coordinator said, "the district really was the driver … deciding, 'Where were we trying to head [with *NGSS*]?' The union was really, 'How can we come in and support?' and it was refreshing … to have the union come in from a professional development, learning [and] instructional lens."

Figure 4. Model for District F Actual Identity, corresponding to Table 5, rows 1-5



District F, Row 1 and Model 1. What goes in?

As shown in Table 5, row 1, and in Figure 4. Model for District F Actual Identity – corresponding to Table 5, rows 1-5, District F participants described some common three-

dimensional instructional resources crossing the classroom doors of some (though not all) biology teachers.

Initial Instructional Resources. In District F, interview participants described the course-based (biology) professional community agreeing that teachers would pilot the *Carbon TIME* units in the first semester of their regular biology classes during the 2019-20 school year.

The decision to pilot the *Carbon TIME* units was teachers' "biggest jump into the [new] science standards" and followed a years-long, start-and-stop transition to *NGSS*-alignment in high school science classrooms. Participants saw *Carbon TIME* as providing a model for what *NGSS*-aligned teaching and learning could look and feel like: "I think having *Carbon TIME* in place for bio this year has been nice [for] at least the people that piloted it, to see [and] help them move forward in 'This is how an integrated storyline looks'."

The *Carbon TIME* instructional resources included three-dimensional assessments, which some pilot teachers described using and modifying. However, these assessments were not considered "official" or "common" across the regular biology classes.

District F, Row 2 and Model 2. What goes out?

As shown in Table 5, row 2, and in Figure 4, District F participants described limited evidence of students' learning leaving the classroom door to be shared with the course-based (biology) professional community.

Some Teachers' Recounts. District F teachers described engaging in dialogue-based recounts of classroom experiences with their peers, though this was primarily with colleagues in their building-based Professional Learning Teams (PLTs). Teachers were "not necessarily … showing each other things, but just talking" through things "that students are struggling with …

to see, 'What do you do to get them to understand this topic?'." It is possible that these recounts included dialogic evidence of students' learning, which could further support teachers in three-dimensional instructional sensemaking.

Some Student Work Artifacts. Participants described that the most beneficial opportunities to make sense of students' three-dimensional classroom experiences was in conjunction with student artifacts providing evidence – that's "where you can really have good dialogue with your colleagues."

Participants shared a few stories suggesting that some student work left teachers' classrooms in ways that prioritized evidence of students' two- or three-dimensional learning. In one example, a teacher informally brought her students' *Carbon TIME* formative assessments to a colleague to discuss students' ideas, and then took the work artifacts to her Professional Learning Team (PLT) for discussion related to their formal teacher evaluation. In another, the full course-based (biology) professional learning community brought student work samples around a specific *NGSS* science and engineering practice (Asking Questions) for discussion and coordinating development of a department-wide practice-specific rubric (see example in 4).

District F, Row 3 and Model 3. Who crosses the classroom door?

As shown in Table 5, row 3, and in Figure 4, building administrators crossed the classroom doors of individual biology teachers when making formal teacher evaluation observations.

Building Administrators. District F participants described their current administrators, who completed teacher observations for the formal teacher evaluation system, as supportive.

Teachers described these observation experiences as helpful to their overall classroom instruction – even if they were not science-focused.

For example, one teacher shared she "like[d] my principal's evaluation. When he comes in … he notices those things that you do that aren't intentional … Then you think … 'Oh, how could I be more intentional with that?'." These post-observation meetings served as opportunities to ask questions about common curricular expectations in biology, though not for more specific conversations about three-dimensional science classroom engagement.

District 4, Row 4 and Model 4. What do teachers do together in their course-based (biology) professional community?

As shown in Table 5, row 4, and in Figure 4, District F's participants described the biology professional community's work as focused on selecting new, three-dimensional instructional resources as well as some sensemaking around *NGSS*-aligned instruction using evidence from student work artifacts. Interviews with District F participants occurred during the science departments' shift to *NGSS*, and participants described ongoing professional-community-level decision-making around organizing the new standards into specific courses, course-design, and sequencing.

Selection of Three-Dimensional Curricular Units. Participants described professional community conversations leading to a recognition that local alignment with the new *NGSS* would not only mean teachers had "to completely reinvent our course[s]," but would also require the development of entirely new instructional units. These perspectives and experiences helped many members of the professional community feel "ready to jump in" and pilot available *NGSS*-aligned curriculum.

As a course-based (biology) professional community, teachers saw presentations from a variety of *NGSS*-aligned curriculum developers, including *Carbon TIME*, organized by a science consultant from the county's regional school district office. Afterward, participants described the course-level (biology) professional community "agreeing that we were going to pilot the *Carbon TIME* curriculum in all of our [regular] biology classes" during the first semester.

Later in the school year, teachers voted to officially adopt the *Carbon TIME* units as the biology course's curriculum. One specific colleague was "sort of struggling against [*Carbon TIME* adoption] because he just [felt] like … 'All of a sudden, we're doing this? We had a vote about whether or not to do [*Carbon TIME*], but there was one thing on the table to vote for. Like, how does that work?'." Though this colleague wasn't described as having anything against *Carbon TIME*, he and other peers wondered, "'How do we know there aren't other options out there that might fit our needs better?'," since nothing was piloted in biology except for *Carbon TIME* units.

Sensemaking About Three-Dimensional Instruction Using Evidence. Patterns across interviews suggested that teachers' time (and therefore opportunities for sensemaking) with colleagues was more frequently spent in smaller, building-based Professional Learning Teams (PLTs) than the full course-based (biology) professional community.

Dialogic Rehearsals & Recounts. Teachers described that "far and above anything else," PLT-time focused on lesson and activity development; "we sit and plan together." It is possible that these planning sessions were dialogic rehearsals that involved sensemaking around three-dimensional instruction.

Analysis of Student Learning Artifacts. There were some examples of teachers sharing student artifacts and analyzing them in ways that supported teacher sensemaking around students' three-dimensional learning. For example, after her students completed a *Carbon TIME* formative assessment, one participant said "I immediately went to [another biology teacher] and was like, 'Let's talk about some of my kid's stuff! Because man, I thought we got there, and we did not get there at all. And I got to go back and do it again'." This happened informally, with teachers finding each other in their building to talk about the students' responses.

The teacher said that student-work-based discussions with colleagues were opportunities to "really learn what's working and what's not working, and where you can get those ideas of, 'Hey, this is what I'm seeing and it didn't work for me. What did you see? What are your kids saying? Did it work for them?'." This teacher also described taking the student work with her to a PLT meeting for discussion and using it as evidence of student growth for her formal teacher evaluation.

The district science coordinator described teachers bringing student work artifacts – focused on students' *NGSS* question-asking practice – to a full course-based (biology) professional community meeting. She said that "not everybody brought [student work] … it's like every classroom, there wasn't 100% engagement, right?" Still, many teachers did bring work samples, and the course-based professional community used a "whole protocol, looking at" the student artifacts, which were generally two- or three-dimensional.

The district science coordinator said teachers "made a rubric for Asking Questions. 'What does that look like to be level one, level two, level three, and level four?'" In this way,

science teachers and the district science coordinator worked together using evidence from classroom experiences to define common standards for measuring multi-dimensional (even if not three-dimensional) student science success around a specific *NGSS* science and engineering practice. The district science coordinator also said that most science teachers "made … their evaluation goal [around] getting students to ask deeper questions" during that school year.

District A: An Individually Oriented Professional Community with Three-Dimensional Science Goals for Students

District A participants' stories portray District A's *actual identity* as an individually oriented professional community with three-dimensional science goals for students. Participants described teachers holding *classroom pedagogical responsibilities* to teacher-valued experiences and outcomes; for many teachers, these were three-dimensional. Teachers' *professional community responsibilities* primarily reflected autonomy, egalitarian beliefs, and norms for non-interference. District and union leaders enabled individual teachers, endorsing stories of both collaboration and autonomy.

In District A, participants described three-dimensional curricular resources as available for teachers to use, with common three-dimensional end-of-course exams crossing the classroom door of every biology teacher. Participants described students' performances on these common assessments and some other student work artifacts leaving the classroom door to be discussed by the professional community. Participants described building administrators crossing the classroom door to make formal teacher evaluation observations, and some non-critical peers from outside of the course-base professional community making observations through Instructional Rounds initiatives. The course-based (biology) professional community

engaged in some work related to what goes out of the classroom door, but largely left what goes into the classroom door up to the individual teacher.

Row A. District A Teachers' Classroom Pedagogical Responsibilities

District A participants shared stories of an actual state of affairs in which biology teachers held individual *classroom pedagogical responsibilities* (Table 5, row A), many of which were to students' three-dimensional classroom science experiences and outcomes.

Participants used similar, *NGSS*-aligned language and emphasized the value of "phenomena-based units" that use connected storylines to engage students in the classroom work of "figuring out" unit driving questions. As one teacher put it, "it's beautiful what is happening in science classrooms. Like, it's so exciting!"

However, participants described other course-based (biology) colleagues holding different *classroom pedagogical responsibilities*, including some "more traditional" experiences for students, emphasizing lecture and one-dimensional rigor, and others to full inquiry- and modeling-based approaches. Teachers' individual *classroom pedagogical responsibilities* were described as strongly held. The district science coordinator said some teachers were "still seeing science as, 'Oh, [students] need to know this and this. And if [students] don't … I'm, maybe, failing at my job'."

Patterns across interviews depicted pervasive egalitarian perspectives. Different *classroom pedagogical responsibilities* were described as existing side-by-side, with individual teachers committed to addressing their "specific student body" and engaging their students in science classroom experiences that they perceived to be "best," reflecting instruction that "they [were] comfortable with." One participant said of a colleague, "[Their students are]

learning content and some kids love [that approach] and some kids don't, and some kids love what I do, and some kids don't." Another described differences in approaches as "[neither way is] better … it's just what works for him and what works for me."

Row B. District A Teachers' Professional Community Responsibilities

District A participants' stories reflected *professional community responsibilities* (Table 5, row B) that valued collaboration and autonomy. Working with course-based colleagues (collaborating) was described as valuable to teachers' classroom work when it was aligned with teachers' individual *classroom pedagogical responsibilities* (Table 5, row A); it was valuable when teachers had autonomy to select with whom and around what they were working.

Selective Collaboration is Valuable (B.1). Participants in District A shared stories of valuing their work with like-minded colleagues – selectively collaborating with colleagues holding similar *classroom pedagogical responsibilities* (Table 5, row A). Working with colleagues who were "interested in the same thing" as a teacher was valuable, according to participants, because teachers "don't want to spend time trying to convince other folks."

Another participant described collaborating with biology-teaching colleagues to discuss "lessons, and what we're going to do, and who has what lab supplies." She described this kind of collaboration as beneficial in reducing her individual work because teachers could "shar[e] lessons and shar[e] tests." The participant described carving out chunks of time to meet "in the morning with these three teachers, and then in the afternoon with these three teachers" to engage in this kind of collaboration. She felt lucky that her colleagues "really buy-in" and were willing to meet outside of their duty day. She said that teachers in other content areas in her building did not meet in this way and just "all do their own thing," in part because teachers are

not “being given time and told that there’s value in that” from building administrators or from District A.

Teacher Autonomy (B.2). In District A, stories about teachers’ autonomy were connected to egalitarian beliefs. For example, even though she described *Carbon TIME* units as part of the district-adopted biology curriculum, one teacher participant also said, “as long as [the curriculum a teacher uses] is good, we don’t really care.” Specifically, when a teacher new to the building told her, “‘I’ll do some of [*Carbon TIME*], but I’m doing this other stuff that I have also’,” she explained that decision “[wa]s okay. Like, if it works and he’s still doing good stuff, then that’s fine.” This idea was a major theme across District A’s participants; teachers described having the autonomy to use the instructional resources they chose as they pursued their individual *classroom pedagogical responsibilities* (Table 5, row A).

Professional Norms for Non-interference and Egalitarian Beliefs (B.3). Stories reflecting norms for non-interference in District A were also connected to teachers’ egalitarian beliefs. One participant said, “[my colleague’s] philosophy is … ‘Let me close my door and do what I’m doing, and it works.’ They might be right. Their thing might be working for them … it is not my domain … to decide what’s good for other teachers.” Participants described no situations in which teachers (or district curricular coordinators) interfered in an individual’s classroom instruction.

These norms for noninterference and egalitarian perspectives maintained positive professional relationships, which contrasts with the peer accountability described in District N and District F. District A’s science coordinator articulated challenges that arose in contexts, like hers, that value both collaboration and autonomy, saying, “Accountability in this context? I

don't think our system has quite figured out yet." She said, "it's hard, but important" to "create some sense of peer accountability for each other. Like, 'I want to do well with my peers,' and try and create an atmosphere where … we're doing it … in support of each other."

The district science coordinator in District A did feel that external science education communities (like *Carbon TIME*) were one of "the places where we have done really well [in terms of] peer accountability," likely because these opportunities have supported many like-minded teachers in collaborating with shared instructional resources and in pursuing what were either already, or what became, similar *classroom pedagogical responsibilities* (Table 5, row A). The district science coordinator recognized, however, that there were still individual teachers who had not "opted in" to these opportunities, and norms for non-interference enabled this.

Independent Experiences with External Science Education Communities (B.4). Individual teachers in District A became connected to external science education communities, such as modeling-in-biology programs or *Carbon TIME*, and were able to convey information about these opportunities to colleagues. The district science coordinator said, "My teachers want to do good things with each other … [so, when one] person found this really exciting *Carbon TIME* thing [then it was] 'Maybe you'd like to go, too', and 'Let's go do that.'"

However, these opportunities were optional. Often, as the district science coordinator explained, "the outliers that don't get connected, are still a little isolated." Teachers with disparate professional learning experiences outside of the district professional community were able to communicate only limited information. Participants noticed that colleagues who hadn't engaged in "more extensive training" were "reluctant … and hesitant" about trying new instructional resources. One participant said that she wasn't comfortable trying the modeling-

in-biology curriculum used by some of her colleagues, even though they were enthusiastic about it. She said she would "need time to … examine it and understand it as a teacher" before she would feel comfortable trying it in her classroom.

For the most part, teachers' independent connections to external science education communities supported their independent instructional change, but not their colleagues'. Individual teachers could not support their peers deeply – in part due to limited time together – and the professional community did not have expectations for independent experiences becoming innovations, used by all members of the course-based professional community.

Row C. Roles of District A and Union A Leaders Related to Teachers' Professional Communities

District A participants' stories about and from District A and Union A included messages of teacher autonomy as well as collaboration in ways that enabled individual teachers to make and execute individual classroom decisions. Transaction costs were not described as being addressed by District A and Union A, despite contractually required after-school meeting time. Conflict costs were minimized through expectations for generalized "good teaching."

District A and Union A Stories. District A and Union A stories endorsed autonomy and collaboration; both teacher collaboration and teacher autonomy was perceived as valuable. For example, the local union president acknowledged that "we know from research that teachers that collaborate … do better. … There's a benefit to working with your peers," but, he explained, "organic, teacher-initiated collaboration" was far more valuable than "forced collaboration." He explained that the union's "goal was to protect teacher autonomy and [support professional communities], not to prevent [them]." He continued, "I think there is tremendous value in working with peers. I just wouldn't want the district to dictate when

teachers find that time to collaborate … it's important that teachers are given that autonomy to decide that and work together."

Both District A and Union A described the purpose of collaboration as benefiting individual teachers. The district science coordinator said exactly this when she explained that it was important for her to "show [teachers] the value" of collaborating by helping each teacher see how working together can "help me grow."

Both the district science coordinator and the local union leaders also shared perspectives in which clear expectations that led to accountability were antithetical to providing support for teachers' classroom instruction. These perspectives were relayed through statements in opposition to district-based accountability for using common instructional resources or for engaging in shared work with colleagues in a professional community.

For example, the district science coordinator said, "I'm never going to motivate teachers by setting rules and through, you know, accountability and compliance." She explained that for teachers who "don't opt in … [she] just keep[s] working on, 'How do we show somebody how it's good and helpful?' … Let's get them on board and help them that way."

Similarly, the local union president said, "I'm not for compelling people to do things at gunpoint. I think leading them there by seeing the value in things is a better way to get people to buy-in and to do things," such as collaborating with their peers. A group of collaborating teachers "might show these impressive results that the [non-participating] colleague did not get with their students. And that might be something… [to make them] think, 'Yeah, … maybe I should be part of this team'."

Union A Stories. Union A was explicit in limiting peer-based accountability. Teachers should not "dictat[e] to other teachers how to do things and what to do … We avoid that at all costs." The local union leaders supported this perspective with egalitarian reasoning, "What's right [or best] could be relative. And what's right for one might not be right for another."

Unmitigated Transaction Costs (C.2). Despite contractual after-school meeting time, District A participants described minimal time with either the full course-based (biology) professional community or with smaller, building-based biology professional communities. Participants in District A also described an additional course-affiliated professional community – an optional science leadership team.

Time. District A participants described contractual obligations for teachers to attend three, 90-minute after-school meetings each month; two were building-based and led by building administrators and one could be either building-based or district-based. Despite this contractual time – which was like that in both District N and District F – patterns across participants suggested that meeting time with one's course-based (biology) professional community was minimal.

Participants described the full course-based (biology) professional community meeting for a full day in August – before each school year started – and then some additional months during the district-led, after-school meetings. Building-based professional community meetings were also infrequent – one biology teacher said, "I was hardly ever with peers," and the other was "carv[ing] out time" before or after school (as described above in B.1). The exception was at a third high school, where the schedule provided an "hour each day … a class period, to

collaborate," in addition to an individual planning period, as part of the school's International Baccalaureate® program expectations.

Compensation. District A's optional science leadership team included 30% – six of eighteen – district biology teachers during the school year in which interviews were conducted. This group was not "exclusive" – any biology teacher could opt-in. The science leadership team worked primarily on selecting or developing available, three-dimensional instructional resources. They typically received three release-days per school year to meet with the district science coordinator. Additionally, they were compensated for meeting time and development work over the summer.

Accountability to Generalized "Good Teaching" (C.3). In District A, multiple participants described building-level principals as "the accountability people." However, participants described no administrator-based expectations for secondary science teachers' use of specific curricular materials or science classroom instructional approaches.

Since peers and the district science coordinator were not involved in instructional accountability, conflict costs among members of the course-based professional community were minimized. Teachers could do what they wanted behind their own classroom doors, without experiencing conflict with colleagues.

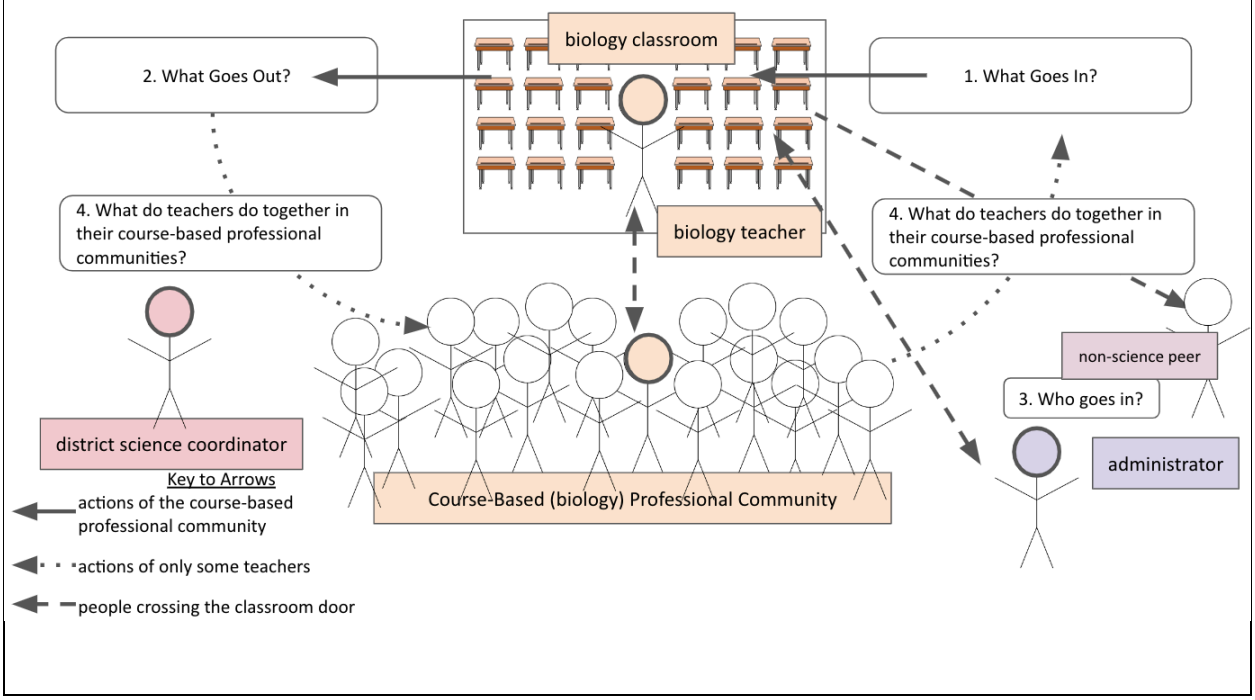
Connecting to External Science Education Communities (C.4). Participants suggested that many District A teachers and the district science coordinator were connected to the external science education research and development community, including the state science teachers' association and curricular-specific programs including modeling-in-biology and *Carbon TIME*. The district science coordinator was especially well connected, describing attendance at

state and national science-specific conferences and programs, and using Twitter to stay connected to experts' work around three-dimensional science instruction and equitable student outcomes.

Multiple biology teachers at each of District A's high schools participated in the NSF-funded, two-year *Carbon TIME* professional learning networks. Several who were also on the district science leadership team worked with the district science coordinator to secure a half-day overview of the curriculum, attended by the course-specific (biology) professional community.

Participants also described additional pull-out *Carbon TIME* professional development, supported by District A and Union A. The district provided release time for teachers interested in attending the training and the local and state teachers' unions supported the *Carbon TIME* professional learning provider (this author). Participants said that their colleagues found this experience "really, really helpful" in getting them to "feel comfortable using" *Carbon TIME* units.

Figure 5. Model for District A Actual Identity, corresponding to Table 5, rows 1-5



District A, Row 1 and Model 1. What goes in?

As shown Table 5, row 1, and in Figure 5. Model for District A Actual Identity – corresponding to Table 5, rows 1-5, District A participants' stories indicated that three-dimensional science curricular resources were available for teachers to use. Common, three-dimensional end-of-course exams crossed the doors of all biology teachers.

Initial Instructional Resources. Participants in District A shared stories in which common, three-dimensional curricular resources were available, though individual biology teachers determined if and how to use them in their classrooms. The district science coordinator said, "we've got the *Carbon TIME* pieces for some of our units. We've got some good [resources], but not everybody's on board with all of them." A teacher shared that, in his

building, “in my little colleague group of biology … generally, only three of the six of us are doing” *Carbon TIME* lessons.

Overall, participants described the value of a good curriculum was in “provid[ing] a framework.” The district science coordinator described how this framework was important – “so teachers aren’t doing it all from zero,” but that teachers wanted and had “a lot of freedom with the curriculum.” She described this freedom as a sign of quality curriculum; “teachers … have a responsibility to know their kids” and quality curriculum provides “space to do even more [supporting] based on the students in your classroom.”

District A participants shared stories of all biology teachers using locally developed, three-dimensional common course-level assessments, modeled off the state’s item-cluster design and incorporating novel phenomena. These were for end-of-course (midterm and final) exams, developed by the biology teachers on the district’s science leadership team.

Ongoing Revisions to Common Exams. District A participants described the science leadership team revising the common assessments each summer – rewriting, for example, a “question [that] didn’t elicit what we needed.” However, participants did not describe if or what evidence was used in making these revisions.

District A, Row 2 and Model 2. What goes out?

As shown in Table 5, row 2, and in Figure 5, District A participants described evidence of students’ three-dimensional learning leaving the classroom door to be explored with the course-based (biology) professional community. This evidence included students’ performances on common end-of-course exams and multi-dimensional student work artifacts.

Students' Performances on Three-Dimensional Assessments. In District A, participants described reviewing student performance data from common assessments alongside professional community colleagues. Teachers described examining students' performances on common end-of-course exams by viewing the performances (including class averages) for their own students as well as viewing course-level data (averages) aggregated by building and by district. The district science coordinator said that teachers could not view other teachers' data, and that they could view item-level analyses.

Student Work Artifacts. Participants described a few opportunities to make sense of students' multi-dimensional classroom experiences using student work artifacts. The district science coordinator described the full course-based (biology) professional learning community bringing student work samples around a specific *NGSS* science and engineering practice (Evidence-Based Argumentation) for discussion and development of a department-wide practice-specific rubric. Another example was through building-based (biology) professional community meetings in which teachers brought samples from a *Carbon TIME* unit to discuss and share with a protocol and outside facilitator – this author – (see example in 4).

District A, Row 3 and Model 3. Who crosses the classroom door?

As shown in Table 5, row 3, and in Figure 5, District A participants shared stories in which building administrators crossed the classroom doors of individual biology teachers when making formal teacher evaluation observations. At one high school, peers from outside of the course-based (biology) professional community entered some teachers' classrooms through Instructional Rounds initiatives.

Building Administrators. Teacher participants were generally positive about their experiences with required formal observations by their building administrators. Still, they recognized their administrators did not have a deep understanding of *NGSS*-aligned instruction. As one teacher shared, "our admin tries to give helpful feedback, but … they don't really get what we're doing … If I were to say, 'I'd really like feedback on … these three-dimensional lessons,' … my admin would have no clue."

Peers from Outside the Course-Based (Biology) Professional Community. District A participants described few experiences in which colleagues crossed the classroom door, and no examples of organized peer observations with other teachers from the course-based (biology) professional community.

One teacher said that her high school "was trying to start Instructional Rounds … 'What can I learn as a teacher from what I saw happening in that classroom?'" During a pilot experience, the teacher explained that she was observed by other teachers in the morning, and then – later that afternoon – she was part of a team of teachers observing a colleague. In both cases, "the person who was observed [did] not" receive feedback about their classroom or instruction. In this design, peer-observations did not connect to the course-based (biology) professional community, and any classroom observation could benefit only the observing teacher.

District A, Row 4 and Model 4. What do teachers do together in their course-based (biology) professional community?

As shown in Table 5, row 4 and in Figure 5, District A participants described the course-based (biology) professional community engaged in some evidence-based sensemaking of

three-dimensional instruction, including analysis of shared student work artifacts. A smaller district science leadership team worked on development and revisions of common instructional resources, though it was not made clear if or how the student learning evidence leaving classrooms affected revisions to common assessments entering classrooms.

Selection and Development of Three-Dimensional Assessments. Participants indicated that most biology teachers were not involved in selecting or developing common assessment items. Instead, the "detailed development" of biology's end-of-course, three-dimensional common exams was primarily the work of the science leadership team, which included about one-third of the biology teachers. Though participants said, "everybody had a chance to give feedback," on the end-of-course exams, they did not describe steps like those described in District N, through which assessment-related feedback or item-level approval was systematically collected.

Sensemaking About Three-Dimensional Instruction Using Evidence. Participants' descriptions of sensemaking around three-dimensional science instruction were primarily about individual sensemaking alongside other individuals in the course-based (biology) professional community. District A participants' stories did not include dialogic sensemaking with peers, and most descriptions of analyzing student outcomes suggested that – as befits an individually oriented professional community – the purpose of any analysis was to make individual meaning that was deemed useful to each individual teacher.

Analysis of Students' Three-Dimensional Assessments. The district science coordinator indicated that high school teachers were beginning to spend more time looking at common assessment data, because teachers could use "item-level analysis on assessments, to see what

that tells us about kids' thinking. That's the only way that I think that falls to an extensive amount of value." For example, she described how looking at "items that give us some evidence about a particular practice or several science practices [that] we're emphasizing [in a] course or that unit [is valuable]. And we can have conversations by looking at the data. Like, 'Oh, our kids are looking pretty good on this practice or this topic bundle. But, man, like we're, we're struggling here'."

Interestingly, this is a different interpretation and assignment of value than that shared by the District N science coordinator. In District N, item-level analysis was described as easier and more comfortable for teachers, but less useful in helping the professional community to consider students' big ideas or in making connections to teachers' classroom instruction.

Finally, the district science coordinator shared that she wanted teachers to consider, "How do I use data to empower myself?," focusing opportunities to review students' common science assessment data (during time together as a professional community) as opportunities for individual teacher improvement.

Analysis of Student Learning Artifacts. Participants described the full course-based (biology) professional community bringing student work artifacts focused on the *NGSS* argumentation practice, in order to begin to "anchor what looks like good work … what are we [even] looking for in a kid's argument?" Though this experience was described as an opportunity for group sensemaking and anchoring, the district science coordinator also described intentionally not pursuing strict standardization across teachers' interpretations and scoring of their own students' work. She prioritized "teacher learning in the moment" over ensuring that all teachers were scoring "a good number two [or] a good number three" the

same. This was the case even as a teacher participant reported, "'I know that person is giving threes where I'm giving twos'."

Participants also described building-based experiences in which they brought *Carbon TIME* student work to a monthly building-level biology meeting and worked with a facilitator (this author) to make sense of students' tracing matter and energy through systems. One participant shared how she valued this looking at student work. She said it supported teachers in taking "time to really understand what [students are] communicating and what their understanding is," as well as opening up opportunities to discuss "what the understanding between teachers is."

Revisions to Three-Dimensional Assessments. District A participants indicated that although the course-based (biology) professional community did not revise common assessments, the district science leadership team did. The district science coordinator said that every year, the science leadership team's summer work agenda had, "'What tweaks do we need to make on the common assessment?'" on it. However, it was unclear what evidence of student learning – if any – was used in revising the common three-dimensional assessments. This district science leadership team was not described as making revisions to other kinds of instructional resources.

District M: An Individually Oriented Professional Community Maintaining the Status Quo for Science Teaching and Learning

District M participants' stories portray District M's *actual identity* as an individually oriented professional community maintaining the *status quo* for science teaching and learning, meaning "quick and snappy" student engagement and one-dimensional rigor. Stories suggest

that teachers perceived their professional community work as disconnected from their classroom work, with teachers having autonomy and authority for their individual classroom decisions. Professional norms for niceness and non-interference prevailed. District and union leaders were described as enabling individual teachers in pursuing their individual *classroom pedagogical responsibilities*.

In District M, teachers described using adopted three-dimensional instructional resources mostly in a pick-and-pull fashion. Minimal evidence of student learning left the classroom door. Participants described building administrators crossing the classroom door to make formal teacher evaluation observations, and some non-critical peers from outside of the course-based professional community making observations through Instructional Rounds initiatives. The professional community was described as engaging in no work that connected to what goes in the classroom (Table 5, row 1) or what goes out of the classroom (Table 5, row 2). The local public community endorsed District M's instructional *status quo*.

Differently than in other districts, teacher participants' stories reflected different perspectives and experiences around three-dimensional classroom instruction. Therefore, these teachers have been identified as "M_T1" and "M_T2" in the text below.

Row A. District M Teachers' Classroom Pedagogical Responsibilities

District M participants told stories in which biology teachers held individual *classroom pedagogical responsibilities* (Table 5, row A), most to students' quick-and-snappy science classroom experiences and one-dimensional science achievement.

District M participants' descriptions of their understanding and value for three-dimensional science teaching and learning varied significantly. The district science coordinator

and M_T1 described visions aligned with the NRC's *Framework* (2012), capturing the major shift away from content checklists and "confirmatory labs … towards, 'Hey, there's this thing that's going on,' … and when we're looking at this phenomen[on], we are trying to figure out, like a scientist … 'What's going on here?'."

Differently, M_T2 described the new *NGSS* as being "more broad" than previous science standards, so teachers were "not told exactly '[students] need to know this, need to know that.' … So that gives you a lot more leeway. But sometimes, it's nice to have more direction so you can make sure that you cover this, cover that." Noticeably, his description of the new standards extended a *status quo*, pre-*NGSS* focus on content coverage. His characterization of *NGSS* did not include students' engagement with scientific practices or sensemaking; his comments do not present *NGSS* as a significant change in teachers' instruction or students' learning.

From the district science coordinator's perspective, a shift in vision and instruction "probably needs to, more than has occurred" in District M's high schools. She said the *NGSS*-aligned shifts were especially challenging for many high school teachers; "It rocks [their] core a little bit" because teachers were "worried about not getting through everything." Though this was described as true across content areas, "biology seems to be one of the stronger ones" in which teachers felt, "if I don't get through this content, then the kids are not prepared." This commitment to teacher-valued content and details – such as human anatomy or viruses – even if these were no longer addressed in the new high school *Next Generation Science Standards,* represented a core *classroom pedagogical responsibility* of most District M high school science teachers to one-dimensional rigor.

Additionally, participants described most District M secondary science teachers as holding *classroom pedagogical responsibilities* for providing students with quick-and-snappy science classroom experiences. This involved most teachers "doing some of the [old] activities that we know students love and that … make them love going to biology class," while also using some of the new *Carbon TIME* activities (like the investigations) that students enjoyed and found engaging. This responsibility to keeping students engaged explained why teachers described choosing not to incorporate curricular aspects of *Carbon TIME* that they found to be repetitive. Such teachers noted, "if you do the same thing over and over, it just drives the kids crazy," which was not perceived as supporting their goal (and responsibility) for having students love coming to biology class.

Stories from District M participants suggested that – among biology teachers – M_T1 was an exception; she was a teacher who held a *classroom pedagogical responsibility* for students' three-dimensional experiences and outcomes. She described how her shift in classroom practice – due to the "new standards – [meant] … shift[ing] from just learning pieces of content to helping the kids figure out [phenomena] … [and] apply [that] to the world around them."

Row B. District M Teachers' Professional Community Responsibilities

District M participants shared stories of teachers working as individuals who had the autonomy and authority to fulfill their individual *classroom pedagogical responsibilities* (Table 5, row A) in their own classrooms and in ways that required no connection to the course-based (biology) professional community. Participants shared stories reflecting norms of non-interference and niceness among colleagues.

No Connections between Professional Community and Classrooms (B.1). In District M, stories from participants provided no examples of course-based (biology) professional community work being necessary for teachers' fulfillment of their individual *classroom pedagogical responsibilities* (Table 5, row A).

Teacher Autonomy (B.2). Teachers' autonomy to make their own classroom-based instructional decisions was described as pervasive and accepted. This essential aspect of District M's identity was captured in M_T2's comment: "I pick and pull the best parts that I think are best for my students." He explained, "teachers … get a feel for [our] students [so if something] is not gonna work with these [kids], [then] maybe I'll throw this in, and use this, [or] use that." The local union president said that this approach was "pretty common …. everywhere [in District M]."

Notably, District M's individual autonomy did allow M_T1 to make her own, very different classroom choices. She was described as the only biology teacher using the officially adopted *Carbon TIME* curriculum and she described herself as "existing on my own island."

Professional Norms for Niceness and Non-Interference (B.3). In District M, M_T2 did not agree with M_T1's classroom decisions; he said that "it [was] frustrating to" him and other biology teachers that M_T1 would "not do [traditional District M biology activities] … that's good stuff. And you don't have to stick with [just *Carbon TIME*] … there's other stuff out there that you can do a lot with." Still, norms for niceness and non-interference were maintained.

These norms were also noticeable in M_T1's discussion of her choices for using an additional non-instructional period she was provided through funding from a philanthropic grant. This additional release period was designated as "time allotted for collaboration" with

other science teachers. M_T1 felt that her peers perceived this support role was solely around implementing the new *Carbon TIME* curriculum, and since "[they] know [they]'re not doing it [and] I know [they]'re not doing it, what kind of common ground can we step on?" So, she said that she made efforts around "just making those [personal] connections … 'Oh, how are your kids doing? How's the volleyball season?' … It's a little awkward."

M_T1 explicitly described concerns that challenging the classroom decisions of other teachers would damage relationships with colleagues in ways that could make her work environment difficult. "I have to work in the building. So, to create an atmosphere that's extremely uncomfortable for me as an employee means that I'm not going to be nearly as effective in my classroom … I don't want to put myself in a position … where … I'm going to be affecting my job [with] my students, because that's the reason I'm there in the first place – that's what's driving me."

In this way, District M's prevailing norms for niceness went hand-in-hand with norms of non-interference in which each teacher maintained their decision-making authority within their own classroom. Despite having extra time allocated for collaborating with her peers, M_T1 did not describe feeling responsible for shifting her colleagues' classroom practice. She instead described her collaboration experiences as infrequent and performative. She "felt like I was checking off boxes. And so [we]re they."

Independent Experiences with External Science Education Communities (B.4). M_T1 shared how professional development experiences she had outside of District M helped her envision what *NGSS*-aligned instruction looked like, making her feel both "really excited" and "more scared … realizing the change that needed to occur" in her science instruction. "I

remember going to [external professional development] and saying, 'Oh my gosh, this is how I'm supposed to be doing this. I have no clue what I'm doing now.'"

However, her professional development experiences did not translate into her colleagues' engagement with new resources and ideas; independent experiences by some teachers did not translate into professional-community-wide innovations.

Row C. Roles of District M and Union M Leaders Related to Teachers' Professional Communities

District M participants shared stories in which District M and Union M endorsed individual teachers as autonomous experts. Participants described minimal transaction or conflict costs and accountability to generalized "good teaching."

District M and Union M Stories (C.1). In District M, stories about teacher autonomy were connected to perceptions of teachers' expertise. The district science coordinated explained, "One of the things that is here [in District M] is this academic autonomy … 'I am the teacher. I am the content expert. And I got this'." The district science coordinator described this as "really cool, on one hand" because of how much teachers were respected – "We've elevated [them], we've given them autonomy, we've given them onus." On the other hand, she pointed out how this meant "trying to make any types of shifts [was] a little bit extra hard … because there's this real ownership and confidence … 'We have been hired because we are the best teachers,' which is true."

These stories of expertise and authority extended to Union M. Participants described the local teachers' union as having "a very strong presence" and a "culture [in which the union is a] group of employees who are working together to make sure that things are fair and

reasonable." This contributed to "a culture [in District M] of the educators are an important group, that their say does mean something."

Transaction Costs Not Incurred (C.2). Participants did not describe transaction costs; in fact, no teacher participant indicated they wanted or needed more time with colleagues.

The district science coordinator did feel that more time was needed as a professional community. She described the current situation – in which "the only thing that we have that is required is district-provided professional development" – as a real "structural barrier" toward science department work. She said that she couldn't "require people to attend things in the same way that we can if it's district-provided PD." She finished, "if I was to organize a mandatory meeting [for science teachers], I probably would get a grievance, unless I paid them."

Unlike other districts, District M participants described no contractual, weekly, after-school staff- or content-area meetings. The local union president explained that District M "used to have a system like that and … we hated it. (Laughter) It was, like, by the time you went to it, you were exhausted from the day, and it was just not very productive … [So, now], the district sprinkles in what we call professional development days throughout the year on the calendar … [which is] split up [among] building and district initiatives and … curriculum time."

Participants described teachers having two daily non-instructional periods, which could be used for meetings with available peers. In some buildings, these were used for non-content-specific Professional Learning Communities (PLCs) with "just [whomever] had the same off-hour as you."

Accountability to Generalized "Good Teaching" (C.3). M_T1 believed that the building administrators knew that what was happening in her biology classroom (*Carbon TIME*) was different than what was happening in others' classrooms. Though she believed that holding teachers accountable to following an officially adopted curriculum "should be a part of [our] boss's role," M_T1 did not believe that building administrators were "ready to push [for common curriculum]."

This was echoed across participants, all describing the District M teaching environment as "pretty loose" with "no real accountability" to any officially adopted curriculum.

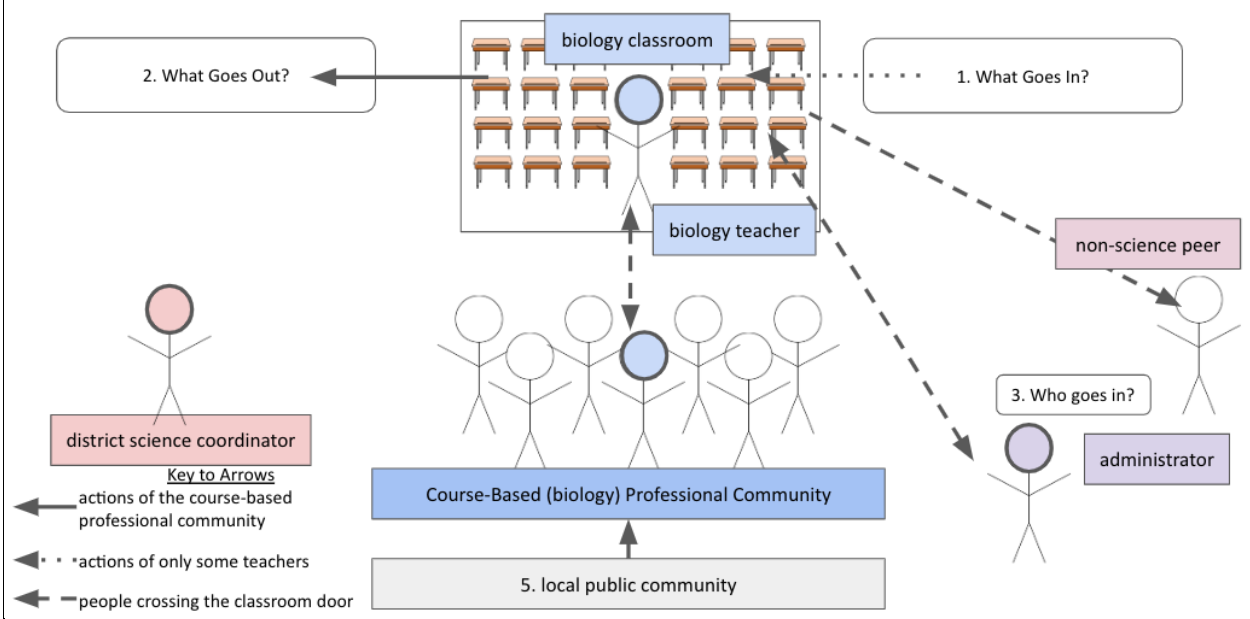
The local union president explained that building-level administrators did not "evaluat[e] too tightly and closely that you're actually following whatever [curriculum] … you [just] need to show that you're addressing the standards." However, "the administrators who are doing the evaluations don't have a science background … [and] in terms of expectations, a good classroom still looks like a good classroom with well-behaved students and engaging activities and those pieces," so "there isn't really an accountability factor" to using the adopted curriculum.

Connections to External Science Education Communities (C.4). Like other districts, District M participants described connections among individual teachers and external science education communities. However, the district science coordinator did not provide specific examples, which may have been related to her many and varied responsibilities outside of science.

Carbon TIME was an external community that was connected to District M through a non-profit philanthropic organization. This happened with the support of a previous district

science coordinator. As M_T1 explained, the current district science coordinator began "at a time when … we were supposed to be implementing [the new *Carbon TIME* curriculum] … You don't necessarily want to shove something down someone's throat when you're not really sure what you're supposed to be shoving, or the pretense that it started with. So, it's kind of an awkward timing factor in there."

Figure 6. Model for District M Actual Identity, corresponding to Table 5, rows 1-5



District M, Row 1 and Model 1. What goes in?

As shown in Table 5, row 1, and in Figure 6. Model for District M Actual Identity, corresponding to Table 5, rows 1-5, District M participants described that district-adopted three-dimensional instructional resources crossed teachers' classroom doors in a pick-and-pull fashion.

Participants described most teachers having limited commitments to the officially adopted curriculum, with M_T2 explaining that he and his colleagues felt they should "include

the *Carbon TIME* units in what we do … [but] not necessarily follow exactly the day-to-day schedule" as outlined in the curriculum's sequential activities. Teachers "agree[d] that 'Okay, we don't want to do exactly what *Carbon TIME* says of everything, but we want to put the good parts in there'." This teacher suggested that he and most of his colleagues identified the "good parts" as the investigations included in the *Animals* and *Plants* units, which comprised only nine days of instruction in a full-year biology course that meets for 180 days. In this way, though aligned with three-dimensional science education reforms, the officially adopted instructional resources were not described as being used in ways that supported students' three-dimensional performances.

M_T1 – the one District M teacher who was described as using the instructional units in their entirety – was very positive about the units' utility in meeting her *classroom pedagogical responsibilities* (Table 5, row A) to students' three-dimensional achievement. This included her use of the *Carbon TIME* assessment items, which she described as "fantastic pieces" that provided her with "an assessment tool that I think is very useful."

In a strikingly different analysis, M_T2 described the *Carbon TIME* assessment items as including "tricky words." For example, in "questions about conservation of mass," he felt students should be alerted: "[The question] say[s] 'created.' That's not the answer. Don't choose this."

District M, Row 2 and Model 2. What goes out?

As shown in Table 5, row 2, and in Figure 6, through the lack of an arrow connecting the classroom and the course-based professional community, District M participants did not describe any evidence of students' three-dimensional science learning leaving classrooms and

being shared with the larger collegial group. Participants indicated that in some department gatherings during district-provided professional development opportunities, teachers shared recounts of non-three-dimensional science teaching and shared content-coverage information.

Teachers' Recounts. Among biology teachers, teaching and learning anecdotes shared with the professional community recounted students' one-dimensional learning experiences and highlighted the ways that new standards and the *Carbon TIME* curriculum were falling short of most teachers' goals for quick-and-snappy teaching and one-dimensional rigor. For example, M_T2 described how a district AP/IB Biology teacher was discouraged and upset during a Fall, 2019 course-based (biology) professional community meeting. She "was just amazed at some of the things … [these high school seniors] didn't know … [like] for plants, they didn't know anything about seeds … [and] there's many topics like that, that [didn't] get touched" during the students' preceding biology course with teachers using *Carbon TIME*. "It's frustrating … that kids have gone through a full year [of] biology and they've never touched a certain topic." These shared teaching and learning experiences were primarily ones of dissatisfaction and misfit.

Content-Coverage Information. In District M, participants described the course-based (biology) professional community discussing content coverage. As M_T2 described, "Everyone wants to cover the same stuff. I would say that's probably the main thing" that felt important to review when teachers met. This was true "even with this COVID-19 [remote instruction], it was, 'What are you covering? What are you covering?'."

District M, Row 3 and Model 3. Who crosses the classroom door?

As shown in Table 5, row 3, and in Figure 6, building administrators crossed the classroom door when making observations for formal teacher evaluations and peers from outside of the course-based (biology) professional community entered some teachers' classrooms through Instructional Rounds initiatives.

Building Administrators. District M participants described building-level administrators entering teachers' classrooms to make observations as part of formal teacher evaluations. However, this evaluation process was described as having little effect on teachers' science instructional decisions. Evaluators were looking for "the same things that you would see in almost any classroom." These evaluations helped maintain the kinds of science teaching and learning that preceded the new *NGSS* standards, because, to administrators, "a good classroom still looks like a good classroom."

Peers from Outside the Course-Based (Biology) Professional Community. Like District A, in District M, participants described opportunities for secondary teachers to cross their colleagues' classroom doors through Instructional Rounds initiatives. These opportunities were described as flexible, infrequent, and disconnected from the course-based (biology) professional community, with teacher observations instead organized around prep hour.

Teachers were clear that "there was no critiquing anything" during or after the observation and no feedback was provided to the observed teacher – though sending "a note, like, you know, 'Great job!'" was encouraged. In this way, participants' stories showed that people crossing into other teachers' classrooms in District M neither contributed to nor interfered with individual biology teachers' autonomous instructional decisions. Further,

individual teacher observers could take from their observation experiences any new ideas that supported their individual *classroom pedagogical responsibilities* (Table 5, row A).

District M, Row 4 and Model 4. What do teachers do together in their course-based (biology) professional communities?

As shown in Table 5, row 4, and in Figure 6, through the lack of arrows connecting the classroom and the course-based professional community, participants' stories did not describe District M's course-based (biology) professional community involved in work connecting to what goes in teachers' classrooms or what goes out of classrooms.

The district science coordinator described the course-based (biology) professional community engaged in "some explicit conversations … about course offerings" as well as an opportunity to establish some "non-negotiables, [like] 'Here are what the standards are'." Notably, the district science coordinator did not indicate that she included the officially adopted *Carbon TIME* curriculum in the list of non-negotiables.

Credit-recovery Consensus Decisions. District M participants shared only one story of a course-based professional-community-level decision, which occurred in the spring of 2020 and was connected to the COVID-19 pandemic-related move to remote instruction. In this situation, teachers "had to decide as a biology team, what our students would need to repeat if they didn't pass [the] semester" and provide district administrators with "credit recovery material." Here, again, is an example in which District M's individually oriented identity is noticeable. M_T1 described clearly informing her peers she was teaching completely different topics than they were, but with no corresponding stories in which either she or they attempted to address (or resolve) those differences.

District M, Row 5 and Model 5. Local Public Community

In District M, participants shared stories about the local public community (parents and district graduates) being satisfied with pre-*NGSS* science teaching and learning in ways that reaffirmed the science instructional *status quo*. “The way we’ve always done things [in District M]; the students have always produced,” so “despite the changes in the expectations with the [new science] standards” teachers could look “at all those [student performance] pieces and [say], ‘This works’.”

The schools’ and local public community’s “biggest … concern[s] [were] college readiness [and] test scores.” Participants shared that the community has “always loved the rank that [District M] had in the state and [our] ability to compare [our]selves to other elite districts” on whatever “the state test [was] at that … time.” Outside of these various test scores, teachers “were getting great feedback from our college-bound students,” who felt they were “getting [those important] skills” including “kill-and-drill, fact-based … scripted” experiences that prepared them to be successful college students. So, teachers and the local public community all perceived success in ensuring “that our students are prepared for this career [or] that career, oftentimes in the medical field.” There was no pressure from the external local public community to make any changes.

Chapter 5 – Results for Research Question 2: Districts' Designated Identities

Results for Research Question 2 describe patterns in participants' interviews addressing the question, *What is each district's designated identity, as shared in stories about teachers' responsibilities; district and union roles; and what and who crosses the classroom door?*

In the text that follows, districts' *designated identities* are first re-introduced from Chapter 1 as a useful concept for making sense of participants' interview responses. Then, results are organized by district and coordinate with district-specific Tables (Tables 6-9). For conciseness, text is only for district characteristics (table rows) in which future *designated identities* are likely to be different than the *actual identities* described in Chapter 4, Results for Research Question 1: Districts' Actual Identities. This is visually represented in Tables 6-9 by darker boxes for characteristics in which districts' *designated identities* are anticipated to be different than the current *actual identities*.

Because each of these four tables covers multiple pages and is in landscape orientation, they are provided together at the end of this chapter, instead of interspersed throughout the text.

Defining Districts' Designated Identities

As Sfard and Prusak (2005) explain, "identity talk makes us able to cope with new situations in terms of our past experience and gives us tools to plan for the future" (p. 16). *Designated identities* consist of "narratives presenting a state of affairs which … is expected to be the case … in the future" (Sfard & Prusak, 2005, p. 18). These stories are consequential because they help us make future decisions and shape future actions.

Sfard and Prusak (2005) suggest that *designated identities* typically use "the future tense" or "words that express wish, commitment, obligation, or necessity" (p. 18).

District N: A Collective Professional Community with Three-Dimensional Science Goals for All Students.

Patterns across interviews suggest that District N's *actual identity* as a collective professional community is likely to continue. In the future, teachers will continue to engage in joint work and seek consensus on decisions within their course-based (biology) professional community. Patterns across interviews also suggest that District N's *actual identity* pursuing three-dimensional science goals for all students is likely to continue. In the future, all teachers will continue to engage students in three-dimensional classroom experiences and will administer the district's common, summative, end-of-unit and end-of-course exams.

As shown in Table 6, stories suggest that teachers' *professional community responsibilities* (Table 6, row B) may change in the future, to include commitments for ensuring every member of the professional community can share their voice in ways that contribute to decisions. Additionally, participants describe the roles of District N and Union N leaders (Table 6, row C) in the future as possibly using clearer definitions to further decrease conflict costs for teachers. Finally, participants anticipated some possible changes in what teachers will do together in their course-based professional communities (Table 6, row 4).

Row B. District N Teachers' Professional Community Responsibilities (in the Future)

District N participants' stories suggest that teachers will continue to perceive what they do in their professional communities as integral to what they do in their classrooms. However, the district science coordinator imagines a future in which there is an additional aspect of

teachers' *professional community responsibilities*; the community will take on the responsibility for ensuring every teacher feels their voice can contribute to collective decisions. This is unique in how it moves the role of "mitigating conflict costs" from District N and Union N leaders (primarily through district-wide accountability systems and district- and union-sponsored training and support, in Table 6 row C, *actual identity*) to become a role taken up by the professional community itself (Table 6, row B, *designated identity*).

The district science coordinator noted limitations with how teachers currently provide input on curricular and assessment revisions. She said, "I want everyone to contribute [revisions] to [our shared instructional resources] and unfortunately, they're not." She expressed confusion; "I can't quite figure out if it's because [teachers are] … afraid that they'll be judged or … we have not built a safe enough space" for all teachers to feel comfortable regularly sharing their ideas. Further, she recognized that there was "one very strong personality" and teachers might be "afraid enough" of this person's reactions to withhold their input.

The district science coordinator believed that the professional community may have been "do[ing] [consensus-seeking decision-making] relationally" – through relationships among colleagues and the teacher-leader. This may have inadvertently discouraged or quieted some teachers who found potential interpersonal conflicts – "rocking the boat," or discomfort that a colleague "will be angry" – not worth it. This was viewed as problematic because limiting the participation of some individuals could consequently limit the development of the highest possible quality instructional resources or the best possible decision.

Professional Community Mitigates Conflict Costs in the Future (B.5). The district science coordinator saw "build[ing] protocols around decision-making" as a helpful strategy to reduce conflict costs and support future consensus-oriented revisions in instructional resources. She indicated that professional communities need methods for establishing "way[s] to say, 'Which way do we go? Who's right and who's wrong?'." She wanted to ensure each teacher in the professional community could contribute, "because what happens is – if those protocols aren't in place – it's simply dependent on the personalities of the people in the [professional community] and that is not good enough. Right? … We can't just let the loudest voice win when it comes to our kids."

An example of "very clear protocols … [providing] more direct structure to get [a] group to come to common ground" was available in another District N course-specific professional learning community. There, the teachers – under the guidance of a teacher-leader – developed their own decision-making protocol to support them in deciding if specific content belonged in their course. For example, after "unpack[ing] the standards," if teachers weren't in agreement about what belonged, then they "dug another layer" into the protocol's next step, referencing another tool connected to expert communities as a guide.

Row C. Roles of District N and Union N Leaders Related to Teachers' Professional Communities (in the Future)

The district science coordinator said, "[District N] had a lot going for us, but it was … not perfect." A more perfect future would use District N and Union N roles to further decrease conflict costs.

Mitigate Conflict Costs in the Future (C.3). Participants' stories suggest a future in which conflict costs can be further decreased through District N actions around new initiatives and through adjustments in and definitions of District N and Union N roles.

Mitigate Conflict Costs through New Initiatives. First, the local union president shared her perception that "stronger personalities and stronger leaders [can make it so] other [teachers] feel like it's not their place" to advocate for changes in common instructional resources. From her perspective, this was particularly the case when the teacher-leaders who led the initial development work "continue to be [the teacher-leaders] and … feel still pretty strongly that they did a really good job."

She saw new district initiatives – such as Universal Design for Learning (UDL) – as an opportunity that could "open the door to be able to look more objectively at those [common] assessments … to see … 'Do they really show us that the students have [the] understanding that we want?'" In this way, a new initiative could allow for review and revision without requiring an individual teacher to risk initiating a potential conflict with a "stronger" colleague or teacher-leader. Instead, professional communities would have the same opportunity to "start fresh" with common assessments that the biology teachers described having through the *NGSS* rollout.

Mitigate Conflict Costs through Clear Roles. The district science coordinator's motivation to consider future roles for district and union leaders stemmed from her perception that, even though the professional communities were "envisioned [as] a place … where [teachers] could [analyze and discuss with peers] … it just feels like there is always a reason that we are [not] doing that." The district science coordinator said teachers just "don't have the

culture where [analyzing student work artifacts is] what we do in our [professional community] meetings," unless an instructional coach is there facilitating.

So, the district science coordinator's vision for a more "perfect" future involves the building administrators "monitoring whether or not [teachers] participate" in such professional community work. She proposed that administrators be in the room "at the beginning of the [professional community] meeting [and say], 'I'm going to … check you all in, make sure everybody has their [student work artifacts] … and then I'm going to let the group have their discussion'" with the teacher-leader. In this way, there is "accountability [from] the person who evaluates" teachers, not solely expectations from a teacher-leader peer.

She saw two important roles for Union N. One was to clearly articulate each position's roles, "[instructional] coaches are inside our union [and] they do these things; teacher-leaders are inside our union … certain pieces of information [like students' assessment data will be allowed] for coaches [and teacher-leaders], too, to help support everybody in growth." And, agreeing that it is "the administrators that [a]re responsible for [monitoring] – making sure that teachers followed" the expectations.

Second would be for Union N to coordinate with District N around policies and plans "so that we felt safe – like this was a trustworthy plan," before the initiative is rolled out. Sometimes, initiatives get "rolled out, and then people complain … and then that communication gets wheeled back, … [not only is it] very inefficient, it also leads to this perspective that 'Wow, I can just ignore this, because it will get pulled back at some point, anyway.'" Instead, if district and building administrators regularly went "to the union [to] say,

'This is what it's going to look like. What kinds of things do we need to put into place to support our teachers?'," that would be a more "ideal world."

District N, Row 4. What will teachers do together in their course-based (biology) professional communities? (in the Future)

Stories of what biology professional community members will do together in the future in District N focused on continuing to use information leaving the classroom to make improvements in instructional resources that go into the classroom, alongside an increased focus on teachers' actual instruction behind their classroom doors.

Revising Instructional Resources in the Future. The District N science coordinator noted that "what should and should not be taught [in a course] is a constant conversation" within a course-based professional community, due to an ever-deepening understanding of the *NGSS*. The district science coordinator anticipates the professional community will continue to wrestle with questions like, "How do we decide what it means to teach the standard?".

Sensemaking around Three-Dimensional Instruction Using Student Assessment Data in the Future. Participants continued to anticipate using students' results from common, three-dimensional assessments to inform revisions to instructional resources, while they also anticipated sharing teacher- or class-level data within the professional community more regularly and in ways that are intended to connect students' performances with teachers' instructional choices when they're behind their own classroom doors.

Both the district science coordinator and the local union president described these as "very valid way[s] to help with [teacher] growth" and a valuable use of professional community time in support of teachers' instructional improvement.

The local union president explained, “We can have the conversation amongst our [professional communities, that] show an average [for each teacher]” so the professional community can say “‘Okay, this is what we’re seeing’,” and then discuss together, “‘What are we doing? What seems to be working? Who seems to have a lot of success this year? What did you do? What do you attribute that to?’.”

Both the district science coordinator and the local union president recognized that presenting data in ways that allowed for comparisons across teachers was uncomfortable for teachers; “You feel very vulnerable.” The local union president indicated that teachers might feel “scare[d]” that they could be “penalized for getting a different data set than their [classroom] neighbor” or they might “feel that their colleagues were judging them” even though District N is “a district where none of those things actually happen.”

Still, the local union president felt that “it is within [the district’s] right” to engage professional communities in such data-based conversations. She believed that “giving teachers [a] chance to say, ‘I’d rather not’ [have my] class’s data” included would likely be helpful in easing teachers’ concerns. She said that these professional community “conversation[s] [are] really rich and not at all punitive” and hoped future positive experiences would further “foster that culture of open dialog and feeling comfortable with sharing those results.”

Summary of District N’s Designated Identity

District N participants describe a future in which the course-based (biology) professional community continues to be a collective professional community with three-dimensional science goals for all students. Changes from the current *actual identity* may occur around teachers’ *professional community responsibilities* (Table 6, row B) and the roles of District N and Union N

(Table 6, row C), focused on decreasing conflict costs in ways that better enable all participants to share their voices.

District N participants recognized that their transition to *NGSS* will continue and talked about future work that will reflect their deepening understanding of the new standards (Table 6, row 4). Finally, both district and union participants anticipate course-based professional communities will review and discuss teacher-level data from students' common assessments because it can support teachers' improved instruction behind the classroom door, even if these kinds of teacher-teacher comparisons can feel uncomfortable.

District F: A Collective Professional Community with Three-Dimensional Science Goals for Students (in the Future)

Patterns across interviews suggest that District F's *designated identity* will be different in the future – participants see it changing from a collaborative (two or more teachers working together) to a collective (teachers acting as a group) professional community.

Participants also suggest that District F's *actual identity* pursuing three-dimensional science classroom experiences for students will likely change to a *designated identity* pursuing three-dimensional science goals for students.

More aspects of District F's identity are anticipated to change than in any other district. This can be seen in Table 7, where most of the table is shaded a darker color.

Row A. District F Teachers' Classroom Pedagogical Responsibilities (in the Future)

In District F, teacher participants shared stories of a near future in which all the biology classes (regular and honors) will be using common *NGSS*-aligned instructional resources that will allow teachers to fulfill their *classroom pedagogical responsibilities* to provide all biology

students with common, three-dimensional science experiences and assess their three-dimensional outcomes. This is different from the current *actual identity*, in which not all teachers hold three-dimensional *classroom pedagogical responsibilities*.

However, it may be that students in the different biology tracks receive different classroom experiences from each other. One teacher described the honors classes as "a place for some memorization, and you do have to know content … I think that [teachers] need to … make sure that [we] integrate enough into an honors-level, because those students are planning on going … [in]to the AP or the IB track, and so they need to be prepared academically or content-wise." This suggests that teachers may feel *classroom pedagogical responsibilities* for enhancing the one-dimensional rigor of honors-level students' experiences.

Separately, another teacher talked about supporting the regular biology students better in the future by "pulling in some more activities. I just felt like the kids were sitting a lot; there was a lot of discourse. … but not enough movement for the kids … [and I need to include] more hands-on activities." This statement may reflect teachers' pedagogical responsibilities for engaging regular-track students in quick-and-snappy classroom experiences. Unfortunately, these can detract from the adopted unit storylines that prioritize students' figuring out phenomena through three-dimensional classroom experiences.

Row B. District F Teachers' Professional Community Responsibilities (in the Future)

In the future, District F participants anticipate that teachers will find work with their course-based colleagues integral to helping them realize their *classroom pedagogical responsibilities* (A). Participants expected teachers to enact the professional community's

decisions, in part due to perceived peer-based accountability. This is different from the current, *actual identity*, in which only some teachers collaborate together.

Professional Community Work is Integral in the Future (B.1). Teachers in District F described looked forward to this designated future; "it will be nice [when] we all are" using *Carbon TIME*. Another teacher said, "I'm looking forward to next year where we're all going to be doing [*Carbon TIME*] … just with the collective mind … everybody has experience[s] and different ideas … that we can incorporate, and I think that [will be] really helpful."

Participants expected that it would be "easy for people to be on board" when other teachers would also be "plan[ning] … and do[ing] all of it." Participants believed that any hesitant teachers would "come around to the idea of" the adopted *Carbon TIME* units through enacting them alongside their colleagues. In this way, participants anticipated a future in which teachers experienced their work with their peers as integral to their success behind their own classroom doors. The district science coordinator expressed that all of the biology teachers would be able to "collaborate and … kids … will have the same experience no matter what teacher."

Peer Accountability in the Future (B.3). In District F, participants anticipated that teachers would feel compelled to use the agreed-upon curriculum, in part because of a sense of accountability to peers and to the decisions made by the full course-based (biology) professional community.

As a case-in-point, participants shared a story about "a little bit of pushback" from members of the course-based professional community who felt that decision-making around a common biology curriculum had moved too fast, without "time to check out … different *NGSS*

curricul[a]." However, teachers' stories about colleagues' disgruntlement around the curricular piloting (and then selection) process did not coincide with expectations that teachers would resist using *Carbon TIME* moving forward. In fact, participants said that hesitant colleagues would "go with it." As one participant described, all biology teachers were likely to teach the *Carbon TIME* units; "I think that no matter what [their] feelings are, [they] will do what [they're] supposed to … I don't see any of us … not following along."

Row C. Roles of District F and Union F Leaders related to Teachers' Professional Communities (in the Future)

Though participants' stories suggest a possible future – a *designated identity* – inclusive of consensus-oriented decision-making and the pursuit of three-dimensional goals for students, stories from District F and Union F suggest that unresolved issues may limit that realization. These limits are discussed further in Research Question 3. Here, patterns in participants' interviews are shared about future roles of District F and Union F in relation to teachers' professional community time and expectations.

Union F Stories in the Future (C.1). Union F communicated a value for teachers' professional community work because of its connection to work teachers do in their classrooms, especially around shared instructional resources. However, the local union president expressed that he just wasn't sure how "high up on that priority list" issues like common instructional resources would be for Union F.

Stories of Union F's future were of prioritizing, "unfortunately, more as a triage." The local union president explained that, for the last "six decades" teachers saw salary increases every year – "it was just a thing that always happened" – but now, pay and salary steps were

members' biggest issues. Union F needed to be a local teachers' union that made economic factors the main concern. He hoped for a time when classroom and instructional issues could be "at the top of the list," but he was skeptical about how quickly these could become Union F's top concerns.

Mitigating Transaction Costs in the Future (C.2). District F participants perceived teachers' multiple and changing preps as an obstacle to professional community work because these limited the ability for all members of the course-based professional community to meet regularly in a single Professional Learning Team (PLT). Unfortunately, the local union president said Union F had "tried limiting the number of preps in our contract and were soundly rejected in our pleas this year." Although minimizing teachers' preps "obviously makes sense from a teaching and learning perspective," he shared that District F's concern was with how that would restrict "hiring and staffing … flexibility." In fact, the local union president shared that he heard District F wanted "to 'deepen the bench,' meaning that they actually want to have teachers have more preps, so that [teachers] can [be prepared to] pick up more classes in the future." He continued, "to be honest … we've tried … I don't know that there's anything we could offer [District F] to make a different decision."

Time. The local union president said that Union F had "tr[ied] to build PLT time into the school-day" so that teachers felt they had more duty-day time to work with their colleagues, but "it's not going to happen in the next three years" because of decisions already made around the next contract. He did see an opportunity for District F to use district-provided professional development days (totaling six teacher-report days beyond their 180 instructional days). He said, "if [District F] scaffolded parts of those other days in a certain way, throughout

the year, it could provide us time for" teachers to meet with their course-based professional communities and engage in instructionally related work. However, he did not know if District F was pursuing that option.

Compensation. The district science coordinator anticipated being able to secure district resources to support individual teachers as they shifted to new, *NGSS*-aligned common expectations. She said that she could offer hesitant teachers, "extra hours of pay [so they can] do some prep and thinking outside of school." However, she did not suggest that this compensation could be used for the full course-based (biology) professional community to complete shared work.

Mitigating Conflict Costs in the Future (C.3). District F participants described a future in which administrators will likely play an increased role in accountability around individual teachers' use of the common instructional resources that have been agreed-upon by the course-based professional community.

Administrator-based Accountability. Already – as described in Research Question 1 around District F's *actual identity* – stories highlighted administrator involvement with two teachers who were not piloting the agreed-upon *Carbon TIME* units in regular biology classes. Moving forward, the district science coordinator felt concerned that a few biology teachers might "shut their door and choose to do what they're going to do." So, she intended to work more closely with administrators. Teacher participants also envisioned building administrators being involved in accountability to common instructional resources; if there were colleagues who were unwilling to use the common units, "principal[s] would then go talk to [them]."

The district science coordinator held concerns that administrator-based accountability would "become [a kind of] compliance piece," with administrators "just com[ing] in and say[ing] [to a teacher], 'You're teaching this and that's it. And teach it'." Still, for the few teachers who might hold reservations about enacting the professional community's decisions, the district science coordinator felt she likely needed administrators to apply "pressure to [the teachers to] say, 'Look, you're getting on board with this'." She said, "ultimately, [it will likely to] come down to the administrator, making sure, 'Hey, you gonna be at this meeting tomorrow? Hey, remember, we're using this next?'."

The district science coordinator perceived Union F to be supportive of leaning into administrator-based accountability to ensure teachers use common instructional resources in the future. She believed Union F "leaders would say [to a concerned teacher], 'Here's all these supports that you have in place'" to enact resources that were selected by the course-based (biology) professional community

Professional Community Training. Finally, both the district science coordinator and the local union president saw a need for teachers to receive training and support on how to work together in their professional communities. Though some teachers had received training around professional learning communities, there had been "enough flux in staffing where there haven't been too many PLTs that have really been consistent over the course of multiple years" leading to "not all PLTs function[ing] at the same level. Some are high-functioning and … others not-so-much."

The local union president felt that one thing Union F could do was "advocate for … training on how [PLTs should be] run." And, one thing District F could do was establish a "real

implementation plan." Participants felt such a plan should be something more than what had been done in the past, which was described as, basically, "'Hey! You guys go do this'."

District F, Row 1. What will go in? (in the Future)

District F participants described a future in which common, three-dimensional instructional resources – including common curricular units and some common three-dimensional assessment items – will cross the classroom doors of all biology teachers. This is different from the current *actual identity*, in which only some regular biology teachers were piloting *Carbon TIME* units and there were no common assessments.

Common Three-Dimensional Units in the Future. Over the course of the study itself, stories from District F participants about common instructional resources were shifting from something that "ideally … all the teachers would be" doing together, to – just a year later – "I think the common curriculum is really the [characteristic] that's the most in place."

Heading into the future, the district science coordinator anticipated all biology teachers would be using common instructional units. She said, "I don't like to put a percentage on this. But [teachers should be] thinking that at least 75% of what I'm teaching is *Carbon TIME*." She anticipated teachers might "say, 'You know what, my students didn't get this, so I'm going to add a 'this' in.' Or, 'I have this other lesson that … I'm going to [use to] replace … this, but I'm going to be conscious of how that might affect the flow of the unit'."

Common Three-Dimensional Assessment Items in the Future. The district science coordinator suggested that initiating "common assessments [would be] pretty simple" for end-of-course (midterm and final) exams. She anticipated using a "common assessment bank" so it would just "be a matter of determining … which questions are we going to make sure we have

on all of our assessments?" This assessment-bank approach would allow for teachers to "say, 'Okay, we may not be in agreement [on everything], but [we can] come to consensus on something'." In this way, teachers could "not all have that same common assessment" while still agreeing "to do 'these five questions' all the same."

Common assessment items were described as needing "to be more than multiple choice," even though participants recognized the logistical challenges of scoring constructed responses in the short grading time available during midterm and final exams. The district science coordinator confirmed, "there needs to be something where students are showing their thinking in some way" in order to "really, truly understand where our students are at."

District F, Row 2. What will go out? (in the Future)

Stories about District F's future suggest that evidence of students' three-dimensional learning from common assessment items may leave the classroom door. This is different from the current *actual identity* in which only teachers' recounts or student work artifacts leave the classroom door.

Students' Three-Dimensional Common Assessment Data in the Future. Future common assessments will provide evidence of students' three-dimensional learning in a way that may leave the classroom door. The district science coordinator said that common assessments were necessary "to measure our progress" and "determine how impactful we've been with students." However, neither she nor other participants shared details about what student assessment data from common assessments might look like, or when or how it might be used by the course-based professional community.

District F, Row 4. What will teachers do together in their course-based professional communities? (in the Future)

Stories about the future suggest that teachers in District F will be developing and selecting common three-dimensional assessment items; they may engage in shared sensemaking using evidence from those assessments; and they will likely be engaged in joint revisions of the common instructional resources.

Selection and Development of Common Three-Dimensional Assessment Items in the Future. The district science coordinator imagined that developing the common assessments "would take a joint effort" across the course-based (biology) professional community, with everyone involved in decision-making even if every teacher was "not necessarily writing" the items. She imagined there would be a group of teachers "that wants to be in there [doing] the [development] work, [and there would be] the group that just wants to give feedback on it, and the group that says, 'You know, I'm okay with someone else doing it'." She felt this kind of a process would help "make[e] sure that everybody has that voice within the work … [and there's] that buy-in of everybody feeling like they've had their opportunity to be a part of it." The local union president agreed, sharing that any common assessments should have teachers as "a part of creating or selecting the assessment."

Something noticeable in this future-facing story is the district science coordinator's emphasis on consensus-seeking around development and selection of common three-dimensional assessment items. This is a change from the decision-making process that was used to select *Carbon TIME* units as the common curriculum. Then, voting was used as a process for decision-making.

Sensemaking Using Students' 3D Assessment Data in the Future. Participants anticipated that teachers would be comfortable reviewing their own students' results from common, three-dimensional assessments, as well as "tak[ing] a whole course and shar[ing] the course data."

However, they were hesitant about sharing (even de-identified) teacher-level data with the course-based (biology) professional learning community. Both the local union president and the district science coordinator described their uncertainty through language like, "I'm not sure," "maybe," and "that's a tough one." They felt it was unlikely that teachers would be comfortable viewing teacher-level data, even if the teachers would have used the consenus- and input-oriented process described just above for selecting and developing the common assessment items.

The district science coordinator explained that she would be "so cautious about putting [students' assessment results by teacher] in front of a group." She was particularly concerned that sharing this kind of data could lead to teachers "feeling inadequate" and, potentially, "could cause a divide [among members of the professional community]. It could cause some people to shut down."

Revisions to Three-Dimensional Instructional Resources in the Future. District F participants' stories about the future were uncertain about opportunities for the course-based (biology) professional community to revise shared instructional resources. A key problem they identified was, "you need time" to compare experiences and make joint revisions. A teacher said, "where … [it] falls apart, is … you need time together to talk about these things and I can talk about it within my building but not with the [other building] … that's where it gets messed

up." Teachers had more frequent meeting time with their smaller, building-based Professional Learning Teams (PLTs) than with the full course-based (biology) professional community. Further, due to multiple preps, not all the biology teachers met with biology-focused PLTs.

Summary of District F's Designated Identity

District F participants described a future in which the course-based (biology) professional community becomes a collective professional community with three-dimensional science goals for students. This is a change from its *actual identity* as a collaborative professional community with three-dimensional science classroom experiences as goals for students.

District F's participants envision becoming a different kind of course-based (biology) professional community – at least in some ways – around most of the characteristics. The probably changes in peer-based accountability due to envisioned consensus-seeking decisions, alongside anticipated changes in District F's administrator-based accountability, seem likely to be particularly instrumental in supporting District F's new *designated identity*.

Even as they imagine themselves in these new ways, however, District F and Union F decisions to prioritize issues other than reducing teacher preps and increasing teachers' course-based professional community time may jeopardize District F's actualization of their *designated identity*.

District A: An Individually Oriented Professional Community with Three-Dimensional Science Goals for Students

Patterns across interviews suggest that District A's *actual identity* as an individually oriented professional community is likely to continue, as will its pursuit of three-dimensional science goals for students.

Participants' stories envisioning the future were in most ways the same as stories describing the present. Especially pervasive were stories of teacher autonomy in their own individual classrooms, stories about teachers' selecting resources and engaging in instruction in the ways they valued. Equally prevalent were stories of autonomous teacher collaboration, meaning teachers will likely continue to choose to work with peers in ways that will continue to enable them to fulfill their own individual *classroom pedagogical responsibilities*. Because many science teachers were described as holding three-dimensional *classroom pedagogical responsibilities*, many are likely to continue engaging students in three-dimensional science classroom experiences. All biology teachers are likely to continue administering the district's common, summative, end-of-course three-dimensional exams.

As seen in Table 8, changes in *What will go in?* (row 1), were shared primarily by the district science coordinator. She talked about District A becoming more responsive to individual students and better positioned to achieve equitable outcomes for students, potentially through revising common assessments to be project- or portfolio-based.

District A, Row 1. What will go in? (in the Future)

The district science coordinator described possible changes to District A's common assessments, branching from experiences teachers had during COVID-19-related adjustments in

the district's common assessment expectations. The assessments during COVID-19-related remote instruction changed from the common, three-dimensional item clusters assessing students' *NGSS*-aligned achievement to more individualized student responses. Examples of these included portfolios and reflection prompts that were evaluated individually by teachers.

Revisions to Common Three-Dimensional Assessments in the Future. The district science coordinator anticipated that the district science leadership team would consider revising the "existing common assessments" in ways that she "hope[d], [would] … bring some of that approach in." Specifically, she imagined asking the science leadership team, "Are there any places where we would like to shift to a project-based assessment … [or] a portfolio-based assessment? Or do we want to keep the same exam, but … [add] at least one reflection item about students' opportunities to understand science, or how their thinking might have changed?"

She described how incorporating reflection questions could eventually provide teachers with student-level indicators allowing them to "look for one kid coming into 9th grade and leaving 12th grade, and [ask], 'How does [a student's] perception of science change over that period of time?'."

Summary of District A's Designated Identity

District A participants describe a future in which the course-based (biology) professional community continues to be an independently oriented professional community with three-dimensional science goals for students. Changes from the current *actual identity* may occur around *What goes in?* (Table 8, row 1) as the professional community pursues revisions in the common assessments to increase attention on students' identities and interests.

These potential changes seem aligned with District A's individualistic and egalitarian orientations toward teachers, though it is unclear what potential affect they may have on students' three-dimensional experiences and outcomes. On one hand, they may support achievement of three-dimensional goals with attention to more equitable, identity-focused student outcomes. On the other hand, these same potential assessment changes could allow teachers to move toward outcomes more aligned with their individual *classroom pedagogical responsibilities*, which may or may not include *NGSS*-aligned student achievement.

District M: An Individually Oriented Biology Professional Community Maintaining the Status Quo for Science Teaching and Learning

Patterns across interviews suggest that District M's *actual identity* as an individually oriented professional community is likely to continue in the future, as is its focus on quick-and-snappy classroom experiences with goals of one-dimensional rigor. Participants' stories envisioning the future were in most ways the same as stories describing the present, particularly around teachers' autonomy in fulfilling their individual *classroom pedagogical responsibilities* (Table 9, row A).

As shown in Table 9, District M's *designated identity* was described as potentially different from the current *actual identity* only around the roles of district and union leaders (Table 9, row C) and the local public community (Table 9, row 5), both with the (very slight) possibility for addressing District M's not-three-dimensional science orientation. Yet nothing in District M's *designated identity* suggests changes in its overall orientation toward individuality.

Row C. Roles of District M and Union M Leaders related to Teachers' Professional Communities (in the Future)

Stories about changing roles of District M and Union M related to teachers' professional communities were minimal and continued to support individual orientations. This included Union M's primary role around "contractual issues" and the endorsement of individual teachers' autonomy to not work with their peers. In such current and future situations, colleagues could simply recognize, "'Okay, this person's not involved [so] we're just going to do our thing'," letting individuals make their own decisions.

Stories below include examples of a District M perspective that teachers needed time and support to work together. These ideas were shared by the district science coordinator, potentially reflecting her recognition that three-dimensional science teaching and learning is too new and complex for most teachers to achieve individual.

Mitigating Transaction Costs in the Future. The district science coordinator described time as a limiting factor in District M's ability to pursue some district-wide goals. She specifically desired an increase in teachers' time together, describing that teachers' having "monthly meetings that were required" would support her and District M's efforts.

The district science coordinator recognized that Union M had been working with District M in planning for teachers' professional time in the upcoming school year and had already agreed to increase teachers' collaborative time. She said, "it's typically 30 hours, but we've increased that. So when our PD calendar [for next school year] comes out, there will be a few more hours [that are] specifically tied to collaboration." She viewed this Union M action as evidence of its support and value for teachers' time to collaborate with colleagues.

However, participants did not describe what District M or Union M thought teachers would be doing during this increased collaboration time; no one shared clear plans or specific tasks that would guide teachers' time together or be the outcomes of their professional community work.

Mitigating Conflict Costs in the Future. District M and Union M differed in whether they anticipated that potential future collegial work could produce conflict or disagreements. The local union president described teachers as "professionals" who could find ways to "work it out with the people [they're] working with." In the unexpected situation that teachers perceive an issue with a colleague, he said they should go to their building administrator, "because that's an administrative responsibility." He could recall no past examples in which teachers had involved an administrator for support in relationships among professional community members.

The district science coordinator did imagine that potential, future (unspecified) decision-making work by teachers could lead to disagreement or conflict. She described facilitation strategies that District M could use to decrease conflict costs by securing teachers' meaningful involvement and ensuring people felt heard. These approaches included "the change matrix;" "the social discipline window;" and "polarity mapping." She also indicated that teachers "need some professional learning on team-based leadership [or] … professional learning communities, or collaborative learning cycles. We need some support with what protocols might we be able to work through together so that we're just not in a room staring at each other."

District M, Row 5. Local Public Community (in the Future)

District M teacher participants shared stories suggesting the potential for state-level science assessment data to initiate dissatisfaction among the local public community and

therefore motivate change in science teachers' instruction. The state assessment – which had recently been re-issued as a three-dimensional science assessment – was "supposed to … look different [and] students are supposed to score differently," though results had not yet been available to districts. Participants believed that "if those test scores changed, because … [the test] was requiring different skills, then the motivation would be there [to change classroom instruction]." It would suggest that "what we used to do isn't working anymore." Low scores or low district-level ranking on the state science assessment "would be a … big push for teachers to say, 'Okay, we really do need to focus on this'."

These comments suggest that maintaining District M's place as a top-ranked district in the state may be important enough to motivate changes in classroom teaching and learning and to pursue a new *designated identity* around students' three-dimensional science achievement. However, there were no corresponding stories suggesting this potential event might also motivate changes in District M's identity as an individually oriented professional community.

Summary of District M's Designated Identity

District M participants describe a future in which the course-based (biology) professional community continues to be an individually oriented professional community maintaining the *status quo* for science teaching and learning. Changes from the current *actual identity* may occur with District M and Union M taking small steps to decrease potential transaction and conflict costs. Participants described the potential of District M receiving low scores or rankings on future state science assessments; this might motivate change among teachers and advocacy among the local public community.

Table 6. District N's Actual and Designated Identities (Research Question 2)			
What were the patterns in participants' stories about?	**District N Actual Identity** A collective professional community with three-dimensional (3D) science goals for all students.	**District N Designated Identity** **(Same as actual identity)**	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
A. Teachers' Classroom Pedagogical Responsibilities	**3D classroom experiences and outcomes; shared across all teachers** District biology teachers were described as holding *classroom pedagogical responsibilities* to students' 3D science classroom experiences and outcomes.	**(same as actual identity)**	**Three-dimensional classroom experiences and outcomes; shared across all teachers** District biology teachers hold classroom pedagogical responsibilities to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities*	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy to experiment instructionally in their classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.	**Professional community work is integral to classroom work.** Stories of the future suggest… 5. The professional community will **mitigate conflict costs** around consensus-seeking decisions using designed protocols.	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.

Table 6 (cont'd)

C: Roles of District and Union Leaders Related to Teachers' Professional Communities*	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Transaction costs addressed through time and compensation (contractual; substitutes; extra pay) 3. Conflict costs addressed through district systems of accountability and support for the professional community. 4. Connections to external science education communities through the district science coordinator and teachers.	**Collective Support with Collective Accountability** Stories of the future suggest… **3.** District and union could use new initiatives and more clearly define roles to further **decrease conflict costs**.	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Mitigate transaction costs through time and compensation. 3. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 4. Connect to external science education communities.
1. What goes in?	**Common 3D Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments and end-of-course exams – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning	**(same as actual identity)**	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning
2. What goes out?	**Evidence of students' 3D Learning** • Teachers' recounts focused on students' 3D experiences and outcomes students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes • students' 3D outcomes (common assessment data), including at the T-level	**(same as actual identity)**	**Evidence of Ss 3D Learning** • Ts recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes • students' 3D outcomes (common assessment data; student work), including at the teacher-level

Table 6 (cont'd)

3. Who crosses the classroom door?	**3D & Connected to the Professional Community** • Building administrators complete observations for formal teacher evaluations and are aware of common 3D instructional resources. • Peers from course-based professional community use observations to support 3D instructional growth.	**(same as actual identity)**	**People are connected to the professional community and the focus is on 3D science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

4. What do teachers do together in their course-based (biology) professional communities?*	**Linked "in" and "out"; 3D & Consensus-Seeking**
	• selection/development of 3D instructional resources
	• sensemaking around 3D instruction, using evidence
	  ○ analysis of student learning artifacts (common assessment data)
	• revisions of instructional resources based on evidence
		Linked "in" and "out"; 3D & Consensus-Seeking
		Stories of the future suggest…
		• revising instructional resources due to deeper understanding of *NGSS*
		• sensemaking around 3D instruction – w/ focus on instructional inferences, using evidence
			Actions links "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional and consensus-seeking.
			• selection/development of 3D instructional resources
			• sensemaking around 3D instruction, using evidence
			  ○ dialogic (rehearsals and recounts)
			  ○ analysis of student learning artifacts (assessment data and student work)
			• revisions of instructional resources based on these two forms of evidence

5. Local Public community	**Common Instructional Resources for Equitable Outcomes** • Local public community supported shift to common instructional resources.	**(same as actual identity)**	• Teachers talk about 3D science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

* Discussion in text focuses on anticipated changes from *actual* to *designated identity* (darker green rows).

Table 7. District F's Actual and Designated Identities (Research Question 2)			
*What were the patterns in participants' stories about?**	**District F Actual Identity** A collaborative professional community with three-dimensional (3D) science classroom experiences as goals for students.	**District F Designated Identity** A collective professional community with three-dimensional (3D) science goals for students.	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
A. Teachers' Classroom Pedagogical Responsibilities*	**3D classroom experiences (many teachers)** Many district biology teachers were described as holding *classroom pedagogical responsibilities* to students' 3D science classroom experiences.	**3D classroom experiences and outcomes; shared across all Ts** Stories of the future suggest all biology teachers will hold *classroom pedagogical responsibilities* to students' 3D science classroom experiences and outcomes, though possibly with differences across biology tracks.	**Three-dimensional classroom experiences and outcomes; shared across all teachers** District biology teachers hold *classroom pedagogical responsibilities* to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities*	**Collaboration supports classroom work (for some teachers).** 1. Teacher collaboration with colleagues helps some teachers realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy within shared common curriculum. 3. Peer-accountability exists through shared decision-making and peer-to-peer conversations. 4. Teachers share independent experiences with the professional community	**Professional community work is integral to classroom work.** Stories of the future suggest … 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 3. Peer-accountability exists through consensus-seeking decision-making.	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.

Table 7 (cont'd)

C: Roles of District and Union Leaders Related to Teachers' Professional Communities*	**Collective Support with some Individual Accountability** 1. District and union stories endorse collaboration; union stories limit peer accountability. 2. Transaction costs somewhat addressed through contractual collegial (PLT) time. 3. Building administrators play a role in accountability to professional community decisions. 4. Connections to external science education communities exist through the district science coordinator and the union in CTIME professional learning network.	**Collective Support with Individual Accountability** Stories of the future suggest… 1. Union F stories prioritize members' economic concerns. 2. Transaction costs remain: teacher preps will not be reduced; professional community time will not be increased. 3. Mitigate conflict costs through administrator-based accountability and professional training.	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Mitigate transaction costs through time and compensation. 3. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 4. Connect to external science education communities.
1. What goes in?*	**Some common 3D units** • Initial: Some regular biology teachers piloted 3D instructional resources, selected by the professional community.	**Common 3D units & some common 3D assessment items** Stories of the future suggest: • Initial: All teachers will use common 3D units. • Initial: All teachers will use selected common 3D assessment items on end-of-course exams.	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning
2. What goes out?*	**Limited evidence of Ss Learning** • Some teachers' recounts focused on students' experiences. • students' 2D/3D outcomes shared through student work artifacts	**Possible new evidence of Ss 3D learning** Stories of the future suggest: • students' 3D outcomes (limited common assessment data) may be available for the professional community	**Evidence of Students' 3D Learning** • teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes • students' 3D outcomes (common assessment data; student work), including at the teacher-level

Table 7 (cont'd)

3. Who crosses the classroom door?	**3D & Disconnected from the Professional Community** • Building administrators complete observations for formal teacher evaluations and are aware of common 3D instructional resources.	**(same as actual identity)**	**People are connected to the professional community and the focus is on 3D science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

4. What do teachers do together in their course-based (biology) professional communities?*	**Limited linking of "in" and "out"; 3D & Collaborative**
	• selection of 3D instructional resources
	• sensemaking around 3D instruction, using (limited) evidence
	  ○ dialogic (rehearsals & recounts)
	  ○ analysis of student learning artifacts (student work)
		Potential for increased linking of "in" and "out"; 3D & Consensus-seeking
		Stories of the future suggest:
		• selection/development of 3D assessment items
		• sensemaking around 3D instruction, using evidence
		  ○ analysis of students' 3D assessments
		• revisions of common, 3D instructional resources [*likely in building-based PLTs*]
			Actions link "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional and consensus-seeking.
			• selection/development of 3D instructional resources
			• sensemaking around 3D instruction, using evidence
			  ○ dialogic (rehearsals and recounts)
			  ○ analysis of student learning artifacts (assessment data and student work)
			• revisions of instructional resources based on these two forms of evidence

5. Local Public community			• Teachers talk about 3D science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

* Discussion in text focuses on anticipated changes from *actual* to *designated identity* (darker yellow rows).

Table 8: District A's Actual and Designated Identities (Research Question 2)			
A.	**B.**	**C.**	**D.**
What were the patterns in participants' stories about?	**District A Actual Identity** An individually oriented professional community with three-dimensional science goals for students.	**District A Designated Identity (same as actual identity)**	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
A. Teachers' Classroom Pedagogical Responsibilities	**Teacher-valued classroom experiences and outcomes (many 3D)** District biology teachers were described as holding individual classroom pedagogical responsibilities to students' science classroom experiences and outcomes valued by the individual teacher.	**(same as actual identity)**	**Three-dimensional classroom experiences and outcomes; shared across all teachers** District biology teachers hold classroom pedagogical responsibilities to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities	**Individual Autonomy** 1. Teachers' selective collaboration helps individual teachers realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy in their classroom decisions. 3. Professional norms for non-interference and egalitarian beliefs maintain positive professional relationships. 4. Teachers may have independent experiences with external science education communities.	**(same as actual identity)**	**Professional community work is integral to classroom work.** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.

Table 8 (cont'd)

C: Roles of District and Union Leaders Related to Teachers' Professional Communities	**Enable individual teachers** 1. District and union stories endorse collaboration and autonomy. 2. Transaction costs not addressed, despite contractually required after-school meeting time. 3. Conflict costs minimized through accountability to generalized "good teaching." 4. Connections to external science education communities through the district science coordinator and teachers.	**(same as actual identity)**	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Mitigate transaction costs through time and compensation. 3. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 4. Connect to external science education communities.
1. What goes in?*	**Individually determined curriculum; common 3D course-level assessments** • Initial: 3D curricular units made available; 3D course-level assessments developed by science leadership team • Ongoing: Revised 3D course-level assessments	**Individually determined curriculum; common 3D course-level assessments** Stories of the future suggest: • Ongoing: potential revisions to 3D course-level assessments to focus on individual students' performances or portfolios	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning
2. What goes out?	**Evidence of students' 3D learning** • students' 3D outcomes (common assessment data at building/district level and item level; student work)	**(same as actual identity)**	**Evidence of Students' 3D Learning** • teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting Ss 3D outcomes • students' 3D outcomes (common assessment data; student work), including at the teacher-level

Table 8 (cont'd)

3. Who crosses the classroom door?	**Disconnected from the Professional Community** • Building administrators enter during formal teacher evaluations. • Non-critical peers from outside the course-based professional community enter during Instructional Rounds (one high school).	**(same as actual identity)**	**People are connected to the professional community and the focus is on 3D science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

4. What do teachers do together in their course-based (biology) professional communities?	**Limited linking of "in" and "out"; 3D**
	• selection/ development of 3D instructional resources [*science leadership team only*]
	• sensemaking around 3D instruction, using evidence
	  ○ analysis of student learning artifacts (common assessment data; student work)
		(same as actual identity)	**Actions link "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional and consensus-seeking.**
			• selection/development of 3D instructional resources
			• sensemaking around 3D instruction, using evidence
			  ○ dialogic (rehearsals and recounts)
			  ○ analysis of student learning artifacts (assessment data and student work)
			• revisions of instructional resources based on these two forms of evidence

5. Local Public community			• Teachers talk about 3D science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

* Discussion in text focuses on anticipated changes from *actual* to *designated identity* (darker orange row).

Table 9: District M's Actual and Designated Identities (Research Question 2)			
A.	**B.**	**C.**	**D.**
What were the patterns in participants' stories about?	**District M Actual Identity** An individually oriented professional community maintaining the *status quo* for science teaching and learning.	**District M Designated Identity (same as actual identity)**	**Goal New Normal** A collective professional community with three-dimensional (3D) science goals for all students.
A. Teachers' Classroom Pedagogical Responsibilities	**Quick-and-snappy & 1D** District biology teachers were described as holding *classroom pedagogical responsibilities* to students' quick-and-snappy experiences and 1D outcomes. One teacher was described as the exception, holding 3D goals for students.	**(same as actual identity)**	**3D classroom experiences and outcomes; shared across all Ts** District biology teachers hold classroom pedagogical responsibilities to students' 3D science classroom experiences and outcomes (aligned with external science education community standards).
B: Teachers' Professional Community Responsibilities	**Individual Autonomy** 1. There are no connections between teachers' professional community work and their individual *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy in their classroom decisions. 3. Professional norms for niceness and non-interference maintain positive professional relationships. 4. Teachers may have independent experiences with external science education communities.	**(same as actual identity)**	**Professional community work is integral to classroom work** 1. Teachers' professional community work is required to realize *classroom pedagogical responsibilities* (A). 2. Teachers have autonomy to experiment instructionally in their own classrooms; success is defined through students' performances on common 3D assessments. 3. Peer accountability exists through consensus-seeking professional community decision-making. 4. Teachers share independent improvements (w/in classrooms or w/ external science education communities) with the professional community, with expectations for innovation.

Table 9 (cont'd)

C: Roles of District and Union Leaders Related to Teachers' Professional Communities*	**Enable individual teachers** 1. District and union stories endorse individual teachers as autonomous experts. 2. Transaction costs not incurred. 3. Conflict costs minimized through accountability to generalized "good teaching." 4. Connections to external science education communities are limited.	**Enable individual teachers** 2. Transaction costs minimized by providing more time for teacher collaboration. 3. Conflict costs minimized through facilitation strategies.	**Collective Support with Collective Accountability** 1. District and union stories endorse professional community work as integral to 3D classroom instruction. 2. Mitigate transaction costs through time and compensation. 3. Mitigate conflict costs through clear systems of accountability and support for individuals through the professional community. 4. Connect to external science education communities.
1. What goes in?	**Individually determined; mostly pick-and-pull, 1D resources** • Teachers used individual 'pick-and-pull' approaches to available 3D instructional resources, selecting classroom activities that prioritized quick-and-snappy engagement and 1D rigor. • One teacher was described as the exception.	**(same as actual identity)**	**Common Three-Dimensional Instructional Resources** • Initial: 3D instructional resources – including common curricular units and 3D unit-level assessments – selected and developed by the professional community • Ongoing: Revised 3D instructional resources, with revisions based on evidence of student learning
2. What goes out?	**Recounts; some with evidence of students' 1D learning** • Teachers' recounts may include evidence of 1D Ss learning. • Teachers share content-coverage information.	**(same as actual identity)**	**Evidence of Students' 3D Learning** • Teachers' recounts focused on students' 3D experiences and outcomes • students' grades, based on shared professional community guidelines and reflecting Ss 3D outcomes • students' 3D outcomes (common assessment data; student work), including at the teacher-level

Table 9 (cont'd)

3. Who crosses the classroom door?	**Disconnected from the Professional Community** • Building administrators enter during formal teacher evaluations. • Non-critical peers from outside the course-based professional community enter during Instructional Rounds.	**(same as actual identity)**	**People are connected to the professional community and the focus is on 3D science.** • Peers from course-based professional community use observations to support 3D instructional growth. • Peer Assistance and Review (PAR) programs link 3D classroom instruction with formal teacher evaluation.

4. What do teachers do together in their course-based (biology) professional communities?	**Minimal Actions**
	• Participants shared one story of consensus decisions, around students' credit-recovery materials
		(same as actual identity)	**Actions link "what goes in" (row 1) with "what goes out" (row 2) and are three-dimensional and consensus-seeking.**
			• selection/development of 3D instructional resources
			• sensemaking around 3D instruction, using evidence
			  ○ dialogic (rehearsals and recounts)
			  ○ analysis of student learning artifacts (assessment data and student work)
			• revisions of instructional resources based on these two forms of evidence

5. Local Public community*	**Affirm *status quo*** • Local public community supports *status quo.*	**Potential Impetus for Change** • Potential low state science scores (in the future) could motivate the public community to desire change.	• Teachers talk about 3D science with community members and consider local public community's goals for consistent and equitable curriculum for all students.

* Discussion in text focuses on anticipated changes from *actual* to *designated identity* (darker blue row).

Chapter 6 – Results for Research Question 3: Benefits and Costs of Changing Identities

Results for Research Question 3 present patterns in participants' interviews addressing the question, *How do participants describe the benefits and costs associated with moving from their actual identities to their designated identities, and what limits districts' designated identities from reaching the goal new normal?*

In the text that follows, I first re-introduce aspects of *narrative identities* and *costs* from Chapter 1 as tools for making sense of participants' interview responses, and I provide a rationale for focusing on student assessments in this analysis of benefits and costs.

Then, results are organized by district in coordination with Table 10, Comparisons across each Districts' Actual Identity, Designated Identity, and the Goal New Normal around Classroom Science Assessments. For each district, I first share results around the benefits and costs associated with the transition from their *actual identity* (Table 10, column A) to their *designated identity* (Table 10, column C), with particular attention to assessments (Table 1, row 1, *What goes in?*) and (when relevant) evidence of students' three-dimensional learning from common assessments (Table 1, row 2, *What goes out?*). In this analysis, solving identified problems with the *actual identity* are benefits of changing to the *designated identity*. Finally, I compare the district's *designated identity* to the *new normal* (Table 10, column E).

Narrative Identities and Costs from Chapter 1

Identifying stories are powerful in how they state to individuals and others "who we are" as a district community and "how we can" interact or behave (our *actual identities*), as well as "what we want, should, can, or cannot" be or do in the future (our *designated identities*) (Sfard and Prusak, 2005, p. 18).

Identifying stories are reifying; they provide predictability for the future by establishing, or making concrete, qualities in the present. Combined with Bateson's (2006) description of continuous stories, some stories told about the past can be interpreted – not as anecdotes of a thing that has happened – but as templates that anticipate future actions. In this way, participants' interviews about how things have been shed light on their likely actions in the future.

As described in Chapter 1, when teachers collaborate with peers, costs are incurred. *Transaction costs* reflect the time and effort required of individuals due to communication with other teachers and administrators (Little, 1990). *Conflict costs* reflect the energy required to anticipate, encounter, and resolve potential threats to relationships that are inherent in disagreements or disputes in pursuit of consensus (Horn & Kane, 2019; Little, 1990; Tannen, 2001).

Why Focus on Costs and Benefits of Three-Dimensional Assessments

In the *new normal*, assessments of students' three-dimensional science performances are used at the classroom level for both formative and summative purposes. In the context of this study, I focus on common *summative* assessments – assigned by teachers at the end of instructional units and/or at the end of the semester or term (end-of-course exams). Three-dimensional assessments are a challenging aspect of the *new normal* because they are different from traditional one-dimensional assessments and developing and using them is recognized as difficult and time-consuming work.

Table 10: Comparisons across each Districts' Actual Identity, Designated Identity, and the Goal New Normal around Classroom Science Assessments (Research Question 3)

Columns A, C & E have information copied from Tables 6-9. Dark grey Designated Identity cells show no change from Actual Identity.

A	B	C	D	E
District Actual Identity *What assessments go in?*	**Transition to Designated Identity** What are the described benefits and costs of moving from the *actual identity* (A) to the *designated identity* (C)?	**District Designated Identity** *What assessments will go in?*	**Comparison with the New Normal** What limits the district from reaching the *new normal*?	**Goal New Normal** *selected aspects*
District N Actual Identity: A collective professional community with 3D science goals for all students. **District N Assessments & Evidence of Student Learning** • In: common 3D unit-level tests and course-level exams, with iterative revisions from evidence of student learning • Out: evidence of students' learning in common assessment data and students' grades	• **Perceived Problems w/ Actual Identity (A):** o stronger personalities limit consensus-seeking • **Perceived Benefits of Designated Identity (C):** o improved consensus-seeking • **Costs Likely Addressed in Transition:** o conflict costs through clearer protocols	**District N Designated Identity:** A collective professional community with 3D science goals for all students. **District N Assessments & Evidence of Student Learning** • In: common 3D unit-level tests and course-level exams, with iterative revisions from evidence of student learning • Out: evidence of students' learning in common assessment data and students' grades	**District N Identity = *New Normal*** There are no described limits.	**Collective** • district biology teachers hold *classroom pedagogical responsibilities* to students' 3D science classroom experiences and outcomes (aligned with external science education community standards). • Teachers' professional community work is required to realize *classroom pedagogical responsibilities*. **Common 3D Instructional Resources - Assessments** • Initial: 3D unit-level assessments – selected and developed by the professional community • Ongoing: revised 3D assessments, with revisions based on

Table 10 (cont'd)				
District F Actual Identity: A collaborative professional community with 3D science classroom experiences as goals for students. **District F Assessments:** • no common assessments • individual regular biology teachers using some 3D *Carbon TIME* assessments	• **Perceived Problems w/ Actual Identity (A)** ○ collaborative dimension ○ three-dimensional dimension • **Perceived Benefits of Designated Identity (C)** ○ teachers fulfilling *classroom pedagogical responsibilities* • **Costs Likely Addressed in Transition:** ○ transaction costs through PLT time ○ conflict costs through agreement on only some 3D assessment items.	**District F Designated Identity:** A collective professional community with 3D science goals for students. **District F Future Assessments:** • All teachers will use selected common 3D items on course-level assessments.	**District F unaddressed costs:** • Unaddressed transaction costs: ○ time as a course-based (biology) professional community ○ multiple teacher preps make PLT membership different from course-based (biology) professional community ○ no additional compensation for writing and revising 3D assessment items	evidence of student learning **Evidence of Students' 3D Learning – from Assessments** • students' grades, based on shared professional community guidelines and reflecting students' 3D outcomes • students' 3D outcomes (common assessment data), including at the teacher-level
District A: An individually oriented professional community with three-dimensional science goals for students. **District A Assessments & Evidence of Student Learning** • In: common 3D course-level exams with iterative revisions • Out: evidence of students' learning in common assessment data	• **Perceived Problems w/ Actual Identity (A)** ○ individual autonomy & norms for non-interference ○ assessment data • **Perceived Benefits of Designated Identity (C)** ○ students' identity and interest • **Costs Likely Addressed in Transition:** ○ transaction costs for science leadership team (summer pay)	**District A:** An individually oriented professional community with three-dimensional science goals for students. **District A Future Assessments** • potential revisions to 3D course-level assessments to focus on individual students' performances or portfolios	**Collective dimension remains unaddressed.**	

Table 10 (cont'd)				
District M Actual Identity: An individually oriented professional community maintaining the status quo for science teaching and learning. **District M Assessments:** • no common assessments • M_T1 using 3D *Carbon TIME* assessments	There were no relevant benefits or costs.	**District M Designated Identity:** An individually oriented professional community maintaining the status quo for science teaching and learning. **District M Future Assessments:** • no common assessments • M_T1 using 3D *Carbon TIME* assessments	**Collective dimension and three-dimensional dimension remain unaddressed.**	

District N Comparison of Identities

District N is described as a collective professional community with three-dimensional science goals for all students. In this "actual state of affairs," common, three-dimensional science classroom unit-level tests and end-of-course (midterm and final) exams – modeled on the state's science assessment – cross the classroom door of every biology teacher. Additionally, evidence of students' three-dimensional learning from these common assessments leaves the classroom and is used by the course-based professional community. Participants imagine a future *designated identity* in which consensus-seeking decision-making is improved using designed protocols.

Described Benefits and Costs of Transitioning to District N's Designated Identity

Perceived Problems with District N's Actual Identity around Assessments. District N participants shared concerns that "stronger personalities" within course-based professional communities could shape collective decision-making. In some cases, participants described these "stronger" individuals simply as having the "loudest voice[s]." In other cases, these dominant teachers may have contributed to colleagues feeling unable or unwilling to pursue a potential disagreement. As the local union president said, some teachers would decide to "just not rock the boat" when it came to advocating for specific assessment-related changes.

Perceived Benefits of District N's Designated Identity around Assessments. District N participants perceived that ensuring every teacher in the professional community had opportunities to contribute would support the best possible decisions; in this case, that meant the development of the best possible assessments. Further, three-dimensional assessment

writing and revising required significant time and effort, so having contributions from everyone in the professional community would support continued accomplishment of that work.

Costs Likely Addressed in Moving from District N's Actual to Designated Identity.

Conflict Costs. The district science coordinator saw "build[ing] protocols around decision-making" as a potential strategy to reduce conflict costs because these provide a structured way to ensure all voices are heard. Strategies like this could support future consensus-oriented revisions in instructional resources like common assessments. Another potential avenue for reducing conflict costs may be through new district initiatives that provide the professional community opportunities to reevaluate completed work, such as in-use common assessments.

Comparison of District N's Designated Identity and the New Normal

District N's *designated identity* aligns with the goal *new normal*. District N's collectively oriented professional community is currently pursuing three-dimensional science goals for all students in ways that align with external science education communities' goals (for example, the state's three-dimensional science assessment). District N has expectations, strategies, and systems in place that are likely to support continued improvements and advancements into the future.

District F Comparison of Identities

District F is described as a collaborative professional community with three-dimensional science classroom experiences as goals for students. In this "actual state of affairs," no common science classroom assessments crossed the classroom door, and therefore no assessment-based evidence of student learning left the classroom door. Participants imagine a future

designated identity as a collective professional community, in which some common, three-dimensional science assessment items will be used on every teacher's end-of-course exam (midterm and final), alongside assessment items that each teacher continues to design or select themselves.

Described Benefits and Costs of Transitioning to District F's Designated Identity

Perceived Problems with District F's Actual Identity around Assessments. District F participants described drawbacks to their "actual state of affairs" around classroom assessments, both in terms of the collaborative dimension of their *actual identity* and in terms of the three-dimensional dimension.

Collaborative Dimension Problem. Participants described many teachers holding *classroom pedagogical responsibilities* for all students to have the same classroom experiences across a course. For these teachers, collective (not collaborative) work was necessary for realizing their *classroom pedagogical responsibilities* (Table 1, row A). For them, a collaborative approach in which some teachers simply chose to work together would not result in students receiving the same classroom experiences, because any teacher who chose to "do their own thing" prevented the professional community from ensuring students had similar experiences.

Every one of District F's interview participants described this problem. One of the local union presidents clearly linked this to a lack of common assessments, saying, "There's really nothing … to [help] people mov[e] in the same direction as [having] the same end in mind." Without common assessments, there was no impetus for teachers to be similar enough to provide students with common experiences, "unless those teachers … got along and felt like working together."

Three-dimensional Dimension Problem. A second major problem with District F's *actual identity* was a three-dimensional, science-specific one. Participants described how challenging they perceived the development of three-dimensional science assessment items to be. The district science coordinator said, "many of [the District F] teachers … have been trained in item-cluster [assessment writing] … they know how difficult that is." In fact, teachers found this development work "a little intimidating." Despite this training, teachers were hesitant and uncomfortable to undertake assessment development alone.

Finally, the district science coordinator felt that – without a common assessment – the district and the professional community could not "measure our progress" or determine how "impactful we've been with students."

Perceived Benefits of District F's Designated Identity around Assessments. District F participants described benefits of a different future – a *designated identity* in which all teachers would use selected, common three-dimensional items on their course-level assessments. These benefits were primarily around fulfilling teachers' *classroom pedagogical responsibilities* (Table 1, row A) to three-dimensional science engagement and outcomes.

Fulfilling Classroom Pedagogical Responsibilities. District F's *designated identity* is a professional community in which all teachers hold *classroom pedagogical responsibilities* to students' three-dimensional science classroom experiences and outcomes. District F teacher participants described feeling truly compelled to provide students across a course with similar experiences, regardless of the teacher, because of how they perceived it benefitting students' success. Having a set of common three-dimensional assessment items would support teachers

in fulfilling this *classroom pedagogical responsibility* by clearly defining a common "end" for everyone to have in mind.

Further, the district science coordinator anticipated how these common assessments would support teachers in fulfilling the "three-dimensional" aspect of their *classroom pedagogical responsibilities*. In her experiences with district math teachers, she found their use of common math assessments had motivated them to adjust classroom instruction. She described how math teachers said, "'Wait a minute, I've got to have these tasks in my classroom in order for [students] to do well on the [common] assessment.'" The district science coordinator foresaw biology teachers using the course-level assessment items as models that would support their individual classroom instruction and tasks to be more three-dimensional.

Costs Likely Addressed in Moving from District F's Actual to Designated Identity. Participants' stories suggested that District F and Union F had mitigated (or had plans to mitigate) some transaction and conflict costs of the professional community's collective work in ways that would support a *designated identity* in which all biology teachers are using some common three-dimensional science classroom assessment items.

Transaction Costs. As described in the results in Chapter 5 around Research Question 2, the district science coordinator's proposed process for selecting common three-dimensional assessment items will require contributions from every course-based (biology) professional community member. However, only some teachers – who choose to – will do the actual development and writing work, with others providing feedback to inform initial revisions. This approach will likely minimize transaction costs by decreasing the collaborative time and effort spent on assessment item development; only some teachers will engage in initial assessment

writing and related communication. Additionally, the course-based (biology) professional community will need to agree to just some common assessment items for their end-of-course exams, not all the items on all the assessments.

District F's existing contractually obligated professional community time (the building-based Professional Learning Teams, PLTs) provides for 45 hours of outside-of-the-school-day time that could be available for (at least some of the) course-based teachers to collaborate around three-dimensional assessment items. This could include drafting, reviewing, and revising assessment items.

Finally, the district science coordinator described that initiating the math common assessments was a "decision actually [that] just came from me." She anticipated the same would be the case for science assessments. This suggests that there will be minimal transaction costs for her, related to conveying this decision to other district administrators.

Conflict Costs. The district science coordinator's proposed process for assessment writing will also likely minimize conflict costs because it avoids a fully common assessment. Teachers will still have "the freedom to put the other items [they] want" on their own assessments for their students in their classrooms. This strategy also addresses a concern the local union president raised, which he described as "the conundrum of 'Who picks?';" consensus will not be necessary on every item, just some items.

Finally, the district science coordinator anticipated a future in which she was increasingly connected to building administrators for their support in encouraging and ensuring teachers' fulfillment of professional-community-based decisions, including teaching agreed-upon curriculum and – in this case – use of common assessment items. This was important to

the district science coordinator because she felt that she could "definitely lose people's trust" if she took on the role of enforcing common expectations. She said, "I can feel very administrative when [actually] I'm a teacher along with them." Knowing that building-based administrators will help with accountability may reduce conflict costs among the district science coordinator and teachers and between teachers because the responsibility of peers' follow-through is not solely on the professional community.

Comparison of District F's Designated Identity and the New Normal

District F's *designated identity* presents a future in which all course-based (biology) teachers are using selected, common three-dimensional assessment items. This action – having common assessment items cross the classroom door – aligns with aspects of the *new normal*, as do many aspects of District F's described *classroom pedagogical responsibilities* (Table 7, row A) and *professional community responsibilities* (Table 7, row B). Further, District F and Union F play roles endorsing professional community work and mitigating some costs. Still, unaddressed transaction costs will be a significant barrier to District F's reaching the *new normal*.

Unaddressed Costs. For common instructional resources to fully support realization of the *new normal*, District F's course-based (biology) professional community will need opportunities to regularly revise assessments using evidence of student learning. This collective work will incur transaction and conflict costs that are likely not yet resolved.

Unaddressed Transaction Costs. Stories about the future suggest that District F and Union F will not be providing more time for the course-based (biology) professional community to engage in joint work.

Though teachers have contractual time together most weeks, these meetings are not in their full, course-based (biology) professional community. Instead, teachers meet in smaller (building-based) Professional Learning Teams (PLTs) for just one of the multiple courses they teach. Therefore, some biology teachers do not meet in biology PLTs at all. Resolving this issue could happen through reducing teacher preps or increasing time for teachers to meet with colleagues, but neither of these was described as likely in the near future.

These unaddressed transaction costs were highlighted in one teacher's concern as she reflected on District F's previous ventures into common assessments (10-20 years ago): "If you're going to write an assessment, then you need to get together at some point and say, 'This is how we need to modify it as a group.' And that part never happens … there was never [time for that]. And so, it just falls apart."

Developing new, three-dimensional common course assessments is the kind of work that is compensated through additional pay in District N and District A. Stories from District F did not suggest this as an avenue for reducing teachers' transaction costs around developing new assessments.

Unaddressed Conflict Costs. In general, conflict costs seemed less salient than transaction costs for District F, where teachers' *professional community responsibilities* support peer-accountability and even direct confrontation among some colleagues. Further, administrator involvement is an avenue for supporting teachers in following through on professional community decisions.

Still, District F participants did not imagine the use of systems-based mechanisms for accountability to support all teachers in using common assessments. For example, the district

science coordinator said that the district's data management system is currently "just kind of a database … there's a lot of data that goes in," but it was unclear who "look[s] at the data in there," and for what purposes.

District A Comparison of Identities

District A is described as an individually oriented professional community with three-dimensional science goals for students. In this "actual state of affairs," common, three-dimensional science classroom end-of-course (midterm and final) exams – modeled off the state science assessment – crossed the classroom door of every biology teacher. Evidence of students' three-dimensional learning from the common assessments does leave the classroom but is not used communally by the course-based professional community. Instead, as described previously, teachers may use common assessment data to inform their own classroom teaching. The district science coordinator imagined a future *designated identity* in which assessment items may change to better reflect students' interests and identities.

Described Benefits and Costs of Transitioning to District A's Designated Identity

Perceived Problems with District A's Actual Identity around Assessments. Some District A participants described dissatisfaction with the "actual state of affairs" around common, three-dimensional assessments. Primarily, this seems related to how teachers' *professional community responsibilities* (Table 8, row B) – including individual autonomy for classroom decisions and professional norms of non-interference – become obstacles to individual teachers' fulfillment of their *classroom pedagogical responsibilities* (Table 8, row A) connected to students' three-dimensional outcomes on common assessments.

Individual Autonomy and Norms for Non-Interference. For example, one teacher participant described what she perceived as a broadly recognized expectation that teachers would not use the common-exam phenomena as instructional phenomena in their classrooms. She perceived this to be agreed-upon because the common exams should be assessing all students' performances in the context of novel phenomena. She (and the district science coordinator) described how students' learning should be evaluated in terms of transfer to novel contexts.

This teacher said there were colleagues "using our protected examples in their classrooms because … that's what they've always taught, and there's no consequences." For teachers to stop using those phenomena would require them to be "willing to [say], 'Okay, I['ve] got to create something new'," and the participant said, "there's no one who's going to hold them accountable for that."

This participant did not suggest that she – or other colleagues – could or should confront peers who were using the assessment phenomena as instructional phenomena (a potential intervention likely aligned with District F's identities); nor that teachers could or should lean on the district science coordinator (a potential intervention likely aligned with District N's identity); nor that building administrators could provide support (another potential action likely aligned with District F's identities).

Instead, the District A teacher expressed dissatisfaction, "It starts to fall apart, right? … If everybody doesn't buy into it, then it is a serious problem." In this case, her *classroom pedagogical responsibility* to students' three-dimensional experiences and outcomes was perceived as jeopardized when colleagues exercised their individual autonomy to use

instructional phenomena that they preferred or perceived to work best for their students. These colleagues' choices infringed on "test security" because this participant could not ensure that her students were achieving her three-dimensional classroom goals when other classrooms were openly engaging with the protected phenomena.

This participant's dissatisfaction was clear as she said, "Why am I killing myself trying to write new phenomena for the test?" and "spend[ing] weeks of my life" developing the common assessments. Her own time and effort as one of the district's assessment writers was perceived as unappreciated and even as being undermined.

Perceived Benefits of District A's Designated Identity around Assessments. The district science coordinator provided descriptions of an assessment-related future in which District A science courses might provide common exams focused on students' science experiences and identities.

Indicators of Students' Science Identities. The district science coordinator was interested in having teachers on the science leadership team make changes to common assessments that would emphasize students' interests and identities. These changes stemmed from recommendations the district science coordinator made to teachers when they adjusted their end-of-course assessments during COVID-19 remote instruction. At that time, she encouraged teachers to try portfolio- or project-based assessments and provided teachers with student-facing reflection questions, including "What did [students] learn about themselves as a result of learning in science? What did [students] think about their opportunities to learn science? How [did students] understand science before and at the end of the year?"

Costs Likely Addressed in Moving from District A's Actual to Designated Identity.

Though any transaction costs around revising District A's common assessment will likely be addressed in moving to the *designated identity*, it's noteworthy how District A's *designated identity* does not directly correspond to problems participants perceived in the *actual identity;* participants described problems with District A's individual orientation in a context with parallel common expectations.

Transaction Costs. District A participants indicated that teachers who were part of the science leadership team were compensated for summer work, both during initial development of the biology common assessments and during continued annual revisions. The district science coordinator said this would continue to be the case for upcoming summer work. In this way, transaction costs around updating the common assessments are addressed.

Comparison of District A's Designated Identity and the New Normal

The gap between District A's *designated identity* and the *new normal* seems to be one of orientation around one important dimension – individual over collective professional communities. Interviews with District A participants did not suggest their explicit awareness of this tension.

Unaddressed Collective Dimension. For District A, an individually oriented professional community, teachers' *professional community responsibilities* (Table 8, row B) provide autonomy for individual classroom decisions, support egalitarian perspectives, and maintain professional norms for non-interference. In this way, teachers can pursue *classroom pedagogical responsibilities* (Table 8, row A) for students' experiences and outcomes that they, as individual teachers, perceive as valuable.

As described in the interview quotes above, this becomes a problem when some teachers are pursuing *classroom pedagogical responsibilities* (Table 8, row A) that prioritize students' three-dimensional outcomes on novel tasks whose novelty has not been maintained by other course teachers.

Evidence of District A's individual orientation abounds, including in participants' discussions of benefits to common assessments (District A's *actual identity*). One of the teachers on the science leadership team, involved in writing the common assessments, described how that work has helped her envision and enact *NGSS* in her classroom, helping her "ask better questions just in my everyday talking to students [and] I can write better questions on their [unit] tests." The district science coordinator focused on individual teacher benefits, as well, when she described why spending time with teachers reviewing students' performances on common assessments was valuable. She said she was striving to "support [teachers in], 'How do I use data to empower myself?'."

In her second interview, the district science coordinator wondered out-loud, "How do I find ways to make the value of the collaboration apparent?" Moving forward, she wanted teachers to see collaboration as an experience that "didn't slow [them] down," but instead "gave [them] a piece of learning" or made "[them] feel good about contributing to a team." She hoped for teachers to see that "everybody really does bring something to the table" and for teachers to have "an asset-based approach to collaborating with [their] peers." Realizing these aspirations seems improbable in the current (and likely future) context of District A's individual orientation. In this context, collaboration requires time, effort, and energy that would not be

perceived as valuable by teachers who can achieve their individual *classroom pedagogical responsibilities* on their own, with less time, effort, and energy.

District M Comparison of Identities

District M is described as an individually oriented professional community maintaining the *status quo* for science teaching and learning. In this "actual state of affairs," there were no common science classroom assessments that crossed the classroom door and therefore no assessment-based evidence of student learning left the classroom door. District M's future *designated identity* continues to include no likely common assessments.

Comparison of District M's Designated Identity and the New Normal

The gap between District M's *actual identity* and the *new normal* seems to be one of orientation around both important dimensions; individual over collective and not-three-dimensional science over three-dimensional science.

Unaddressed Collective Dimension. For District M, an individually oriented professional community, teachers' *professional community responsibilities* (Table 9, row B) are disconnected from individual teachers' *classroom pedagogical responsibilities* (Table 9, row A). The course-based (biology) professional community's work together does not connect what-goes-out of classrooms and what-goes-in. Pursuing one's own goals in one's own classroom does not require or connect to any joint work with one's professional community. Teachers recognize one another's individual autonomy and expertise around their own individual classroom decisions. Further, there are strong norms of non-interference, so a *new normal* in which the community works together to realize shared *classroom pedagogical responsibilities* is unlikely.

Unaddressed Three-Dimensional Dimension. Most teachers hold *classroom pedagogical responsibilities* (Table 9, row A) to students' quick-and-snappy engagement and one-dimensional rigor, so common three-dimensional assessments are simply not a solution to any identified problem. District M participants described feeling generally individually successful to their responsibilities in their own classrooms and described perceiving the local public community as also supporting their good work and decisions – whether or not those were oriented toward students' three-dimensional science experiences.

Chapter 7 – Discussion

This paper begins with a vignette of Ms. Nolan, engaged with her students in three-dimensional science teaching and learning, along with a recognition that hers is an exemplary classroom. It prompted the question, *What would it take to change Ms. Nolan's vignette from exemplary to ordinary?* What would it take to make three-dimensional science classroom engagement *normal*, so that this is what you would experience, walking into any biology classroom in any high school in any public school district in the state? In the educational world around us, How can school districts support *all* the biology teachers in enacting phenomena-centered instruction using three-dimensional curriculum and assessments?

This study addressed these questions by looking at four districts that were similar in important ways. They were of similar size, with course-specific (biology) professional communities of at least seven teachers. They had similar economic resources. All of them had adopted *Carbon TIME* units as their biology curriculum or had provided teachers access to these resources, and all had teachers who completed *Carbon TIME* pull-out professional development programs. All had district science coordinators and local teachers' unions who supported (or described wanting to support) teachers' three-dimensional classroom practices and students' science achievement. However, despite these similarities, our *Carbon TIME* interactions with these districts had indicated they were not the same in either their classroom teaching and learning environments or teachers' collegial environments.

In an effort to better understand how to secure a *new normal* in which all students experience three-dimensional science classroom engagement and outcomes, this study pursued an explanation for the differences across these four districts. Interviews were

conducted with teachers, district science coordinators, and local teachers' union leaders to collect data about the actual state of affairs – districts' *actual identities* – and hopes and plans for the future – *districts' designated identities*.

My analytical framework in Chapter 1 (Figure 1 and Table 1) delineates the ideas and content of participants' identifying stories that were relevant to the research questions; different across districts; and connected in meaningful ways to the *new normal*. Rows A-C reflect professional roles and responsibilities in the *new normal* and rows 1-5 reflect professional actions in the *new normal* – particularly ones that "cross the classroom door" to connect individual teachers' classrooms with their course-based professional communities.

The related analyses were shared in Chapter 4 – districts' *actual identities* (Research Question 1); Chapter 5 – districts' *designated identities* (Research Question 2); and Chapter 6 – comparing these identities with the *new normal*, while looking at costs and benefits of change around the characteristic of common three-dimensional assessments (Research Question 3).

A key finding from this study is the two core dimensions undergirding the details of participants' stories and along which districts differed – collective versus individual and three-dimensional science versus not-three-dimensional science. To reach the *new normal*, attention to these two dimensions is requisite.

In the following discussion, I first summarize each districts' identities and discuss how the districts are positioned moving forward. Next, I discuss possible causal connections between communities of practice – through boundary-crossing people and artifacts – and within a community of practice through professionals' roles and responsibilities (Table 1, lettered rows) and professional actions (Table 1, numbered rows). To address questions about

what makes district-level identifying stories so consistent, this discussion of causal connections includes Figure 7, a revised version of Figure 1, which more clearly identifies key communities of practice that study participants described in each district and relationships among them. Then, I suggest implications for research and practice, using a specific example of efforts to connect students' science classroom performances with teachers' classroom instruction. Finally, I provide study limitations and conclusions.

District Summaries and Looking Forward

District N – Collective and Three-Dimensional

District N participants' stories suggest District N was prepared for change as the *Next Generation Science Standards* arrived. District N already had expectations for common curriculum and common assessments and had in-place systems for accountability and support through teachers' course-based professional communities. The *NGSS*, in fact, provided an opportunity to improve shared instructional resources and enhance teachers' work within their local professional communities because collective work was viewed as instrumental to selecting, designing, and revising three-dimensional curriculum and assessments. Participants recognized that *NGSS*-aligned classroom materials were different and complex in ways that required collective effort; teachers did not believe they could develop or use these materials in isolation. Teachers' work with colleagues certainly incurred costs – teachers' time, effort, and relational engagement – but District N and Union N mitigated those costs. District N's *actual identity* provided a template for future action, so that who District N had been and what they had designed before *NGSS* served as a model for who they were becoming and what they were doing with the *NGSS*.

This template is likely to serve District N moving forward; District N's collective, three-dimensionally oriented professional community is prepared for future change. District N is connected to external science education communities through multiple individual teachers and the district science coordinator. The professional community's expectations for innovation ensure that individual's experiences with external education communities will be shared in ways that will allow the entire professional community to consider new information and jointly make decisions about continued changes.

District F – Collaborative-to-Collective and Three-Dimensional

District F participants' stories described a *designated identity* as a collective, three-dimensional course-based (biology) professional community. The district is already oriented toward this future through teachers' shared *classroom pedagogical responsibilities* (Table 1, row A) and *professional community responsibilities* (Table 1, row B) in which teachers experience autonomy within their use of common curricula and express peer-based accountability. However, unresolved transaction costs – limited time with their peers, too many course-based professional communities (due to multiple and changing teacher preps), and no system for compensating teachers for additional work – will likely hamper District F's progress.

District F participants did not describe themselves as positioned to evaluate and respond to external science education communities as successfully as District N because fewer individual teachers described external connections and because the district science coordinator is responsible for connections to more external communities (math and science). However, District F's and Union F's successful experiences with a state-teachers'-union-supported district-union partnership for curriculum-specific (*Carbon TIME*) professional learning may provide an

avenue for future connections to external professionals. In this partnership, the state teachers' union and Union F provided financial and organizational support that was aligned with District F's – and, notably, District F's course-based (biology) teacher professional community's – decisions around science instructional resources.

District A – Individual and Three-Dimensional

District A's *actual* and *designated identity* as an individually oriented professional community provides barriers to ensuring that every biology classroom is pursuing three-dimensional engagement with natural phenomena. District A and Union A described advocating for a non-instrumental approach to collaboration, meaning that working with teacher peers is available and encouraged, but neither required by administrators or peers, nor necessary for successful classroom teaching. District A and Union A leaders described wanting teachers to find individual value and fulfillment in collegial work. Though such intrinsic motivation is meaningful, these ideals do not address the conflict costs of collaborating, which are particularly high when teachers hold differing *classroom pedagogical responsibilities* (Table 1, row A). As the district science coordinator shared, teachers were reluctant to collaborate with some peers "because [the teachers] know [they]'re not already in agreement on the vision … 'I'm not going to give up mine for yours'." Without addressing such conflict costs, changing optional collaboration to collective decision-making in the course-based professional community seems unlikely.

Along the three-dimensional science dimension, District A has many individuals connected to external communities in ways that will likely continue to bring information and developments in science education into district classrooms. However, these will likely continue

to be independent, not innovative. District A is a place in which virtuoso teachers might thrive, but in which the entire course-based professional community is unlikely to achieve three-dimensional classrooms.

District M – Individual and Not-Three-Dimensional

District M's *actual* and *designated identity* as an individually oriented and *status quo* professional community suggests a future that is a continuation of the present. As explained at the end of District M's *designated identity* (Research Question 2), it is possible that students' scores on the state-level science assessment may – in the future – cause District M participants to re-evaluate their current *status quo*. However, since what teachers do together with their course-based peers is not connected to what goes in or what goes out of their classrooms (Table 1, rows 1 and 2), there are no current professional actions and routines in District M that would support the joint work that is a hallmark of a collective professional community. Further, District M participants did not describe any current or desired professional community roles and responsibilities (Table 1, row B) reflecting a collective orientation, making future peer-based and consensus-seeking decision-making unlikely.

Comparing the Districts

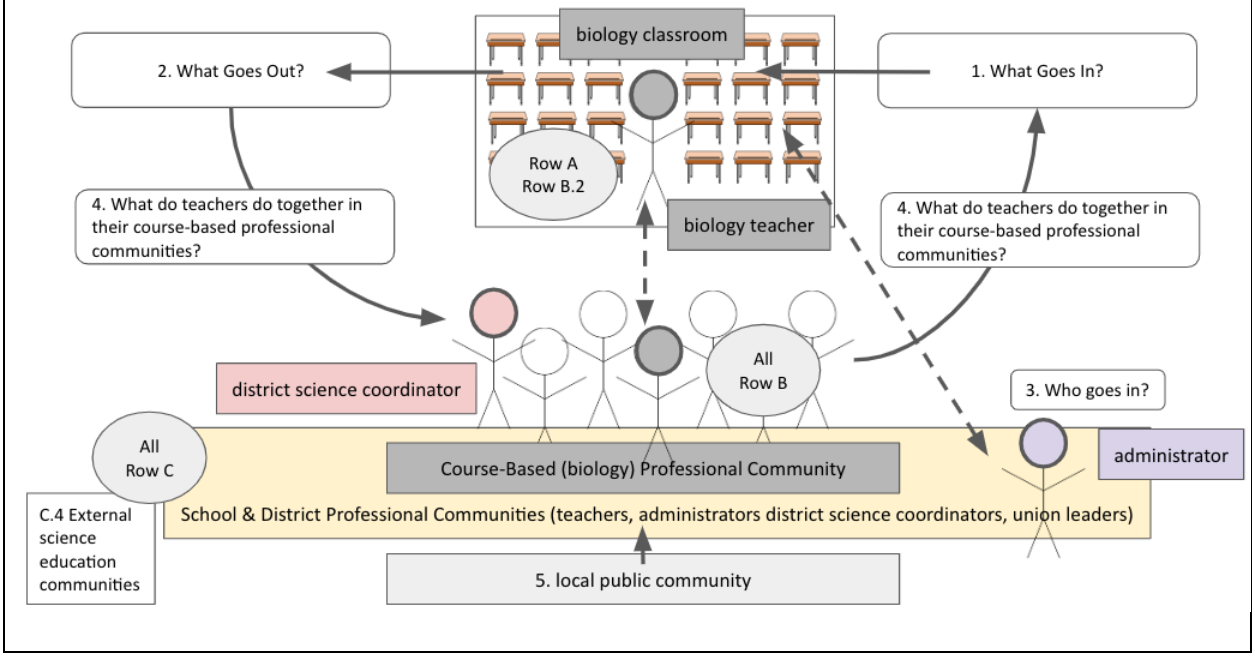
As is apparent in looking across the four districts, these two dimensions – collective versus individual and three-dimensional science versus not-three-dimensional science – have important consequences for districts' stories and for their pursuit of students' three-dimensional science achievement.

Collective (and collaborative, moving toward collective) identities in District N and District F are supporting these teacher professional communities in responding to the new and

significant classroom expectations of *NGSS* together. Teachers select and develop instructional resources together, share experiences and artifacts as evidence of student learning, and revise resources and instruction toward improvement. As one District F participant shared, she was "looking forward to … the collective mind" available when all the biology teachers would be working together collectively, pursuing shared *classroom pedagogical responsibilities* (Table 1, row A) to students' three-dimensional engagement and outcomes.

Individual identities in District A and District M enabled interested teachers to take up *Carbon TIME* and use these instructional resources in *NGSS*-aligned ways in their classrooms. District A's three-dimensional orientation supports more teachers independently pursuing these goals than in District M's *status quo* orientation. Still, in both districts, teachers with *classroom pedagogical responsibilities* (Table 1, row A) to non-three-dimensional science pursued those, using *Carbon TIME* instructional resources (and other resources) for their own purposes.

Figure 7. Revised Figure 1 – Model for District Identity, corresponding to Table 1



Causal Connections Between and Within Communities of Practice

As the results showed, participants' stories within each district – and therefore each district's *actual* and *designated identities* – were exceedingly consistent. This was even the case for study participants who were not members of the course-based (biology) professional community, such as local union leaders and some district science coordinators. This is important in reaffirming the utility of identifying stories as a way of making sense of participants' interviews, but it poses another question: What causes district-level identifying stories to be so consistent, and what makes districts' stories different from each other?

Causal Connections Between Communities of Practice

Communities of practice – here describing the various groups of people that individual teachers interact with as they engage in their professional work, each of which have shared experiences and ways of communicating (Wenger, 1998) – are connected through people and

artifacts that move across their boundaries. Though these connections are necessary in explaining how ideas and expectations spread among related communities, they are not sufficient. The professional roles, responsibilities, and actions (Table 1) of the community are also required in order to explain causal connections. Evidence for this is in the findings shared in Chapters 4-6: Otherwise similar people and artifacts have different meanings due to different orientations across different districts' communities.

Explaining the consistency across each district's identifying stories and the differences across the districts' stories requires revising Figure 1 to better represent how teachers' course-based professional communities are situated within the larger school- and/or district-level communities of practice. Figure 7 – the revised version of Figure 1 – represents causal connections that influence teachers' course-based professional communities to be oriented collectively or individually, or to be oriented toward three-dimensional science or not-three-dimensional science. It shows how people and artifacts move between larger and smaller communities in which roles, responsibilities, and actions have common meaning. As described next, these shared orientations cause otherwise similar people or artifacts moving between smaller and larger communities of practice in different districts to be made sense of differently.

Chapters 4-6 described people and artifacts connecting multiple communities of practice, including the local public community (particularly in District N and District M); external science education communities; teachers' course-based (biology) professional community; and the individual teacher's classroom community. Primarily, the findings focused on connections across two key communities of practice – the individual teacher's biology classroom community and their course-based (biology) professional community, describing causal connections

through professional roles and responsibilities (Table 1, lettered rows) and professional actions that "cross the classroom door" (Table 1, numbered rows). Because of their importance in affecting classroom science instruction, aspects of the connections between these two communities of practice are reiterated further below.

Causal Connections Between Teachers' Course-based Professional Communities and School/District-based Professional Communities. In Table 1, row C, the study's analytical framework outlines roles that school- and district-level professionals play related to teachers' course-based professional communities. In these roles, district and union leaders help enable or discourage particular orientations in teachers' course-based professional communities, so that these are collectively or individually oriented or are oriented toward three-dimensional science or not-three-dimensional science. Specifically, district and union leaders endorse certain identities (Table 1, C.1); make decisions that mitigate transaction and conflict costs (Table 1, C.2 & C.3); and form connections to external science education communities (Table 1, C.4).

People Crossing Community Boundaries. In collectively oriented District N, people moving in-between larger school and district professional communities and smaller course-based professional communities endorsed collective (and three-dimensional science) orientations. District N's design of roles was such that educators in content-specific leadership positions (such as the District N science coordinator) and local union leaders were also teaching courses, making them simultaneously members of smaller, course-based professional communities. This differed from other districts, in which the district science coordinators were not also in teaching positions. As these district and union leaders moved among communities, they brought with them expectations for working with colleagues as required for teachers to

meet classroom goals for students (Table 1, B.1); and they described teacher autonomy through experimentation toward collective student outcomes (Table 1, B.2). In these ways, expertise and professionalism were aspects of the course-based teacher community, not of individual teachers. Additionally, in District N, district curriculum leaders (like the District N science coordinator) held responsibilities for both peer-level support and peer-level accountability to the course-based professional community's decisions (Table 1, B.3).

Differently, in District A, educators in leadership positions were not perceived with accountability-related responsibilities; only administrators were viewed as "accountability people." This hindered – for example – any science educator's ability to address another teacher's use of assessment-phenomena for instructional purposes. In individually oriented districts like District A, district and union leaders were not themselves members of course-based professional communities. They endorsed stories of individual teacher decision-making and autonomy, and they supported identities in which expertise and professionalism were aspects of individuals, not the collegial community. In District A and District M, where this was the case, the larger school, district, and union communities did not express that working together was required to meet classroom goals for students. Instead, they promoted individual autonomy as paramount and the individual teachers as the singular professional responsive to the students in their classroom.

Artifacts Crossing Community Boundaries. Artifacts also cross community boundaries between teachers' smaller, course-based professional communities and their larger school/district communities. Some artifacts were unique in supporting collective orientations, such as District N's common grading policies. In District N, as generic common grading policies

moved from the larger district community into the course-based (biology) professional community, teachers worked together to determine common units and summative assessments, described initially as "ugly compromise[s]." District N participants described using new, *NGSS*-expectations to revise these "ugly" versions to collectively developed and agreed-upon common, three-dimensional units and unit-level summative student assessments.

Importantly, though the common grading policies were initiated at the district level, each course-based professional community had autonomy for designing its own grading system and common assessments and making decisions that would best meet needs and goals of teachers and students. As importantly, policies mitigating transaction costs (through District N's and Union N's contractual agreements providing regular time and compensation for teachers' course-based work) were simultaneously crossing community boundaries. In these ways, artifacts crossing community boundaries in District N supported both collective and three-dimensional orientations.

Different professional roles, responsibilities, and actions meant that otherwise similar artifacts had different meanings in different districts. For example, District A participants also described common end-of-course exam policies moving from the larger district community into the course-based (biology) professional community. However, in District A, professional actions including the development, revision, and approval of the common assessments did not involve the full course-based (biology) professional community. Further, teachers holding individual *classroom pedagogical responsibilities* (Table 1, row A) alongside professional norms for non-interference and egalitarian beliefs (Table 1, row B) made their own decisions about classroom instruction, despite a common end-of-course exam. In District A, this artifact continued to

support individual orientations in ways that did not motivate three-dimensional instruction in all biology classrooms.

Causal Connections Between Classroom Communities and Teachers' Course-Based Professional Communities. As explained in Chapter 1, the ultimate goal is scientifically literate citizens, with relevant school-based outcomes being students' three-dimensional performances and their science identities. The individual classroom teacher is critical in achieving these goals because teachers' *classroom pedagogical responsibilities* (Table 1, row A) fundamentally drive their decisions with their own students within their own classrooms (Horn, 2020). In this study, teachers with *classroom pedagogical responsibilities* to students' three-dimensional science classroom experiences and outcomes were deeply committed to ensuring their students were *figuring out* natural phenomena and therefore described using instructional resources and evidence of their students' learning to such ends.

As demonstrated with Teacher A in District M, teachers can hold three-dimensional science *classroom pedagogical responsibilities* and be individual virtuosos in their local context, without peers sharing their instructional or student learning commitments. This falls short because not every student is in a three-dimensional science classroom community.

This study suggests that attention to teachers' course-based professional communities is critical for reaching a *new normal* in which all teachers are engaged in three-dimensional science classroom experiences. This can happen as people and artifacts move between teachers' classroom communities and their course-based professional communities; in other words, as teachers engage in "crossing the classroom door" professional actions described in Table 1 (numbered rows).

Further, participants in collectively oriented professional communities described *professional community responsibilities* (Table 1, row B) as necessary for meeting their own *classroom pedagogical responsibilities* (Table 1, row B.1). Their perception of their classroom autonomy was connected to individual experimentation with success defined through agreed-upon student outcomes (Table 1, row B.2). They described peer accountability existing through professional community decision-making (Table 1, row B.3).

Causal Connections Within Communities of Practice

Within communities of practice (the classroom; course-based professional communities; school/district professional communities), there were two-way causal connections between roles and responsibilities (Table 1, lettered rows) and actions (Table 1, numbered rows) in ways that made available and reinforced individual or collective professional identities. In this discussion, I focus on causal connections within teachers' course-based (biology) professional community because this particular community was the focus of this research study.

Roles and Responsibilities Affect Actions. Teachers' *professional community responsibilities* (Table 1, row B) affect actions within their course-based professional community (Table 1, numbered rows).

In collectively oriented districts like District F and District N, teachers viewed their collegial work as necessary for realizing their individual *classroom pedagogical responsibilities* (Table 1, row A). This shaped their actions together, with teachers spending time selecting, developing, making sense of, and revising three-dimensional science instructional resources.

Differently, in individually oriented districts like District A and District M, teachers' held differing *classroom pedagogical responsibilities* (Table 1, row A) and their *professional*

community responsibilities (Table 1, row B) did not include shared work being required to realize individual teachers' classroom goals. Therefore, using time and effort for actions like coordinating instructional resources or jointly making sense of student responses was unwarranted. The few individual teachers able to independently realize three-dimensional *classroom pedagogical responsibilities* (Table 1, row A) are described as virtuosos.

Actions Affect Roles and Responsibilities. When teachers bring common, three-dimensional instructional resources into their classrooms (Table 1, row 1) and bring evidence of students' three-dimensional learning out of their classrooms (Table 1, row 2), they can use time together as a course-based professional community (Table 1, row 4) for sensemaking and revisions. These actions reinforce collective *professional community responsibilities* (Table 1, row B).

In District N, for example, stories suggested that teachers did not all initially share *classroom pedagogical responsibilities* (Table 1, row A) to students' three-dimensional student experiences or outcomes; some teachers were concerned that new *NGSS*-expectations were not best for students because they perceived the standards to reduce academic rigor. However, with time to use common instructional resources (Table 1, row 1) and make sense of students' learning evidence (Table 1, row 2) together, initially skeptical teachers adjusted their own *classroom pedagogical responsibilities* (Table 1, row A) and recognized that work together would continue to be necessary (Table 1, row B) because of the complexity of *NGSS*-aligned instruction and assessments. In this way, teachers' collective professional actions influenced teachers' responsibilities.

Implications for Research-Practice Partnerships

In research-practice partnerships, educational researchers work alongside practitioners to ask relevant questions and solve problems of implementation (Coburn & Penuel, 2016). Practitioners benefit from external expertise that is relevant to their own practice, while researchers benefit from relationships and opportunities that support the development of usable knowledge. Current science education research generally already includes the three-dimensional science dimension important in teachers' course-based professional communities; this study establishes the utility of the collective-versus-individual dimension in science education research-practice partnerships.

Implications for Course-based Teacher Professional Communities

A key finding of this study is that *collective course-based teacher professional communities are essential* for establishing and maintaining the *new normal*. An illustrative example is provided below, sharing researchers' and practitioners' perspectives on causal links between students' classroom achievement and teachers' instructional practice, and how practitioners' perspectives reflect collective and individual orientations.

Teachers, district science coordinators, and union leaders in this study described hesitations about linking students' performances to teachers' instruction. They provided long lists of caveats, including non-random student placement, classroom community make-up, and daily schedules.

These practitioners' concerns are reasonable, but an important characteristic of the *new normal* is that evidence of students' three-dimensional learning leaves teachers' classrooms to be used by the course-based (biology) professional community toward classroom-level

instructional adjustments. This characteristic is based on the research community's recognition that what teachers do in their classrooms affects students' performances (Bleiberg, Brunner, Harbatkin, Kraft & Springer, 2021). Our *Carbon TIME* project findings provide specific evidence that teachers matter for students' three-dimensional science outcomes (Covitt et al., 2020; Lin et al., 2021).

This dissertation study's findings suggest that a collective orientation supports practitioners' use of student performance data in ways that can be connected to teachers' instruction because the analysis and improvement work is viewed formatively – it informs improvements – versus a summative perspective, which provides a judgement about an individual teacher's performance. District N and District A provide an informative comparison. Both are three-dimensional professional communities using a characteristic of the *new normal* – common, three-dimensional, summative end-of-course biology assessments – while they differ in respect to the other dimension; District N is a collective professional community, while District A is individually oriented.

District N's Collectively Oriented Course-Based Teacher Professional Community. District N participants described the belief that teachers' instruction matters for students' science classroom achievement. They described teachers regularly using time as a course-based professional community to review students' performances on common three-dimensional assessments. With an instructional coach, they also compared (de-identified) teachers' performances, intentionally making inferences about classroom instruction.

District N's collective identity supported the professional community's formative work with student assessment data. Collectively, they could look at students' performances and

consider what it meant for them as a biology course. As noted in Research Question 1, teachers still "didn't really like" the experience of comparing teachers. Yet District N stories suggest this exercise supported teachers' instructional improvement and will continue in their *designated identity*.

District A's Individually Oriented Course-Based Teacher Professional Community. Differently, in District A, participants described teachers spending time together reviewing their own students' performances on common three-dimensional assessments and making comparisons as individual teachers to aggregated building- or district-data. These were designed as opportunities for individual improvement – as shared in Research Question 3, the district science coordinator wanted teachers to consider, "How do I use data to empower myself?"

As an individually oriented community, students' common assessment data could inform teachers' individual improvement processes, but when used communally, it was perceived as having only summative purposes. Rightly so, participants were left concerned about the potential unfair and high-stakes consequences.

Comparing District N and District A. As a community of practitioners and researchers working to improve students' science classroom experiences and outcomes, this comparison between District N and District A is valuable. It suggests that individual teachers and their local teachers' unions can and do use student performance data in ways that directly inform improvements in classroom instruction when the local professional communities have a collective orientation. In such course-based professional communities, teachers can and do

engage in difficult conversations that compare teachers' performances because this work is viewed as supporting the entire professional community in improvement.

Alternatively, in individually oriented local professional communities – like District A – comparisons across teachers are viewed as summative judgements and teachers and local teachers' unions work to limit or stop such comparisons, since they are fraught with idiosyncrasies and viewed as unfair and potentially punitive.

This example reiterates points made around causal connections across communities of practice. Similar people (teachers, district science coordinators) and artifacts (common, three-dimensional, summative end-of-course exams and related student assessment data) crossed between district-level and course-based professional communities in District N and District A, and such boundary crossings were necessary for moving information. Despite similarities across the people and artifacts, however, the districts' differing orientations (one collective and one individual) led to different outcomes.

Implications for External Science Education Professionals

Educational professionals outside of classrooms, schools, and districts include researchers, often connected to university-based research and development programs; assessment and instructional specialists in county and state education agencies; state- and national-level staff and leaders in science professional organizations; and others providing professional learning and expertise around classroom science teaching. Because the science education field's understanding of students' science learning and identity development continues to advance and change beyond the NRC's *Framework* (2012) and the *NGSS*, school-

and district-level connections to external experts are necessary for defining and achieving students' science success.

This research study suggests that those of us striving to improve students' science outcomes by developing instructional materials, supporting teachers in their classroom instruction and assessment, or developing systems for instructional support through research-practice partnerships, should endorse teachers' course-based professional community work as integral to three-dimensional science classroom instruction; should organize and facilitate professional actions that "cross the classroom door" within teachers' course-based professional communities; and should include district and union leaders in ways that support teachers' local success.

Endorsing Teachers' Course-Based Professional Communities. External researchers and professionals working to support teachers in three-dimensional science classroom teaching should keep in mind that teachers' local, course-based professional communities are relevant to shifting teachers' classroom practice.

Every district in this study had teachers participating in external *Carbon TIME* professional development and engaged with external *Carbon TIME* researchers, but that did not lead to similar identifying stories across districts. Only in District N – where the course-based professional community had a collective orientation – did study participants describe all biology classrooms engaged in three-dimensional instruction and all teachers assessing students' three-dimensional performances.

Despite the external *Carbon TIME* professional development and instructional resources, participants in District A and District M suggested that only some teachers were

using the reform-aligned instructional resources in three-dimensional ways in their classrooms. Individual orientations in these districts enabled virtuoso teachers alongside *status quo* teachers; they did not support a *new normal* in which every student was experiencing phenomena-centered classrooms and making progress toward three-dimensional performances.

This means that our success in reaching a *new normal* relies both on our expertise in science education reforms and on our support and development of local, course-based professional communities.

Three-Dimensional Science Classroom Instruction. External science education professionals can keep in mind that three-dimensional science classroom teaching itself may be an avenue for developing local collective identities.

One reason is the newness and complexity of the *NGSS*; participants in District F and District N described the significance of *NGSS*-expectations as compared to their previous classroom instruction and assessment; they recognized they were developing new *classroom pedagogical responsibilities* (Table 1, row A). This suggests that science education professionals working with practitioners should help identify and emphasize ways that *NGSS*-aligned expectations are different from *status quo* science teaching and encourage and support teachers in developing new *classroom pedagogical responsibilities* to three-dimensional science experiences and outcomes.

Another reason that three-dimensional science classroom engagement may be an avenue for developing local collective orientations is teachers' recognition that such complex instructional and assessment work is too significant to accomplish in isolation, but that such

work can be accomplished within peer-based professional communities. Participants in District F and District N expressed how their professional work with peers was requisite for meeting *NGSS*-aligned classroom expectations.

Supporting Actions that Cross the Classroom Door. As external science education professionals, our work to advance both three-dimensional science teaching and learning and the development of collective orientations can be pursued through professional actions that "cross the classroom door" among teachers in a course-based professional community. This means our organizing, facilitating, or otherwise supporting teachers' opportunities to select and develop three-dimensional instructional resources and to make consequential revisions using evidence with their local, course-based peers. It means supporting teachers in sensemaking activities around their three-dimensional instruction, using dialogic and artifact-based evidence with their colleagues. It means encouraging or leading peer observations among the course-based professional community that include constructive discussions of three-dimensional science classroom instruction.

Working with District and Union Leaders. This study makes the case that local teachers' unions and school districts are relevant in research-practice partnerships and instructional improvement because of their roles in endorsing collective or individual professional community identities and mitigating transaction and conflict costs related to teachers' professional community work. As external science education professionals, engaging with school districts and teachers' unions can support improved students' science experiences and outcomes. Our responsibilities and actions include opening conversations with these leaders, listening to their experiences and concerns, and sharing our rationales for pursuing three-

dimensional science outcomes for students and our understanding of the complexity of such ambitious science instruction for teachers.

Implications for District and Union Leaders

This dissertation study suggests that district and union leaders trying to improve students' science classroom experiences and outcomes or trying to improve teachers' experiences and working conditions should address the individual-versus-collective dimension of teachers' local professional communities and should support the development of collective orientations. This is because collective orientations support goal, *NGSS*-aligned, three-dimensional science classroom instruction and equitable student learning outcomes without diminishing teachers' perceptions of classroom autonomy and in ways that support teachers' feelings of efficacy with their students.

School Districts' and Local Teachers' Unions' Roles and Actions. School districts and local teachers' unions can endorse professional community work as integral to teachers' three-dimensional science classroom instruction and identify teachers' autonomy to experiment instructionally, with success defined through students' performances on peer-developed or approved common assessments. Districts and unions can recognize the transaction and conflict costs inherent in collective professional communities and use policies and approaches that mitigate these costs. These include crafting schedules that support regular time for teachers to meet with course-based peers during their duty day; providing additional compensation for the development and revision of common instructional and assessment materials; and developing and supporting systems of accountability and support through teachers' course-based professional communities.

School districts and local teachers' unions can recognize that connections to external education experts is necessary as understanding of equitable and successful science student engagement continues to develop and expand. Selecting external experts who provide support for collective orientations alongside content- or instructional related professional learning experiences is one avenue for continuing to support collective orientations. Another is to ensure that individual teachers who participate in external development opportunities have time, compensation, and support to share independent experiences with the larger course-based community for evaluation and innovation.

State and National Teachers' Unions' Roles and Actions. Finally, for state and national teachers' unions, this study suggests supporting local affiliates in recognizing the value of collectively oriented professional communities for teachers' experiences and their students' success. Additionally, state and national unions can provide strategies and models for negotiating (or otherwise achieving) lowered transaction costs and conflict costs for members.

These suggestions contrast with common narratives about teachers' unions endorsing individual orientations in which teacher professionalism coordinates with teacher autonomy; peer collaboration should be optional; and collective action is used to secure individual rights such as salary and benefits. But stories from Union N and Union F suggest that strong local unions can embrace collective instructional and collegial orientations.

For the most part, state and national teachers' unions are primarily involved in teacher professional development and instructional support through opportunities for interested individual members. This kind of support is valued by members, especially those unable to receive specific curricular or instructional support through their school districts. However, this

design – in which professional development is available to interested individuals – promotes virtuoso teachers and independence, not common expectations and innovation. This study suggests that state and national teachers' unions can take new roles and actions that support collectively oriented local, course-based teacher professional communities.

Unanswered Questions for Researchers

This study leaves open a variety of unanswered questions and avenues for future research. One avenue is to empirically investigate students' science outcomes in different districts. This could be done by comparing district-level scores on state monitoring assessment; through comparing student performances on similar unit-level assessments; or through evaluating students' science identities.

Another opportunity for investigation focuses on teachers within course-based communities of practice and their identifying stories, since individual teachers have been consistently identified as the most important in-school factor in students' classroom success (Lin et al., 2021; Papay, 2012). As mentioned in Chapter 1, *Carbon TIME* research shows correlations between teachers' identifying stories and students' higher learning gains, with teachers in higher learning gains classrooms identifying as facilitators who were using instructional materials to scaffold students' sensemaking about natural phenomena (Morrison Thomas, et al., 2022). Project data also show correlations between teachers' descriptions of collectively oriented, three-dimensional professional communities and higher student learning gains, though these correlations were weak.

We hypothesize that individual teachers within collectively oriented, three-dimensional course-based professional communities are more likely to tell identifying stories as facilitators.

We wonder how such identifying stories affect teachers' roles, responsibilities, and actions in their classrooms and in their local professional communities? We understand that stories can lead to actions (Sfard & Prusak; Wegner) but could seek evidence of causation in classroom and school district contexts.

Finally, there are a set of important questions focusing on how these districts' identifying stories came to be. *How did District N become the collective, three-dimensionally oriented professional community described in this study? How did District M become the independent, status quo community described in this study? How do individual teachers decide to accept three-dimensional roles and responsibilities in their classrooms and find benefit and support in working with their local, course-based professional communities? How do they determine the benefits outweigh the costs?* Addressing such questions would likely require a longitudinal, comparative case-study approach. Answering such questions would provide important insights for other practitioners and researchers striving to change orientations of current school/district-level communities and could support future research-practice partnerships.

Limitations

One important limitation for this study concerns the sample of teacher, district, and union participants. These were purposefully selected due to existing relationships and previous experiences with *Carbon TIME*, including preceding involvement with pull-out professional development. Therefore, the participating districts, unions, and individuals are not representative of larger populations. These districts and unions may not be representative of

other districts and unions in the state, and these teacher participants may not be representative of other teachers in their course-based (biology) professional communities.

Still, the stories that participants shared were extremely consistent within districts. There were no significant places – across the entire data set – in which stories shared by one participant did not align with stories shared by another in the same district. This suggests that these identifying stories are communal and consistent; to me, it reinforces their value as an avenue for productive change.

Second, this study collected and analyzed interview data only. This met the study's purposes for investigating identifying stories. It does not, however, triangulate these stories by connecting them to other data sets, such as copies of districts' instructional resources, artifacts of students' work, observational data of teachers working within professional communities, or records of district-union engagements. Connecting across data sets is valuable; it is one of the reasons our *Carbon TIME* research has been so informative.

Still, this design was an intentional outcome of the study's timing, which has occurred – even its initial development phase – entirely during COVID-19 pandemic-related stresses on public schools. While securing other kinds of data was possible, it seemed unethical to ask for more time and effort from study participants who were already strained by the times and contexts.

Conclusion

This study set out to see how vignettes like Ms. Nolan's could become the *new normal* – in any biology classroom in any high school in any public school district in the state – by investigating how teachers described working together in their local course-based professional

communities following *Carbon TIME* pull-out professional development. Results show that these professional communities can support classrooms in which students are engaged in three-dimensional classroom discourse. Districts and local teachers' unions can play important roles in reducing transaction and conflict costs and in endorsing stories that support collective orientations.

Researchers and external experts seeking to work with teachers, schools, and districts around science classrooms should pay attention to these two important dimensions – collective/individual and three-dimensional science/not-three-dimensional science. In the end, all of us seek better ways to engage students in science classrooms and better ways to organize time, resources, and course-based, school-level, and district-level work.

In their interviews, union leaders said, "our vision is always to advocate for public education." External experts should "bring on the research … If we know there's a better way, how better a way to advocate for public education than to implement those better ways?"

APPENDICES

Appendix A. Study Participants

Table 11. Overview of Study Participants, by Local Context	
State Teachers' Union Participants	
Vice President (governance)	• Elected (2017) on a platform prioritizing union role in teacher professional learning • Key elected leader for organizing staff into state union professional development center • Key elected leader for reorganizing governance into new state union professional development committee • Key decision-maker for supporting state union sponsored *Carbon TIME* Professional Learning Networks • Former HS Teacher in District N
UniServ Director (staff)	• Staff member in state union professional development center • Staff coordinator *Carbon TIME* Professional Learning Networks • Work includes state union training program designed to support individual Ts in developing and running their own professional learning workshops • Former HS Teacher
District A Participants	
Local Union President (governance)	• Full-time release from elementary classroom • Involved in negotiations and grievances • Involved in District A *Carbon TIME* Professional Learning Network • In weekly communications with District A Central Office Administrators
Local-Option UniServ Director (staff)	• Full-time staff dedicated to District A (5 locals) • Involved in all negotiations and grievances
District Science Coordinator	• District 6-12 Science Department Chair • Above-school-level employee on teacher contract and Union A member • Involved in decision-making for District A *Carbon TIME* Professional Learning Network • previous District A HS Biologylogy Teacher
District A HS Biology Teacher 1 (HS#1)	• *Carbon TIME* pilot Teacher SY14-15 & *Carbon TIME* Case Study Teacher SY15-16 • Carbon TIME Network Teacher SY15-16 & SY16-17 • On District A Science Teacher Leadership team • Completed *Carbon TIME* Network Teacher Interview
District A HS Biology Teacher 2 (HS#2)	• State Union *Carbon TIME* Network Teacher SY16-17 & SY17-18 • On District A Science Teacher Leadership team • Completed *Carbon TIME* Network Teacher Interview

Table 11 (cont'd)	
District A HS Biology Teacher 3 (HS#3)	• State Union *Carbon TIME* Network Teacher SY16-17 & SY17-18 • Completed *Carbon TIME* Network Teacher Interview
District F Participants	
Local Union President (Rnd 1) (governance)	• Full time HS Teacher (no release time) • Involved in development of District F *Carbon TIME* Professional Learning Network
Local Union President (Rnd 2)	• Full time HS Teacher (no release time) • Worked with *Carbon TIME* Biologylogy teachers in his HS teaching position
Local UniServ (staff)	• Provides staff services to 8 locals in 2 school districts • Involved in all negotiations and grievances • Involved in development of District F *Carbon TIME* Professional Learning Network
District Science Coordinator	• K-12 Math & Science District Coordinator • Above-school-level employee on teacher contract and Union F member • Union F Secretary-Treasurer • Involved in development of District F *Carbon TIME* Professional Learning Network
District F HS Biology Teacher 1 (HS#1)	• Involved in development of District F *Carbon TIME* Professional Learning Network • Did not pilot *Carbon TIME* because did not teach Regular Biologylogy SY19-20
District F HS Biology Teacher 2 (HS#1)	• Piloted *Carbon TIME* in Regular Biologylogy classes SY19-20
District F HS Biology Teacher 3 (HS#2)	• Piloted *Carbon TIME* in Regular Biologylogy classes SY19-20 • Content Area Leader at District F High School 2
District F HS Biology Teacher 4 (HS#2)	• Piloted *Carbon TIME* in Regular Biologylogy classes SY19-20

Table 11 (cont'd)	
District M Participants	
Local Union President	• Middle school teacher • part-time release
District Science Coordinator	• District M Secondary Curriculum and Instructional Specialist • Administrator position
District M HS Biology Teacher 1 (HS#1)	• Grant-funded *Carbon TIME* Network Teacher SY16-17 & SY17-18 • Out of classroom SY17-18 & SY18-19 in Temporary Administrator position, supporting K-12 science • Teaches *Carbon TIME* and release-time to support teachers in using *Carbon TIME* (grant funded) • Completed *Carbon TIME* Network Teacher Interview
District M HS Biology Teacher 2 (HS#2)	• Participated in *Carbon TIME* workshops in school district
District N Participants	
Local Union President (governance)	• Part-time release elementary teacher
Local UniServ (staff)	• Interim position; limited long-term knowledge of District N
Past Local Union President (governance)	• Former HS Chemistry Teacher and Local Union President in District N • Full-time Union staff dedicated to another district
District Science Coordinator	• K-12 Science Coordinator; extra-duty position • Full-time HS classroom teacher • State Union *Carbon TIME* Network Teacher SY16-17 & SY17-18 • Completed *Carbon TIME* Network Teacher Interview
District N HS Biology Teacher 1	• State Union *Carbon TIME* Network Teacher SY16-17 & SY17-18 • Completed *Carbon TIME* Network Teacher Interview
District N HS Biology Teacher 2	• State Union *Carbon TIME* Network Teacher SY16-17 & SY17-18 • Completed *Carbon TIME* Network Teacher Interview

Appendix B. Round 1 Interview Protocols Combined

Read this text BEFORE recording:
Thank you for taking the time to participate in this interview today. I'm interested in your experiences and ideas about connections between science classrooms and teachers' professional communities (specifically, school districts and unions). I hope these conversations will help us understand and even improve the work of science teaching and learning.
To ensure that I understand you, I may ask additional clarifying questions, even around topics or ideas that you think I already know. I will record and transcribe this for research purposes. Do you have any questions before we start?
Start the recording, and then read this text with the appropriate information:
This is an interview with [name] on [date].

Note: Text versions planned for Union Leaders & Staff is placed in text boxes.

1. First, I'd like to ask a little bit about your professional work as a [teacher, district science coordinator]. *Note: some participants have multiple roles; ask about each.*
    a. How would you describe what you do as a [participant's role] in [location]?
        i. *[For District Science Coordinator]*: In what ways do you think your work affects what's happening inside secondary science classrooms?
            1. *[selection/development/adaption of curricula and assessments; PD]*
        ii. *[For District Science Coordinator]*: How is this work similar and different to the work of other (admin/above-school-level personnel) in [location]?
            1. *[probes: Instructional support and/or (or versus) teacher evaluation; decision-making around time and goals – PD, common assessments; decision-making around district initiatives]*
    b. And, I'm curious about the ways that some of the organizations you are a member of (or work with) affect what's happening inside science classrooms …
        i. How would you describe the work of your school district; what does the district do? How does that work affect what's happening inside science classrooms?
        ii. What about your local union? State union? … what is their work? How does that work affect what's happening inside science classrooms?

1. First, I'd like to ask a little bit about your professional work as a [union leader, union staff].
    a. How would you describe what you do as a [participant's role]?
        i. In what ways do you think your work affects what's happening inside secondary science classrooms?
            1. *[probes: calendar, PD time, PD choice, class size, members on curricula- and other decision-making teams, critical professional discourse]*
    b. How is this work similar and different to the work of others in your organization [staff, governance]?

i. And, in what ways do you think [the organization's] work affects what happens inside science classrooms?
ii. And what about other organization's? [district, local union, state union]

2. Next, I'd like to ask you about your vision or goals for classroom communities – a science teacher with his/her students – and for professional communities – groups of science teachers and related professionals together.
    a. So, to start, let's think about science classrooms. What vision do you have for what should be happening in secondary science classrooms [in location]?
        i. [probes: What are students doing? What is the teacher doing? (clarify if common words are used: inquiry, student-centered, etc.)
        ii. Where does this vision come from? Who do you talk to about visions/goals for science classrooms? (listen for outside experts)
        iii. Can all students and teachers meet your vision?]
        iv. How does this compare to what you think is currently happening in science classrooms?
            1. [probe: How do you know? When was the last time you were in a science classroom (besides your own)? What were students and teachers doing?]
    b. And, second, what about for groups of teachers: What visions/goals do you have for what could/should be happening when science teachers work together during meetings and other professional development experiences [in location]?
            1. [probes: What are teachers doing? (completing district tasks? observing each other? sharing students work? studying students data? using protocols?)
            2. How are teachers engaging with their peers? (nice? critical?)
            3. Who do you talk to about science teachers professional communities?
            4. Can/will all teachers engage in this way?]
        ii. How does this compare to what you think is currently happening in science teachers' professional communities?
            1. [probes: How do you know? When was the last time you met with science teachers?
            2. Why do you think it's like this (as compared to your vision)?
    c. Finally, let's talk a little about the relationships between these two communities – between the teacher's classroom community and their professional community.
        i. In [location], how is what a teacher does in their classroom connect to what they do with their colleagues during meetings and professional development experiences?
            1. [probes: What role does selecting/modifying/developing common curricula play? Common assessments?
            2. *How do you know? Why do you think it's like this?]*

2. Next, I'd like to ask you about your vision or goals for classroom communities – a science teacher with his/her students – and for professional communities – groups of science teachers and related professionals together.
    a. So, to start, let's think about science classrooms.
        i. When was the last time you were in a secondary science classroom? What were the teacher and students doing?
            1. How does this compare to what you think is happening in most science classrooms?
                a. *[probes: How do you know? Who do you talk to about science classrooms? Why do you think it's like this?]*
        ii. And, what is your vision for what could/should be happening in secondary science classrooms [in location]?
            1. *[probes: What would teachers and students be doing? (clarify if common words are used: inquiry, student-centered, etc.)*
            2. *Where does this vision come from? Who do you talk to about science classrooms? Can all students and teachers meet your vision?]*
    b. Second, let's think about what happens when groups of teachers work together.
        i. What do you should be happening when [secondary science] teachers work together during meetings and other professional development experiences [in location]?
        ii. How does this compare to what you think is currently happening in [science] teachers' professional communities?
            1. *[probes: What are teachers doing? (completing district tasks? observing each other? sharing students work? studying students data? using protocols?) How are teachers engaging with their peers? (nice? critical?)*
            2. *How do you know? Who do you talk to about science teachers professional communities? Why do you think it's like this? Can/will all teachers engage in this way?]*
    c. Finally, let's talk a little about the relationships between these two communities – between the teacher's classroom community and their professional community.
        i. In [location], how is what a teacher does their classroom connected to what a they do with their colleagues during meetings and professional development experiences?
            1. *[probes: What role does selecting/modifying/developing common curricula play? Common assessments?*
            2. *How do you know? Why do you think it's like this?]*
3. OK, so now I'd like to discuss some of the visions and goals you've just you've shared alongside your initial statements about professional work.
    a. What kinds of resources or changes would support your vision/goals for what should be happening inside secondary science classrooms?

i. How can the district support those? The union?
ii. *[Probes: How could the district and union work together? What tensions do you foresee (time; teacher evaluation; teachers holding other teachers accountable; trust)?*
iii. *Are there things that you are currently required to do that you could give up in order to work toward your vision? Would you expect opposition to this tradeoff; from whom, why?]*

b. What kinds of resources or changes would provide support in reaching your goals for what should be happening in science teachers' professional communities?
   i. How can the district support those? The union?
   ii. *[Probes: How could the district and union work together? What tensions do you foresee (time; teachers moving beyond 'nice'; teachers holding other teachers accountable; trust)?*
   iii. *Are there things that you are currently required to do that you could give up in order to work toward your vision? Would you expect opposition to this tradeoff; from whom, why?]*

3. OK, so now I'd like to discuss some of the visions and goals you've shared alongside your initial statements about professional work.
   a. What kinds of resources or changes would support your vision/goals for what should be happening inside secondary science classrooms?
      i. What can the union do? The district?
      ii. *[Probes: How could the district and union work together? What tensions do you foresee (time; teacher evaluation; teachers holding other teachers accountable; trust)?*
      iii. *Are there things that you are currently required to do that you could give up in order to work toward your vision? Would you expect opposition to this tradeoff; from whom, why?]*
   b. What kinds of resources or changes would provide support in reaching your goals for what's happening in [science] teachers' professional communities?
      i. What can the union do? The district?
      ii. *[Probes: How could the district and union work together? What tensions do you foresee (time; teachers moving beyond 'nice'; teachers holding other teachers accountable; trust)?*
      iii. *Are there things that you are currently required to do that you could give up in order to work toward your vision? Would you expect opposition to this tradeoff; from whom, why?]*

4. *General questions to ask anytime to probe for more information: What do you mean by …? Can you tell me more about that? Can you give me an example of that?*

Appendix C. Round 2 Interview Protocol Example

<table>
<tr><td colspan="2">Table 12. Round 2 Interview Protocol Example for a District Science Coordinator</td></tr>
<tr><td colspan="2">Professional Action 1a. Common Curriculum</td></tr>
<tr><td colspan="2">I want to mention two reasons that others in District X shared, around why having a common curriculum is beneficial:
Most HS science teachers suggested that having a common curriculum for yearlong courses (like Biology) is valuable because it provides students with similar experiences and expectations across teachers, since students may have different teachers different semesters.
You shared that the previous local union president felt that common instructional materials could support teachers in “having conversations” and collaborating.</td></tr>
<tr><td>I wonder, how would you like to comment or add to these two reasons?
1a. In what other ways do you see a district common curriculum as supporting Teachers in teaching toward new, challenging science standards?
• What other kinds of benefits (if any) do you think your science teachers might add?
• What kinds of drawbacks do you think your science teachers would express?
• What about other District X Administrators; how do you think their responses might be the same or different to yours or your science teachers?</td><td>Listen for ideas about:
<u>student outcomes</u>:
• goals for?
• improvement of?
<u>student common experiences</u>
<u>teachers’ time – allow for</u>:
• responsiveness?
• feedback to students?
• other tasks?
<u>teacher autonomy</u></td></tr>
<tr><td colspan="2">Listening to HS science teachers here in District X not everyone has been using the same curriculum. Teachers indicate that some of their peers “do their own thing” or are “more traditional” in their instructional approaches.</td></tr>
<tr><td>1b. Let’s imagine that both groups of teachers came to you seeking support: one group is seeking support for more adherence to the common curriculum, while the other group is seeking support for more classroom autonomy.
• How would you respond? What do you think motivates you to respond that way?
• In responding that way, what could go wrong? (what are the problems? for whom?)
• What if these groups went to you as a union leader, or went to other union leaders (building reps and/or the local union president) for support? How would you want Union X to respond? Why?
○ In what ways do you think building reps or the local union president would respond differently than you?</td><td>Listen for motivation:
• student outcomes?
• quality classroom instruction?
• maintaining teacher-teacher professional relationships?
• maintaining teacher-district-science-coordinator professional relationships?
• maintaining union membership?</td></tr>
<tr><td colspan="2">Professional Action 1b. Common Course Assessments</td></tr>
<tr><td colspan="2">Let’s talk a little about common course assessments, like a common end-of-semester Biology exam or even common unit-level exams.</td></tr>
</table>

Table 12 (cont'd)

2a. In what ways (if at all) do you see having common course assessments as supporting teachers in teaching toward new, challenging state science standards? • What other kinds of benefits (if any) do you think your science teachers might add? • What kinds of drawbacks do you think your science teachers would express? • What about other District X Administrators; how do you think their responses might be the same or different as yours or your science teachers?	*Listen for ideas about*: <u>student outcomes</u>: • goals for? • improvement of? <u>Teachers' instruction</u>: • usable info for teachers? <u>teacher autonomy</u> <u>teacher accountability</u>
2b. Let's imagine that two groups of members came to you seeking support; one group seeking support for adoption of a common course assessment and one group seeking support for autonomy in the course assessments they use. • How would you respond? What do you think motivates you to respond that way? • In responding that way, what could go wrong? (what are the problems? for whom?) • What if these groups went to you as a union leader, or went to other union leaders (building reps and/or local union president) for support? How would you want Union X to respond? Why? ○ In what ways do you think building reps or the local union president would respond differently than you?	*Listen for motivation:* • student outcomes? • quality classroom instruction? • maintaining teacher-teacher professional relationships? • maintaining teacher-district-science-coordinator professional relationships? • maintaining union membership?

2c. In District X, you mentioned that 10+ years ago, there were "Google common assessments" (because everyone could Google the answers), and some teachers didn't give them, while one actually lost their job for falsifying data, and you said you didn't think District X has a "consistent accountability system".
• What would need to happen so that all the Biology teachers use the same common exam?
  ○ What role could you play in making that happen? Building administrators? Union X?
  ○ Would you …*review individual teachers exams? Check data in a district system?* What steps would go too far, and what are the costs to you?
	Listen for:
	• transactional costs
	• confrontational costs

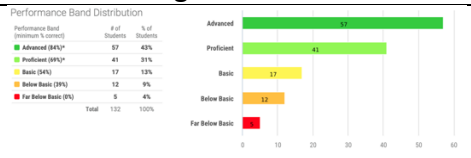
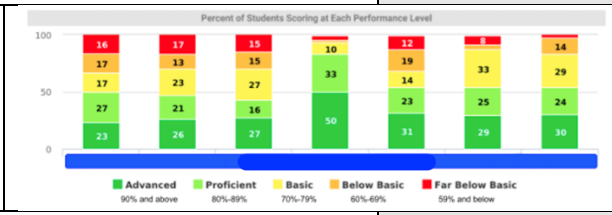
Professional Action 2. Evidence of Student Learning	
In some districts, HS science teachers indicate that they can see their own students' results on common course assessments:	

Table 12 (cont'd)

3a. In what ways (if at all) could you see using student data from common course assessments as supporting teachers in teaching toward new, challenging state science standards? • What qualities would the assessments need to have, to ensure they could be useable to teachers? [ex: who writes them? who has input on drafts?] • What other kinds of uses or benefits (if any) do you think your science teachers might add? • What kinds of drawbacks do you think your science teachers would express? • What about District X Administrators; how do you think their responses might be the same or different as yours or your teachers? • Under what conditions (if at all) do you think common assessment data is useable to link student outcomes with a teacher's classroom instruction? [ex claim: classrooms with more students scoring proficient/advanced have teachers doing a better job instructing toward new standards]	*Listen for ideas about*: student outcomes: • goals for? • improvement of? Teachers' instruction: • usable info for teachers? • limited info? teacher autonomy teacher egalitarianism
We could also imagine HS science teachers being able to see students' results on the common course assessment for their peers:	

3b. From your perspective, who should have access to a teacher's common course assessment results? [only the teacher? all the Biology teachers? You as the district science coordinator? Other administrators?].
• Why those people, and not others? What could go wrong if others had access to the results, too?
• How would your science teachers respond similarly or differently to you?
• What about District S Administrators; how do you think their responses might be the same or different as yours or your teachers?
• What are appropriate ways to use teachers common course assessment results?
  ○ For measures of student growth in formal teacher evaluation?
  ○ For identification of "lead" teachers who can support/coach others?
  ○ What comparisons can be made across teachers, using common assessment data?
	Listen for ideas about:
	student outcomes:
	• improvement of?
	Teachers' instruction:
	• usable info for teachers?
	• limited info?
	Listen for motivation:
	• student outcomes?
	• quality classroom instruction?
	• maintaining teacher-teacher

<table>
<tr><td colspan="2">Table 12 (cont'd)</td></tr>
<tr><td></td><td>• professional relationships?
• maintaining teacher-district-science-coordinator professional relationships?</td></tr>
<tr><td colspan="2">Professional Action 4. Teachers' Professional Time</td></tr>
<tr><td colspan="2">You and others in District X all discussed the value of teachers collaborating together during non-instructional time. When people sorted possible tasks for teacher-teacher time together, B – teachers share examples of their students' classroom work and discuss using conversation protocols – was one of the most valuable.</td></tr>
<tr><td>4a. In what ways do you see teachers sharing and discussing student work examples as supporting teachers in teaching toward new, challenging science standards?
• What other kinds of benefits (if any) do you think your science teachers might add?
• What kinds of drawbacks do you think your science teachers would express?
• What about District X Administrators; how do you think their responses might be the same or different as yours or your teachers?</td><td>Listen for ideas about:
<u>student outcomes</u>:
• goals for?
• improvement of?
<u>Teachers' instruction</u>:
• usable info for teachers?
• limited info?
<u>Teacher autonomy</u></td></tr>
<tr><td colspan="2">We've both had experiences with science teachers sharing and discussing student work samples. Both of us found that some teachers didn't bring examples of student work with them, which affected the way they engaged in the professional learning experience.</td></tr>
<tr><td>4b. Let's imagine that both groups of teachers came to you seeking support; one group seeking support for everyone bringing their student work and engaging together professionally and one group seeking support for not doing it.
• How would you respond? What do you think motivates you to respond that way?
• In responding that way, what could go wrong? (what are the problems? for whom?)
• What if these groups went to you as a union leader, or went to other union leaders (building reps and/or local union president) for support? How would you want Union X to respond? Why?
○ In what ways do you think building reps or local union president would respond differently than you?</td><td>Listen for motivation:
• student outcomes?
• quality classroom instruction?
• maintaining teacher-teacher professional relationships?
• maintaining teacher-district-science-coordinator professional relationships?</td></tr>
</table>

Table 12 (cont'd)

	• maintaining union membership?

4c. I understand that District X's contract outlines 45 hours of PLT time during the school year. teachers indicated that they would actually like more non-instructional time to work with their colleagues, and they would like this time during their duty day (ex: 1/2 days or common planning periods).
• Do you see providing teachers with more time during their duty day to meet and work with each other as supporting them in teaching toward NGSS?
  ○ What could you do to help make that happen?
  ○ What do you think Union X could do to make this happen?
• What concerns might you have about advocating for that kind of time; what could go wrong?
  ○ In what ways (if at all) does teachers having more non-instructional time affect your job?
  ○ Who sets the agendas (teachers; you; principals)? paper-work?
  ▪ *paperwork: "they'll walk in and they'll hand you a worksheet and say, 'here, try this. Look, we PLTed! I'll mark it down an hour,' and walk out."*
  ▪ *Something you mentioned previously was that PLCs "don't know what they're supposed to be doing with that time."*
  ○ What role could Union X take in addressing those concerns?	

Overall	

5a. To what extent is engaging with these strategies (common curriculum, common assessments, student work, and sharing student work during teacher-teacher work time) already a part of your district science coordinator work?
• In what ways would doing more affect your ability to do other important DSC work? What is that work would be affected?
5b. Would you want Union X playing a more active role in decisions and expectations around these strategies? Why or why not?
• What might it look like for Union X to be in a more active role? What might Union X leaders or staff do or say differently?
  ○ How could Union X involve curriculum & instruction folks like you?
  ○ Who else would need to be involved and how? (Instructional Leaders from building departments?)
  ○ *You mentioned you would like Union X to play more of a coaching role – whereas sometimes the district focuses more on the compliance piece*. Can you say more about that?
• What could go wrong?
5c. Some teachers talked about a sense of peer accountability in which they want to do well with their peers and do this hard work in support of each other.
• How could you support this sense of peer accountability, as the district science coordinator? How could Union X?	

Table 12 (cont'd)
Teacher Assignment (scheduling)

District X HS science teachers suggested their department can do a better job teaching to new standards if teachers have 1 or 2 preps (not 3) and teach the same science course year after year.
• Do you see these changes as supporting science teachers in teaching toward NGSS?
  ○ What could you do to support reduced preps and keeping teachers in the same course year-after-year? What concerns would you have about your involvement?
  ○ What do you think Union X could do to support these kinds of scheduling decisions? Do you want them involved? What concerns would you have about their involvement?
• How would you respond if District X coaches and the HS principals said yes to these changes, and indicated they expected to see improvements in student outcomes (grades or common course assessment)?

Appendix D. Quantitative Analysis of Participants' Costs and Benefits

As described in Chapter 3, Methods, participants' quotes about costs and benefits of professional actions in the *new normal* were quantitatively analyzed around two dimensions – individual versus collective and three-dimensional science versus not-three-dimensional science.

For the first dimension, costs and benefits were analyzed as an individual teacher benefit or a collective benefit to the larger, course-based teacher professional community.

For the second dimension, a list of key words and phrases related to three-dimensional science were used to consider the cost or benefit as three-dimensional. These included: *NGSS [or standards, meaning NGSS]; 3D; phenomenon/a; SEPs or practices (or specific ones like modeling, explanations); CCCs; DCIs; item-clusters; item-level analysis; topic strands; storyline; figuring out [or 'not learning about' or 'not mass content']; students' sensemaking; reveal students' understanding or thinking or ideas; progressions; names a specific 3D curriculum (Carbon TIME) or 3D aspect of that curriculum; naming the district science coordinator as meaningful observer*.

Table 11 includes the quantitative results with district-specific matrixes showing the percent of costs and benefits along each dimension (% collective vs. individual; % 3D vs. not-3D. Table 13 includes the full list of costs and benefits from the interviews. In Table 14, costs and benefits not addressing teachers (student- or administrator-facing costs and benefits) are colored in purple.

Table 13. Costs and Benefits as Collective vs. Individual and 3D Science vs. not-3D Science				
	District N	District F	District A	District M

Table 13 (cont'd)												
	All	Benefits	Cost	All	Benefits	Cost	All	Benefits	Cost	All	Benefits	Cost
percent individual	65%	56%	81%	72%	65%	82%	82%	76%	89%	84%	81%	91%
percent collective	35%	44%	19%	28%	35%	18%	18%	24%	11%	16%	19%	9%
percent 3D	50%	64%	24%	27%	33%	18%	33%	38%	27%	36%	29%	34%
percent not-3D	50%	36%	76%	73%	67%	82%	67%	62%	73%	64%	71%	66%

Table 14. Benefits and Costs of Professional Action Characteristics of the New Normal
Benefit of Common Assessments Crossing the Classroom Door
Supports teachers' vision of quality classroom instruction and assessment and/or motivates such classroom-level instruction.
Teachers can use common assessments and/or their experiences developing those assessments to improve their own classroom-level assessments.
Common assessments help ensure that teachers are using the common curriculum
Common assessments give teachers something to have PLC conversations around (both the assessments and related curriculum)
Teachers' experiences are fair because all students take the same common assessment (exam/grade)
Teachers' experiences are fair b/c they have access to the same resources (instructional & assessment) and same understanding (of resources & standards)
External community: Common assessments help ensure consistency across classes/teachers [benefit to parents & admin]
[benefit to students only] Common assessments help ensure students get similar (fair) experiences, regardless of Teacher
[benefit to students only] students learning over time
[benefit to the district/system] measure progress toward high quality instruction
Costs of Common Assessments Crossing the Classroom Door
Teachers feel anxious or worried, due to perceived competition with peers; perceived concerns about use of common assessment results in formal Teacher evaluation; concern about layoffs
Teachers cheat – use the common assessment as a review or otherwise misuse it
Common assessments aren't a fair way to compare teachers
Teachers experience a loss of control; are "locked in" to the assessment's content (and related common curriculum) as well as its format & timing
Can stifle innovation; we can't do this one thing b/c we agreed to this other thing
Attempting to make changes to the common assessment can cause conflict in the PLC
Classroom instruction that aligns with 3D assessments is hard
Developing/writing 3D assessments is hard
Grading 3D assessments is time-consuming

Table 14 (cont'd)
Revising common assessments takes time and w/o those revisions, the whole thing falls apart
District Science Coordinator can lose teachers' trust if they advocate for or enforce teachers using them
Someone has to check that teachers are using the Common Assessments
Problematic if common assessments come with too many other initiatives at once
[cost to students] Teachers feel the common assessment may be unfair
Benefits of Common Curriculum Crossing the Classroom Door
Common curriculum allows teachers to collaborate and provides value to teachers' collaboration time
Common curriculum can reduce teachers' workload; can allow teachers to support each other (especially new teachers and teachers with multiple preps, as well as during COVID-related remote instruction); collaboration around common curriculum can expand to other opportunities for teachers to support each other
Common curriculum can provide a framework for teaching and learning expectations and a model for instructional enactment
When assessments are aligned with the common curriculum, students' assessment performances are better when teachers use the common curriculum
Common curriculum holds teachers accountable
Because it's common for all teachers, it's easier to secure district funding for materials and professional learning
Easier for district administrators to support teachers because resources would be aligned with common curriculum
External communities: [benefit to families & Admin] Common curriculum makes it easier for administrators to respond to and support families; public accountability
[benefit to students] There is consistency across teachers (in case of changing buildings or teachers); students who need additional support (IEP, etc.) are more likely to get it from the support teachers
[benefit to students] Baseline/common expectations for all students are important and more equitable/fair
[benefit to Admin] Common curriculum makes it easier for administrators to complete formal teacher evaluation observations, and potentially complete them better
Costs of Common Curriculum Crossing the Classroom Door
Teachers feel uncomfortable with new standards, curriculum & pedagogies; Teachers may disagree with the new standards/curriculum (or not understand them)
Teachers don't want to change; teachers feel that what they've been doing is working, so what's the need for change?
Teachers feel they are losing autonomy/academic freedom; Teachers could become replaceable widgets
Teachers are unsure to what extent they need to be the "same"
Teachers can feel angry or upset; Teachers need to have tough conversations
Teaching new (and *NGSS*) curriculum is hard work/overwhelming
If held accountable by peers, Teachers may lose trust in each other

Table 14 (cont'd)
Piloting, selecting, developing, and using common curriculum (and related professional learning) takes time
[cost to district] Losing a Teacher is an acceptable cost
[cost to district] Piloting, selecting, developing, using common curriculum (and related professional learning) and revising/updating it takes district-level commitment to time and money
Benefits of People Crossing the Classroom Door
Teachers can learn – get ideas, strategies, models – from watching another teacher teach
Teachers can learn/improve from post-observation discussions and from receiving feedback from observers
Observing others in the Professional Community can raise the clout of an individual, allowing their voice/ideas to have more value
Observing others can help the Professional Community identify how to improve student outcomes
Benefit of Common Assessments Crossing the Classroom Door
Teachers' time – including the logistics of observing another teacher and giving up prep time
Teachers are vulnerable; can feel uncomfortable or attacked
Cost to trust/relationships among teachers if improvement (ex: instructional coaches; knowledgeable peers) and evaluation are linked
Teachers can't grow through observations/feedback as currently connected to formal teacher evaluation system b/c the system is punitive and competitive, and not designed for support toward growth (true for current evaluators or hypothetical peers-as-evaluators)
Won't be valuable without scaffolded conversations (among peers) and/or without constructive, honest feedback from knowledgeable peers or evaluators
[Admin cost] Evaluators/Admin's time (including district science coordinator's time)
[District cost] Planned, facilitated peer observations with conversation are expensive
Benefits of Students' Performance Data Crossing the Classroom Door
Teachers can use the data diagnostically, to better identify and understand the performances and (and potential needs) of individual students, classes, and/or particular groups of students.
Teachers can use the data responsively, to adjust instruction (prescriptively) and/or related supports.
Teachers can compare their performances to other teachers' and adjust their instruction to improve students' performances
Sharing student performance data with each other can hold teachers accountable and ensure movement toward common goal
Provides value/necessity for collegial (PLC) time
Ensure that the system is equitable
Ensure the system is aligned
Assessment data is related to public school funding and public perceptions of student success
Costs of Students' Performance Data Crossing the Classroom Door
Teachers feel bad; feel they're not "good enough"

Table 14 (cont'd)
Teachers are concerned about being compared/ranked; about being punished or treated unfairly by administration; about unfair T evaluation
students Performance Data can be unfair at the T-level because of so many reasons related to the students: IEPs; 504s; ELLs; advanced/Honors/regular kids; how many classes of that course the T teaches; how many preps the T has; groups of students in (or not in) the class due to scheduling; students' motivation around value of the grade
Teachers cheat when they perceive that students' assessment data is too high stakes (ex: in T evaluation)
Sharing T-specific (even de-identified) students assessment data could affect PLC's work together and collaboration
Teachers/Administrators don't have enough assessment literacy to interpret students' assessment data
students performance data really reflects non-school-based and non-instructional factors (ex: socioeconomics of families, resources of school)
Benefits of Student Work Artifacts Crossing the Classroom Door
Teachers can prepare to better understand 3D science teaching and learning and/or use 3D curriculum and assessments by seeing student examples; student exemplars (goal outcomes); anticipating students ideas; noticing students strengths
Teachers can revise curriculum and assessments
Teachers can improve instruction by listening to what's working for other teachers; receiving ideas/input from other teachers; around specific students (individuals or groups) or around specific content/ideas
Teachers can learn from (and/or enjoy) their own study and reflection
Groups of teachers can have deeper discussions about students
Other initiatives (compliance training) can become more meaningful b/c of surrounding PLT conversations
Costs of Student Work Artifacts Crossing the Classroom Door
Time: Studying Student Work (reflecting) isn't "urgent" or doesn't feel as valuable as other things
Teachers have to be vulnerable to share with other teachers
Teachers can lose their autonomy if the district micromanages their time with colleagues
Costs money – for common planning time (more expensive model) or for subs or for extra duty pay
Parents don't want it b/c then teachers aren't with students or students aren't in school
Could harm students if teachers have deficit-mindset or aren't cautious of students' privacy issues
Cost to the district science coordinator-teacher relationship

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