Implementing the Next Generation Science Standards: How Instructional Coaches Mediate Standards-Based Educational Reform to Teacher Practice

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Abstract

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This dissertation takes a close look at how district-level instructional coaches support teachers in learning to shifting their instructional practice, related to the Next Generation Science Standards. This dissertation aims to address how re-structuring professional development to a job-embedded coaching model supports individual teacher learning of new reform-related instructional practice. Implementing the NGSS is a problem of supporting professional learning in a way that will enable educators to make fundamental changes to their teaching practice. However, there are few examples in the literature that explain how coaches interact with teachers to improve teacher learning of reform-related instructional practice. There are also few examples in the literature that specifically address how supporting teachers with extended professional learning opportunities, aligned with high-leverage practices, tools and curriculum, impacts how teachers make sense of new standards-based educational reforms and what manifests in classroom instruction. This dissertation proposes four conceptual categories of *sense-making* that influence how instructional coaches interpret the nature of reform, their roles and in instructional improvement and how to work with teachers. It is important to understand how coaches interpret reform because their interpretations may have unintended consequences related to privileging certain views about instruction, or establishing priorities for how to work with teachers. In this dissertation, we found that re-structuring professional development to a job-embedded coaching model supported teachers in learning new reform-related instructional practice. However, individual teacher interpretations of reform emerged and seemed to be linked to how instructional coaches supported teacher learning.

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Dedication

To my family and friends

Introduction

In the spring of 2013, the State of Washington adopted the Next Generation Science Standards ("NGSS") (NGSS Lead States, 2013), a document intended to be the cornerstone of reform in U.S. science education. On one level, the NGSS represents ambitious new content standards. However, in addition to changes in what students need to know, the new standards also call for changes in how teachers and students interact with the content and with each other in the classroom.

A Framework for K-12 Science Education: Practices, Crosscutting Concepts and Core Ideas (NRC, 2012) is a preparatory document that provided the foundational vision for NGSS, primarily addressed what concepts would be taught in each grade level, possible course trajectories, and the design of curriculum. The NGSS and foundational Framework call for classroom instruction to support students in learning through three-dimensional experiences, which refers to the three dimensions of NGSS: disciplinary core ideas, science and engineering practices and cross-cutting concepts. Students are expected to learn disciplinary core science ideas through engaging in the science and engineering practices and crosscutting concepts to construct scientific explanations for how and why natural science phenomena occur. The kind of instruction that students need to support learning science in this particular way is a major shift from how teachers have been teaching. In most science classrooms in the United States, teacher instruction supports students in learning science by participating in daily, disconnected science activities (Carey, Evans, Honda, John & Unger, 1989; Weiss *et al*., 2003; Windschitl, 2008). For students to experience the rigorous learning environment and gain meaningful, deep understanding of science concepts, as specified by NGSS, it will be necessary for teachers to learn use practices that support students in making sense of multiple science concepts across

activities (Hopkins *et al.,* 2014; Hull *et al*., 2014; Lampert, 2001; Lehrer & Schauble, 2006; Lesh, Hoover, Hole, Kelly, & Post, 2000; Metcalf, Krajcik, & Soloway, 2000; Weiss *et al*., 2003). Neither the Framework nor the NGSS articulate specifically how teachers should make shifts in instruction to accommodate this vision. Therefore, implementing the NGSS requires supporting professional learning in a way that will enable educators to make fundamental changes to common forms of science teaching.

Historically, standards-based reforms have not been represented to teachers as actionable, principled instructional practices (Marx, 2012). Instead, teachers make sense of policy to interpret and negotiate the meaning and implications of the reforms (Chrispeels, 1995; Coburn, 2001; Coburn et al., 2009; Cohen & Hill, 2001; Datnow, 2012; Gioia et al., 1994; Harris, 1994; Simon, 1991; Spillane et al., 2002; Weick et al., 2005). Because of this, policy does not translate unproblematically to outcomes at the local level, and implementation is ultimately a challenge situated at the level of the instruction in teacher's classroom (Elmore, 2004; McLaughlin, 1987; Schneider, Krajcik & Blumenfeld, 2005; Weatherly & Lipsky, 1987). Teacher sense-making about reforms (a component of teacher learning) has been a process of conserving and reinforcing what practitioners already know and do (Allen & Penuel, 2014; Cuban, 1993; Spillane, Reiser, & Reimer, 2002; Tyack & Tobin, 1994). This is because teachers tend to ignore or fail to notice aspects of policy that are inconsistent with what they already do (Firestone, 1989), and integrate more familiar representations of policy into their existing practice (Beck, Czerniak, & Lumpe, 2000; Cohen, 1990; Firestone, et al., 1999; Gioia et al., 1994; Vesilind & Jones, 1998).

The implementation of standards-based reforms is also a challenge of supporting teacher learning on a systems level. Teachers make sense of policy in groups and with guidance from

teacher leaders or coaches to collectively interpret and negotiate the instructional implications of standards-based reforms (Chrispeels, 1995; Coburn, 2001, Coburn et al., 2009; Cohen & Hill, 2001; Datnow, 2012; Gioia et al., 1994; Harris, 1994; Simon, 1991; Spillane et al., 2002, Spillane, 2004; Weick et al., 2005). Recent research emphasizes that the use of common tools across classrooms and schools, allows teachers to engage in better sense-making conversations about policy and practice (Cohen, Raudenbush & Ball, 2003; Lampert, Boerst & Graziani, 2011). Most importantly, identifying and taking up a core set of shared "high-leverage practices" that embody the reform goals is critical when supporting teachers in learning to enact new forms of instruction (Ball & Cohen, 1999; Hatch & Grossman, 2009; Lampert, 2001; Grossman, Hammerness & McDonald, 2009). Shared practices typically allow teachers to speak a common language about reforms and make pedagogical experimentation more coherent across groups of educators working together (Brown, 2009; Cochran-Smith, 2003; Cohen, Raudenbush & Ball, 2003; Windschitl, Thompson, Braaten, & Stroupe, 2012).

To support large-scale implementation, districts need to consider how to coordinate such tools and language with complementary leadership roles to support teacher sense-making (Darling-Hammond et al., 2012; Firestone & Martinez, 2007; Firestone et al., 2008; Hull et al., 2014; Mangin & Dunsmore, 2015; Spillane, 2012; Spillane & Kim, 2012; West & Staub, 2003). Research suggests that reforms can be unsuccessful because critical actors in these reforms, like district coaches, develop their own varying interpretations about how teachers should engage in pedagogical practices to implement new standards (Coburn & Woulfin, 2012; Cohen & Hill, 2001; Elmore, 2000; Elmore, 2004; Hargreaves & Fullan, 2012; Mangin & Dunsmore, 2015; Meyer & Rowan, 1978; McLaughlin, 1987; Spillane, 2004).

District-level coaches are typically thought of as critical "change agents" for supporting

teacher learning (Fullan & Knight, 2011; Neumerski, 2013). However, what coaches do in these roles has yet to be thoroughly explored (Lampert, Boerst & Graziani, 2011; Mangin & Dunsmore, 2015). The field has few examples of how coaches use tools and strategies to impact how teachers work around problems of learning high-leverage or ambitious teaching practices (Lampert et al., 2011). Many district coaches lack the organizational tools and resources needed to support their own learning about new reforms and how to support teacher sense-making (Atteberry et al., 2008; Bean, Draper and Hall, 2010; Fullan & Knight, 2011; Lampert et al., 2011; Mangin & Dunsmore, 2015; Neumerski, 2013). Therefore, it is important to gain a better understanding about how coaches interact with teachers to make sense of large-scale standards-based reforms and new pedagogical practice (Elmore, 2000; Leithwood, Seashore, Louis, Anderson & Wahlstrom, 2004; Lord & Miller, 2000; Mangin & Stoelinga, 2008; Mangin & Stoelinga, 2015; Neumerski, 2013; Spillane & Diamond, 2008; Spillane, Halverson & Diamond, 2004).

Washington is a "local control" state. Although the state office of public instruction provides a broad-level transition plan, individual districts are left with the task of developing implementation plans for NGSS, targeted at support teachers in shifting their instructional practice. Because implementing the NGSS is ultimately a problem of supporting teacher learning, this dissertation will take a close look at how district-level coaches make sense of and mediate reform messages for teachers, support teacher learning, and support teachers in shifting their instructional practice related to the NGSS. I selected this this case because it is timely, as the state of Washington is early in the stages of implementing the NGSS. This dissertation is a comparative case study (Miles & Huberman, 1994; Merriam, 2009; Yin, 1991) of two district-level instructional coaches and six science teachers working in a high-needs school district. The

district has a partnership with the local university for developing the professional development that will support the implementation of the NGSS by focusing teachers on learning to enact Ambitious Science Teaching. Ambitious Science Teaching is a set of high-leverage instructional practices designed to support teachers in developing a classroom environment conducive to the NGSS learning experience. This specific district-university partnership has designed a highly-structured, job-embedded coaching model professional development system to support teacher learning. This dissertation aims to address how re-structuring professional development to a job-embedded coaching model supports individual teacher learning of new reform-related instructional practice. Because the relationship and work between instructional coaches and teachers usually around some version of instructional reform, this case is a prime opportunity to learn more about how instructional coaches are mediating reform while supporting teachers in learning reform-based instructional practice. I acknowledge that district-level instructional coaches often have a variety of different clerical duties in their role. However, in this dissertation, I am studying instructional coaches whose role is primarily dedicated to working with teachers in the classroom.

This study pursues the following research questions:

Research Questions

1. How do district-level instructional coaches mediate teachers' translation of policy to shifts in instructional practice?
    a. What interpretive frames about reform teaching do coaches use when making decisions to support teacher learning?
    b. How do coaches' sense-making frameworks influence how they interact with teachers when supporting them in learning to enact reform-related instructional

practice?

2. How do instructional coaches interact with individual teachers to enact new reform-related instructional practice through their participation in a year-long, job-embedded professional development?

Literature Review

Over the past three decades policy makers have made considerable efforts to improve public education with standards-based reforms. Although many standards-based reforms that have emerged since the late 1980's focused on specifying content and skill-based instructional goals, some states began to design standards-based reforms that aim to improve the level of academic rigor in classrooms with more challenging academic content and student engagement with disciplinary activity (McDermott, 2006; Smith and O'Day, 1991; Spillane, 2004). Such reforms called for "higher standards for all students' oriented around challenging subject matter, acquisition of higher-order thinking skills, and the application of abstract knowledge to solving real-world problems" (McLaughlin & Shepard, 1995, as referenced in Swanson and Stevenson, 2002, p.3).

Following in this tradition, the Next Generation Science Standards ("NGSS") (NGSS Lead States, 2013) aim to improve the level of rigor in science classroom instruction and provide all students with an internationally benchmarked science education so that students are better prepared to participate in the world global economy. The NGSS are a set of content standards that focus science instruction around three domains of learning: (1) science and engineering practices, (2) themes that cut across science domains, and (3) disciplinary core ideas. In addition to new changes in science content, the NGSS are also calling for changes in how teachers and students interact with the content. By explicitly stating that students need to engage in learning science content through various science and engineering practices, the NGSS are suggesting that teachers will need to shift their role in the classroom. However, while the science and engineering practices of the NGSS describe the broad context for learning content, the NGSS does not say anything about the design and enactment of instruction, which leads many to

wonder what NGSS instruction looks like. What seems clear is that current reforms are not addressed merely by aligning teaching with new curriculum or by creating instructional resources for teachers to use. It is calling for fundamental changes in how teachers interact with students and their science ideas. If such changes in instructional practice are going to be realized through the implementation of NGSS, then the challenge is one of supporting teacher learning.

The following sections of this literature review pull together important ideas from a wide range of research related to policy implementation, sense-making, teacher learning, professional development and instructional coaching. The following sections of this literature review will further explain 1) major lessons learned about policy implementation aimed at instructional change, 2) the importance of teacher-sense-making (or teacher learning) during implementation, 3) "best practices" for supporting teacher learning with professional development, and 4) coaches as critical system actors who support teacher learning. The literature review will conclude with an overview of Ambitious Science Teaching practices and how they are related to supporting the implementation of the Next Generation Science Standards.

Lessons Learned from Policy Implementation, the Larger Context

One of the most important lessons learned from reform implementation research is that policy cannot always mandate action at the local level (McLaughlin, 1987). This happens for a variety of reasons, ranging from a lack of clarity about the means to achieving reform goals to principals buffering their teachers from instructional change. Some researchers explain that large-scale standards-based educational reforms are hindered when teachers lack the motivation or skills to implement new policies (McLaughlin, 1987; Meyer & Rowan, 1978), while others cite the variations of individual's interpretations of the intent of reform (Cohen & Hill, 2001; Elmore, 2004; McLaughlin, 1987; Spillane, 2004).

There have been many attempts in history to mandate the implementation of large-scale standards-based reforms with accountability policies that specify learning targets measured by student performance on standard-aligned assessments (Elmore, 2004; Fullan, 2006; Fullan & Knight, 2011; Hopkins et al., 2013; McDermott, 2006; Mintrop & Sunderman, 2009; Moon et al., 2007). *No Child Left Behind (NCLB)* and *Race To The Top (RTTT)* are prominent examples of how policy-writers have focused on improving public education using standards and accountability strategies. Both *NCLB* and *RTTT* emphasize that student achievement on high-stakes testing is the primary measurement used to demonstrate learning and teacher effectiveness (Berry, 2005; Hull et al., 2014; McDermott, 2006: Nelms, 2004). Due to the policies that accompanied *No Child Left Behind*, student performances on state-wide, high-stakes achievement tests are the most common data used to compare student learning, teacher effectiveness and teacher compliance with implementing the new standards-based reforms (Ferris, 1992; Hull et al., 2014; Nelms, 2004).

Unintended consequences develop when policy attempts to mandate implementation of new reforms. *RTTT*'s requirement to build a longitudinal data system ultimately defines "all the children in some communities as successes and almost all those in others as failures," (Meyer & Rowan, 1978, p.87). To avoid public embarrassment for producing low test scores, local actors, such as district administrators and school principals, adopt local standards of what constitutes as a success or failure. Administrators can develop strategic "buffers" to protect teachers from public scrutiny and instructional intrusions of standards-based reform (Daly and Finnigan, 2010; Elmore, 2000; Kelly, 2004; Marsh, 2012; Spillane et al, 2002; Spillane et al., 2010).

Accountability pressure causes under-resourced schools to become hyper focused on improving and maintaining high scores on high-stakes assessments rather than on improving

teacher practice to support rigorous student learning (Chrispeels, 1997; Cohen & Hill, 2001; Firestone et al., 2008; Mintrop & Sunderman, 2009; Moon et al., 2007; Murnane and Cohen, 1986; Slavin et al., 2012). "'High-stakes' test-score indicators will lead most teachers (often through local administrative mandates) to spend a considerable portion of their energy doing whatever it takes to help students raise their test scores. Whatever else they may want to accomplish instructionally is likely to become secondary" (Oakes, 1989, p.184, also see Darling-Hammond, 1990). For example, narrowing the curriculum is a strategy that under-resourced schools often fall back on when they decide that the state-mandated standards are too challenging for its students (Crocco & Costigan, 2007; Heafner & Fitchett, 2012; Lasky, 2012; Paige, 2006,). When faced with the dilemma of improving test scores with limited resources, teachers tend to focus on test content and lower the level of rigor in lessons through by increasing their use of test-prep teaching practices (Chrispeels, 1997; Darling-Hammond, 1990; Darling-Hammond, 2007; Darling-Hammond et al., 2012; McDermott, 2006; Spillane, Parise & Sherer, 2010). Such practices have a negative impact on student engagement in learning and contribute to increased dropout rates in low-socioeconomic areas (Betts & Costrell, 2001; Ludke & Boing, 2012; Nelms, 2004).

Not all problems that develop are a result of system-level pressures, rather they originate in how individuals interpret the reform and accountability policies. Studies of policy implementation suggest that large-scale standards-based reforms are unsuccessful during implementation because districts and teachers are left to develop their own interpretations about how the policy relates to practice (Coburn, 2001; Elmore, 2004; McLaughlin, 1987; Spillane, 2004). Some reforms do not clearly describe how teachers are to change their instruction when implementing the new standards (Chrispeels, 1997; Darling-Hammond, Amrein-Beardsley,

Haertel & Rothstein, 2012; Elmore, 2000; Fullan & Knight, 2011; Hargreaves & Fullan, 2012; Johnson, 2012; McDonnell, 1994; McLaughlin, 1987; Meyer & Rowan, 1978; Spillane, Reiser & Reimer, 2002). When teachers have to sort through a "barrage of messages" about policy, teachers intentionally distort the policy so that it fits in with their individual classroom "interests and motives" (Groggin, Lester & O'Toole, 1990, as referenced in Hill, 2006, p.67). McLaughlin (1990) states that "consequences of even the best planned, best supported, and most promising policy initiatives depend finally on what happens as individuals throughout the policy system interpret and act on them" (p.172).

Research has found that local instructional leaders are critical capacity-building resources who can help teachers navigate the ambiguities of reform and influence change in classroom practice (Coburn, 2001; Chrispeels, 1997; Cunningham, 2007; Elmore, 2000; Hulls et al., 2014; Fullan & Knight, 2011). Developing teacher leaders who are experts in content knowledge, curriculum and high-leverage pedagogical practices can support teacher learning and influence teaching practice in a large-scale reform effort (Firestone et al., 2008). As a result, districts are developing informal and formal leadership roles where experienced teachers are positioned as pedagogical experts and are given tools and time to work with peers around problems of practice and teacher learning (Coburn, 2001; Elmore, 2000; Fullan & Knight, 2011; Fullan, 1995; Fullan; 1996). Formal leadership roles have been found to influence how teachers plan and organize instruction in-house collaborations (Spillane & Kim, 2012). Instructional leaders also influence the types of conversations teachers have about assessment data, curriculum and instruction (Spillane, 2012). It is reasonable to assume that how leaders frame messages about the NGSS will influence how teachers shape their conversations about the standards (Coburn, 2001; Datnow, 2012). Leaders impact teachers by influencing where sense-making happens and what

teachers make sense of by privileging certain message about policy reforms and by being "strong voices in the construction of understandings, and by structuring the collaboration in formal settings" (Coburn, 2001, p.160). To successfully support large-scale implementation, districts have considered how to coordinate multiple complementary leadership roles to support teacher learning with meaningful feedback and guidance (Darling-Hammond et al., 2012; Firestone & Martinez, 2007; Hull et al., 2014).

In summary, the lessons learned from the research focused on policy implementation point out that policy cannot mandate what happens at the local level and that successful change requires a strategic balance of pressure and support. However, unintended consequences tend to develop when policy attempts to mandate implementation with pressure around standardized achievement scores because individuals tend to respond to what they are held most accountable for (like improving scores with test-prep practices) rather than focus on improving instruction to support the development of rigorous learning environments. Perhaps the most important lesson learned from policy implementation points to the power of individual interpretation (or sense-making) of reforms because actors like teachers and administrators impact learning most directly.

Importance of Individual Sense-Making in Policy Implementation

Supporting teacher sense-making is a critical component of teachers learning to enact new reform-related practice. As Spillane et al. (2006) suggests, "viewing implementation failure exclusively as a result of poor policy clarity or deliberate attempts to ignore or sabotage policy neglects the complexity of the human sense-making process consequential to implementation" (p.47). The reforms central to this dissertation—the NGSS—are based on a set of content standards that specify what student should learn and be able to do. Like many previous large-

scale standards-based reforms, the NGSS do not translate into behaviors for teachers to enact in their classrooms. Therefore it can be assumed that there will be a great deal of discretion and room for interpretation during implementation (McLaughlin, 1987; Spillane et al., 2002). Sense-making is a useful framework when trying to explain how teachers will develop different interpretations of the NGSS (Allen & Penuel, 2014). Research has provided strong evidence to show that teachers do not "simply assimilate new texts and curriculum guides" (Cohen & Ball, 1990, p.1) when implementing new standards-based reforms. "When teachers changed in response to the policy, they did so in terms of their pre-existing practice, knowledge, and beliefs. They reframed the policy in terms of what they already knew, believed, and did in classrooms" (Cohen & Ball, 1990, p.1 also see Elmore, 2004, Hill, 2001; McLaughlin, 1987; McLaughlin, 1990; Spillane et al., 2002, Spillane, 2004; Spillane, 2012).

Individuals develop their understandings about policy messages and ideas through a complex, social, sense-making process. Whether they are consciously aware of it or not, individuals are constantly engaging in sense-making to better understand something that they do not fully understand (Gioia, Thomas, Clark & Chittipeddi, 1994; Gioia & Mehra, 1996; Weick, Sutcliffe & Obstfeld, 2005). As part of an "adaptive sense-making process" (Weick et al., 2005, p.413), individuals simultaneously modify their pre-existing "frameworks" and "routine practices" when they encounter and interpret new knowledge and experiences (Coburn, 2001; Coburn et al., 2009; Gioia & Mehra, 1996; Gioia et al., 1994; McLaughlin, 1987, Wieck et al., 2005). However, sense-making research also states that it is difficult to change a person's deeply-rooted beliefs, values and practices. Due to the rational limits of individuals' continuously evolving frameworks, and an individuals' natural inclination be risk averse, individuals fall back on actions that have been the most successful, based on their past

experiences (Simon, 1991). In particular, individuals tend to plan retrospectively, where their most recent past experiences are the most influential in their decision-making (Denrell & March, 2001; Gioia & Mehra, 1996; Wieck et al., 2005). Individuals tend to simplify their actions by adapting new policy with already existing routines (Wieck, 1996; Wieck et al., 2005). Intentional or not, individuals under stress tend to regress to what they know best, holding true to their initial frameworks (Gioia & Mehra, 1996; Wieck, 1996; Wieck et al., 2005).

Collective sense-making. Recent research has found that teachers engage with a wide variety of formal and informal social networks when understanding new educational policy in relation to their teaching practice. Research also stresses the importance of accounting for the social networks that teachers engage in during sense-making and specifically who teachers interact with (Coburn, 2001; Coburn et al., 2012; Datnow, 2012; Dorner, Spillane & Pustejovsky, 2010; Penuel, Frank, Sun, Kim, & Shingleton, 2013; Spillane & Kim, 2012). Teachers tend to interact with other professionals who have similar perspectives (Coburn, 2001). Groups of teachers working together tend to mediate educational reforms so that they align with their perspectives (Siskin, 1997). Penuel et al. (2013) observe that:

> Policies may set the stage for adopting particular practices and direct resources towards certain kinds of supports and not others through kinds of curriculum and professional development programs they incentivize. Interactions with colleagues, however, mediate the response to these directions and incentives in ways that can produce outcomes that diverge widely from policymaker's intentions. (p.27)

It is therefore important to consider the relationships that teachers have with other teachers when they engage as groups of sense-makers (Spillane & Kim, 2012). Teacher relationships in a group will impact the type and amount of knowledge that is transferred

between individuals, thus impacting the common understanding that groups of teachers can develop (Coburn, 2001; Coburn & Woulfin, 2012; Simon, 1991; Siskin, 1997). For example, teachers who have similar frameworks or worldviews will not necessarily interpret standards-based reforms in ways that challenge their pre-existing ideas about classroom instruction. As a result, they will conflate the new policy with their existing framework and routine practices (Coburn, 2001; Denrell & March, 2001; Gioia & Mehra, 1996; Perrow, 1986; Simon, 1991; Wieck, 1996; Wieck et al., 2005).

In summary, reform implementation depends on a teacher's understanding of a policy and the development of their understanding is more complex than local actors "transmitting messages" to them (Cohen & Ball, 1990; Hill, 2006). Large-scale standards-based reforms can vary in their success because critical actors, like teachers, develop different interpretations (individually or collectively) about the standards and how to engage in instruction to implement the new standards in their classrooms (Cohen & Ball, 1990; Cohen & Hill, 2001; Elmore, 2000; Elmore, 2004; Hargreaves & Fullan, 2012; Meyer & Rowan, 1978; McLaughlin, 1987; Spillane, 2004). Due to their various interpretations, what eventually gets implemented in the classroom may not necessarily align with the original intentions of the reform (Elmore, 2000).

Supporting Teacher Learning with Professional Development

Professional development is the principle activity that schools, districts and states use to support teacher learning during the implementation of new standards-based reforms. The literature focused on understanding professional development and teacher learning stresses a need for a dramatic change in how districts design professional learning or sense-making opportunities to support teacher learning. In the US, most of the professional learning opportunities that teachers have access to are "intellectually superficial, disconnected from deep

issues of curriculum and learning, fragmented and noncumulative" (Ball & Cohen, 1999, p.214; also see Cohen & Hill, 1997; Cohen & Hill, 2001; Little, 1993; Spillane, 2004; Elmore, 2004). Research has found that teachers can participate in professional development purposed at learning new standards, content, and practices, but may never actually change their own approach to teaching and learning in their classrooms (McLaughlin, 1987; Schorr, Firestone & Monfils, 2001; Weiss et al., 2003). Considering the lessons we have learned about how schools respond to accountability pressures (see above sections), it is not surprising that administrators and professional development providers tend to design professional development opportunities for teachers that are focused on improving student outcomes on standardized test scores, rather than improving teacher learning and knowledge of high-quality instruction related to improving test scores (Firestone et al., 2008).

There are specific components of professional learning that can prompt teachers to change their classroom practice. Implementation of large-scale standards based reforms are most successful when teachers participate in extended learning opportunities aimed at implementing new standards through improving teaching practice (Cohen & Hill, 2001; Elmore, 2004; Spillane, 2004). According to Desimone (2011), there are five features of effective professional development. 1) Professional development activities should have an explicit content focus related to content-specific subject matter and pedagogical-specific subject matter. 2) In professional development, teachers should be active learners by engaging a multitude of activities such as observing and receiving feedback, analyzing student work. 3) Effective professional development should have coherence between what teachers learn in other professional development activities, teacher's knowledge and beliefs, and with school, district or state reform policies. 4) Teachers should also participate in professional development activities

that extend over time. Extended learning opportunities typically last for at least three consecutive days (Cohen & Hill, 2001), allowing time for teachers to engage in deep conversations about policy and practice (Coburn, 2001). Desimone (2011) recommends that professional development should extend over a semester and include over twenty hours learning time. 5) Professional development should incorporate groups of teachers from the same grade and subject and be purposed at building an interactive learning community. (Desimone, 2011).

The literature focused on understanding teacher learning emphasizes teachers learn best when they are engaged in learning through "high-leverage" teaching practices (Ball & Cohen, 1999; Hatch & Grossman, 2009). High-leverage teaching practices are strategically designed to prompt teachers to reflect on their current teaching practices through evidence of student learning (Ball & Cohen, 1999). Teachers who engage in learning "high-leverage" (Hatch & Grossman, 2009) or "ambitious teaching" (Ball & Forzani, 2009; Cohen, 2011; Hopkins et al., 2014; Lampert 2001; Lampert & Graziani, 2009; Windschitl et al., 2010) practices tend to deliver lessons with higher levels of rigor (Hull et al., 2014; Weiss et al., 2003). High-leverage and ambitious teaching practices are not only designed improve student learning in the classroom, but they are also designed to allow teachers to learn from their own teaching practice through analysis and reflection of student ideas on a multiple types of formative assessments (Coburn et al., 2009; Black et al., 2004; Maras et al., 2012; Nelms, 2004; Windschitl et al., 2008; Windschitl et al., 2010). High-leverage practices provide teachers with an approach to analyzing their own teaching practice. High-leverage practices not only allow teachers to learn more about students and student learning but they also allow teachers to learn about their own teaching and the complexities of teaching practice so that they can better support student learning (Grossman, Smagorinsky, & Valencia, 1999; Grossman, Hammerness & McDonald, 2009; Hatch &

Grossman, 2009; Hatch et al., 2009; Lampert, 2001; Lampert, 2009; Lampert & Graziani., 2009; Windschitl et al., 2010).

"In the education of professionals, discourse serves additional purposes, which are related to building and sustaining a community of practitioners who collectively seek human and social improvement" (Ball & Cohen, 1999, p.215). During extended learning opportunities, teachers should work in groups to analyze and discuss a variety of student work and assessment data in relation to the standards-based reform policy documents to prompt discussion about how to better support student learning (Cohen & Hill, 2001; Elmore, 2004; Spillane, 2004; Spillane, 2012). During professional development, teacher conversations need to be grounded in classroom-specific curricula and assessments (Cohen & Hill, 2001) enabling teachers to visualize new practice and policy in their classrooms. Engaging teachers in conversations about their teaching practice enables teachers to learn about their practice so that they can develop better teaching practices (Hatch & Grossman, 2009; Weiss et al., 2003; Windschitl et al., 2010). Teachers need to discuss teaching strategies that build understanding about how and why a student arrives to a particular conclusion about what they are learning (Ball & Forzani, 2009; Windschitl et al. 2010). "Teaching rigorously is a complex, demanding, intellectual activity that requires the teacher to understand interactions between the content knowledge needed, the student-centered instruction required, and the student actions related to" (Hulls et al., 2014, p.xii) the content standards. Through choosing specific instructional moves and coordinating content goals to what students are thinking and how they are engaging with the material, teachers can adapt their practice to meet the learning needs of students (Ball & Forzani, 2009; Ball, Thames & Phelps, 2008; Bransford, Berlinger, Hammerness & Beckett, 2005) while implementing the NGSS.

In summary, there has been an extensive amount of research aimed at understanding how teachers learn to enact instructional practice. The literature explains that professional development needs to engage teachers in extended learning opportunities designed so that teachers can learn and reflect about new standards-based reforms through curriculum and high-leverage pedagogical practice. The question remains, however: What does that look like? How do principles for supporting student learning unfold in the classroom as "instruction"? There are few examples in the literature that clearly articulate an actionable vision of how this kind of teaching happens, especially in science. There are also few examples that make explicit connections to how the professional development purposed at learning instructional practice relates to policy implementation.

Coaches as Critical Leaders that Support Teacher Learning

Attending to the structures of professional development is important when supporting teacher learning. However, research studying policy implementation also suggests that it is important to consider how instructional leadership roles impact teacher sense-making. The literature suggests that there are many different kinds of formal and informal leaders, such as principals, coaches and peer teachers, who impact how teachers make sense of new policy and instructional practice (Neumerski, 2013). Leaders influence how teachers plan and organize instruction during planning and in-house collaboration (Spillane & Kim, 2012). Leaders also influence the types of conversations teachers have about assessment data, curriculum and instruction (Spillane, 2012). Leaders can impact teacher learning by influencing where sense-making happens and what teachers make sense of by privileging certain message about policy reforms and by being "strong voices in the construction of understandings, and by structuring the collaboration in formal settings" (Coburn, 2001, p.160). How leaders frame messages about the

NGSS will likely influence how teachers begin to interpret the standards and their implications for the classroom (Coburn, 2001; Coburn & Woulfin, 2012).

Instructional coaches are one type of local district leader that are critical capacity-building resources. They can influence change in classroom practice related to new reforms more directly than other resources (Anderson, Feldman, & Minstrell, 2014; Campbell & Malkus, 2011; Coburn, 2001; Coburn & Woulfin, 2012; Cornett & Knight, 2008; Chrispeels, 1997; Cunningham, 2007; Elmore, 2000; Fullan & Knight, 2011; Hulls et al., 2014; Killion, 2009; Mangin, 2014; Neumerski, 2013; Poglinco, 2003). Although instructional coaches are only one type of leadership role from which teachers receive messages about policy, teachers are more likely to make changes in their instructional practice when they learn about new policy messages from coaches, rather than from other sources (Coburn & Woulfin, 2012). Instructional coaches play "an important role in shaping the interplay between information, ideology, and interests" (Mangin, 2014, p.4). Researchers emphasize that "good coaching gets results—and it gets them fairly quickly" (Fullan & Knight, 2011, p. 51) because coaches influence teachers by helping them to learn and integrate new instructional approaches into their existing classroom practice (Coburn & Woulfin, 2012).

There has been a significant amount of research that highlights the importance of instructional coaches related to supporting teachers sense-making of new policy and instructional practice. However, most research focuses on describing what coaches do to support teacher learning and we know significantly less about how coaches enact their craft. In general, coaches typically engage with teachers through a broad variety of activities such as planning lessons, modeling lessons, observing instruction, debriefing observation, facilitating meetings and reviewing student data (Anderson et al., 2014; Atteberry et al., 2008; Bean, Drapper & Hall,

2010; Campbell & Malkus, 2011; Coburn, 2001; Coburn & Woulfin, 2012; Cornett & Knight, 2008; Deussen et al., 2007; Fullan & Knight, 2011; Gibbons & Cobb, in press; Killion, 2009; Neumerski, 2013; Poglinco, 2003; Spillane et al., 2003). For example, many instructional coaches use a four-step process of co-planning, observing, modeling and debriefing with teachers (Atteberry et al., 2008; Bean, Drapper & Hall, 2010; Neumerski, 2013; Spillane et al., 2003). These coaching activities or sequences of coaching activities are potentially productive (Gibbons & Cobb, in press; Mangin, 2014; Poglinco et al., 2003), however, there is little known about how coaches enact these practices with teachers.

Studies of coaching tend to focus on what activities coaches engage in, without explaining why there is variation in how coaches do the work. It is not clear what experiences actually move teacher practice or how coaches mediate teacher learning of new practice, other than supporting teachers in learning to implement model lessons with fidelity (Cantrell & Hughes, 2008; Poglinco et al., 2003). Neufeld and Roper (2003) suggest that coaching "must be focused on instructional goals and planned, but it must also be responsive to the needs of the learners and the exigencies of specific classroom situations" (Neufeld & Roper, 2003, p.20). However, they do not directly connect how instructional coaching supports change in teacher practice (Cantrell & Hughes, 2008; Neufeld & Roper, 2003). Some researchers have attempted to explain how instructional coaching supports change in teacher practice, but their evidence is limited to teacher-report out survey data (Deussen, Coskie, Robinson and Autio, 2007). Campbell & Malkus (2011) suggest that changes in student achievement on high-stakes assessments are a measure of change in teacher practice due to the amount of time coaches spent working with teachers (Campbell & Malkus, 2011). These studies, however, do not connect teacher and coach self-report data to observations of teacher instruction or coaching practice. The

connection to teacher practice is limited to describing how coaches supported teachers in learning to implement a prescribed routines (Campbell & Malkus, 2011) or implement model lessons with fidelity (Polinco et al., 2003).

In addition to describing in broad-level practices of what "good coaches" do to support teacher learning, research has also found that most instructional coaches rarely engage in work related to coaching teachers. Fullan & Knight (2011) found that most coaches spend less than 25% of their time engaging in "coaching" teachers to improve their instruction. Atteberry et al., (2008) found similar trends where coaches "engaged in the desired four-step process of planning, observing, modeling and debriefing with teachers only 4% of the time" (Neumerski, 2013, p.323). Bean, Draper & Hall (2010) found significant variability among how coaches spend their time. Despite official requirements to spend 60-80 percent of their time working in the classroom with teachers, Deussen et al (2007) found that coaches only spent an average of 28 percent of their time working in the classroom with teachers (Also see Rollers, 2006; Bean & Zigmond, 2006; Knight, 2006). Fullan & Knight (2011) found that "many coaches explained that because their roles and responsibilities were poorly defined—and because their principals weren't clear how best to employ them---they ended up doing quasi-administrative or clerical work rather than improving instruction" (p.52).

Research suggests that districts need to focus on strategically developing formal leadership roles where coaches are positioned as pedagogical experts and are given tools and time to work with teachers around problems of practice and teacher learning (Coburn, 2001; Elmore, 2000; Firestone et al., 2008; Fullan & Knight, 2011; Fullan; 1996). However, there is little in the literature that explains how instructional leaders, like coaches, interact with teachers to improve teacher learning of instructional practice. There is even less that explains why

coaches enact with teachers in different ways. While we may know some of the broad-level activities (i.e. planning, observing, modeling and debriefing) that coaches should use to support teacher learning, we know less about how coaches enact activities on a daily basis (Elmore, 2000; Leithwood, Seashore, Louis, Anderson & Wahlstrom, 2004; Lord & Miller, 2000; Mangin & Stoelinga, 2008; Neumerski, 2013; Spillane & Diamond, 2008; Spillane, Halverson & Diamond, 2004). We lack a detailed vision about how coaches interact with teachers around new instructional reforms; we know little about the "content, purpose, or focus of the coach" (Bean et al., 2010, p.90, also see Neumerski, 2013, p.324).

We know little about how coaches learn to enact practices that support teacher learning. Research has found that many coaches currently experience working environments with unclear goals and few professional learning opportunities to support them in making sense of their role (Bean et al., 2010; Deussen et al., 2007; Elmore, 2000; Fullan & Knight, 2011; Neumerski, 2013; Spillane et al., 2004). In addition, research has found that coaches receive limited support from administrators in learning how do their job. For example, "in some schools, the principals directed their coaches to take a top-down, assertive approach to their work that left little room for the professional discretion of individual teachers. Not surprisingly, the coaches' efforts prompted resistance, with little change occurring in classrooms" (Fullan & Knight, 2011, p.51). Even though the research suggests that districts need to strategically position formal leaders, like instructional coaches, as pedagogical experts who have tools and time to work with teachers around problems of practice (Coburn, 2001; Elmore, 2000; Firestone et al., 2008; Fullan & Knight, 2011; Fullan; 1996), there is still not enough understanding about what supports coaches' learning about new reform-related instruction and how to engage in practice that supports teachers in shifting instruction. Research related to understanding how coaches support

the implementation of standards-based reforms, in particular, is limited. Some research has found that even though coaches have teaching experience, few coaches have "extensive experience with standards-based reform" (Poglinco et al., 2003, p.13). Gallucci et al. (2010) "challenge the notion that people who enter their role of coaching are established experts, well-prepared to support the learning of others" and suggest that "coaches are also learners and that we know little about their professional learning processes" (p.4). Recent research suggests the importance of understanding more about how the role of a coach is framed within a district and that a "lack of congruence between district goals, coach training, and coach practices can challenge coaches' efforts" when supporting teacher learning of reform-related practice (Mangin & Dunsmore, 2014, p.205).

Ambitious Science Teaching and the Next Generation Science Standards

By explicitly identifying that students need to engage in learning science through eight science and engineering practices, the NGSS are indirectly suggesting that teachers will need to make changes in their practice to support students learning in such a way. These shifts in practice are dependent on the quality of professional learning opportunities (Allen & Penuel, 2014; Ball & Cohen, 1999; Elmore, 2004; Spillane, 2004). When considering how to structure the "curriculum" of such learning opportunities aimed at implementing the NGSS, districts and professional learning providers have engaged teachers in learning high-leverage practices that allow students to engage in sense-making and disciplinary activities such as modeling, argumentation, and evidence-based explanation. High-leverage refers to teaching practices that can be used frequently in a classroom and that have been shown to positively influence student participation and reasoning. *Ambitious teaching practices* (Thompson, Braaten, & Windschitl, 2009; Thompson, Windschitl, & Braaten, 2010; Windschitl et al., 2010) represents a pedagogical

framework that not only supports teacher learning of high-leverage practices, but also supports the implementation of the new standards and the NGSS goals of improving the level of rigor in science classroom instruction.

The framework is grounded in research about rigorous and equitable science classroom pedagogy and how teachers learn to enact changes in instructional practice over time. Ambitious teaching practices, in general, are aimed at engaging all students in classroom discourses that support student learning (Cohen, 2011; Hopkins et al., 2014; Lampert, 2001; Lampert, 2009; Lampert & Graziani., 2009; Thompson et al., 2010; Windschitl, et al., 2010). "Ambitious teaching aims to get students of all racial, ethnic, class, and gender categories to understand key subject matter ideas, participate in the discourses of the discipline, and solve authentic problems" (Lampert & Graziani, 2009; Newmann & Associates, 1996 as referenced in Windschitl, et al. 2010, p.4). The University of Washington's framework for Ambitious Science Teaching includes four sets of practices designed to provide teachers with "an evidence-informed system of learning opportunities, tools, and formative assessments" to support teachers in developing "effective and equitable classroom practice" (Windschitl et al., 2010, p.2). The four sets of practices are: 1) planning for engagement with important science ideas, 2) eliciting students' ideas to adapt instruction, 3) supporting on-going changes in thinking and 4) pressing for evidence-based explanations. The following sections will explain how Ambitious Teaching Practices support the implementation of the NGSS. These sections will pay particular attention to explaining how each of the Ambitious Teaching Practices relate to the eight science and engineering practices, cross-cutting concepts, and disciplinary core ideas.

1) Planning for engagement with important science ideas. To best support student learning, it is important for teachers to identify and build a unit of instruction around a central

"big idea" in the curriculum and standards. While this may seem like a simple task, most teachers struggle to recognize the "big idea" in content that they are teaching. Research has shown that teachers tend to "take mundane curricular topics (e.g. "glaciers", "sound", "solutions" at face value and not seek deeper or more comprehensive scientific ideas that could help students make sense of the many activities prescribed in the support materials" (Windschitl et al., 2010, p.7). Research has also found that a teacher's skill in being able to identifying the big idea in a unit of instruction "was a critical pre-condition to trying out sophisticated forms of instruction" (p.8). By focusing on unpacking the big ideas of a unit of instruction, teachers develop a deeper understanding of the content they are going to teach and are able to better focus and organize the instructional activities so that students engage in meaningful learning. This high-leverage planning practice supports teachers in developing deeper understandings about the crosscutting concepts and disciplinary core ideas that form the basis of the new standards.

Another practice in this set is selecting an "anchoring event" to situate student learning over the course of a unit of instruction. Anchoring events are complex and puzzling phenomena in the natural world. The purpose behind using anchoring events is for students to be able to develop causal explanations and models. In doing so, students are prompted to identify and integrate multiple crosscutting science concepts and disciplinary core ideas. Research indicates that "students need to see a purpose to the instruction, not necessarily the disciplinary learning goals the teacher has in mind, but some purpose that will motivate their engagement" (Weiss et al., 2003, p.41). Students learn best when teachers strategically plan units of instruction so that scientific ideas are connected to their lies in ways that allow students to apply scientific knowledge to different contexts, outside of the classroom (Ball & Forzani, 2009). Anchoring events can be a powerful tool for teachers when trying to build student buy-in to learning.

Supporting ambitious classroom discourses. High-leverage practices are strategic and discussion-heavy practices where teachers build on student background knowledge to help students gain meaningful understanding about how science content relates to real-world phenomena. Ambitious teaching practices support teachers in orchestrating rigorous ways for teachers and students to engage with each other in talking about science ideas (Cohen, 2011; Hopkins et al., 2014; Lampert, 1986; Lampert, 2009; Lampert & Graziani, 2009; Thompson et al., 2010).

The following three sections describe three ambitious teaching practices where teachers engage students in meta-cognitive discussion about science ideas. Teachers "create a discourse community working in rich problem spaces that provide all students with opportunities to engage in scientific discourse" (Kurth, Anderson & Palincsar, 2002, p.290). Supporting and developing student-to-student discourse is a critical high-leverage practice necessary to provide students with rigorous learning opportunities because it enables students to unpack meaning and interpret concepts amongst peers (Lampert, 1986; Lampert, 2001; Lampert 2009; Lampert, et al., 2009; Weiss et al., 2003).

2) Eliciting student ideas. When teachers engage in the high-leverage practice of eliciting student ideas, they use the anchoring event as a centerpiece for student discussion about science concepts. For example, in the "Tanker Implosion," a teacher would facilitate a classroom discussion about student's observations of the anchoring event, followed by an activity where students draw their initial ideas and hypotheses on a three-phase, "before, during and after" model of the tanker. In this practice, teachers utilize a variety of questioning patterns to prompt students to reveal their initial ideas and understandings of science concepts. Teachers also support the goals of NGSS by having students ask questions and define problems, and having

students develop and use models to explain science concepts related to the anchoring event. This teaching practice also supports teachers learning to become "adaptive experts" (Bransford, Berlinger, Hammerness, & Beckett, 2005) in changing instruction to better support student learning. Eliciting student ideas can formatively assess the knowledge that students have about science concepts. Having students use their everyday language and experiences in classroom conversations related to the anchoring event helps teachers gain a better understanding of student's partial understandings or alternate conceptions about science (Ball & Forzani, 2009, p.497, also see Black et al., 2004; Coburn, Toure, and Yamashita, 2009; Cohen, 2011; Lampert, 2001; Lampert, 2009; Lampert & Graziani., 2009; Maras et al., 2012; Nelms, 2004; Tatto, 2006; Windschitl, 2008; Windschitl et al., 2010; Weiss et al., 2003).

3) Supporting on-going changes in thinking. As a high-leverage practice, supporting on-going changes in student thinking is enacted several times over the course of a unit of instruction to support student sense-making across multiple lessons or activities. Research has described that in most science classrooms in the United States, students experience science by participating in daily, disconnected science activities (Carey, Evans, Honda, John & Unger, 1989; Weiss et al., 2003; Windschitl, 2008). For students to experience a rigorous learning environment and gain meaningful, deep understanding of science concepts, it is necessary for teachers to use practices that support student sense-making across activities (Hopkins et al., 2014; Hull et al., 2014; Lampert, 2001; Lehrer & Schauble, 2006; Lesh, Hoover, Hole, Kelly, & Post, 2000; Metcalf, Krajcik, & Soloway, 2000; Weiss et al., 2003).

Supporting on-going changes in thinking, helps teachers engage with four of the eight science and engineering practices: planning and carrying out investigations, analyzing and interpreting data, obtaining, evaluating and communicating information, and using mathematics

and computational thinking. In this practice, teachers scaffold sense-making conversations for students by combining hands-on activities with written work, readings and classroom conversations to support students in developing their understanding of the science concepts needed to explain an anchoring event (Rouse, 1996). For example, in a small group or whole class discussion, a teacher may prompt students with questions "How does today's reading help us better understand the results from yesterday's lab?" or "How do the data results from today's activity help us explain what is happening in the anchoring event?" Because this ambitious teaching practice is discourse intensive, teachers can also use this practice for formative assessment. By hearing how students are reasoning with science ideas, teachers can modify their instruction to better support student learning (Bransford et al., 2005, Lampert, 2001; Lampert, 2009; Lampert & Graziani., 2009).

4) Pressing for evidence-based explanations. Teachers conclude units of instruction by pressing students to develop final evidence-based explanations. Students use "words and drawings, a chain of reasoning linking observations and information from a variety of sources students have had experience with (first—hand data, second-hand data, information resources, known facts, concepts, laws, etc.) to unobservable events, structures, or purposes" (Windschitl et al., 2010, p.15) to construct an evidence-based explanation. Teachers also structure rich discussion opportunities where students are prompted to use evidence from classroom-based activities to engage in conversations, or argument, with other students. Students develop rich understanding of content when they use evidence to support claims because they develop "academic language as a resource for communicating concepts and making sense of scientific ideas within the classroom community" (Windschitl et al., p.15 also see Windschitl, 2008). While this type of instruction happens at the end of a unit, there are elements of this practice that

can occur throughout the unit of instruction when teachers ask students to think meta-cognitively about how new knowledge learned during science activities relates to their pre-existing science ideas. As a formative assessment of student learning, this type of practice reveals more usable information to inform teacher practice than measures of student learning based on multiple-choice standardized state assessments. Teachers can adapt future instruction, based on what students reveal about their understanding of the science concepts in conversation or in their written construction of evidence-based explanations.

Conceptual Framework

This study's conceptual framework draws on the literature about individual and collective sense-making to explain how and why instructional coaches and teachers develop varying interpretations of instructional practice related to implementing NGSS. It is important to understand policy implementation of the NGSS because large-scale, standards-based reforms have had a long history of unsuccessful implementation in education.

> Attention to how implementing agents interpret policy is especially relevant considering attempts over the past decade by public policy-makers to press for even more complex changes in local behavior—changes that necessitate fundamental transformations of local practice (Spillane, Reiser & Gomez, 2006, p.48).

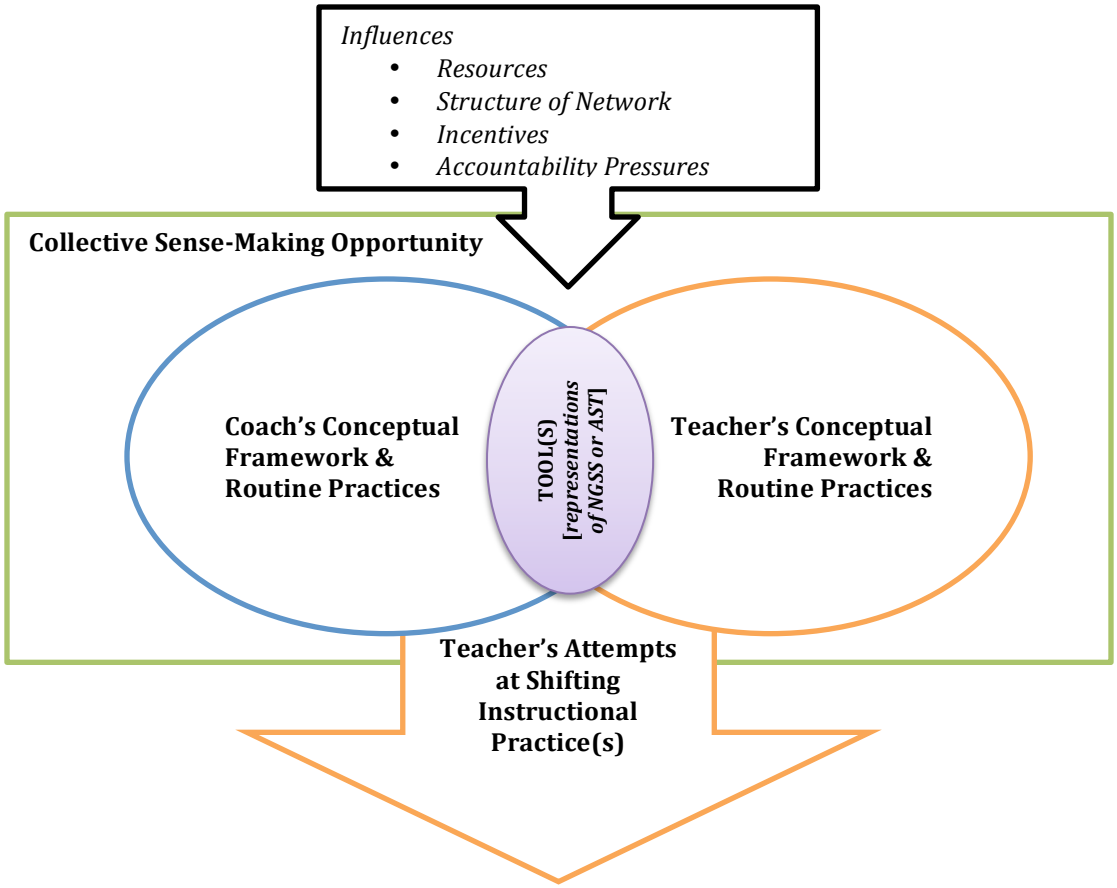
Although a wide variety of explanations for unsuccessful implementation exist, some researchers suggest that large-scale standards-based reforms are unsuccessful because critical actors in implementation develop widely varying about the standards and how teachers should engage in pedagogical practices to implement the new standards (Cohen & Hill, 2001; Elmore, 2000; Elmore, 2004; Hargreaves & Fullan, 2012; Meyer & Rowan, 1978; McLaughlin, 1987; Spillane, 2004). "From a cognitive perspective, implementation hinges on whether and in what ways local implementing agents' understanding of policy demands impacts the extent to which they reinforce or alter their practice" (Spillane, 2004; Spillane, Reiser & Reimer, 2002 as referenced in Spillane, Reiser & Gomez, 2006, p.47). In this dissertation, I incorporate components of sense-making to develop a framework for explaining how instructional coaches mediate new educational policy to instructional practice and how teachers learn to enact new instructional practice.

Although sense-making can be a social process, it is important to understand how individuals influence the sense-making that happens in a group (Harris, 1994). Teachers and coaches, alike, bring ideas and perspectives that are deeply rooted in their individualized mental frames and routine practices (Wieck, 1995; Weick, 1996a; Weick et al., 2005). Mental frames and routine practices are built from an individual's life-long compilation of knowledge and experiences. An individual's relevant knowledge and experience interact in an "interdependent relationship" (Spillane, 2004), forming "working knowledge" of a situation or state of affairs (Coburn, 2001; Coburn and Stein, 2006; Coburn et al., 2009; Denrell & March, 2001; Spillane, 2004; Wieck, 1995; Weick et al., 2005). Working knowledge informs and shapes an individual's traits, such as, values (Harris, 1994; Simon, 1991), beliefs (Coburn, 2001; Coburn et al., 2009; Harris, 1994; McLaughlin, 1987; Simon, 1991, Spillane, 2004; Wieck, 1996a), motivations (McLaughlin, 1987) and attitudes (Harris, 1994; McLaughlin, 1987; Spillane, 2004). Ultimately, these traits and working knowledge shape an individual's "mental frames" (Wieck, 2005), also called "worldviews" (Coburn 2001; Coburn et al., 2009) or "schemas" (Spillane, 2004), influence "routine practices" (McLaughlin, 1987). Mental frames and routine practices collectively filter and inform how individuals interpret and respond to presentations of new ideas or professional goals, such as educational policy.

Collective Sense-making is when a group of individuals, like teachers and coaches, interact around common ideas and practices. Collective sense-making occurs when individuals develop a common enough language and conceptual grasp of practice so that they can use each other's shared examples to advance, or make shifts in, their own practice (see Figure 1: Conceptual Framework for Interpreting New Policy to Practice).

Figure 1

Conceptual Framework for Interpreting New Policy to Practice



My conceptual framework for interpreting new policy to practice was built from components of individual and collective sense-making theories. Figure 1 represents a model of how teachers and coaches develop interpretations to collectively make sense of something uncertain (i.e. new practice or educational policy). To each interaction, both individuals (coaches and teachers) bring with them their deeply rooted conceptual framework, which includes routine practices grounded in their working knowledge, values, beliefs, attitudes and motivations. In the center of their conversations are tools, which can include common language, common practice and/or representations of policy and practice. The overlap of participant's conceptual frames with the tools is an opportunity for individual sense-making and group sense-making to occur.

From that opportunity, shifts in teaching practice could result. There are four key constructs in this conceptual frame that can impact sense-making in this framework: resources, accountability pressures, incentives and the structure of the network. Resources are anything that a participant shares with the group to aid in sense-making conversations, such as past experiences, curriculum, standards, lesson plans and activities, documents, websites, readings, and/or referencing ideas and interpretations of ideas brought to the group. Resources can also include an individual's experiences with failures and/or breakdowns. Accountability pressures are outside mandates and pressure from colleagues, teacher leaders and/or principals, school, district or state offices that motivate teacher response. Similarly, incentives are anything that motivates participants to respond in particular ways. For this research, incentives include an individual's personal frameworks, relationships to others in the group, perceptions about the group, perceptions about policy or practice, and anything related to accountability pressures. The structure of the network includes the formal and informal structures that could impact how the teachers and coaches work together, such as tools, time, group discussion, language and goals. The structure of the network is important because it teachers and coaches opportunities for interaction, the kinds of interactions that they have and what they interact about.

Methodology

This study is a case-study (Miles & Huberman, 1994) comparison to learn how district coaches support teacher learning, or "sense-making" around new instructional reforms. This research analysis is a compilation of nested cases (Merriam, 2009; Yin, 1991) using 1) individual coaches, 2) individual teachers and 3) teachers-coaches interactions as "units of analysis" (Patton, 2003). Focusing on individual teachers and coaches as a "unit of analysis" in each case allows for in-depth observations designed to capture the "subtle and iterative process" (Coburn, 2001, p. 147) by which teachers construct and reconstruct policy messages through formal and informal sense-making interactions with instructional coaches and teaching colleagues. Comparing and contrasting participants within and across groups of teachers and coaches strengthens my findings (Miles & Huberman, 1994) of how coaches support teacher learning, interpretation, and implementation of the NGSS.

Context

The district. Hill Top, an urban school district in the Northwest United States, supports a population 18,882 students and 1,071 classroom teachers. Hill Top School District has a racially diverse student body (See Table 1: School District Racial Demographics) where 21.5% of students speak at least two languages and 69.3% of students qualify for free and reduced lunch.

Table 1

School District Racial Demographics

Race	% of Student Body
Hispanic/Latino	37
White	24.1
Asian	14.3
Black/African American	11.5
Multiracial	7.6
Pacific Islander	4.3
American Indian/Alaskan Native	1.1

Hill Top School District has historically produced low student achievement scores on the state-wide student achievement assessments in mathematics and science when compared to the state average (See Table 2: Science Student Achievement.) In 2014-15, the fifth grade science passing as proficient rate was 49.7%, the eighth grade science passing as proficient rate was 45.8% and the High School Biology End of Course Assessment rate was 54.2%.

Table 2

Science Student Achievement

Assessment	District Average (%) as proficient	State Average (%) as proficient
5th Grade Science	49.7	66.8
8th Grade Science	45.8	67.2
High School Biology	54.2	70.2

Related in part to the district's low performance on state student achievement assessments, Hill Top was one of seven participating districts in a collaborative partnership that was awarded a Race to the Top Grant, a federally funded grant award. (Clarification: Hill Top's low performance on student achievement was part of the grant's needs assessment.) As a condition of receiving the award, all seven districts participating in the grant had to be focused

on improving student career and college readiness as measured by student performance on the state-wide assessment data. The grant also required that each district develop a four-year strategic plan outlining how each would support students in achieving career and college readiness.

Hill Top School District's Strategic Plan focused all school district initiatives on six goals that the district sought to achieve by 2017. The Strategic Plan centralized district-wide alignment to "Four Pillars" designed to support their instructional vision and guide for professional practice. All initiatives related to teaching, leadership or organizational practices had to be aligned with the following: 1) *Equitable Access* to rigorous, standards-based instruction, 2) *Results Focused* professional learning and collaboration, 3) *Strong Partnerships* with families and community, and 4) A *Culturally Responsive* organization. The following paragraphs describe the Science Academy, a district-developed program aimed at supporting the improvement of student achievement in science.

The Science Academy. To support their work in implementing the strategic plan and improve student performance in science achievement, Hill Top Public Schools engaged in a partnership with a local university's science education group. The district administrators, instructional coaches and university researchers collaboratively designed an innovative teacher professional development program called the "Science Academy." The Science Academy was a two-year long, job-embedded professional learning opportunity designed to support the implementation of the NGSS in seven of the district's most under-resourced and lowest performing schools. The Science Academy focused on supporting teachers in schools that were ranked as having the lowest student performance on the state-wide science assessment.

The goal of the Science Academy was to build a network of elementary teacher leaders as science specialists. The network's purpose was to build capacity and awareness in the district to support the implementation of NGSS, as well as to improve overall teaching. The Science Academy's NGSS implementation strategy was for teachers to collaboratively learn the new standards through the NGSS-aligned instructional practices of Ambitious Science Teaching.

The Ambitious Science Teaching Framework ("AST") is a set of high-leverage instructional practices developed by the local university's Ambitious Science Teaching Research Group (www.ambitiousscienceteaching.org). AST practices and tools are designed to support teacher learning of better instructional practice that is aligned to the NGSS and the vision of instructional practice in the *Framework for K-12 Science Instruction*. AST comprises a set of teaching practices designed to support teachers in developing and sustaining a highly rigorous and equitable learning environments. There are four "meso-level" practices of Ambitious Science Teaching: 1) planning for engagement with important science ideas, 2) eliciting students' ideas to adapt instruction, 3) supporting on-going changes in thinking and 4) pressing for evidence-based explanations. The four practices, as a group, incorporate seven characteristics of Ambitious Science Teaching designed to provide teachers with an evidence-informed system of learning opportunities, tools, and formative assessments to support teacher's in developing effective and equitable classroom practice. The seven characteristics of Ambitious Science Teaching are 1) Anchor Learning: Teachers anchor students' on-going learning experience in the press to understand complex and puzzling science phenomena. 2) Students' Ideas Used as Resources: Students' everyday ideas, experiences, and questions are treated as resources for the classroom community to advance everyone's thinking. 3) Complex Understandings Get Built Over Time: Learning experiences are sequenced to help students build toward cumulative

understandings of "big science ideas." 4) Talking is Thinking: Teachers provide varied opportunities for students to reason through talk. 5) Students Engage in Science Practices for a Purpose: Students are apprenticed into using ensembles of scientific practices to test ideas they believe are important to their developing explanations and models. 6) Making Thinking Visible and "Working on Ideas" Together: Student thinking is made visible and subject to critique by the classroom community and 7) Scaffold Talk, Writing & Participation: Students have access to specialized tools and routines that support their attempts at science-specific forms of writing, talk, and participation in activity. During professional learning activities, instructional coaches focused on supporting teachers to enact the practices and the seven characteristics of Ambitious Science Teaching.

District science instructional coaches, aided by researchers from the local university, facilitated all phases of professional development. During the first phase, teachers attended a five-day professional development institute to learn about the ambitious science teaching practices with district-written curricular units of instruction, that were aligned to the NGSS. During the Summer Institute, teachers learned about the Ambitious Science Teaching framework and had opportunity to practice enacting parts of the framework with students during a summer "science camp." Each day of the summer institute, teachers and district instructional coaches co-debriefed their experiences and co-planned instructional tasks for the following days activities. The first half of each institute day was devoted to having groups of teachers co-teach science and mathematics lessons to groups of incoming fifth and sixth grade students. Morning sessions were followed by an afternoon debriefing and co-planning session (without students) where teachers reflected on instruction and student learning.

The second phase of the Science Academy occurred throughout the school year in the form of three kinds of structured professional learning activities

- Studio Days
- After School Professional Development
- In-the-Classroom Coaching

All of these types of professional learning were planned and facilitated by instructional coaches. Learning was purposed to support teachers in learning to enact the new NGSS-aligned district units of instruction through Ambitious Science Teaching. Throughout the school year, each teacher learned and enacted three new units of instruction. At the beginning of each unit, teachers attended a three-hour after-school session to learn about the new kit-based units of instruction that they were to implement in their classrooms. Mid-course through implementing the unit, teachers attended a full-day of professional learning called a Studio Day. During studio days, teachers and instructional coaches co-planned, co-taught an instructional lesson in unit. During co-teaching, participating teachers focused on collecting student data (written & verbal evidence) as evidence of student learning that was used in a co-debriefing session. Throughout each unit, teachers received additional one-on-one in-classroom support from their assigned instructional coach purposed at supporting teachers in enacting the units through an NGSS-aligned/AST-aligned vision of instructional practice.

Participants. The participants in this study are composed of a "criterion sample" (Kuzel, 1992; Patton, 1990). All participants were chosen to be a part of this study because they were either teachers or instructional science coaches who participated in the Science Academy for the entire year. I recruited both district science coaches who facilitated all phases of professional learning for the Science Academy. Each instructional coach was partnered with three classroom

teachers and they provided individualized coaching support, focused on the uptake of Ambitious Science Teaching practices and the implementation of the district-written, NGSS-aligned units of instruction. Sara and Claire are the two coaches in the Hill Top School District that worked with the Hill Top Science Academy. Sara has worked in the district for twenty years, working as a science instructional coach for the past five years. Claire is also an elementary science coach in the district. However, Claire is an employee of the local university and her coaching time has been contracted to the district by the university as part of a grant project. Claire also works as a science methods instructor for the university's elementary teacher education program. Prior to her work in the university, Claire worked as a district instructional coach in Texas for four years. (See Table 3: Instructional Coach Participants)

Table 3

Instructional Coach Participants

Coach	Years of Coaching Experience in District	Primary Affiliation	Teachers they *primarily* worked with in the classroom coaching.
Claire	2 – Hill Top (*4 – Other District)*	University	Amanda Johanna Ellie
Sara	5- Coaching (*20 working in District Office*)	District	Hank John Bryn

The elementary teachers who participated in this study were either fifth or sixth grade science teachers. All teachers in the study were certified elementary teachers by the state of Washington, participated in the Science Academy throughout the entire school year. (See Table 4: Teacher Participants)

Table 4

Teacher Participants

Teacher	Grade Taught	Total Years of Teaching Experience	Years of Teaching Experience in District	Subject Taught during year
Johanna	5	3	3	Science, Writing
Ellie	5	5	1	Science, Writing
Bryn	5	3	3	Science
Hank	5	1	1	Science, Math
Amanda	6	7	2	Science, Writing
John	6	5	1	Science, Writing

Data Collection

Data collection in this study entailed following a group of elementary science teachers and two instructional coaches from summer 2014 to the end of the school year in 2015. In "an attempt to gather in-depth data on the content and organization of an individual's knowledge" (Grossman, 1989, p.25), I collected "comparable data points (Miles & Huberman, 1994) related to each participating elementary teacher and instructional coach. Collecting multiple data points and sources were necessary to "provide a base for exploring how policy was implemented and sustained across time and actors" (Chrispeels, 1997, p.457) and provided "contextual validation" (Diesing, 1972; Lincoln & Guba, 1985) to the findings analysis. To "collect recurrent instances of events across a wide range of events in the setting, so that the typicality or atypicality of certain event types within their attendant characteristics could be established" (Erickson, 1986, p.143), I collected observational data, interview data, survey data and artifacts. This was necessary in my study because "once a proposition has been confirmed by two or more measurement processes, the uncertainty of its interpretation is greatly reduced" (Webb,

Campbell, Schwartz, Sechrest, & Grove, 1966, p.3, as referenced in Lincoln & Guba, 1985, p.306).

The focus of this study was to understand how teachers collectively and individually make sense of new reform-related policy aimed at influencing practice. A second aspect of this study was to develop understandings about how instructional coaches use tools and interact with teachers to support shifts in teacher instructional practice. Based on the sense-making literature, I focused data collection on potential influences of individual and collective sense-making (Table 5: Categories of Influences on Individual and Collective Sense-making) and influences on supporting shifts in teacher practice (Table 6: Categories of Influences on Supporting Shifts in Teacher Practice). Several of these influences played significant roles in coach and teacher practice, and are reflected in the conceptual framework used in this study.

Table 5

Categories of Influences on Individual and Collective Sense-making

Construct	Indicators
Resources	Anything that a participant shares with the group during to aid in sense-making conversations, such as past experiences (stories/narratives), curriculum, standards, lesson plan and activities, documents, websites, readings, referencing ideas and interpretations of ideas brought to the group, failures and breakdowns.
Accountability Pressures	Outside mandates, obligations and pressures from colleagues, teacher leaders and/or principals, school, district or state offices that motivate teacher response. For example, if a participant mentions a principal's request for teachers to comply with certain amounts of classroom instruction dedicated to math and literacy, then teachers may feel accountability pressures from the principal to focus classroom instruction on math and literacy.
Incentives	Anything that motivates participants to respond in particular ways, including their personal frameworks, messages about NGSS or AST, or messages from district or principal related to district/school initiatives.

Structure of the Network	The formal and informal structures of the Science Academy network including tools, time, group discussion, language, goals, and relationships to others in the group, perceptions about the group,

Table 6

Categories of Influences on Supporting Shifts in Teacher Practice

Construct	Indicators
Coach's Organizational Frame	Any representation of the NGSS or AST, any story intended to serve as an organizational functions, tasks the coach engages teachers in doing for sense-making, any distributed materials
Teacher Frameworks	What tools teachers use frequently to support their instructional practice and how teachers talk about tools in relation to their practice. How teachers talk about science, the NGSS, and AST in relation to what they do in the classroom. How teachers talk about student learning and classroom instruction. How teachers collaborate or talk about collaborating in a socio-professional culture.
Tools	Curriculum, worksheets, tasks or language that teachers and coaches use to directly support instructional practice.
Shifts in Practice	How teachers interact with students around content throughout the year, including • How teachers implement components of Ambitious Science Teaching • How teachers focus science instruction • How teachers attend to student ideas during instruction • How teachers frame activities and intellectual work in classroom practice • How teachers scaffold instruction to support students in developing causal explanations

Observational data. To ensure prolonged engagement with data collection opportunities and to learn to "ascertain the degree to which teachers use reform-related instructional approaches" (Coburn et al., 2012), I collected observations for each participating teacher and coach in a variety of formal professional development settings. I collected observational data when elementary teachers and coaches met in larger groups (i.e. Summer Institute, Studio Days and After-School Professional Development Sessions), as well as several individual or partner coaching sessions where the instructional coaches observed and debriefed lessons with teachers. Observing teachers and coaches in formal professional development settings enabled me to look at events that occur at the system level (Erikson, 1986).

A. Summer Institute (Summer)

Participating teachers attended a five-day professional development institute in August designed to teach and enact ambitious pedagogical teaching practices with curriculum aligned to the Next Generation Science Standards (NGSS). I observed participants and recorded field notes of teachers and coaches interacting during the summer institute (See Appendix A: Teacher Sense-making and Perceptions Observational Rubric).

B. Studio Days & After-School Professional Development Sessions (during school year)

Participants attended two day-long Studio Days and three After-School Professional Development sessions throughout the school year(s). I observed participants and recorded field notes of teachers and coaches interact during studio days (See Appendix A: Teacher Sense-making and Perceptions Observational Rubric).

C. Individual Classroom Observations & Coaching Support (during school year)

Teachers received continuous coaching support throughout the study. Throughout the school year, I observed teachers and coaches interactions in the classroom (See Appendix A:

Teacher Sense-making and Perceptions Observational Rubric) while taking observations on how teachers implement AST in the classroom (See Appendix B: Teacher Practice Classroom Observation Rubric). Teachers and coaches also videotaped themselves during these observations and used video to reflect upon their teaching practice with coaches. Coaches and teachers will meet after the lesson to discuss student learning. I observed participants and recorded field notes of how teachers and coaches interacted during individual classroom observations and debriefing sessions.

Table 7

Collected Observation Data

Type of Observation	Total Hours **estimated*	Teachers Present	Coaches Present
Summer Institute	40	Y	Y
After School PD	18	Y	Y
Studio Day	35	Y	Y
In-the-Class Coaching	180	Y	Y
Coaches Planning Meetings	40	N	Y
District Coach Meetings	8	N	Y
Total Hours	316	268	316

Artifacts. As an "overlap method" (Lincoln & Guba, 1985) and to enhance dependability of findings, I collected artifacts from meeting and classroom observations. This is important to the credibility of my observation and interview findings because "validity of a piece of evidence can be assessed by comparing it with other kinds of evidence on the same point" (Diesing, 1972, p.148 as referenced in Lincoln & Guba, 1985, p.305). Artifacts were collected during each observation, including PowerPoint slides, all hand-outs, video of teacher/coach engagement, photos of teacher work and enactment of practice.

Interview Data. Interviews were administered at the beginning and end of the school year. Interviews were designed to reveal who teachers and coaches interact with when making sense of science instruction, and why they interact with certain people to learn more about the enactment of reform teaching (Coburn, *et al*., 2012). Following Coburn's (2001) recommendations, interviews also included questions designed to capture teacher's worldviews, descriptions of their practices, and perspectives on the reform process (Coburn, 2001). I conducted a "standardized open-ended interview" (Patton, 2003) with each of the elementary teachers and district instructional coaches to ensure that each participant was asked to respond to the same set of questions with the same set of stimuli. Using a standardized interview format allowed me to uncover systematic differences in teacher's responses to the same types of questions (Patton, 2003) (See Appendix C: Teacher Interview Protocol #1, Appendix D: Teacher Interview Protocol #2, Appendix F: Coach Interview Protocol #1 and Appendix G: Coach Interview Protocol #2). In addition, district science coaches conducted and recorded several semi-structured interviews when debriefing teachers after lessons (See Appendix E: Individual Semi-structured Lesson Debrief Interview). Based on the data collected in interviews with focal teachers and coaches, I selected additional teachers or personnel in the school and district, using the same interview questions to uncover more information about the district and teacher's network structures, and as a form of triangulating data collected from the focal teacher interviews.

Table 8

Collected Interview Data

	Pre-Interview	Post-Interview
Teachers	60 min per teacher	45 min per teacher
Coaches	60 min per coach	60 min per coach
Additional Interviews (member-checking & supplemental information)	~240 min	

Data Analysis

Data collection and analysis occurred simultaneously throughout the study (Miles & Huberman, 1994). The literature on individual and collective sense-making (described in the conceptual framework portion of the dissertation), influenced data analysis for how individual teachers, groups of teachers and instructional coaches interact to makes sense of implementing the NGSS. Using the sense-making conceptual framework allowed me to find examples of how individual teachers interpret the NGSS, based on how the policy is represented to them, their personal theories of action around science instruction, and other influences outside of the Science Academy professional development.

A main focus of my initial and on-going data analysis of professional development observations was to look for examples of how the NGSS were represented to teachers and how teachers responded to or interpreted messages about the NGSS (Chrispeels, 1995; Coburn, 2001; Cuban, 1993; Datnow, 2012; Firestone, 1989; Firestone et al., 1999; Gioia et al., 1994; Harris, 1994; Spillane, Reiser & Reimer, 2002; Spillane, 2004; Tyack & Tobin, 1994; Weick et al., 2005). During instructional coaching and classroom observations, I looked for evidence of how teachers interpreted and made initial attempts to implement the NGSS and Ambitious Teaching Practices in the classroom and how instructional coaches supported teacher sense-making and interpretation of policy to practice. Lesson planning materials, instructional materials and

samples of student work were helpful artifacts in analyzing how teachers were making instructional decisions to implement the reform-based pedagogy. After transcribing teacher and coach interviews and interactions, I looked for evidence relating to who is part of the teacher and/or coach's sense-making network, which allowed me to identify other non-focal persons to interview for supplemental data and "member checking" with participants (Lincoln & Guba, 1985). Because individual sense-making frames are very difficult to detect, I was intentional about comparing what teachers and coaches claimed during interviews to how they acted on their claims during professional learning events and/or classroom instruction. To gain initial insights and hunches about the data I collected (Merriam, 2009), I developed initial "open codes" (Merriam, 2009). These codes (See Table 9: Preliminary Open Codes) were based on the influences of individual and collective sense-making lists (Table 5: Influences on Individual and Collective Sense-making and Table 6: Influences on Supporting Shifts in Teacher Practice) described in the previous section. During early analysis of observational field notes, surveys and interviews, these preliminary open codes helped me "identify emerging themes and highlight areas for additional data collection" (Coburn, 2001, p.149).

Table 9

Preliminary Codes

Code	Description
Resources	Anything that a participant shares with the group during to aid in sense-making conversations, such as past experiences (stories/narratives), curriculum, standards, lesson plan and activities, documents, websites, readings, referencing ideas and interpretations of ideas brought to the group, failures and breakdowns.
Accountability Pressures	Outside mandates and pressures from colleagues, teacher leaders and/or principals, school, district or state offices that motivate teacher response. For example, if a participant mentions a principal's request for teachers to comply with certain amounts of classroom instruction dedicated to math and literacy.
Incentives	Anything that motivates participants to respond in particular ways, including their personal frameworks, messages about NGSS or AST, or messages from district or principal related to district/school initiatives.
Structure of the Network	The formal and informal structures of the Science Academy network including tools, time, group discussion, language, goals, and relationships to others in the group, perceptions about the group.
Coach's Organizational Frame	Any representation of the NGSS or AST, any story intended to serve as an organizational functions, tasks the coach engages teachers in doing for sense-making, any distributed materials
Teacher Frameworks	What tools teachers use frequently to support their instructional practice and how teachers talk about tools in relation to their practice. How teachers talk about science, the NGSS, and AST in relation to what they do in the classroom. How teachers talk about student learning and classroom instruction. How teachers collaborate or talk about collaborating in a socio-professional culture.
Tools	Curriculum, worksheets, tasks or language that teachers and coaches use to directly support instructional practice.
Shifts in Practice	How teachers interact with students around content throughout the year, including • How teachers implement components of Ambitious Science Teaching • How teachers focus science instruction • How teachers attend to student ideas during instruction

	• How teachers frame activities and intellectual work in classroom practice • How teachers scaffold instruction to support students in developing causal explanations

After further analysis, I re-organized the open-codes into meaningful "clusters" (Miles & Huberman, 1994) to group pieces of data that seemed aligned or "conceptually congruent" (Merriam, 2009). In addition, I modified the preliminary open codes list to include "emergent codes" The initial open codes overlooked a few critical categories that seemed to play an important role in how participants were making sense of the NGSS. (See Table 10: Modified Emergent Codes).

Table 10

Modified Emergent Codes

COACHES	
Category	**Code**
Coach Frames	References to Accountability
	References to AST
	References to CCSS
	References to NGSS
	References to Teacher Learning & Ability
	References to Instructional "Best Practice"
	References to Student Learning
Experiences	Experience as a Teacher
	Experience as a Coach
	Experience as a Student
	Coach Learning Support
	Competing Messages
	Coach Concerns about Implementing
	NGSS
Actions that Mediate Policy Implementation	Tools
	Partnerships
	Interactions with other Coaches
	Curriculum & Use of Curriculum
	Interactions with Teachers

TEACHERS	
Category	**Code**
Teacher Frames	References to Accountability
	References to AST
	References to CCSS
	References to NGSS
	References to Student Learning & Ability
	References to Teacher Learning
	References to perceptions of science as a discipline
	References to Incentives
Experiences	Experience as a Teacher
	Experience as a Student
	Competing Messages
Reference to Professional Development As Meaningful in Teacher Learning	Summer Institute
	After School PD
	In-Class Coaching
	Studio Day
	Other Professional Development
	Collaborating with Colleagues
Teacher Actions to Implement NGSS/AST	Tools
	Attending to Student Ideas
	Focus on Science Instruction
	Interactions with Students

After using the coding program, Atlas/TI, to code transcripts, observational field notes, and artifacts and using a teacher learning progression for Ambitious Science Teaching (See Appendix B: Teacher Practice Classroom Observation Rubric), I organized the coded data into meaningful "clusters" (Miles & Huberman, 1994). These clusters of coded data were used to build themes. The themes were then developed to shape my initial hypotheses about how teachers and instructional coaches make sense of how to interpret the NGSS into instructional practice. These hypotheses were then tested with continued analysis of more data. Alternative hypotheses were considered and their plausibility for explaining patterns in data was assessed.

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FINDINGS

Organization of Findings

The findings are organized into five sections: 1) understanding the differences in coach's interpretive frameworks, 2) how coaches interacted with teachers, 3) the impact of professional development on teachers learning new instructional practice, 4) teacher attempts to experiment with reform-related instructional practice and 5) teacher interpretation of reform.

Understanding the Differences in Coach's Interpretive Frameworks

Sara and Claire are the two coaches in the Hill Top School District who worked with the Hill Top Science Academy. Sara has worked as a district-paid employee for the past for 20 years, but has only worked as the elementary science coach for the past 5 years. In her past, she has attended summer institute workshops aimed at learning about coaching activities that support teachers' development of new instructional practice. Claire is also an elementary science coach in the district. In addition, she is an employee of the University of Washington and her time was contracted to the district by the university as part of a grant project. Throughout the study, both Claire and Sara repeatedly engaged teachers in learning through several common "job-embedded" coaching activities (i.e. co-planning, observation and feedback, modeling and co-teaching, and providing tools).

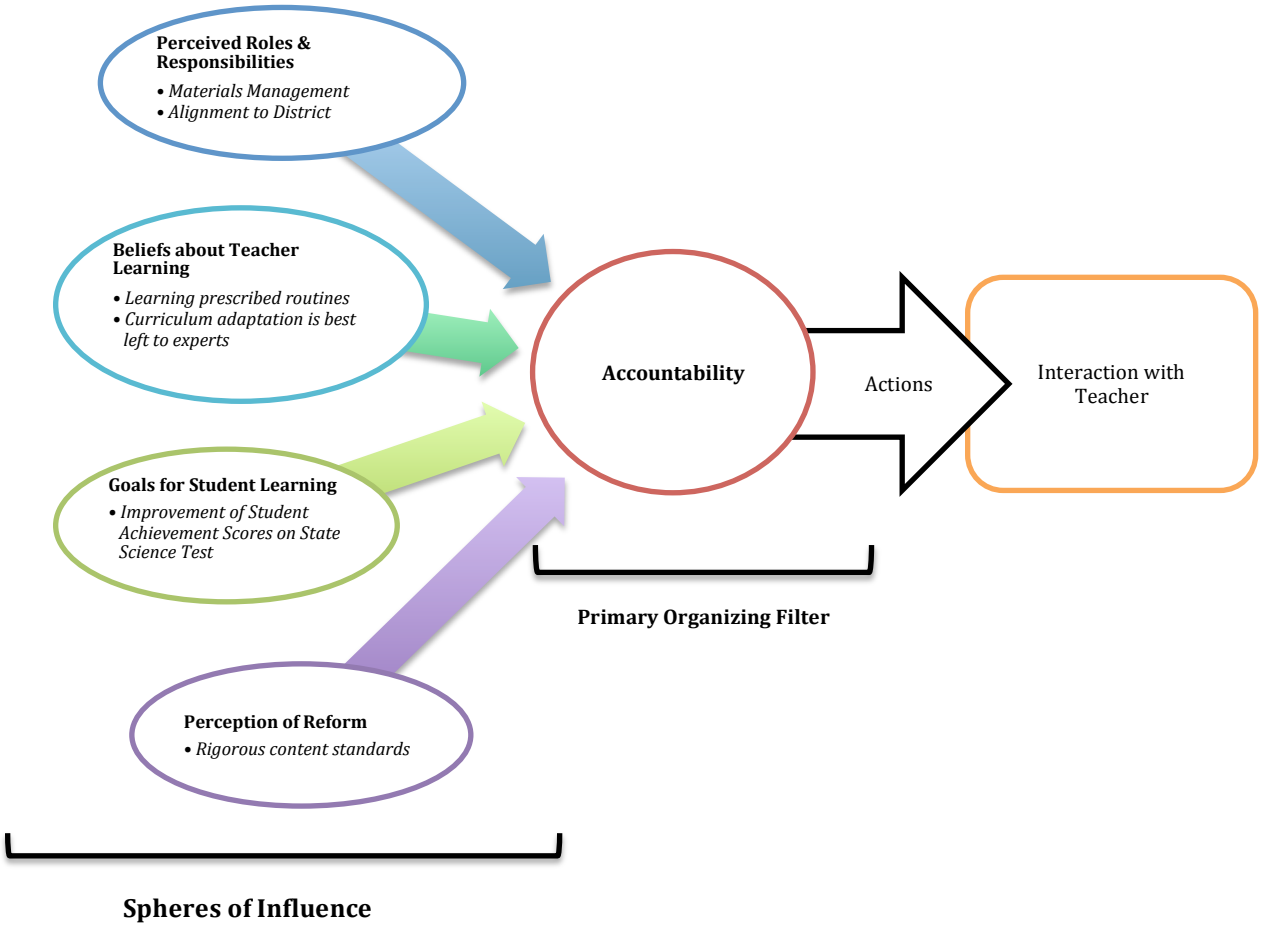
In order to understand how these instructional coaches mediated teacher's translation of policy to shifts in instructional practice, this section of the Findings will focus on explaining the coach's interpretive frames. This study found that there were four central spheres of influence that seemed to shape how coaching activities designed to support teacher learning of reform-related instruction were enacted: 1) coach's perceived roles and responsibilities, 2) beliefs about teacher learning, 3) goals for student learning and the relationship between teaching and student

learning, 4) perception of standards-based reform. These four spheres were reflected in the talk, ideas and interactions of the coaches with teachers. However, the data indicated fundamental differences in the two coaches' underlying beliefs, values, and experiences that seemed to shape how they interpreted their role when supporting teachers. Taken together, these differences in interpretation acted as a filter, or *Primary Organizing Filter*, which strongly influenced how they interacted with teachers, what they heightened teacher awareness to, and how they supported teachers in attempting to enact reform-related instructional practice.

Accountability as a primary organizing filter for Sara. Over the course of the year, Sara's work within the activity system allowed us to see how her perceptions and decision-making were filtered through the POF of accountability (See Figure 2: Sara's Interpretive Framework). This section will describe each part of Sara's larger framework, providing supporting evidence from transcript passages as well as field notes describing Sara's actions.

Figure 2

Sara's Interpretive Framework



Sara held a strong sense of professional commitment to demonstrate that her work with teachers was aligned to the school district initiatives. Throughout the study, Sara frequently referred to the fact that everyone in the district office is formally held accountable to upholding and aligning to the district-wide strategic plan. When interviewed about what was important to the school district around science instruction, Sara's strong sense of commitment to district alignment was apparent: "Right now, it's alignment in our district and it comes down to even the templates that we give consultants…presentation templates and such…it has to be aligned to our strategic plan."

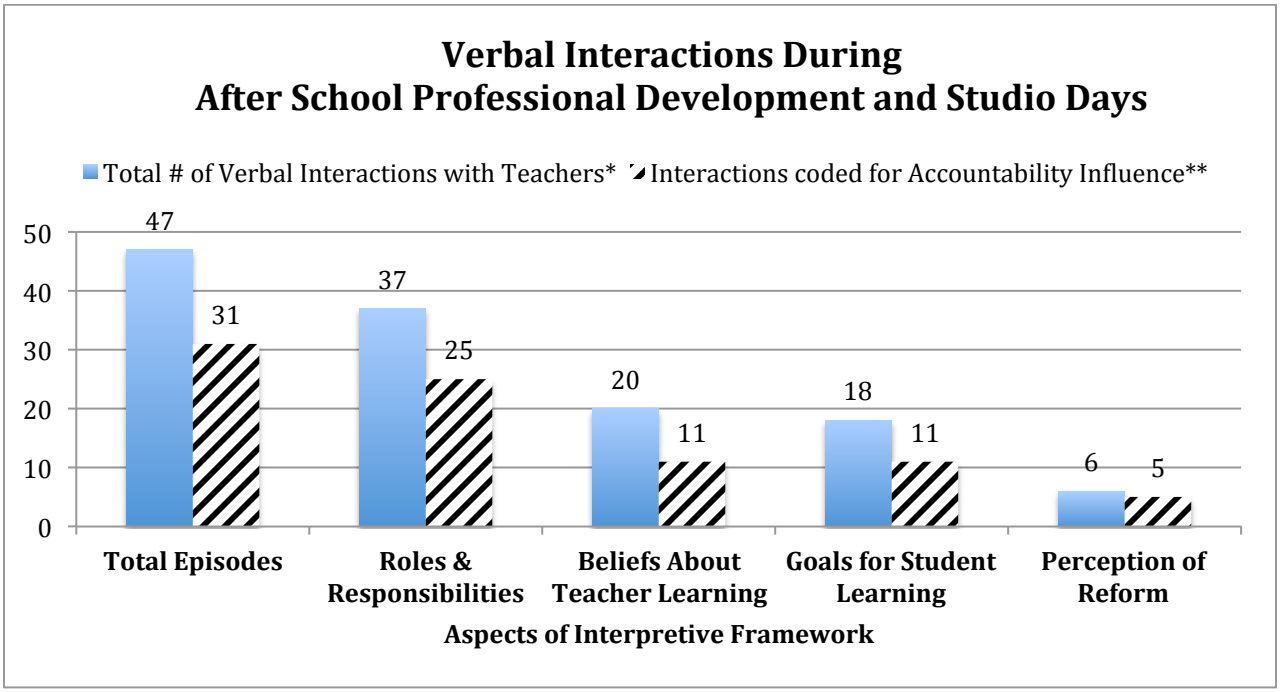
Evidence also suggests that Sara feared being perceived as non-compliant. Throughout the study, Sara referenced past experiences in the district office when individuals were found unaligned to district initiatives. Many times over the course of the study, Sara expressed fear of "getting in trouble" if someone accused them (the coaches) of not cohering their professional development to the district strategic plan. Throughout the year of this study, Sara was meticulous about documenting exactly how she was supporting the district strategic plan during each of her encounters with teachers, principals and colleagues. During interviews and coaching planning sessions, Sara stressed that everything on the professional development calendar must formally and publically document how it is supporting the district's strategic plan.

In order to understand the components of Sara's spheres of influence, I analyzed her talk during after school professional development sessions and studio days (See Figure 2: Sara's Verbal Interactions During After School Professional Development and Studio Days). I coded each passage of unbroken talk by Sara that included 1) when she was initiating some substantive part of her role with teachers, 2) interacting with teachers (i.e. responding to questions, asking teachers to provide examples, commenting on examples), or 3) responding to other non-teacher participants in the room (i.e. the other coach). A total of 47 passages were analyzed. Each passage could range from a sentence to a paragraph-length statement. Within each passage, multiple codes could be applied. For example, passages that could have codes applied for Roles and Responsibilities could also be coded for Beliefs about Teacher Learning. Of the 37 passages that were coded reflecting Sara's perceived roles and responsibilities as a district instructional coach, there were 25 instances of coding related to accountability. Sara's talk reflected that she was largely focused on alignment of teacher's work with district tools and curriculum, maintaining an awareness in teachers of other initiatives by the district that could impact science

instruction, and perceived pressure to document the work that they were doing with concern about "getting in trouble" for being perceived as un-aligned or not supporting district initiatives. Data suggests that her concerns about demonstrating alignment and consequences for being perceived as deviating from district initiatives appears to have been related to Sara's perceived roles and responsibilities, her beliefs about teacher learning, her goals for student learning and her perception of standards-based reform.

Figure 3

Sara's Verbal Interactions During After School Professional Development and Studio Days



*Totals for the four spheres of influence are more than the "Total Episodes" because a passage of talk may have more than 1 code applied to it.
**The left hand column of each code represents the total number of episodes relating to that sphere of influence. The right hand column is the subset of those utterances that can directly be linked to their primary organizing filter.

This section of the findings will describe each part of Sara's framework, providing supporting evidence from transcript passages as well as field notes describing some of Sara's actions. (Note: The next section of the findings will focus on demonstrating how Sara's POF for

accountability became more apparent over time by examining closely how Sara interacted with other actors in the system.)

Perceived roles and responsibilities. During after school professional development sessions and studio days, Sara primarily took up management-related roles such as coordinating logistics, administering and collecting paperwork and explaining to teachers how the professional learning activity was aligned to the district strategic plan. Although both types of professional development sessions were co-facilitated by Claire and Sara, Sara consistently led only portions of the sessions to justify to teachers that the professional development was aligned to the district strategic plan. The following excerpt is from an after school professional development session. Notice how Sara explained how she aligned the PowerPoint slides by simply substituting NGSS in place of the CCSS. In the same passage of talk, she referenced the district-adopted Danielson Framework to further demonstrate alignment. It appears as though Sara perceives her role and responsibility as using sanctioned district PowerPoint slides, purposed originally for CCSS, to justify the goals of the after school professional development.

> So, this is one of the standard slides, but when we do the science work when it says Common Core and the Strategic Plan, I just conveniently put in NGSS. And so that's really our connection to the strategic plan…and also what we do in sixth grade builds into that goal of last year's 9th graders are this year's 10th graders that we're tracking…but it's all kids, um, passing their courses in 9th grade and graduating college and career ready. So, and then the Danielson Framework—it's hard because so many things fit—but I wanted to pull out because we tried to build in some support in the unit for questioning—and then obviously we will be looking at science as a discipline and content knowledge too. I wanted to point

> out with the Roles and Responsibilities slide—these are the slides that we're asked to put in our professional development. (Transcript from After School Professional Development Session)

During after school professional development sessions, studio days and in-class coaching, Sara frequently took up the role of materials manager. The following excerpt is from an after school professional development session where Sara tells teachers what she thinks her role is when supporting their learning. It appears as though Sara perceives her responsibility for supporting teacher learning is to physically give teachers "documents" aligned to what they are working on.

> In my role today as a facilitator and coach…and I'll speak for Claire too…we try to, in the supporting documents that we're giving you, give you support in a couple of things. One is regular use of the summary table because that's something that we're hearing that people are trying on, so we try to be intentional about that. (Transcript from After School Professional Development Session)

Sara also focused on aligning activities to district initiatives. The following excerpt is from an after school professional development session where Sara justifies why she selects a specific tool to include in a unit plan. Notice how Sara's perceived responsibility for demonstrating alignment to district initiatives influences how she enacts her coaching role as a materials disseminator. In this section, Sara selects a specific tool, the Rapid Response for Student Thinking ("RSST"), that is used by secondary science teachers and intentionally inserts the tool into the unit plan. This transcript is one of several related to Sara's beliefs about teacher learning, because it suggests an assumption that if she provides teachers with a tool, they will acquire an understanding of it and its use with students.

> So, then we will be focusing on the phenomena, like we typically do, focusing on our own content knowledge…and using the summary table as a way to get a quick overview and a quick tour of the lessons. And then…part of this was a request from me…so one of the tools from the Ambitious Science Teaching Practices that they use quite a bit in secondary that I'm not that good at yet is the Rapid Survey of Student Thinking…and so Claire has inserted it intentionally in a few places throughout the unit. (Transcript from After School Professional Development Session)

Sara tended to advocate for teachers to adopt specific routines or tools and highlight teacher successes in using those tools or routines in their classrooms. She did not however, unpack the logic behind the tools or hint at the need to adapt them to particular circumstances. This is significant to understanding Sara's sense-making frames because it demonstrates how Sara perceived her roles and responsibilities as primarily to align teachers in the Science Academy to use the same tools and routines. The following transcript is from an after school professional development session where Sara highlights a few teachers who have "sentence starter" posters in their rooms to support student talk. Highlighting teachers successes when using specific tools seemed to be how Sara both encouraged and justified to teachers why they should take up particular tools or routines. How these tools are used is left un-analyzed.

> So I think that since we're talking about this as practices, I heard John say—and I saw it in Amanda's room too—'you know, I need to teach them that. I need to teach them how to have a discussion and share different ideas and how to respond to those ideas and press them.' Amanda does it by having different sentence starters up (points to a poster in the room). (Transcript from After School Professional Development Session)

In summary, Sara demonstrated that her perception of roles and responsibilities as a district science instructional coach was to encourage alignment to district-wide initiatives and support teacher learning by managing the distribution of district-aligned policy documents, presentations, curricular tools, and routines.

Beliefs about teacher learning. Sara's beliefs about teacher learning are inter-related to her perceived roles and responsibilities as an instructional coach. Evidence suggests that she believed teachers learn new instructional practice through the adoption and execution of prescribed routines, tools, and curricular resources. If teachers are visibly using a specific tool or enacting a prescribed routine, then teachers are assumed to have learned to enact reform-related instruction. Sara did not seem confident that teachers had the experiences to make curricular or instructional adaptations based on students' ideas.

When supporting teacher learning, Sara typically instructed and modeled for teachers a "run through" of how to enact the district units, exactly as written. During an after school professional development session, Sara broadly suggested that teachers "use [their] talents and skills to adapt and modify" the district units. However, when working with teachers in the classroom, she typically instructed teachers to implement the units with fidelity, using the tools and activities in the exact sequences that they were ordered in the unit guide. Data from her interview responses and interactions with teachers suggest that Sara believes that teachers learn to enact reform-related instruction by reproducing prescribed procedures, routines and curricular tools (designed by experts) with fidelity. An example of how Sara supported teachers in learning to enact reform-related instruction with fidelity is related to her interpretation of a teaching tool called "Back Pocket Questions." Back Pocket Questions are a set of teacher-developed questions designed to probe and press student thinking about their science ideas during an activity. Sara

interpreted this tool as a set of questions to be used in a specific, sequential order with a prescriptive approach to supporting student sense-making. During in-class coaching, when teachers asked Sara how to proceed with instruction, she directed them to use the Back-Pocket Questions ("BPQ"), as written in the unit guide. When interviewed about this tool, Sara explained:

> These questions are to be used as a flow chart—if this happens, then do this. The real craft of teaching in that 20 minutes is when kids are working in groups and teachers go around and do all of those steps (Referring to BPQ as 'steps'). (Transcript from Coaching Session with John)

Another example is Sara's interpretation of the "Summary Table" tool. A Summary Table is a tool designed to support students in developing a public representation of whole-class consensus of science ideas. It is meant to be a revisable public representation of student's science ideas. It is also a tool that teachers can use to keep track of what and how students are making sense of activities during a unit so that they can make instructional changes to better support student sense-making. Sara, however, interpreted it as a tool that teachers could use to funnel students toward a correct idea. "It focuses students on what teachers expect kids to learn out of an activity and how it connects to the phenomena." This statement seems to suggest that the value of a summary table is to direct students' attention to correct answers, rather than to be a tool for public reasoning.

When learning to enact reform-related instruction, Sara explained that teachers must first have "good, highly controlled classroom management before they can learn to enact Ambitious Science Teaching instruction." During a district instructional coach meeting, Sara highlighted that the "first studio day was a success because the teacher had impeccable classroom

management routines in place." This suggests that Sara believes that classroom management is something for teachers to work on, separate from science instruction.

Another dimension of Sara's beliefs about teacher learning was her assignment of "expert status" to individuals or groups of individuals other than teachers. Throughout many conversations related to developing tools or curriculum, Sara deferred to "experts," that she seemed to believe had a more privileged status of knowing. For example, during an interview, Sara explained that teachers are less capable of developing high quality science curriculum and stressed that she did not think teachers should be writing their own lessons. Furthermore, Sara also believed that she did not hold "expert-status" to write curriculum. Sara felt that the other coach, Claire, was capable of writing high quality science curriculum due to her affiliation with the university research group. The following is an excerpt from Sara's post interview. Notice that Sara reserves the expectation for curriculum writing for teachers who are "really good at it"—suggesting that this is a fixed skill that others may not be capable of or interested in learning.

> Kat: So earlier in the school year you told me that you didn't think teachers should write curriculum because you didn't think they were qualified to do so or have the expertise to do so. Do you still think that?
>
> Sara: I don't think it should be an expectation for all teachers. I think that there will be teachers who not only want to do it, but who'd be really good at it. I just listen to Mary, (a university doctoral student) just the amount of…you know, her apple phenomenon. The amount of reading that she did and the connections she made to that kind of stuff. Like she has a lot of motivation for doing that. A passion and time set aside because that's where she is in her career and what she's doing right now. You can't expect that from every teacher, and I don't. I think that if we had classroom teachers, particularly at

this point, writing that first grade unit…or me…I don't think we'd get the results. (Transcript from Susan's End of Year Interview)

The following excerpt is from an after school professional development session early in the project where Sara explains to teachers where their new curriculum comes from and who develops it. Notice that even though she is giving the teachers high-quality NGSS-aligned units, she considers it to be "75-85% there" and that there are publishers who will eventually produce a product that is better aligned.

> So just real quickly, in Hill Top, so you know what's been going on. In Kindergarten and first grade, we have totally switched to NGSS—and NGSS, that's just a short way of saying the Next Generation Science Standards. So with colleagues that work with Claire, we have actually modified these units and gone purely by these standards. We're thinking now that by the time these kids are in fifth grade, when they are assessed in science on some state-level test, that we will have switched entirely to NGSS. Currently, you, at fifth grade, will still have the fifth grade MSP, which tests the 2009 standards. So we're doing a slower transition. One of the reasons—and this is my personal bias—is that in a few years, publishers will actually have created materials that align to these standards. Right now, anyone who says that they have, have just jumbled things up and slapped a sticker on it. I'd like you to be able to have something that's close…75-85% there. (Transcript from After School Professional Development Session)

In summary, Sara seemed to believe that teachers learn reform-related instructional practice through the application of prescribed routines tools and curricular resources. If teachers are visibly using a specific tool and or enacting a prescribed routine, then teachers are assumed to have learned to enact reform-related instructional practice. Sara does not seem to believe that

teachers have the intellectual resources to adapt curriculum or make judgments about substantially modifying instruction from what was originally designed by more knowledgeable others.

Goals for student learning. Throughout the study, evidence from Sara's interviews and interactions with teachers, principals and other coaches, showed that Sara's goals for student learning focused mostly on preparing them to perform well on the state standardized assessment. Sara seemed most concerned with students learning correct vocabulary and facts so that they could perform well on the assessment.

Sara's focus on improving test scores was not surprising because the school district's strategic plan explicitly focuses on using student achievement data from the state assessment system as their primary measure to demonstrate success. However, it is important to note that the current state assessment is not aligned to the NGSS. The following transcript is from an after school professional development session. In this session, Sara introduces a new district-aligned unit to teachers and explains that the unit is divided into two sections with two different anchoring phenomena (science events that guide a unit of instruction). When advising teachers which section to focus student learning on, Sara advises "if you're making a choice, I would always do the piece that Claire re-wrote before I would do the second piece." Rather than advising teachers to follow the second phenomena, aimed at deepening student's conceptual understanding of science content (an NGSS goal), Sara advises teachers to spend more time focusing on teaching the portion of the unit that includes specific vocabulary, with the intention that students will perform well on the state student achievement assessment. She rationalizes this to teachers by explaining that they need to prepare students for the state assessment, even though they are shifting to the NGSS and new assessments in the near future.

> And so, the advice is, do this (Claire's re-written units), but if you have extra time, there's always that second story line that you can follow through. As we transition to NGSS where the earliest assessment is ready in 2018, it's a bit of a funny world with MSP and we want to make sure that the students have the vocabulary to be successful on the test, like "variable." (Transcript from After School Professional Development Session)

During professional learning sessions, Sara frequently pointed out to teachers' specific activities in units that would support students in performing well on the state science assessment. The following excerpt is from an after school professional development session. In the following excerpt, Claire was leading the teachers through a curriculum walk. Sara interrupted her to point out an activity that would support students in learning specific vocabulary that is assessed on the state test.

> Claire: The first lesson you'll see is the potato activity and the only reason it's first is because it takes a while to set up…a few days…the kids will see how bacteria grows on the potato over time. There are a lot of ways to do this activity and set it up with your kids. You can change all kinds of variables. The one I set up for today was super simple—just dirty hands vs. a control…(explains other variations teachers have tried)…if you want to have the students design an experiment, this would be a great activity for students to do.
>
> Sara: So if you want to get at the MSP vocabulary—manipulated and measured variables—this is a great one to do.
>
> (Transcript from After School Professional Development Session)

Throughout the study, Sara emphasized student achievement on the state science assessment and stressed this focus by developing and providing the district benchmark tests, designed to prepare students for the science assessment. The following transcript is from an after school professional development session. This shows Sara revealing to teachers that one of the goals of the Science Academy is for Sara to demonstrate student achievement improvement on standardized benchmark assessments that are aligned to the state assessment.

> We have some tests, some district benchmark tests for each of these units. Anyone can do it, but the RTT schools have to do it. These are tests with multiple choice and we're tying it to the 2009 standards….and then we have a free response question where students write a new procedure. So it's an opportunity to have them show what they know in the 2009 standards. So in fifth grade we want to be able to support you in both things because we know that that piece of data gets reported out. So that's where we are.
>
> (Transcript from After School Professional Development Session)

In the same passage of talk, Sara justifies to teachers why using Ambitious Science Teaching Practices will help teachers support student achievement by explaining how a high school teacher switched to using these practices and now has the highest student achievement scores in the district.

> One of the people, she happens to be in our office now working as a secondary science specialist with me—she switched to this (NGSS) and the Ambitious Teaching Practices—and she had the highest scores in the district on the EOC, which is the graduation requirement. And she pulled these (SEPs) and adopted the unit the way that Claire just shared (AST)…and she just kept her eye on the 2009 standards and the EOC.

> But her kids could write conclusions; her kids could do all the things the MSP asked her to do. (Transcript from After School Professional Development Session)

In summary, despite transitioning to the NGSS which engages students in different kind of conceptual science learning, Sara's goals for student learning focused primarily on improving student achievement scores on the state standardized science assessment. Sara believed that providing students with a rich vocabulary, knowledge of science procedures and a basic grasp of science concepts was a priority.

Perceptions of reform. Sara believed that the NGSS are "rigorous, but possible" science standards that are "based on what research says that we know student can do and learn and based on what is developmentally appropriate." She believed that the NGSS is a chance for the school district to "clean the slate of inquiry and the scientific method" and a chance for the district to re-visit how students really learn science. Sara explained that in the previous adoption of state standards, "inquiry" became a problematic buzzword because there was lack of consensus about what teachers were supposed to do in science instruction that supported "inquiry."

Sara recognized that the NGSS only tells teachers what students need to learn, and does not support teachers in learning how to enact instruction differently. She also does not consider the Framework for K-12 Science Education as a critical part of the NGSS that teachers need to know about. This Framework document contains the justification for the new standards, and the research that supports them. During interviews, Sara explained "teachers will learn more about the NGSS and get more out of professional development if the standards is embedded in the context of the units that teachers are learning to implement." This quote is evidence that Sara believed that the NGSS are a body of content for teachers to learn about and that teachers need to learn new tools and routines that are aligned to new standards.

Sara admitted that she has done no awareness or overview learning about NGSS with her elementary teachers.

> We have a limited amount of time to work with teachers, and the district would rather work with them on instruction, than developing their awareness and understanding about what NGSS is. We might spend fifteen to twenty minutes to discuss the architecture of the standards so they know how to read them, but then the rest of the context of professional development is focused on Ambitious Science Teaching. (Transcript from Sara's Beginning of Year Interview)

In the summer institutes and after school professional development sessions, Sara made sure to have a single PowerPoint slide and/or a single hand-out that showed teachers what NGSS standard the unit was aligned to. There was rarely any conversation about NGSS beyond reading what was on the slide. The following transcript is an example of how Sara presented the NGSS to teachers using district sanctioned slides. Notice that she focused mainly on highlighting how the slides and the professional development are aligned to the strategic plan and that she highlighted that the professional development is "connected" to the NGSS, but never explained any further connection.

> Sara: Claire had a beautiful template for this presentation but I had her change it...It is important. I've been in this district since the mid 90's. I came here because we had an NSF Grant on Science Assessment. And there are lots of good things that have happened in the past 25 years but this is the first time I've ever seen the Strategic Plan drive the work that everyone is doing in the district. They want to make sure that when we do a PD we connect it to the Danielson Framework and we connect it to the Strategic Plan and

connect it to Common Core or Next Generation Science Standards. So I'll give you a moment to read the slide.

Claire: Those always seem so lofty when you read them…it's a process, people…

Sara: Yeah, but teachers know this better than us because they're all on this evaluation system…so they have to have these components.

(Transcript from After School Professional Development Session)

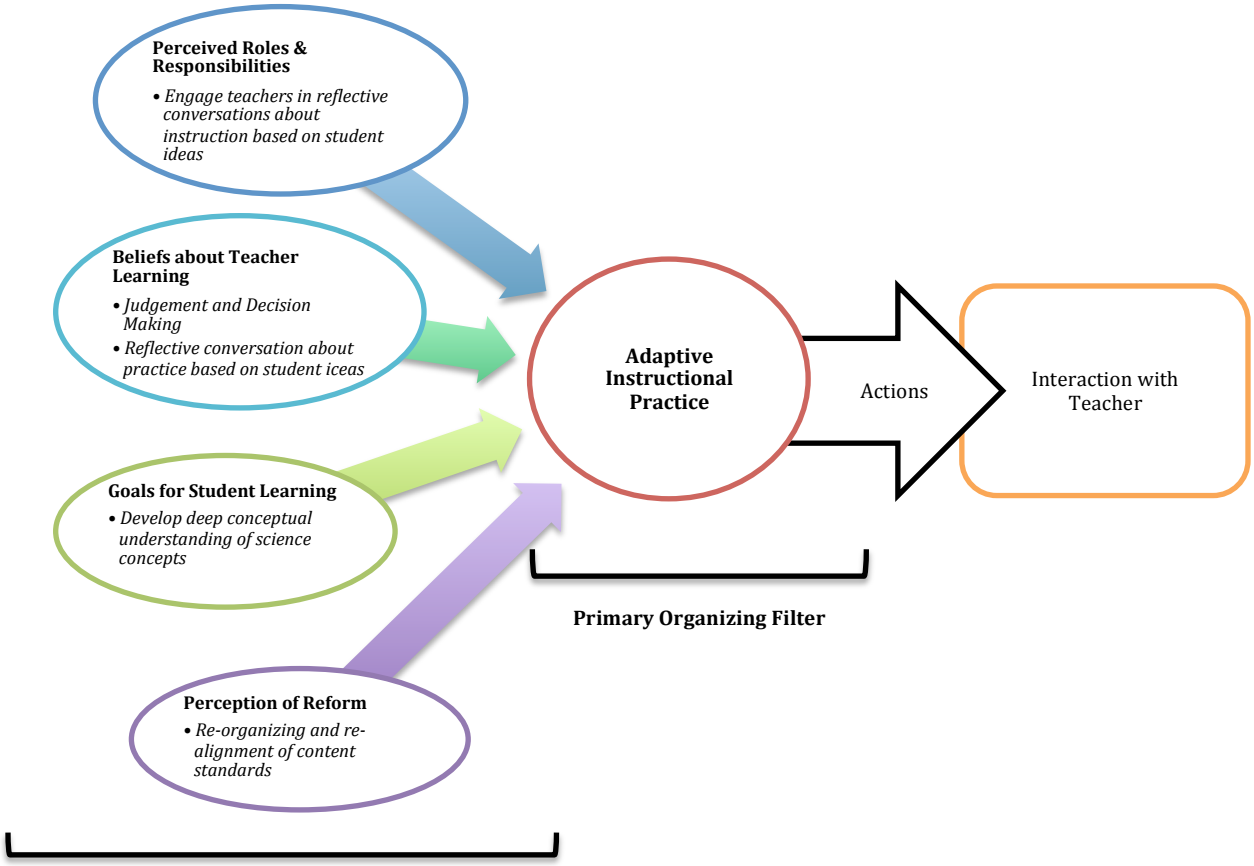
In summary, Sara seemed to perceive that the NGSS was a reform purposed at content re-alignment, which suggests that Sara held a limited understanding about the reform. While she mentioned that the NGSS aimed to "clean the slate of inquiry," she rarely engaged in conversations with the researcher, teachers or other colleagues about how instruction was supposed to shift and how Ambitious Science Teaching was related to NGSS instruction.

Claire: Adaptive Instructional Practice as Primary Organizing Filter

Over the course of the year, Claire's work within the activity system allowed us to see how different elements of her interpretive framework were filtered through the POF to focus teacher learning on adaptive instructional practice (See Figure 3: Claire's Interpretive Framework).

Figure 4

Claire's Interpretive Framework



Claire held a strong sense of professional commitment to supporting teachers in developing **adaptive instructional practice**. Instead of supporting teachers in learning to implement the district units with fidelity (like Sara), Claire supported teachers in learning how to

elicit student's science ideas and make instructional decisions based on their ideas. Claire explicitly and intentionally modeled for teachers how to deviate from the district unit.

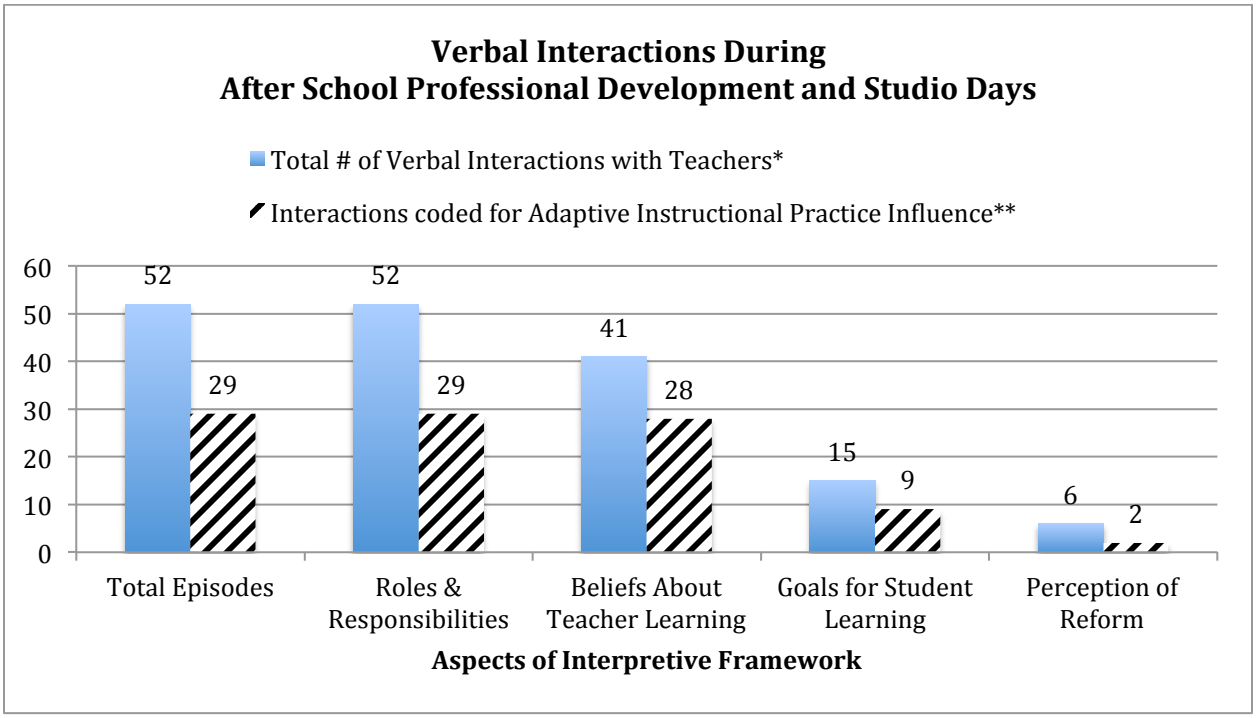
Claire's interactions with teachers demonstrated that she believed teachers needed extensive in-classroom coaching support and an instructional partner to engage in reflective conversations about enacting instruction. Claire spent most of her contracted time working with individual teachers in the classroom, engaging them in reflective conversation about student's science ideas. She also frequently supported teachers in learning how to deviate instruction from the district-planned units based on student interest and ideas. For example, during a forces and motions physical science unit, many students were curious about the role of friction in the science explanation for why a boy fell off his skateboard. The next lesson in the district unit focused on students understanding the role of gravity in the phenomena's explanation. However, Claire pushed this particular teacher to skip several lessons in the unit trajectory to engage students in a lesson specifically targeted on sense-making about friction.

In order to understand the components of Claire's spheres of influence, I analyzed her talk during after school professional development sessions and studio days (See Figure 4: Claire's Verbal Interactions During After School Professional Development and Studio Days). I coded each passage of unbroken talk by Claire that included 1) when she was initiating some substantive part of her role with teachers, 2) interacting with teachers (i.e. responding to questions, asking teachers to provide examples, commenting on examples), or 3) responding to other non-teacher participants in the room (i.e. the other coach). A total of 52 passages were analyzed. Each passage could range from a sentence to a paragraph-length explanation. Within each passage, multiple codes could be applied. For example, of the 41 passages that were coded reflecting Claire's beliefs about teacher learning, there were 28 instances of coding related to

advocating adaptive instructional practice. Claire's talk reflected that she was largely focused on supporting teachers in learning to develop such practice, where teachers make in-the-moment instructional decisions and changes to the curriculum based on student's current science ideas. Data suggests that her focus on adaptive instructional practice appears to have been related to Claire's perceived roles and responsibilities, her beliefs about teacher learning, her goals for student learning and her perception of standards-based reform.

Figure 5

Claire's Verbal Interactions During After School Professional Development and Studio Days



*Totals for the four spheres of influence are more than the "Total Episodes" because a passage of talk may have more than 1 code applied to it.
**The left hand column of each code represents the total number of episodes relating to that sphere of influence. The right hand column is the subset of those utterances that can directly be linked to their primary organizing filter.

This section of the findings will describe each part of Claire's framework, providing supporting evidence from transcript passages as well as field notes describing some of Claire's actions. (Note: The next section of the findings will focus on demonstrating how Claire's POF

for adaptive instructional practice became more apparent over time by examining closely how Claire interacted with other actors in the system.)

Perceived roles and responsibilities. Claire's perceived roles and responsibilities were to support teachers in learning to adapt curriculum and instruction based on student's science ideas, interests and experiences. During the project she seemed strongly influenced by her past experiences working as an instructional coach in Texas and her experiences while working at the university, studying responsive instructional practice in science.

Claire's primary role during all professional learning events, which is also related to her beliefs about teacher learning, seemed to be purposed at engaging teachers in conversations to reflect on their own ideas of what supports student learning. During these episodes, Claire frequently pressed teachers to use evidence from student work to help them articulate how specific instructional moves were supporting student learning. The following transcript is from a studio day in the middle of the year. Here Claire uses pressing and probing questions to encourage teachers to explain more about their ideas. She also re-voices teacher ideas, and asked clarifying questions to make teachers further articulate what they think.

> Claire: So why do you think connecting talking to literacy is a good move? Why is making that explicit helpful?
>
> Amanda: because they've done it before! And you know…sometimes when it's in a different subject, they think that it's different, you know, or it's going to be harder.
>
> John: You know, Kat and I were talking last week about how maybe for students it's now that I'm hearing this evidence that maybe I'm changing my thinking…and we want kids to not just be married to their thought as they get more information…

Claire: So I'm hearing…so I was hearing and interpreting—and I might have skipped some steps—but when you were talking, I was thinking about when kids hear evidence from other students, it changes how they were thinking…but is that what you said?

John: Yeah and what I want from them…if they get new information and they see it as inconsistent…it should change their thinking, or it could change their thinking…I just don't want them to be close minded and that their own thought is the actual answer.

Claire: Okay, so hearing new evidence helps change new thinking? So what would be a practice or a move that we would do that would help this happen?

(Transcript from After School Professional Development Session)

Unlike Sara, Claire did not feel compelled to tailor her interactions with teachers to the district's initiatives outlined in the strategic plan. Throughout the study, aligning to the district strategic plan seemed like a parallel frame that was only nominally included in Claire's work. When asked about the strategic plan, Claire said "Yeah, I read the strategic plan and I guess that fits in with what I'm doing with teachers." While she acknowledged that the strategic plan fits in with what she is doing, she did not make changes to her plans, nor did she feel obligated to do so. One example is she opted not to include the district-mandated slides in after school professional development and studio days. Even though the district mandated that coaches use specific PowerPoint slides during professional development to show alignment to the strategic plan; Claire did not feel that there was any value in doing that. Claire did not normally lead the teachers through the district-mandated slides—as Sara was always careful to do. The following transcript passage from an after school professional development session shows Sara orienting teachers to the session using the slideshow that Claire developed. When Sara showed the district-

mandated slide, Claire interrupts and states that she purposefully did not complete the information on the slide template.

> Sara: So this was very typical of the previous two workshops because we're talking about implementing the curriculum. We're going to spend a little bit of time going into the practices in the Next Generation Science Standards—particular explanations with evidence, which ties really nicely with what Jerald (she meant to say John) did that day. And then we'll be talking about the Ambitious Science Teaching practices--
>
> Claire: So I didn't fill in our roles on the slide—we can just say it…
>
> (Transcript from After School Professional Development Session)

The following transcript passage from a studio day shows another example of Claire's interpretation of the district-mandated materials. In her initial slideshow, Claire did not include the district-mandated slides. Notice Claire's response to Sara's commentary about using the provided images. Claire expressed her feelings about the slides seeming "lofty."

> Sara: Claire had a beautiful template for this presentation but I had her change it...It is important. I've been in this district since the mid ninety's. I came here because we had an NSF Grant on Science Assessment. And there are lots of good things that have happened in the past twenty-five years but this is the first time I've ever seen the Strategic Plan drive the work that everyone is doing in the district. They want to make sure that when we do a PD we connect it to the Danielson Framework and we connect it to the Strategic Plan and connect it to Common Core or Next Generation Science Standards. So I'll give you a moment to read the slide.
>
> Claire: Those always seem so lofty when you read them…it's a process, people…
>
> (Transcript from Studio Day)

During an interview, Claire pointed out that there was one part of the district strategic plan that she strongly supported. She highlighted the district's mandate for aligning to the Danielson teacher evaluation framework because it specifically "focuses teachers on learning how to be responsive to student ideas." During after school professional development, studio days and in-class coaching sessions, Claire demonstrated that her roles and responsibilities were to support teachers in learning to enact adaptive instructional practice based on student's science ideas during instruction while using components of the Ambitious Science Teaching framework. This to her, was consistent with the evaluation framework. Throughout all professional learning opportunities, Claire tended to engage teachers in collaborative conversation that focused teacher learning on developing an understanding about student's science ideas during instruction. She also always encouraged teachers to modify unit and lesson plans, based on student's interests and ideas.

Another role that Claire assumed during the project was to further refine the modified units of instruction, based on teacher feedback. During after school professional development and studio day sessions, Claire frequently asked teachers to share stories about how their students were responding to the unit, activities in the unit, and what teachers felt they needed to continue to support students at a deeper level of scientific reasoning. The following transcript is from an after-school professional development session when Claire and Sara introduced a new unit. Notice how Claire encourages teachers to change the unit if students volunteer other interesting phenomena. This was a very frequent and typical way that Claire would encourage teachers to respond to students' ideas during a formal learning session.

> Sara: And so we actually organize this unit around two phenomena. I think that's nice because a lot of kids—and Stephanie will support this—when the units are too long, the

kids will go "I do not want to talk about this Venus Fly Trap anymore…I don't want to talk about the skate boarder anymore." I think the fact that there are two different phenomena in this unit, and so kids are spending fewer weeks on each phenomena, we'll be looking for your feedback on what you think is best.

Claire: You can always pull in other phenomena. I mean, if they bring up something and you think about it over night and go read about it and are like "oh, that's a good phenomena to bring in"—you can always change something based on what kids bring up. (Transcript from After School Professional Development Session)

In summary, Claire demonstrated that her perception of roles and responsibilities was to engage teachers in reflective conversations about instruction practice, based on student's science ideas. While she supported the district by developing initial district-wide units of instruction for the teachers, she adapted the units based on teacher feedback about students' science ideas. Rather than telling teachers what to do or how to enact instruction, she tended to engage teachers in reflective thought and conversation through the use of questioning techniques.

Beliefs about teacher learning. During after school professional development sessions and studio days, Claire always structured significant time for teachers to engage in reflective conversations based on student work samples and pressed teachers to think about how they would respond to support student thinking. She also structured time for teachers who had experienced the unit to share their experiences, specifically related to the different kinds of student ideas that they heard during a unit. The following transcript is from an after-school professional development session. Notice how Claire introduces a new unit by priming teachers to reflect on student ideas from another class in order to predict ideas that may unfold in their classrooms and to begin thinking about how they will respond to student ideas.

> So today we're going to use a lot of science modeling as our professional learning for this evening. We'll be looking at student work from the unit so that you can see some ideas that kids might come up with in your classroom and then you can start thinking about how you're going to respond to some of the ideas in your classroom.
>
> (Transcript from After School Professional Development Session)

In an interview, Claire explained that her biggest concern about teachers learning to enact NGSS-aligned AST units was that teachers will say "Hey, this is just like what we've been doing before." Claire stressed that "Even if the district is re-vamping curriculum and giving it out to teachers, that is not enough. When you start listening to what kids are talking about, the curriculum does not give the teacher the confidence or the skills to be flexible in their instruction." When learning to enact the NGSS through AST, Claire believed that

> Teachers need a framework for enacting the NGSS—just reading the standards won't necessarily help NGSS get implemented. Teachers will oversimplify NGSS if they don't have a lens for enacting it, like Ambitious Science Teaching. Otherwise, teachers will just check off the Performance Expectations on a list and teach them in isolation. (Transcript from Claire's Beginning of Year Interview)

During interviews, Claire stressed that teachers needed time and structure to collaborate. She found the fact that the district's choice to departmentalize teachers in this program to be "problematic," because for all of the teachers in the study worked in a departmentalized school, they were the only grade-level science teacher and did not have a colleague to engage in daily conversations with about science instruction.

In summary, Claire believed that teachers learn best through reflective conversation about instructional practice with other classroom teachers. Claire believed that teachers need to learn

and are capable of learning the important skills of judgment and decision-making. Her beliefs about teacher learning are strongly inter-related to her perceived roles and responsibilities. Notice in the transcripts from the previous section, Claire engages teachers in reflective conversations with other teachers about instructional practice and encourages teachers to adjust curriculum and instruction based on student ideas. (NOTE: This is a fundamental difference from Sara who primarily believes teachers need to learn to enact prescribed routines and curriculum with fidelity.)

Goals for student learning. Claire's goals for student learning are for students to develop deeper conceptual understanding of science content by engaging them in reflective sense-making conversations about how their ideas were changing over the course of a unit. Claire believed that students learn science best when they are asked to engage in metacognitive discourse about their science ideas as well as their own thinking. During an after-school professional development session, Claire explained an overview of Ambitious Science Teaching and characterized the teaching practices:

> And so the whole purpose behind Ambitious Science Teaching practices is that we focus a lot on student thinking and learning, and eliciting their ideas and understanding of how they're thinking about why something works in order to provide them with opportunities to help them revise their models, revise their thinking, question each other.
>
> (Transcript from After School Professional Development Session)

Claire explained to teachers that the purpose of this kind of instruction is to engage students in reflective talk about how their science ideas are changing over the course of the unit. When describing the four core practices of Ambitious Science Teaching, Claire emphasized the need to adapt instruction based on student ideas.

> Unit plans are sometimes given to us and then you're reading this going "I might change the order of this" or "Hey, this kid had that question, so I might follow that kid's question because it still relates to the standards and I might skip the lesson in the kit because it doesn't address that." So we can make changes to the existing curriculum to be responsive to student's ideas…So we elicit student's ideas, we support their ongoing changes in thinking by providing them multiple activities and experiences to help them question or press on or revise how they think something works.
>
> (Transcript from After School Professional Development Session)

Throughout the study, Claire did not focus students on memorizing vocabulary and facts. She tended to seed teachers with the idea that students should be engaged in higher cognitive demand tasks, reasoning with evidence, and building explanations for complex and puzzling phenomena. The following transcript is from an after school professional development session when Claire introduced an instructional tool designed to support student learning. Notice when introducing a tool called the summary table, Claire states that their goal for student learning should not be focused on memorizing and that the summary table is a tool for students to record things they want to remember. Claire further explained that the learning goal is for students to think more deeply about their science ideas through conversation and the summary table is a tool that can support students engaging in such a conversation.

> So the point of this (summary table) is to help kids remember. We don't want their cognitive power to be working on memory. We want them to work more deeply with the ideas. So that's why I say that the setting up of the lessons and collecting the data in the lessons might take 45 minutes, so the next 45 minutes might be the discussion about why this is important, what does it tell us about the growth, how does it relate to the

chicken…etc. This filling out of the summary table might be another whole 45 minute conversation. (Transcript from After School Professional Development Session)

In summary, Claire tended to focus on supporting students in developing deep conceptual understanding of science ideas. She believed that students did this when teachers engaged students in frequent sense-making conversations strategically designed to support students in re-thinking their initial conceptions after new evidence is introduced. Claire was not particularly concerned with students developing canonical science conceptions early in the instructional cycle and believed that not all students need to learn science concepts in the same way.

Perceptions of reform. Claire believed that the NGSS is purposed at reorganizing and realigning what students learn at each grade level. She typically referred to the NGSS as science content and that the standards were designed for students to learn content at a deeper level of understanding. When discussing what the NGSS was in an interview, Claire compared the NGSS reforms to her prior work as an instructional coach in Texas, where a large portion of her time was spent on standards-alignment. Her past experience in working with standards in Texas seemed to have a strong influence on how Claire interpreted the NGSS. "In Texas, we implemented standards only through alignment, operating through the frame 'this is what you teach, so teach it.'"

When incorporating the NGSS into her unit-design, Claire focused all of her attention on the Disciplinary Core Ideas. In interviews and during professional development session, Claire frequently explained that she considered the Science and Engineering Practices and Cross Cutting Concepts as suggestions related to each standard. When using the NGSS in professional development sessions, she tended to only refer teachers to read parts of the standards when teachers asked her questions like 'What is the purpose of this lesson?' or 'What are kids going to

get out of this lesson?' The following transcript passage is from an after school professional development session where Claire introduced the NGSS in a newly developed district unit. She briefly mentions the standards and focuses on alignment. She asks teachers to trust her that the unit content is aligned to the standards content and quickly moves on to the Ambitious Science Teaching practices as something separate, but related to NGSS.

> We will mention the Next Generation Science Standards, but you can also trust me that I aligned them, as best I could, with the kit that is now currently in fifth grade with the standards. So it pulls a little bit from sixth grade because cells are now in the sixth grade standards. But kids do fine with it—they did last year. So we're going to use some Ambitious Science Teaching practices today.
>
> (Transcript from After School Professional Development Session)

During an interview early in the study, it seemed apparent that Claire held an incomplete conception about the scope of NGSS. For example, Claire seemed to isolate the Science and Engineering Practices (SEPs) as another type of science content that students are supposed to learn about instead of students using SEPs to learn science content. It was not until late in the study when Claire realized the limits to her understanding the NGSS and the potential problems that could develop if she did not explicitly support teacher learning of what the NGSS is and its relationship to AST.

How Coaches Interacted with Teachers

Both coaches in this study interacted with teachers in three types of learning events: one-on-one classroom coaching, after school professional development, and studio days. This section is broken into three parts to characterize how coaches interacted with teachers during these events. The first section summarizes how coaches interacted with teachers during after school

professional development and studio days, the second characterizes activities both coaches used during one-on-one coaching, and the third section further describes a detailed picture of how Sara and Claire enacted specific coaching activities with teachers in their classrooms.

Coaches' interactions with teachers during after school professional development and studio days. Throughout the study, Claire and Sara co-planned and co-facilitated all studio days and after-school professional development days. After-school professional development days were three-hour sessions designed to support teachers in learning about an upcoming science unit that they would implement in the classroom. This implementation was to be aligned with NGSS reform principles. Studio days were eight-hour sessions designed to study teachers' uptake of reform-related instructional practice so that they could learn how to improve their teaching. Overall, Sara and Claire interacted with teachers in fundamentally different ways during these group learning events, which influenced how they framed the problem of implementing the NGSS for teachers. To avoid redundancy, Table 11 summarizes what Claire and Sara did during after-school professional development and studio days, based on the previous section of the Findings.

As described in the previous section pertaining to both coaches' interpretive framework, neither Claire or Sara presented a detailed understanding about NGSS. Both coaches seemed focused on the idea that NGSS is new science content and that the NGSS calls for students to engage in learning through science practices. However, both coaches' primary organizing filter became important when representing NGSS to teachers. Sara (POF: alignment and accountability) framed NGSS as a problem of aligning instruction with district-designed resources and emphasized this by encouraging teachers to use only approved curricular tools. Whereas Claire (POF: developing adaptive instructional practice) framed NGSS as a problem of

improving instructional practice by helping teachers to adapt curricular tools, based on students' experiences and science ideas.

Table 11

Coach's interactions with teachers during group learning events

Sara	Claire
▪ **Framed** NGSS as a problem of alignment of current to new content and coverage	▪ **Framed** NGSS as a problem of improving instruction
▪ **Articulated** how current learning event and curriculum was aligned to district strategic plan	▪ **Articulated** how and why she modeled instructional practice
▪ **Engaged teachers** in reflecting on their alignment with curricular tools	▪ **Engaged teachers** in reflecting on student experiences and students' science ideas
▪ **Encouraged** teachers to use specific district-approved tools with students (Summary Table, Curriculum Guide, PDSA)	▪ **Encouraged** teachers to share ideas, tools and routines in context (productive and unproductive examples) when trying out the instructional practices
▪ **Emphasized** curriculum connections to state science assessment (vocabulary, concepts, activities)	▪ **Emphasized** that teachers share student science ideas they heard during a studio day and/or from previous lessons/years

How coaches interacted with teachers during one-on-one classroom coaching. One-on-one coaching opportunities were the most direct opportunities to guide teachers' attempts at reform-oriented instruction. This section focuses on explaining how the coaches interacted with teachers when supporting them during one-on-one coaching. I characterize the broad-level routines, norms and habits of both coaches in the study. The following section articulates a more detailed description of the difference between Claire and Sara's coaching activities when they were engaged in one-on-one classroom support with teachers. While both enacted the same general types of professional learning activities, it appears as though there were differences in

how these two coaches utilized specific learning strategies with the teachers. The individualized support, guidance and messaging that instructional coaches provide to teachers in their classrooms is a critical component for understanding of how teachers may or may not develop different interpretations of how they should enact new forms of instruction.

Broad characterization of coaching. Within the context of one-on-one coaching, Claire and Sara enacted four coaching activities at various times:

1. **Co-Planning**: coaches visited teachers to prepare with them for an upcoming lesson.
2. **Observation & Feedback**: coaches observed teachers instruction, recorded data and gave teachers feedback.
3. **Modeling and Co-teaching**: coaches modeled a reform oriented teaching practice and/or co-enacted a portion of a lesson with teachers.
4. **Providing Tools**: coaches provided tools for teachers to support them in one of three categories a) planning, b) supporting student participation and c) making student thinking public and/or revisable

The coaches used each of these four activities as part of a larger system of support (including studio days and after-school professional development sessions) for teachers. These descriptions are broad, in part, because they include only elements of the activities that both coaches enacted. Each enacted these activities with teachers in fundamentally different ways. At this level of comparison, Sara and Claire coupled the activities differently and within each activity, they enacted practices with qualitative differences (See Table 12).

Sara focused on supporting teachers in learning to use the district unit guide to enact a skillful lesson. Sara typically visited each of her teachers in person one time per week and enacted the following coaching activities as a step-like progression. She began by 1) scheduling

a pre-planning meeting with the teacher, and then 2) observed the teacher enact the lesson while recording observation notes. Following the observation, she gave the teacher a copy of her observation notes as feedback, usually via email. Modeling of instruction by Sara was infrequent. If she modeled, Sara tended to demonstrate procedures or segments of activities to set up a lesson. For example, one teacher did not know how to set up a laboratory experiment with students and Sara volunteered to demonstrate this for the teacher to observe. There were no recorded instances of co-teaching, spontaneous or planned. Sara's interactions with teachers seemed focused on helping teachers implement common, district-approved curriculum and tools.

In contrast to Sara, when Claire interacted with teachers during classroom coaching, she did not assume that a single visit would be enough to shift teachers' practices. Instead, Claire interacted with teachers over multiple, consecutive science lessons, in which she integrated various coaching activities to address perceived student and teacher learning needs. Claire's first few visits to the classroom were mainly to observe, and teacher's practices during those lessons became objects of inquiry for testing new forms of instruction. Claire seemed focused on supporting teachers in their instructional decision-making, grounded in the relationship between canonical science ideas and emergent student science ideas. She also focused on observing lessons to learn more about what should be done with students' ideas so as to continuously improve the lesson(s) and/or unit of instruction. For example, when observing a lesson, Claire tended to periodically pull the teachers aside and engage them in brief reflections designed to help them adapt in-the moment instruction, based on student needs.

Table 12

Characteristics of Support Within the Context of One-on-One Coaching

Sara	Claire
▪ **Mediates risk of the appropriation of reform practice** by asking teachers to follow the curriculum guide, as written.	▪ **Mediates risk of the appropriation of reform practice** by legitimizing principled experimentation and "*we are doing it together*"
▪ **Privileged** university-based curricular tools as products designed by "experts"	▪ **Privileged** teacher experiences and student's needs to co-develop curricular tools.
▪ **Impacted teacher practice** at the single lesson level	▪ **Impact teacher practice** at the lesson level, but within the context of consecutive lessons
▪ **Coaching Practice**: Routinized with a pre-determined coaching activity agenda	▪ **Coaching Practice**: Responsive to needs of teachers and students with in-the-moment coaching decisions
▪ **Dosage**: one visit per week	▪ **Dosage**: multiple visits per week
	▪ **Hybridizing** coaching activities (using multiple strategies together)

Detailed characterization of how coaches enacted one-on-one coaching activities. In this section evidence from observations and interviews are used to describe a more detailed picture of how Sara and Claire enacted the four coaching activities with teachers in their classrooms.

Sara's Enactment of Coaching Activities

The following sub-sections provide a detailed account for how Sara interacted with teachers during the four coaching activities 1) co-planning, 2) observation and feedback, 3) modeling and co-teaching, and 4) providing tools.

1. Co-Planning

Prior to observing teachers in the classroom, Sara typically scheduled a pre-planning event visit with each teacher. During this visit, Sara reviewed the district unit plan and the upcoming lesson. Their conversations focused primarily on "talking the teacher through" the unit guide and explaining how the lesson should unfold. When volunteering to work with a teacher in the classroom, Sara always explained her purpose to teachers and administrators:

> "I can come out next week to look at the lessons with you and go over how to set them up. We can talk about how to set up the summary table to kind of pre-plan before we launch a lesson." (Planning Conversation with Bryn)

During the co-planning visit, it was customary for Sara to ask if there was something specific, related to their formal teacher evaluation and/or school-specific priority that the teacher was trying to improve during the year. Occasionally Sara suggested a few strategies that teachers could try to work on their goal. Despite these initial inquiries, Sara tended to focus the planning conversation on helping the teacher understand the trajectory of the unit plan and/or how to set-up and enact a single lesson as written in the unit guide. For example, the following excerpt is from an initial planning conversation between Sara and Bryn, when Bryn was preparing to begin a new unit of instruction with students. Notice that the teacher wants to work on improving student performance on assessments and Sara suggests a few routines that the teacher could try. However, when the teacher is explaining past experiences with using activities in the unit, Sara abruptly interjects and re-establishes her purpose to the teacher as going over the lessons, talking about how to set them up and collecting data on ELL students.

> Sara: Is there something that you would like to focus on or practice this year? Does your school have a priority?

Bryn: Assessments. I'd like to practice improving student performance on assessments. Math has a lot of easily accessible assessment questions to practice. In science, there isn't.

Sara: We could try focusing on exit tickets for assessments. Using exit tickets as an assessment each day is a routine that (math teacher) uses in math. Moving successful math routines into science routines for assessment…we could use student work from exit tickets to drive the entry task or floor discussion for the next day?

Bryn: Yeah, so the labs in the last unit were really fun and easily relatable to students...in this unit, I think it's easily relatable for kids to talk about on the floor…fever, kids get sick a lot.

Sara: You should encourage kids to talk about the home connection to science.

Bryn: Yeah, sometimes I think it's off topic…but I can see how it might be important in that way…keeping them interested.

Sara: I can come out next week to look at the lessons with you and go over how to set them up. We can talk about how to set up the summary table to kind of pre-plan before we launch a lesson. Claire and I are committed to doing PDSA cycles in the classroom. It's a district commitment to collect data about how we are attending to ELL students. I'd like to focus my time and observations on collecting data from three of your ELL students.

(Transcript from planning conversation with Bryn)

The above transcript, shows that despite the teacher's interest in learning more about "improving student performance on assessments," Sara presses on with her routinized coaching activity to "doing PDSA cycles in the classroom" and "collect data about how we are attending

to ELL students." In addition, the teacher mentions her struggle with relating science instruction in lab activities to student floor discussion and Sara responds with a brief suggestion to encourage students to talk more about their "home connection," as if the teacher intuitively knows how that will solve her problem of practice.

When supporting teachers in learning to enact new reform-related practice, Sara tended to reduce risk-taking by asking teachers to follow the written curriculum guide. The following is another example of how Sara began planning the enactment of a single lesson with a teacher. Notice that the teacher suggests a desire to change the lesson based on student's science ideas and experiences. However, Sara re-directs the teacher back to using the lesson in the unit guide because she is concerned that student-designed experiments will not focus on the "correct" set of science ideas.

> John: So we can teach science in here every day because of the scheduling. We're focusing on the puzzling phenomena…or essential question…why do plants grow—it's written up on the board here. We've only done some initial conversations about plants—you know, what kids know about plants or what experiences they've had…maybe planting gardens at home. I know for this initial eliciting ideas lesson, I also need to have the students set-up the lab to grow plants. I was thinking of changing it a little from the original lesson and leaving it more open ended. Maybe students could manipulate the soil…I might have the class make a list of things that they think would influence the plant…maybe they could pick their experiment?
>
> Sara: Oh, okay. Well, one problem with that is that kid's experiments won't always work or give them the correct answers that they need. I think there might be an updated lesson

> in the unit guide that lets the students choose from a few different suggested ways for doing the lab…let's see if we can find that.
>
> (Transcript from planning conversation with John)

The NGSS Science and Engineering practices articulate that students need to plan and carry out investigations purposed at learning from engaging in that practice as a process. The above transcript shows how Sara interpreted the enactment of reform-related practices. When the teacher suggested to modify the lesson and leave it "more open ended," Sara's response that "kid's experiments won't always work or give them the correct answers that they need" is counter to the vision for science instruction in NGSS. Sara interpreted that designing and carrying out an investigation meant for students to choose from a list, rather than engage in an authentic experimental design process. Sara deferred to the district curriculum as if it held "expert status" for implementing the reform.

2. Observation & Feedback

As transcribed in the passage above, Sara frequently explained to teachers and administrators that her primary role during an observation was to collect data about the ELL using a specific data-collection tool, called "PDSA" (Plan-Do-Study-Act):

> Claire and I are committed to doing PDSA cycles in the classroom. It's a district commitment to collect data about how we are attending to ELL students. I'd like to focus my time and observations on collecting data from three of your ELL students. (Transcript from planning conversation with Bryn)

When observing teachers during a science lesson, Sara typically sat near three identified ELL students and recorded what they were talking about during the lesson on the PDSA tool. There were rarely any interactions with the teacher or students during the lesson. Her method of

giving feedback was to give the teacher a copy of what she recorded when listening to the ELL students. If Sara could not stay for an entire lesson, she gave the teachers feedback through email. Occasionally teachers being observed asked Sara for input/advice, and Sara offered suggestions for the teacher to focus instruction on specific vocabulary or science concepts that were important for students to learn. For example, during an observation a teacher who was initially trying out the Ambitious Science Teaching practice "Eliciting Student Ideas," asked Sara for advice in how to bridge the student's conversation about plants to the experiment and when to do the demonstration. The teacher was interested in using students' ideas as a lever for sense-making. However, Sara's only advice for the teacher at that time was to "Walk them through a few examples of variables and controlled experiments because that's an important concept students need to remember." Sara responded to the question with a teaching routine that did not have anything to do with working on or with student's ideas. Providing suggestions for teachers that encouraged direct-instruction of specific vocabulary, procedures or science concepts demonstrates how Sara mediated risk-taking for teachers when experimenting with new reform-related instruction.

3. Modeling and Co-teaching

Sara rarely modeled practice for teachers or engaged in co-teaching. However, when modeling a teaching practice, she tended to demonstrate procedural practices. The following excerpt is from a planning conversation between Sara and a teacher. Notice that the teacher did not know how to set up the plant lab with students, so Sara volunteered to lead the lab set-up portion of the activity so that the teacher would know how to do it in future lessons. She also emphasized the importance of making sure students understood specific vocabulary during the experiment.

John: So, how long will it take to set-up the lab? I've never done this before with kids and don't really know how to set it up.

Sara: Well I can come in on Wednesday morning to help set it up and can walk the students through how the experiment will work. So there are different steps to experimentation. There are particular vocab words that students need to be familiar with—and they should already be familiar with from fourth grade…variables, designing experiments, controlled experiment. I think your students should've had experiences in fourth grade with a potato investigation. If students don't remember what these words are, then we might just teach it to them. But you could remind them that they did an experiment…it was either yeast or potato…and ask them "did you do…" to jog their memory. (Transcript from planning conversation with John)

The above quote gives clues to how Sara thinks about the reform version of the scientific practice of developing investigations. For example, an experiment "will work" and she can "walk students through" the procedure using "different steps" is her interpretation of how to enact instructional practice to support a scientific investigation. There are "particular vocabulary words" that students need to be familiar with to be successful. Sara's interpretation of reform unfolds in this example; there is no epistemic uncertainty or construction of science knowledge in this practice.

4. Providing Tools

Sara tended to provide tools that she believed should work, in theory, and she promoted the use of tools that were perceived as district-approved or recognized. Sara seemed to present teachers with the university-developed tools as if they held "expert" status. For example, when teachers had questions about what they were supposed to do in a particular lesson or activity,

Sara directed them to specific pages in the unit guide where the authors suggested tools. Throughout the study, Sara provided teachers with the RSST and Summary Table to support teachers in planning:

> So, then we will be focusing on the phenomena, like we typically do, focusing on our own content knowledge…and using the summary table as a way to get a quick overview and a quick tour of the lessons. And then…part of this was a request from me…so one of the tools from the Ambitious Science Teaching Practices that they use quite a bit in secondary that I'm not that good at yet is the Rapid Survey of Student Thinking…and so Claire has inserted it intentionally in a few places throughout the unit. (Transcript from planning coaching conversation with John)

Sara mediated teacher risk-taking of reform-related practices by suggesting that teachers adopt tools that were widely-recognized I the district as university-developed tools to support student sense-making. For example, Sara confirmed that she received requests from school principals and administrators that they wanted to see more summary tables in their teacher's science classrooms. In response to administrator requests, Sara encouraged teachers to use the Summary Table and emphasized that it was an important pre-planning tool to "help teachers know what students should be getting out of each lesson." She justified (to teachers and principals) that the summary table supports student learning because "it helps them remember what they did" during a science activity. The following pictures (Figures 7-10) are examples of how teachers supported by Sara used the Summary Table in their classrooms. Notice how each picture shows posters that emphasize correct science facts and vocabulary.

Figure 6

Picture of Summary Table in Bryn's Classroom

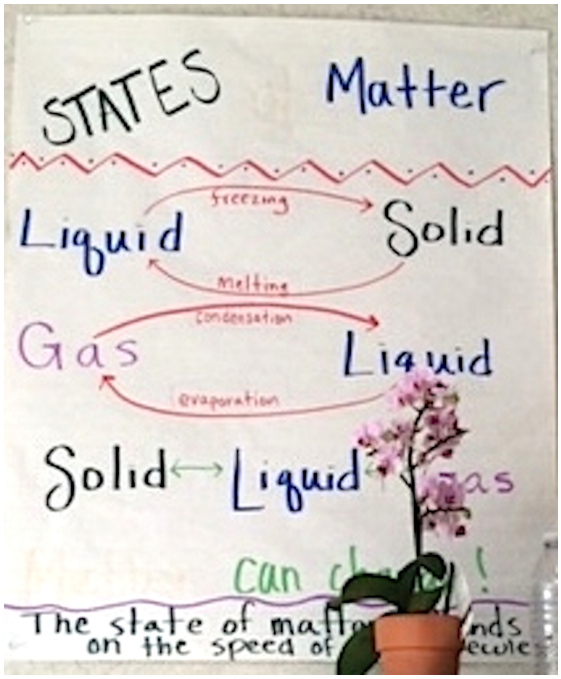


Figure 7

Picture of Key Words Tool in Bryn's Classroom

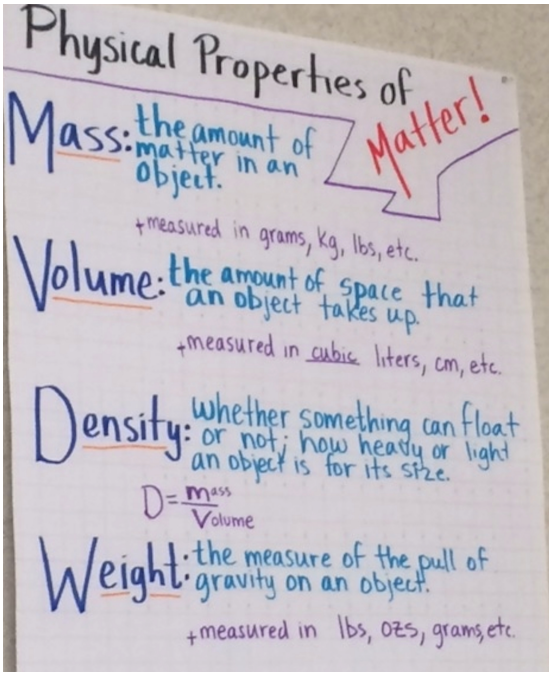


Figure 8

Picture of Summary Table in Hank's Classroom

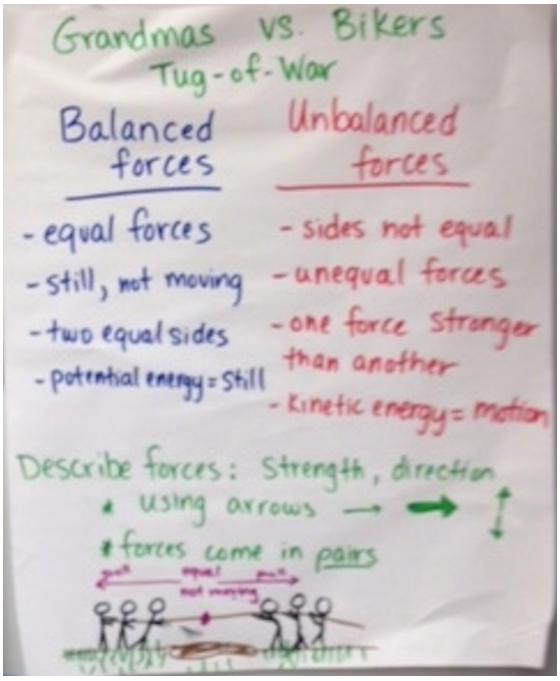
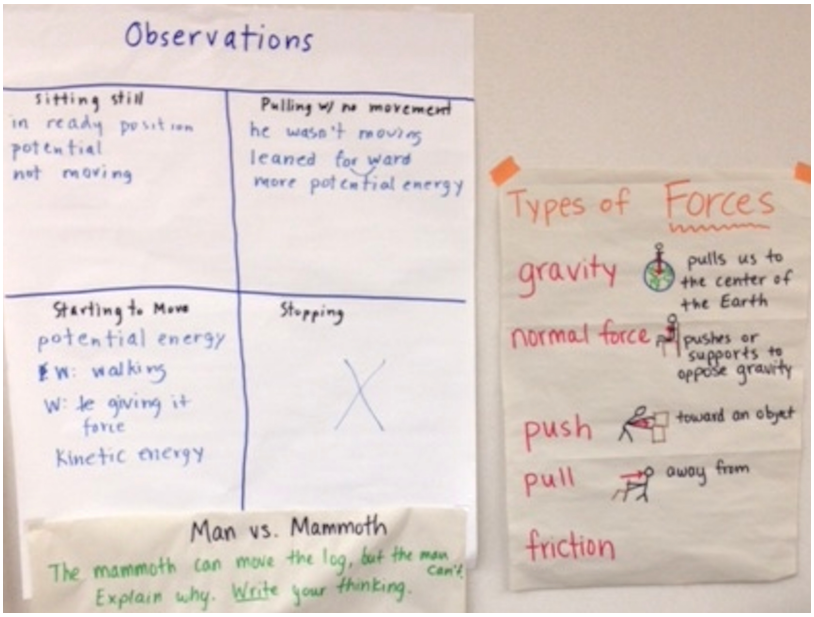


Figure 9

Picture of Summary Table and Key Words Tool in Hank's Classroom



These pictures show how Sara supported teachers in adopting a Summary Table as an instructional tool to at publically displaying correct science ideas. Framing the use of a summary table as a tool to support students in learning "correct" science ideas, shows Sara's goal for student learning seems more focused on learning and remembering specific content, rather than a tool that supports students in engaging in deeper reasoning and sense-making.

Claire's Enactment of Coaching Activities

The following sub-sections provide a detailed account for how Claire interacted with teachers during the four coaching activities 1) co-planning, 2) observation and feedback, 3) modeling and co-teaching, and 4) providing tools.

1. Co-Planning

When co-planning with teachers, Claire began by developing a relationship with the teacher and a thorough understanding of the classroom context. Claire initiated pre-planning conversations for the purpose of learning more about the teacher and their perceptions of student learning and science instruction. She asked teachers to explain what they were trying to improve in their instructional practice, why they thought it is important and how the teacher attempted to shift their practice prior to Claire's arrival. During initial visits, Claire also tried to learn more about the students in the classroom, their learning needs and behaviors. Following an initial pre-planning visit, Claire observed the classroom for consecutive science lessons to gain a better sense of the environment by studying how the teacher and students interacted together around science ideas.

When co-planning with teachers, Claire primarily focused on supporting teachers in learning how to develop responsive instructional practice. To do this, engaged teachers in co-

planning conversations designed to support them in learning how to deviate from the district-planned units based on student's science ideas.

Claire always co-planned multiple consecutive science lessons with teachers over a period of several weeks. The following transcript is from one of Claire's initial planning visits with a teacher. Notice how she seeds the idea that the teacher can manipulate the lessons in the unit through "discourse and extensions…and letting the kids manipulate the activities…"

> Ellie: Well, four days a week because I only have them for 45 minutes on Friday and I save that for writing time. But I teach three sections. So Sara and I talked about these ten lessons extending to about Thanksgiving…and then spending after Thanksgiving to Christmas doing Lego Robotics Unit. I haven't seen that unit, so that's when she was like, 'lets get together to plan and go over it.'
>
> Claire: Well, I don't know anything about that unit. But, I'm thinking wow, you have science every day! I'm excited! These ten lessons could each take up a whole week…with discourse and extensions…and letting kids manipulate the activities…so we could really stretch this out for some deep sense-making.
>
> (Transcript from planning conversation with Ellie)

This co-planning example shows how Claire mediates risk of the appropriation of reform practice by legitimizing principled experimentation. Her excitement that "we" could be "stretched out" each lesson to "take up a whole week" of instruction shows how Claire planned to engage in the risk-taking as an equal partner. This example also demonstrates how Claire supported teachers in learning by co-planning consecutive lessons. Her emphasis on manipulating the lesson to include more "discourse and extensions" so that students can engage

in “deep sense-making” shows how Claire frames the purpose of the reform-based instructional practices.

Claire frequently prompted teachers to listen to their student’s science ideas and engaged teachers in reflective debrief conversations aimed at helping teachers adapt the unit trajectory based on what student’s were talking about. Claire usually started with a series of questions to get the teacher to talk about their student’s science ideas. For example, “What science ideas did you hear students talking about during today’s lesson?”, “What do you think your students were most interested in?”, or “Do you think there is an idea that most of your students are really wrestling with or puzzled about?” After identifying a student science idea to work on, Claire tended to suggest a lesson in the district unit plan related to that particular science content. Instead of talking the teacher through the lessons as written, Claire engaged them in reflective conversations about how they could adjust the lesson to best support students in metacognitive sense-making. If there was not a lesson in the unit related to the student’s science ideas, Claire and the teacher co-developed new lessons to fill the void.

The following transcript is another example of co-planning conversation between Claire and a teacher. The teacher initiated the conversation because she was frustrated that there were too few science ideas circulating in the classroom. The teacher wanted the students to make more connections to a video shown in class. Notice that Claire’s initial response to the teacher is a question where she asked the teacher to articulate exactly what ideas she was hearing from students.

Johanna: So, do you think they would benefit from re-watching the video or just going up to group share their explanations?

Claire: Well, what are you hearing so far?

Johanna: I'm really only hearing them latch on to the "not washing the chicken" idea and I'm hearing them latch on to that "97%" of chicken tested idea.

Claire: Okay, why don't we go back and only watch the first part where it talks more about symptoms and pause it after that to make sure we get all of the symptoms written down. And if they don't get them all, it's okay to say, 'well something I observed was that they said __' to give it to them…there might be one that will be important later and we want to make sure that we have it on the list for later.

(Transcript from coaching conversation with Johanna)

This example shows how Claire supported the teacher in making an instructional decision based on evidence in student's science ideas. Claire asks the teacher to specify what she heard before offering a suggestion so that she could offer a solution that focused on supporting the students in developing more ideas. Instead of telling students a list of symptoms, Claire suggested to re-watch a specific portion of the video. She also emphasizes that "it's okay" if student's do not suggest all of the symptoms and suggests a scaffold for how to share out an idea; "well, something I observed was that they said ___." Claire is helping the teacher learn how to respond to student ideas and how to scaffold with small instructional moves to better elicit student ideas.

2. Observation & Feedback

Claire observed teachers and students for multiple purposes and for consecutive science lessons before engaging in any form of feedback to the teacher. Initially, she observed to learn more about the students in the classroom, their learning needs and behaviors. She also observed to learn more about how the teacher already enacted science instruction with students. It was

commonplace for Claire to interact with students and the teacher during the lessons. She tended to talk with small groups of students, pressing them to tell her more about their science ideas.

Once Claire felt that she had a better sense of the classroom environment, Claire's feedback on instruction took form as an on-going reflective conversation with the teacher. Claire's observation and feedback seemed frequently interwoven with co-planning. When observing and giving feedback to teachers, Claire prompted teachers to listen to their student's science ideas in order to support teachers in engaging in reflective debrief conversations. Claire never told the teacher what she noticed the teacher doing or not doing. If she volunteered observations, Claire only told the teacher what she heard students talking and/or writing about pertaining to their science ideas.

The following transcript is of a conversation between Claire and a teacher after observing a lesson. Notice how Claire begins the conversation by asking the teacher to articulate the student ideas that she heard. When the teacher responded with "they were really engaged," Claire followed up by offering a student idea that she heard, which prompted a deeper content-focused conversation about attributes of friction. Based on their conversation and what they saw in student work, they decided to deviate from the unit-plan and support student sense-making by further exploring the role of friction in the unit's phenomena.

Claire: So what were some of the ideas that are sticking with you from the kids? That you heard?

Ellie: So, they were really engaged. And I was happy about that.

Claire: It was interesting, the girl with the green pants. I didn't get to hear her whole idea, but she had was wondering about can there still be friction there if things are still moving?

Ellie: We didn't talk about that yesterday, but I think that's an attribute of friction, isn't it?

Claire: Like, friction itself--like materials themselves have coefficients of friction?-- but that's only meaningful if they're interacting with something else. So it has to be rubbing to have some friction.

Ellie: That's what I think.

Claire: But I don't think that the table of students were to that level of phrasing…like, I didn't hear them say that you could have different amounts of friction. [Teacher and Coach have a five-minute casual discussion about the science content.]

Ellie: Okay, so my next question is—taking this information and knowing what the next lesson is in the unit…we've already derailed from it.

Claire: And you can totally de-rail from it—we can stretch this unit out until Christmas! Like, I love all the connections your students were making. They were saying that this part of the video was like this experience they've had and that part of the video was like another experience they had.

Ellie: Where do I go tomorrow? Here's the motion and design unit. We just did our own lesson between lessons four and five—like yesterday we did the blanket test with the ideas.

Claire: I'd like to keep it something around Friction and rubbing between two surfaces. You could even stop and have them apply it to the skateboarder…like let's look in our skateboard story and see where Friction might happen.

(Transcript from planning conversation with Ellie)

This example shows us how Claire supported teacher learning by focusing decision-making on student science ideas. After Claire suggests that the "girl with the green pants" was "wondering about" friction, Claire uses the student's interest to engage the teacher in a five minute conversation targeted at supporting the teacher (and Claire) in developing their own understanding about the properties of friction and friction's role in the phenomena. By participating in this conversation as a learner (rather than an expert), Claire minimizes teacher risk and legitimizes the need for both of them to engage in on-the-spot development of their own science understanding. The later portion of the transcript shows how Claire supported the teacher in "de-rail[ing]" from the district unit-plan because students were making "connections" to their personal "experiences" when trying to understand the role of Friction in the skateboarder phenomena.

3. Modeling and Co-teaching

Claire explicitly and intentionally encouraged teachers to deviate from the district unit lesson guide because they needed to be responsive to student's science ideas. However teachers tended to need support in learning how to enact intentional changes to the lessons and unit curriculum. To support teachers, Claire spent a significant portion of her in-class-coaching time modeling teaching practice for teachers through developing a co-teaching relationship. What was unique about the relationship was that Claire did not treat her instructional ideas with a different kind of status; she did not assume that her ideas were best or that she was an expert.

Co-Modeling Hybridization: Co-Modeling is a hybridization of modeling and co-teaching that Claire often enacted with teachers. Co-modeling, as an activity, opens the doors to talking about instruction as something that can and should be continuously improved. Claire believes

that teachers need to see something enacted in their classroom but also be part of a planning and debriefing conversation around a teaching practice;

> "There needs to be an authentic need or purpose to modeling a practice…If it's something that helps students better talk about or articulate their science idea, then it's a practice that should be modeled if the teacher does not know how to do it." (Transcript from Beginning of Year Interview with Claire)

Claire identified herself as a co-participant when experimenting with instruction. She treated her instructional ideas as a hypothesis, rather than an authoritative recommendation. When she modeled instruction and co-taught, Claire acknowledged that the teacher had valuable expertise by naturally passing back and forth the responsibility of leading instruction. Claire was intentional about co-designing practice with teachers so that both Claire and the teacher co-modeled new instructional practice. During instruction, Claire modeled how to be responsive to student's ideas by frequently engaging teachers in Teacher-Time-Out conversations. Claire always had verbal debrief conversations with teachers to discuss student ideas, the lesson, and how they could adapt instruction for the immediate next lesson.

The following transcript is from a debrief conversation between Claire and a teacher after experiencing a unit lesson that did unfold as planned. In the lesson, students began suggesting science ideas that were un-predicted by Claire and the teacher and neither felt comfortable responding to student's science ideas during the whole-class discussion. Notice how Claire is very open in admitting her lack of content expertise to the teacher. Her vulnerability allows a non-threatening opportunity the two to engage in an extended science content discussion. Following their content conversation, Claire invites the teacher to share what she thinks they should do next and incorporates the teacher's idea into the lesson plan and unit trajectory.

Ellie: So, I'm not sure about all of the content in this lesson today.

Claire: Yeah, I felt a little outside of my content area too during the lesson! I wasn't totally primed on kinetic and potential…and as I'm thinking about it, it's not like you only have potential at the top and kinetic at the bottom…I think I remember seeing bar-graphs that show the relationship between the amount of potential and kinetic and how it changes as you're going down [continued five-minute conversation about science content]…but I think we're good with today's conversation. So if they can use this information to help them explain the skateboarder—

Ellie: Yeah, because now I'm dying to give them their model again. Because this was a class that wasn't drawing at all. At the beginning, they weren't drawing anything.

Claire: So where do you think we should go next?

Ellie: Well, I think we should do the whole story on energy. We could do the experiment that we talked about designing today, where they run the car into the book ends to see the transferred energy…but that might be killing it.

Claire: I think using the rubber band and talking about the rubber band and the number of twists as the potential energy could help…but let's try to build one first to make sure it works!

(Transcript from planning conversation with Ellie)

The above example shows how Claire and the teacher changed the lesson trajectory based on student's science ideas. When Ellie was unsure "about all of the content" in the lesson, Claire includes herself as a learner with the teacher by empathizing that she also felt "a little outside" of her content expertise. She used this as an opportunity to engage the teacher in a conversation purposed at developing their understanding of how the science content introduced by the student

was relevant in the phenomena. Claire asks Ellie "where do you think we should go next?," demonstrating Claire's co-modeling intent that they are going to experiment with instruction together. In this example, we see how they discuss experimenting with instruction, as partners in risk-taking, by "designing" a new lesson help students think deeper about their student's science ideas.

"Teacher-Time-Out" as a Co-Modeling Hybridization: When working in the classroom with teachers, Claire frequently engaged the teacher in brief conversations purposed at making an immediate change to the lesson, based on students' responses to the lesson. Claire referred to as "Teacher Time Outs" and they occurred during live instruction. While co-teaching lessons or observing the teacher enact a lesson, Claire periodically pulled the teacher aside to ask the teacher about aspects of student talk. Her questions focused teacher attention on the accessibility of the lesson and/or how to support students in thinking deeper about their science ideas. For example, if Claire noticed that only a few students were having turns at talking about their science ideas, Claire asked the teacher "who are we hearing the most from and who are we not hearing from in the discussion?" This tended to be followed by "What could we change about the lesson so that more students will share their ideas?" or "What tool could we develop or question could we ask to get the students to a deeper level of thinking about their scientific reasoning?" The following transcript is a teacher-time-out between Claire and a teacher during in-class coaching. Notice how Claire asked the teacher to verbally articulate the science ideas that the teacher was hearing during small-group conversation and to think about how to use those ideas during the whole-class discussion. Claire helped the teacher connect multiple student ideas. By discussing student ideas together before the share-out, they realized different groups of students held conflicting scientific explanations that could foster a worth-while whole-class discussion.

Claire: So what are you hearing and how do you think you want to run the discussion?

Johanna: They (group of students) have a "multiplying—cells multiplying" idea. So I'm going to have them come up and share, for sure, at some point. She (different group) also has a similar idea.

Claire: Yeah, they (different group) had 'cells growing' and they started talking about heat, but they weren't sure why it mattered.

Johanna: With what panel?

Claire: The first one with the sun—they were talking about the heat from the sun. And in the second one because of the microwave—they thought the microwave could make the bacteria grow because it would make it hotter. They weren't sure what to do with the body but they wrote that it would grow more in the stomach, which would be an interesting contrast to their stomach acid idea.

Johanna: Yeah, the one group talked a lot about stomach acid and about it breaking down the bacteria.

Claire: So that would be an interesting contrast to have them think about…

Johanna: Okay, so help me call up people to share out as you see things unfold in our discussion…

(Transcript from coaching conversation with Johanna)

This transcript shows how Claire and the Johanna paused in the middle of instruction to discuss students' science ideas so that they could co-develop an on-the-spot modification to the lesson. Because Claire and Johanna were listing to individual students and small groups of students during their work-time, they were able to collect a wide scope of student's science ideas and identify "an interesting contrast" idea that would prompt a rich student sense-making

discussion. Notice how Johanna asked Claire to "help me call up people to share out as you see things unfold." This shows how the coach and teacher were engaging in co-modeling a new instructional plan as partners.

4. Providing Tools

Claire frequently provided tools to teachers but also encouraged them to modify and adapt tools, based on student needs. Like Sara, Claire supported teachers in using the summary table. However, unlike Sara, Claire did not present tools to teachers as fixed curriculum supports. Instead, she promoted the message that tools are always flexible and ever-changing, based on student's needs and ideas.

Co-developing Purposeful Tools: When working with teachers in the classroom, Claire always engaged teachers in co-planning conversations designed to co-develop tools aimed at supporting deeper student sense-making or eliciting more about student's science ideas. For example, the following excerpt is from a debrief conversation where Claire introduces the idea of adding a purposeful tool for a specific student need. Claire suggests that they modify a curricular tool with "zoom in" bubbles to make sharing unobservable science ideas more accessible to students. By doing this, she invites the teacher into a co-planning conversation aimed ad adjusting the district curriculum with a tool to better support students in sharing ideas.

Claire: So what were some of the ideas that are sticking with you from the kids?

That you heard?

Ellie: So, they were really engaged. And I was happy about that.

Claire: Are they not normally?

Ellie: Well, yeah, they are in the beginning but then they get quiet…but they could still be listening and engaged…Oh, did you draw that? (referencing something Claire drew on a blank model scaffold)

Claire: Yeah, I did. I noticed that some of them didn't really know what we mean when we say 'draw with your microscope eyes'…maybe if we introduced a 'zoom in' bubble on the model, it might help them show what we mean. What's happening right here if we blow this part up?

(Transcript from coaching conversation with Ellie)

The following pictures (Figures 11 – 13) are examples of how Claire's teachers used the Summary Table in their classrooms. Notice the variety in ways that student's science ideas were displayed. Each example attempts to include multiple opportunities for students to contribute science ideas. Capturing "correct" ideas was not the focus of either example.

Figure 10

Picture of Summary Table in Johanna's Classroom

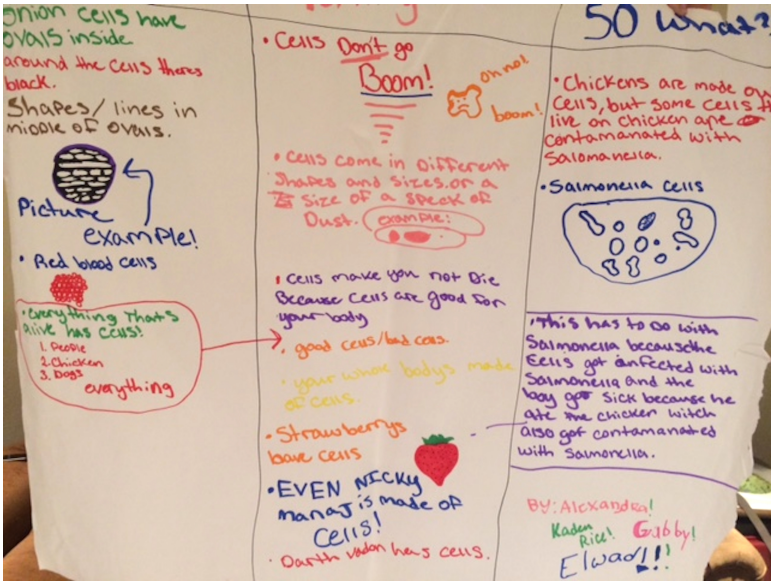


Figure 11

Picture of Summary Table in Amanda's Classroom

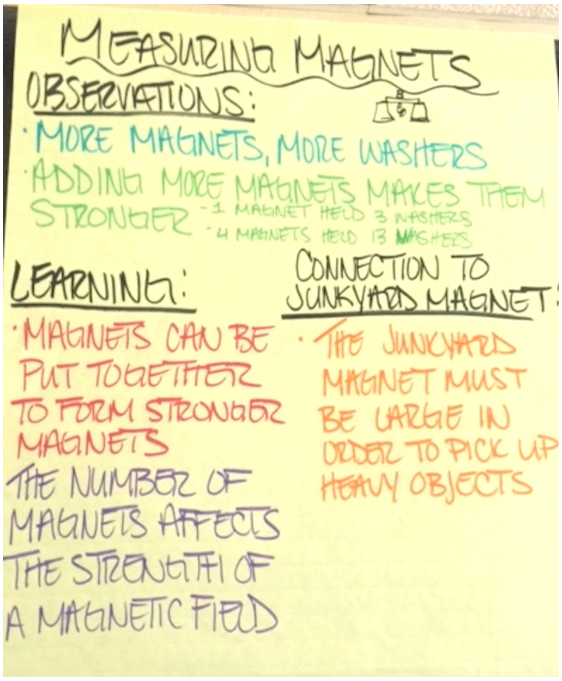
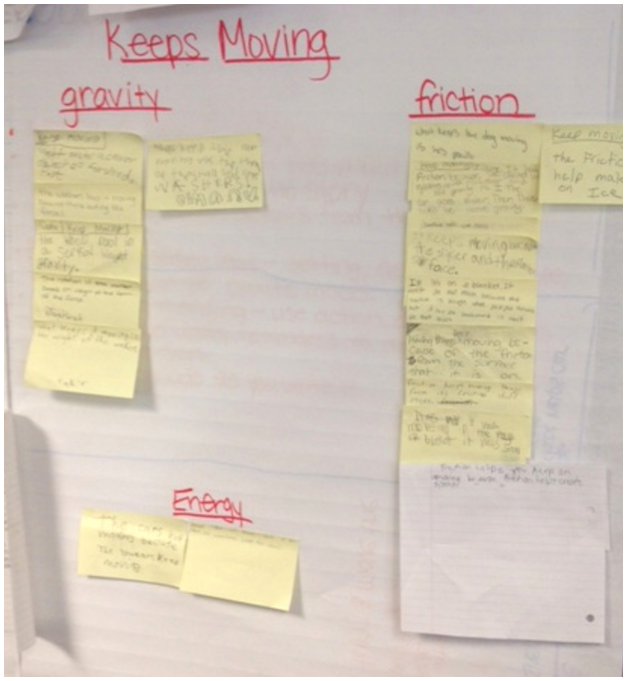


Figure 12

Picture of Summary Table in Ellie's Classroom



These pictures show how Claire supported teachers in adopting instructional tools purposed at supporting teachers in displaying student's science ideas publically. The pictures include a variety of students' observations and ideas pertaining to how they made sense of activities and related their findings to better understanding the overarching science phenomenon.

The Impact of Professional Development on Teacher Learning New Instructional Practice

Throughout the year, the six teachers in this study regularly participated in after school professional development, studio days, and received in-class coaching from Claire and Sara. Claire and Sara interacted with all of the teachers during studio days and after school professional development. Overall, Claire mostly supported Johanna, Amanda and Ellie throughout the school year and Sara mostly supported John, Hank and Bryn during in-class coaching. Like the coaches in this study, teachers also have sense-making frameworks that influence how they interpret policy. In order to understand how individual teachers learn to enact new practice, it is important to conceptualize teacher perceptions for how they interpreted their own work. This section of the findings will describe trends in how teachers perceived science, student learning, classroom teaching and began to enact reform-related instruction.

To characterize teachers' lenses on their own work, data was distilled from multiple interviews and conversations with teachers collected over the course of the study. During pre and post interviews, teachers responded to thematic clusters of questions pertaining to their perceptions of 1) the disciplinary nature of science, 2) student learning, and 3) classroom teaching. Transcripts for each teacher were analyzed using three progressions pertaining to each of the three conceptual categories (See Appendix A: Teacher Sense-making and Perceptions Observational Rubric). Within each category of the learning progression are sub-categories that range from "unproblematic" to "problematic" perceptions. For example, individual perceptions

of the disciplinary nature of science can range from unproblematic to problematic. Unproblematic means that science facts are known and waiting to be uncovered. Whereas a problematic view is that science ideas are human constructions, not objective facts out there in the world, waiting to be discovered. In these findings, problematic is a more sophisticated perception.

When characterizing teacher perceptions, I identified passages in the transcripts that were relevant to a progression and made a determination about where on the progression a teacher was. Each teacher referenced particular categories, multiple times, that pertained to the same progression. The final step for each progression was interpreting the sum of comments relevant to each section and identifying the place on the progression that matched up with most of the passages. Each "X" represents at least 1 passage from one teacher. This process was repeated for each of the three progressions. The following three tables organize teachers' perceptions of science, student learning and classroom teaching. The tables group teachers based on whether their primary instructional coach was Claire or Sara. However, these tables do not aim to claim that teacher believes were influenced by coaches alone. To clarify, there are many factors, other than coaches, that influence teacher perceptions, such as (but not limited to): school site, messages from the principal, interactions with other teachers, previous experiences with learning science, etc.

When comparing teacher perceptions of science as a discipline, there seems to be a notable trend in how these teachers perceived science as a problematic or unproblematic discipline (See Table 13). All of the teachers in this study seem to have a similar interpretation of the disciplinary nature of science. Notice that all six teachers perceived that scientific knowledge takes the form of facts, is a complex set of ideas that explain phenomena and that science ideas

are well-known and accepted by those in the science community. In addition, most perceive science as an unproblematic, fixed body of knowledge that is learned from experts through a systematic procedural approach. (It is important to note that Johanna worked with Claire in the previous year on learning the reform-related practices. During an interview, Johanna explained how her perceptions of science changed from engaging students in learning through reform-related practice. In the previous year, Johanna claimed to have had a similar perspective to the other teachers in the study.) Four of the teachers (Johanna, Amanda, Ellie and John) held a partially unproblematic stance of science and referenced that science happens by building, evaluating and refining theories and models. Only two of the teachers (Johanna and Amanda) referenced that science ideas, methods and experiments could be negotiated. These two teachers work in the same school.

Table 13

Teacher Perception of Science

	Primary Instructional Coach	Claire			Sara		
Teacher		Joh	Am	Eli	Jon	Han	Bry
1	Science is an unproblematic method for finding out about the world	"X"	X	X	X	X	X
	Science skills such as a systematic procedures and data collection techniques are of central importance		X	X	X	X	X
2	Science is a well-known body of knowledge that is codified in texts and experts		X	X	X	X	X
	Scientific knowledge takes the form of facts and assertions	X	X	X	X	X	X
3	Science is a complex set of ideas that explain phenomena	X	X	X	X	X	X
	Ideas are well-known and accepted by those in the science community	X	X	X	X	X	X
4 (Problematic	Science happens by building, evaluating and refining theories and models.	X	X	X	X		
	Scientific ideas and methods of observation and experimentation can be negotiated.	X	X				

When comparing teacher perceptions of student learning, there seems to be a notable trend in how these teachers perceive student learning (See Table 14: Teacher Perceptions of Student Learning). All six teachers perceive that learning happens through acquiring and processing information and that learning is aided by guidance from a more knowledgeable person. This suggests that teachers may have perceived that they need to be "science experts" in order to support students in learning science. However, it is interesting to compare this similarity with the differences in their perceptions of how learning happens or is demonstrated. John, Hank, Bryn and Ellie seem to perceive that students learn through engagement in activities and that

learning happens when student's misconceptions are corrected. Johanna and Amanda seem to perceive that learning happens when students gradually build, refine and test their emerging science ideas through social engagement that requires sense-making, puzzlement and reasoning.

Table 14

Teacher Perceptions of Student Learning

	Primary Instructional Coach	**Claire**			**Sara**		
Teacher		Joh	Am	Eli	Jon	Han	Bry
1 (Unproblematic)	Learning happens through engagement in activities			X	X	X	X
	Engagement in tasks such as "hands on" science and frequent "lab" activities is expected to result in learning			X	X	X	X
2	Learning happens through acquiring and processing information	X	X	X	X	X	X
	Learning is demonstrated by reporting information accurately in response to verbal or written questions			X	X	X	X
3	Learning happens through conceptual change from naïve misconceptions to scientifically correct understanding			X	X	X	X
	Learning is aided by guidance from a more knowledgeable person	X	X	X	X	X	X
4 (Problematic)	Learning happens gradually by building, refining, and testing emerging understandings within a social group.	X	X	X			
	Learning requires sense-making, puzzlement, and reasoning	X	X	X			

Teacher perceptions of classroom teaching are important to consider when teachers are expected to experiment with new reform-based instructional practice. Table 15 displays teacher perceptions of classroom teaching. All six teachers overlap in most of the progression. There is a notable difference between the perceptions of Johanna, Amanda and Ellie, who believe that

teachers should support student sense-making over time and engaging students in discourse to support metacognitive sense-making. Notice that John, Hank, Bryn and Ellie seem to believe that teaching is about correcting students' misconceptions and serving as a knowledgeable guide. The difference in these teachers' perceptions of classroom teaching is important to consider how teachers engage in risk-taking by attempting new forms of instruction. Johanna, Amanda and Ellie seem to view practice as something to be experimented with in service of supporting students in metacognitive revision of science ideas. Whereas John, Hank, Bryn *and Ellie* seem to view practice as something to be experimented with, but purposed at correcting student's misconceptions.

Table 15

Teacher Perceptions of Classroom Teaching

	Primary Instructional Coach	Claire			Sara		
Teacher		Joh	Am	Eli	Jon	Han	Bry
1 (Unproblematic Stance)	Teachers support student work through scientific activities and scientific methods			X	X	X	X
	Teaching is about organizing activities and keeping students "on task."	X	X	X	X	X	X
2	Teachers provide access to information through texts and media, confirmatory/discovery activities, and direct instruction.	X	X	X	X	X	X
	Teaching is about making information accessible and clear	X	X	X	X	X	X
3	Teachers pre-assess students' misconceptions & provide key science activities/information to help change their understanding	X	X	X	X	X	X
	Teaching is about correcting students' misconceptions and serving as a knowledgeable guide			X	X	X	X
4 (Problematic Stance)	Teachers support sense-making through discussions, activities, and "just in time" instruction in response to students' unfolding ideas	X	X	X			
	Teaching is about connecting students' ideas to each other and to additional science ideas	X	X				

Teachers' pre-conceived perceptions for how they interpret the disciplinary nature of science, student learning and classroom teaching is important when trying do understand how teachers learn to enact new-reform related instruction. How teachers view their work supports us in understanding how and why they may or may not take risks when experimenting with their instructional practice. In a broad level comparison, the teachers in this study are fundamentally similar in their perceptions of science; all seem to have a mostly unproblematic perception of science as a discipline. The teachers in this study also have many common perceptions about

how students learn; all perceive that students learn from acquiring and processing new information and that a more knowledgeable person is needed to guide students in learning new information. However, Johanna, Amanda and Ellie seem to have the most different lenses for how they perceive student learning and classroom teaching, which may be helpful when interpreting how teachers attempt to experiment with new reform-related practice.

Teacher Attempts to Experiment with Reform-Related Instructional Practice

As expected, none of the teachers in this study completely "shifted" their instructional practice over the course of one year. However, all of the teachers made attempts at trying out new reform-related practice. This section focuses on explaining some of the broad-level trends observed when teachers began to experiment with reform-related instructional practice.

As described in the Literature Review, the Ambitious Science Teaching Framework focuses instruction on a set of four core instructional practices, 1) Selecting Big Ideas, 2) Attending to Student's Ideas and Experiences, 3) Using Activity to Support On-going Changes in Reasoning and 4) Pressing for Explanation that support teachers in implementing reform-related instruction. Teacher observations of classroom instruction were analyzed using a teacher learning progression (Appendix B: Teacher Practice Classroom Observation Rubric), that categorized teacher practice using these four dimensions (Thompson, Windschitl & Braaten, 2013). There are five levels of sophistication identified within each of the four dimensions (See Table 16). Levels are listed vertically from least (at the top) to greatest (at the bottom) within each practice. For example, "Selecting Big Ideas" includes five levels of sophistication; 1) missing science content, 2) focus on topic or things, 3) focus on observable processes, 4) focus on observable-unobservable and 5) explanation as model. The least sophisticated version of this practice, "missing science content," is when the teacher builds a lesson or unit on topics that are not

connected to phenomena in the natural world. In this type of instruction, teachers tend to stand and deliver science facts. A slightly more sophisticated version of this practice is to "focus on topic or things," which means that a teacher has selected concrete or abstract entities (things) to learn about in varying degrees of detail. In this type of instruction, students are often asked to describe, name, label and identify using correct vocabulary. In the next sub-level of sophistication, "focus on observable processes," the teacher has selected a natural system for students to identify what is changing within a system or how conditions affect a naturally occurring event. Teachers tend to focus on logical relationships among concepts. A more sophisticated version of that level is for teachers to "focus on observable-unobservable" processes, events or entities and how they relate to observable phenomena. In such cases, teachers frame a unit around complex, situated phenomena to be explained. Finally, the most sophisticated version of "Selecting a Big Idea" is when a teacher emphasizes links between observable and unobservable in order to support student sin developing an explanatory model that students make sense of over time. In this level, students make links between observable and unobservable science content to help them continuously develop an explanation for a naturally occurring science phenomena.

Table 16 shows teachers' enactment of reform-related instruction, based on observations over the course of the year. Multiple lessons were observed and analyzed over the course of the study. The table represents teacher's attempts at enacting new practice. Each "X" represents at least 1 attempt by the teacher to enact an instructional practice related to the learning progression. When learning to enact new forms of instruction, teachers tended to enact a variety of different levels of sophistication within the same lesson and received an "X" in multiple levels of sophistication during the same lesson. Teachers received an "X" if they attempted a more

sophisticated form of instruction. None of the teachers in this study unproblematically learned to take-up sophisticated forms of reform-based instructional practice. In fact, when experimenting with their instruction, teachers tended to oscillate back and forth in varying levels of sophistication within the same lesson. For example, teachers tended to start in least sophisticated practices in the beginning of a lesson (i.e. during warm-up activities or when orienting students to new procedures and materials). Later in a lesson, teachers tried out more sophisticated levels of instruction when students participated in small group sense-making conversations but reverted to less sophisticated levels of instruction during whole-group consensus building conversations. Teachers were given credit for their attempts.

Table 16

Teacher Enactment of Reform-Related Instruction

(Vertical Sub-listing: Least Sophisticated to Most Sophisticated Practice)

Primary Instructional Coach		**Claire**			**Sara**	
Teacher	Joh	Am	Eli	Jon	Han	Bry
Selecting Big Ideas						
Missing science content						
Focus on topic or "things"			X	X	X	X
Focus on observable processes	X	X	X	X	X	X
Focus on observable-unobservable	X	X	X		X	
Explanation as model	X	X	X			
Attending to Student's Ideas and Experiences						
No access to students' ideas						
Monitoring for correctness of students' ideas			X	X		X
Eliciting students' initial & unfolding understandings	X	X		X	X	
Referencing students' ideas	X	X	X			
Using students' ideas and experiences to adapt instruction	X	X	X			
Using Activity to Support On-going Changes in Reasoning						
Students not engaged in activity						
Primarily focusing on procedure			X	X	X	X
Discovering or confirming science ideas	X	X	X	X	X	X
Linking concepts within and across investigations	X	X	X			
Model-based inquiry focus	X	X	X			
Pressing for Explanation						
No press for a scientific explanation						X
"What happened" explanation		X	X	X	X	
"How/partial why" something happened explanation	X	X				
Causal explanation	X		X			
Arguing from evidence about an explanatory model						

Least → (↓)

Table 16 captures the broad-level comparisons of teacher attempts to enact reform-related instruction over the course of the year. When walking into these teachers' classrooms, an observer would see similar features of all of these teacher's classrooms. All of the teachers attempted to implement the district-revised units of instruction and focused instruction on

supporting students in developing their understanding of observable processes to explain naturally occurring phenomena. All of the teachers attempted to use similar tools to support student learning, like Summary Tables, and visual tools and procedures that support student-student talk. However, teachers attempted reform-related instructional practice at different levels of sophistication, which supported a different purpose for student sense-making of science.

When observing the teachers, there was a noticeable characteristics in how teachers attempted instruction. The most notable difference was teachers who attempted to incorporate students' science ideas during instruction. When *Attending to Student's Ideas and Experiences*, Johanna, Amanda and Ellie frequently attempted more sophisticated levels of practice. They tended to experiment more with their instruction and adapted lessons and curricular tools based on student interests and science ideas. They also tended to develop on-the-spot tools to eliciting more about student's science ideas so they could understand more about why individual students held particular science beliefs. When supporting on-going changes in student reasoning, Johanna, Amanda and Ellie tended to use activities to help students make content connections across multiple activities or lessons with a model-based inquiry focus. When doing this practice, these teachers introduced new science concepts and asked students to use the new ideas to make sense out of activities. They also asked students to consider how the new science ideas could be included (or not) in student's developmental model explanations of a phenomenon.

In comparison, John, Hank and Bryn tended implement the new science units with fidelity. While they elicited student's ideas and experiences during lessons, they did not necessarily incorporate student ideas and interests into the unit lessons or trajectory. Instead, they continued to enact lessons in the order that they were listed in the unit guide and followed the lessons flow as written. When using activities to support on-going changes in reasoning, they

tended to monitor for correctness of ideas and used activities to confirm or discover science facts. They tended to use instruction tools to displaying correct science ideas, not necessarily student's science ideas. When attempting new to enact new forms of instructional practice, John, Hank and Bryn focused on supporting students in learning canonically accepted science ideas, facts and vocabulary of phenomena.

Teacher's Interpretations of Reform

An interesting commonality between all of the teachers is how little they knew about the NGSS. During pre and post interviews, all of the participating teachers were unable to explain what the NGSS was and how the Science Academy was supporting them in implementing the standards. Only one of the teachers could comment on information about the science content in the standards because she was ordering literacy books for her school that were aligned to the science content. Table 17 shows teacher perceptions of the reform and the reform-related instructional practice. During pre and post interviews, teachers were asked a series of questions related to their understanding of the reform, "NGSS." Teachers were asked "What do you know about NGSS? And what problems do you think NGSS is trying to solve, or change, in instruction?" Recall that all of these teachers participated in a year-long, job-embedded professional development program, yet none of them were able to articulate a complex understanding of the reform. However, when the researcher asked the teachers the same questions but used the context of the Science Academy, teachers offered up a much more complex answer about what they were trying to change about their instructional practice.

Table 17:

Teacher Interpretations of NGSS

	What is NGSS asking you to change in instruction?	What is the Science Academy asking you to change in instruction?
Johanna	When you say Next Gen science Standards, I would have no idea what you're talking about.	I guess it would be that like example of how I was taught science. Of, "Here, read a textbook and answer a few questions. Take a test. Oh, you have the content." Supposedly. Do I remember any of that now? No. And so I think some of those practices that are embedded within there, like changes the way…it makes science more meaningful.
Ellie	I have no idea because I don't know anything about the Next Gen.	Scientific thinking, critical thinking. Reasoning, critical reasoning. I mean that's what I would say. That these kids are thinking like scientists and the focus is more on the process than the output.
Hank	I know that it's coming. And they've also tied it to the state standards, like the Common Core, right? I honestly don't know (what problem NGSS is trying to solve or get you to do in practice.)	It's student-directed. For me, I feel like. Or there's a lot of student discourse. Putting things in students' hands. Right?
Bryn	I don't necessarily know what Next Gen is or what we're doing that is aligned.	It's just asking students to deeply understand and comprehend what they're doing and what they're learning.
Amanda	Students making a claim and using evidence to support claims; building on ideas; students discussing arguments/claims and using evidence to support ideas.*	Kids talking to each other more and having that conversation. Being able to be flexible in their thinking. Going back and changing models…this idea of capturing their thinking after each lesson… It definitely seems like the teacher is not the keeper of all the knowledge. You know the idea of stand and deliver is not the goal of this. There's some other way we're going to present it and let the kids do the heavy lifting and try to figure out what they saw. We're leading them but we're not…you know there's this focus question that's…or a list of questions you want to do to push their thinking but it doesn't seem that there's any point where we necessarily give them the right answer.

John	A connection between next gen and ambitious teaching is the idea of evidence-based reasoning. There is also a connection between the changing of ideas based on new evidence.*	They're putting the kids' thinking and their explanations, I think, deeper. With explaining how and why things are happening. Or what they're doing. And a lot of the getting kids just to talk about it. And talk about science and build. Like just building on the ideas too. I think that like these other science…I mean even probably when I was a kid I don't really remember them always building off of one. Like the phenomenon and that's building on top of each lesson. To help explain it. Because I feel like every other…it's kind of just like disjointed and you just do this lesson and you don't know why you're doing it. And these it's more like just built and it's kind of more streamlined for the kids and for their thinking. Because you're always relating back. "Okay, so how does this lesson relate back to helping us explain?"

**These teachers were asked to make a targeted connection between the reform and the reform-based instructional practices during an after school professional development session, late in the school year. They were only asked to make this connection after the researcher explained to the instructional coaches that the teachers did not know what NGSS was or how it was related to Ambitious Science Teaching.*

All of the teachers in this study participated in a year-long, job-embedded professional learning activities that encompassed all of what the research has identified as necessary to supporting teacher sin learning to take up new reform-related instructional practice. However, Table 17 shows us that despite participating in a high-quality professional development program, none of the teachers seemed to what NGSS was or how it was asking them to change their instruction. Even Amanda and John, who were engaged in a unique sense-making activity did not seem to make a connection between NGSS and their instructional practice. Notice, that both of their answers have to do with what students should be doing, not teachers.

When asked more specifically about the Science Academy (rather than the reform), teachers were able to give a more detailed rationale for what they were being asked to do in their

instructional practice. Each responded with a unique articulation of what they thought they were being asked to do and how it related to instruction. However, all included descriptions that related to developing a learning environment purposed at supporting students in talking to each other about science ideas. For Johanna and Amanda, the goal of instruction as not to present science facts and expect students to reproduce facts on a test. Their interpretation of what they were being asked to do was to "present" new information to students in "some other way" than to "stand and deliver" science content. Amanda explains that kids were expected to "do the heavy lifting" to "figure out what they saw." The teacher's role was to "push their thinking" and that it didn't matter if student's acquired "the right answer." Bryn and John referenced the idea that students need to be learning science content at a deeper level. Bryn emphasized that teachers need to "ask students" to "deeply understand and comprehend" what they are learning and expanded that each lesson is "always building off of" another one to support students in building "their explanations" for "phenomenon." The teachers' role is to "streamline" learning of science content to help kids "relate" new information "back" to the phenomenon.

Discussion

Assertion 1: Value of Interpretive Frames: The four spheres of influence contributing to a coach's larger interpretive framework were helpful conceptual categories for describing how these professionals reasoned about the nature of reform, how they viewed their roles in instructional improvement, and how to work with teachers.

Studies of policy implementation tell us that, due to the complexity of sense-making, large-scale standards-based reforms are unsuccessful because critical actors in implementation, like teachers and coaches, develop widely varying interpretations of the standards and how to engage in instruction to implement the new standards in their classrooms (Cohen & Ball, 1990; Cohen & Hill, 2001; Elmore, 2000; Elmore, 2004; Hargreaves & Fullan, 2012; Meyer & Rowan, 1978; McLaughlin, 1987; Spillane, 2004). There is little in the research that explains how coaches understand the purposes of reform and interact with teachers to improve instruction and even less explaining systematic variations in how coaches use their sense-making frames to shape their work with teachers. My findings reinforce that standards-based educational reforms do not translate unproblematically to outcomes at the local level and that implementation is ultimately a challenge situated at the level of the classroom teacher (Elmore, 2004; McLaughlin, 1987; Schneider, Krajcik & Blumenfeld, 2005; Weatherly & Lipsky, 1987). However, by focusing on understanding the role of the instructional coach, my findings provide a plausible explanation for how and why different interpretations of reform develop within the same local system (Allen & Penuel, 2014).

Instructional coaches mediate teachers' translation of policy to shifts in instructional practice. The explanation for how this happens is at least partially rooted in the instructional coach's interpretive framework for reform. The idea that individuals filter policy messages

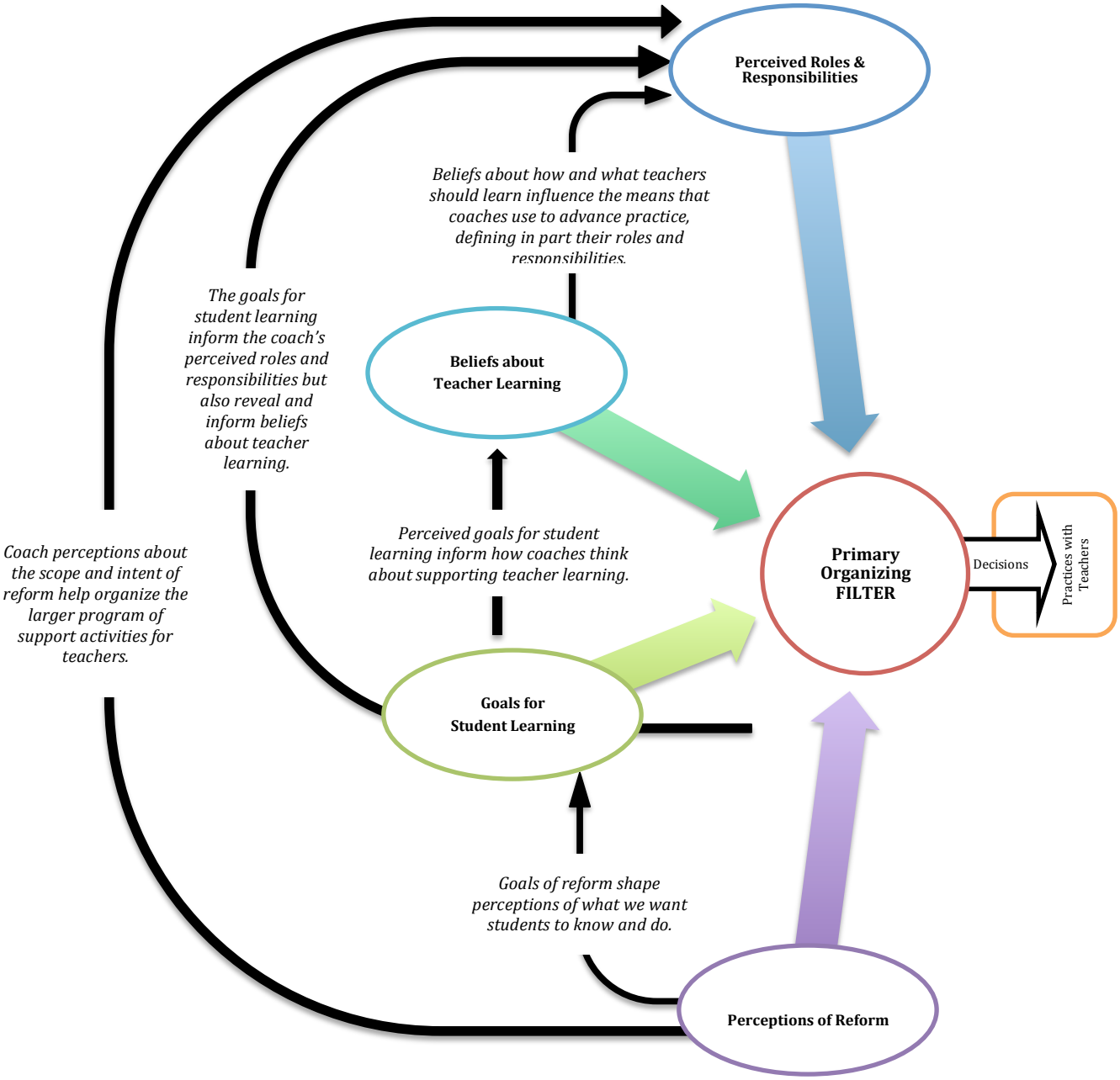
through their own interpretive lenses is not new. There has been a significant amount of research that highlights the importance of instructional coaches related to supporting teachers sense-making of new policy and instructional practice (Allen & Penuel, 2014; Anderson *et al.,* 2014; Atteberry *et al.,* 2008; Bean, Drapper and Hall, 2010; Coburn, 2001; Coburn & Woulfin, 2012; Cornett and Knight, 2008; Fullan & Knight, 2011; Killion, 2009; Mangin & Deussen, 2015; Neumerski, 2013; Spillane *et al*., 2003). When trying to explain the complexity of reform implementation, the literature on sense-making emphasizes that an individual's "mental frames" or "worldviews" act as filters for developing interpretation for how to enact new educational policy in classroom instruction or deciding whether reforms are asking for shifts in practice at all (Cohen & Ball, 1990; Cohen & Hill, 2001; Elmore, 2000; Elmore, 2004; Hargreaves & Fullan, 2012; Meyer & Rowan, 1978; McLaughlin, 1987; Spillane, 2004). However, little of this research examines the specifics of how coaches filter and reconstruct instructional reform messages when working with classroom teachers. Few, if any, studies have talked about the idea of coaches using unique frames that are central in influencing how they develop interpretations of new policy. This study developed a framework that was helpful for explaining how and why coaches develop varied interpretations for how they should support new instructional reform with teachers. I identified four spheres of influence that contribute to a coach's interpretive framework about reform, and appeared to be specific to the role of working with teachers around changes in practice.

While individuals can use multiple interpretive lenses in the context of their work (Coburn, 2001; Harris, 1994; McLaughlin, 1987; Simon, 1991, Spillane, 2004; Wieck, 1996), this study specified four *spheres of influence* that were linked to the coaches talk and actions

around reform: 1) perceived roles and responsibilities, 2) beliefs about teacher learning, 3) goals for student learning, and 4) perceptions of reform (See Figure 13).

Figure 13

Revised Coach's Conceptual Framework for Interpreting New Policy to Practice



Identifying these *spheres of influence* for each coach helped the researcher understand how and why they framed and responded differently to similar problems of practice. These spheres of influence were also helpful in interpreting how and why coaches made choices while working with teachers, and suggested coaches' motivations to engage in particular activities with teachers.

During their work with teachers, coaches tended to draw upon specific spheres of influence for decision-making and action, depending on the nature of the work. For example, Sara provided teachers with curricular tools that were always district-approved and relied on these tools to catalyze changes in practice. In taking this course of action she appeared to foreground beliefs about teacher learning and her perceived role as coach that if teachers are using a specific tool or enacting a prescribed routine, then they are assumed to have learned to enact reform-related instruction. When Claire regularly prompted teachers to articulate what student ideas they heard during a lesson, she drew upon the same two spheres of influence to take action based on the belief that teachers learn primarily through reflective conversation about what supports changes in student sense-making. These coaches engaged specific frames and/or combinations of frames to help them develop a better understanding for how to act.

When looking at multiple instances in which the coaches invoked their spheres of influence, it became evident that there was a *Primary Organizing Filter (POF)* that predominantly shaped how coaches made decisions in their work with teachers. By identifying each coach's POF and spheres of influence, this study was able to conceptualize how and why different interpretations of reform developed between them and gave rise to different coaching practices, despite working as a team in a highly-coordinated program of professional development.

Sara's POF for accountability tended to influence how she engaged teachers during coaching activities. Sara had a strong sense of professional commitment for demonstrating that her work with teachers was both aligned to the school district's initiatives and easily communicated back to her supervisors. During coaching activities, Sara focused teacher learning on district-approved initiatives, such as collecting classroom observational data about ELLs. She tended to enact coaching activities in a uniform way so that she could provide routine and "equal" support for all of her teachers. No teacher received "tailored" coaching from Sara and all teachers received identical messages from her about what was important in science instruction. Because her coaching practice was pre-determined and routinized, it was easy for Sara to document to the district office exactly what support she provided for teachers and how frequently they received support.

Sara's POF for accountability, and the individual spheres of influence worked together to both reflect her choices and help explain them. Sara seemed to hold to an unproblematic perception of teacher learning; she assumed that teachers learn new instructional practices best by enacting prescribed routines designed by more knowledgeable others, with fidelity. For Sara, reform was best implemented through district-wide alignment of curricular tools, and teachers demonstrating their learning by showing mastery of a new lesson, routine or tool.

Like Sara, Claire believed that reform was primarily about new content standards and that teachers needed to learn how to support student reasoning through the Science and Engineering practices outlined in NGSS. However, Claire differed from Sara because she believed that, in order for teachers to change their instructional habits, they needed to actively inquire into how small changes in their instruction were impacting students' ability to participate in science and in sense-making. Claire, as different from Sara, seemed to have a strong professional commitment

for supporting teachers in learning how to elicit students' science ideas and make instructional modifications based on student ideas.

Claire's POF for adaptive instructional practice tended to influence how she engaged teachers. While enacting the same categorical types of coaching activities as Sara, Claire tended to use a responsive coaching practice with teachers, in which she frequently made in-the-moment coaching decisions during class based on student or teacher needs. Claire spent most of her time co-instructing, co-planning and co-debriefing with teachers for extended days at a time, rather than during once-a-week visits. She supported teachers in learning by engaging them in reflective conversations about specific instructional moves and how they impacted students' reasoning with new ideas. Supporting teachers to develop their use of high-leverage instructional practices, in a way that focused on student ideas, reveals Claire's conceptions about teacher learning, goals for student learning, and perception of reform.

Assertion 2: Interpretive frameworks appear consequential because coaches use them to privilege certain views about instruction, or establish priorities for how to work with teachers.

As critical change agents (Full & Knight, 2011; Neumerski, 2013) for supporting teachers in learning to enact new instructional innovations, research suggests that districts need to position instructional coaches as pedagogical experts with tools and time to work with teachers around problems of practice (Coburn, 2001; Elmore, 2000; Fullan & Knight, 2011; Fullan, 1995; Fullan, 1996). Recent research also recommends that professional development be focused on learning a core set of shared "high-leverage practices" that embody reform goals (Ball & Cohen, 1999; Hatch & Grossman, 2009; Firestone *et al.,* 2008, Lampert, 2001; Grossman, Hammerness & McDonald, 2009, Little, 1993). There are few examples however, that explain how

instructional coaches impact teachers' work around problems of learning high-leverage practices (Gallucci *et al.,* 2010; Lampert *et al.,* 2011). Both of the coaches in this study focused on supporting teachers in learning high-leverage practices aligned to the reform, but in very different ways. Instructional coach's interpretive frameworks were consequential during the implementation of new instructional reform because they used them to privilege certain views or establish priorities for working with teachers.

When comparing the kinds of coaching activities Claire and Sara's enacted when working with teachers in the classroom, it would be easy to make surface-level assumptions that both coaches supported teacher learning in the same way. Although both instructional coaches in this study enacted the same categorical types of coaching *activities* with teachers, they did not have uniform *practices* for how they engaged teachers in learning reform-related instruction during these coaching activities. The nominal categories of "coaching activities" that are common in the literature such as planning lessons, modeling lessons, observing instruction, debriefing observation, facilitating meetings and reviewing student data (Anderson *et al*., 2014; Fullan & Knight, 2011; Gibbons & Cobb, *in press*; Neumerski, 2013) may obscure the unique forms of professional practices that characterize coaches day to day work with teachers. By "practices" I am referring to the essential routines and skills that members of a field are socialized into as part of their professional repertoire (Bourdieu, 1977; Reckwitz, 2002).

Sara's repertoire of practices include: ask all teachers to use the same tools to organize and enact instruction, visit classrooms for the purpose of recording data about how frequently ELLs would speak, and provide her written notes and participation data as feedback for the teacher. Her POF for accountability, reinforced a message to teachers that maintaining alignment to district initiatives and implementing curricular units with fidelity was most important. Her

coaching practices reflected these commitments when she supported teachers in enacting their routines by giving them all the same curricular tools and emphasized that it was important for students to learn specific science concepts and vocabulary so that students could perform well on state science achievements. While focusing teacher attention on supporting students to perform well on state tests is not necessarily unproductive, using this as the primary aim of instruction can have an impact on how teachers make choices in their instruction. Over the course of the year, Sara's teachers made fewer attempts at more sophisticated versions of reform-related practice and were less inclined to experiment with their instructional practices (other than using new curricular materials). The teachers that Sara coached became more focused (although not exclusively) on supporting students in using "correct" concepts and vocabulary to explain science phenomena. They were less inclined to use students' ideas as resources for reasoning or to engage students in sense-making.

She supported teachers in enacting new practice routines by giving them the same curricular tools and emphasized that it was important for students to learn specific science concepts and vocabulary so that students could perform well on state science achievements. While focusing teacher attention on supporting students to perform well on the state test is not necessarily a bad goal, it can have an impact on how teachers make choices in their instruction. Over the course of the year, Sara's teachers made fewer attempts at more sophisticated versions of reform-related practice and experimented less with their instructional practices (other than what Sara recommended to them). The teachers that Sara coached were more focused on supporting students in using "correct" science concepts and vocabulary to explain science phenomena.

In contrast, Claire's POF for adaptive instructional practice reinforced a message to teachers that adapting instruction to student's science ideas was most important. Her coaching practices reflected this ideology when she adjusted her coaching approaches, based on teacher learning needs and state of instructional skill. She supported teachers in adapting and enacting new practices and routines by co-inquiring into instructional practice with them, as a partner—not an "expert." She frequently modeled the idea that there was not a perfect lesson and continually emphasized to teachers that they needed to change daily routines and instructional tools based on student's current science ideas. Claire did not focus teacher attention on students reproducing "correct" science explanations. Instead, she reinforced the idea that teachers allow students to engage in authentic scientific experimentation, argumentation, and metacognitive reasoning to develop a deeper understanding for how and why science phenomena occur. Claire's teachers attempted to enact more sophisticated levels of reform-related instructional practices. When experimenting with their instructional moves, they tended to continuously puzzle with how to incorporate more student ideas and strategically structure small and whole class discussions for students to talk with each other about their science ideas and the evidence they used to support their reasoning.

In this study, explaining how teachers learn to enact new reform-related instructional practice requires examining the intersection of the teacher and coach sense-making frames during professional development (Coburn, 2001). It appeared that similarities between coach and teacher frameworks influenced how messages about instructional practice were interpreted, and what teachers attempted in their instruction. The instructional coach's POF seemed to affect which teacher frames were activated during sense-making. If an instructional coach and teacher had similar frames for how they thought about instruction, then a coach's interactions would

reinforce a teacher's pre-existing frames. For example, Sara coached Bryn, who was one of the teachers who already tended to monitor for correctness of students' ideas and focused student learning on procedures, vocabulary acquisition and facts. This can be at least partially explained because the teacher-coach frameworks were aligned (in addition to other institutional factors) with a focus on improving student achievement scores (that assessed factual knowledge and procedure). Bryn held a strong belief that improving student performance on the state assessment was her primary responsibility as a science teacher and a clear indicator of learning. In addition to Sara's coaching, Bryn received similar institutional messages from her principal that improving MSP scores through content acquisition was an important goal of instruction. By no means did Bryn and Sara perceive that this teaching was inequitable. However, their similar frames reinforced how they worked together to achieve goals consistent with their views of valued learning. Reform was about alignment with new content standards, not about fundamental shifts in practice. They likely saw their practice as doing the best for students in under-resourced schools and using tools and practices that made sense to them within their interpretive frames and institutional context.

Another example is Ellie, one of Claire's teachers, who attempted more sophisticated forms of reform-related instructional practice. In the beginning of the school year, Ellie believed her role was to improve student achievement scores and was highly focused on making sure that her teaching aligned with the district mandates and messages about reform. In addition, she taught in a school where the principal publically rewarded and ranked teachers and students for their performance on the state assessment. Prior to interacting with Claire during one-on-one coaching, Ellie was focused on making sure that she covered all of the science content and vocabulary so that students would be prepared for the state assessment. Claire's interactions with

her was a prime example of how an instructional coach could engage teachers in sense-making events that could then precipitate a re-thinking of initial frames for instruction. Claire worked with Ellie over the course of the year and her coaching practice seemed to push against Ellie's strong accountability frames. During a post-interview, Ellie explained how her own perception of the goals for student learning changed to allow more time for students to engage in rich, meaningful discussion in order to learn content in more depth. In order for a teacher to intentionally make meaningful changes in their instructional practice, it seemed necessary for instructional coaches to engage them in some type of sense-making event that caused a re-thinking of their initial framework.

Equity is one of the messages about new reforms on the website Next Generation Science Standards: For states, by states (NGSS Lead States, 2013) and *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). When comparing how coaches mediated translation of policy to shifts in instructional practices, both seem focused on two different interpretations of what equity means in science instruction. Sara's messaging and support focused on teachers enacting instructional practice aligned with high quality curriculum, in order to ensure equal exposure to ideas that would appear on state tests. Claire's messaging and support fostered the development of classroom science learning environments with higher levels of rigor and responsiveness in teacher instructional practice. She focused teacher attention on making sure students were engaged in deep conceptual learning of science ideas.

The research on how under-resourced schools respond to accountability pressures to improve scores on high-stakes assessments (Chrispeels, 1997; Cohen & Hill, 2001; Darling-Hammond *et al*., 2012; Firestone *et al*., 2008; Mintrop & Sunderman, 2009; Moon *et al*., 2007;

Murnane and Cohen, 1986; Slavin *et al.,* 2012; Spillane, Parise & Sherer, 2010) helps explain why Sara may have taken this equity stance. The focal school district in this study had historically produced low student achievement scores on the state-wide tests in mathematics and science. The schools that were part of the Science Academy were the district's lowest performing institutions. Feeling pressure for improving student achievement scores may have influenced many of Sara's actions. In particular, Sara, like many actors in the system, may have viewed equity as a problem of alignment and fidelity, and its' impact measured by standardized test scores.

When comparing the difference in messages that Sara and Claire privileged when supporting teachers in learning reform-related instructional practice, a disparity around equity was evident. How will the classroom learning environments, influenced by the coaching practices of Claire and Sara, impact how students are prepared to become STEM literate? Students in these classrooms will likely be prepared with different skill sets, possibly impacting their access to 21st century STEM careers. In addition, the differences between these learning environments may have a long-term impact on student's interest in pursuing a career-path in the STEM fields.

Assertion 3: Re-structuring professional development to a job-embedded model supported teachers in learning new reform-related instructional practices, however categorically different types of classroom practices emerged. How teachers interpreted the purpose of their instruction was related to how the instructional coach supported teacher learning.

Part of this dissertation aims to address how re-structuring professional development to a job-embedded model supports individual teacher learning of new reform-related instruction. The teachers in this study participated in a job-embedded learning program that included many

components of high quality professional development (Desimone, 2011). To support teachers in learning the NGSS, The Science Academy focused teacher learning on a set of "high leverage" instructional practice (Ball and Forzani, 2009; Hatch and Grossman, 2009; Lampert 2001; Windschitl *et al.,* 2010) as catalysts for change. During the Science Academy instructional coaches used the same tools, same coaching activities and same framework for enacting reform-related instruction of the NGSS. Through the summer institute, after school professional development sessions, studio days and one-on-one classroom coaching sessions, teachers participated in extended learning opportunities aimed at implementing new standards through improving teaching practice (Allen & Penuel, 2014; Cohen & Hill, 2001; Elmore, 2004; Spillane, 2004). During learning events, teachers were engaged in deep conversations about instructional practice (Coburn, 2001) and were strategically prompted in reflecting on their current teaching practices (Ball & Cohen, 1999).

Despite having most of the components that research describes as "best practice" for supporting teacher learning of new policy and practice, different interpretations of high-quality teaching still developed by teachers and coaches. Similar to other studies pertaining to teacher learning of reform-related instructional practice (McNeill & Krajcik, 2007), teachers in this study enacted practice at varying levels of rigor and sophistication. Some enacted instruction that supported students in recognizing "correct" science ideas, whereas others tried to work with student's ideas, fostering the development of meta-cognitive reasoning skills. An administrator observing the classroom might not notice much of a difference between these science classrooms. They would have seen common tools being used and they would have seen instructional moves that support students in talking to each other about science ideas. The

difference in instructional practice, that may only be noticeable to a researcher, is *how* students were talking about science ideas and *whose* ideas they were talking about.

There seemed to be an overall difference in instructional routines and habits when comparing teachers who were supported by Claire and teachers who were supported by Sara. Teachers supported by Claire tended to experiment more with their instruction, to enact more sophisticated forms of instruction that recognized and "worked on" student's ideas, and deviated from district lessons to adapt instruction based on students' science ideas. The teachers that were primarily supported by Sara tended to implement the new science curriculum with fidelity, focused on monitoring and correcting student's misconceptions, and purposed instructional tools to support the learning of "correct" science ideas, facts and vocabulary.

In order for a teacher to intentionally learn to make changes in their instructional practice, it is necessary for instructional coaches to engage teachers in some type of sense-making that causes teachers to re-think their initial frameworks related to what supports student learning (Coburn, 2001; Coburn *et al.,* 2009; Spillane, 2004; Spillane *et al.,* 2002; Spillane *et al*., 2006). When coaching, working with student's science ideas was intentionally foregrounded by Claire. By leading with questions that ask teachers to articulate the science ideas they heard from students, Claire elevated the idea that students have science ideas worth reasoning with. Claire carefully observed teachers and listened to their student's science ideas so that she could engage the teacher in an authentic, reflective feedback conversation while inter-weaving co-planning and the co-development of tools to better support student needs in learning. Working with students' science ideas was the priority for learning.

Unlike Sara, Claire did not assume teachers intuitively knew how to reflect on student's science ideas. In order to ask teachers to think about student learning, Claire believed that she

needed to model this. Claire felt that the extended amount of time spent in classrooms was imperative to her ability to support teacher learning, because she needed a deep understanding of the classroom context and of student's science ideas. Because she was in the classroom with teachers and working with students (in a supportive teacher role), Claire was able to engage the teachers in authentic, reflective feedback conversations. In essence, Claire modeled to teachers how to listen to student's science ideas and use them to further a conversation.

Claire enacted coaching activities in the same manner that she expected teachers to enact instructional practice because she believed that learning happens when individuals (students and teachers alike) engage in metacognitive reflection. Students similarly learn when participating in conversations about how their science ideas have changed over the course of a unit. Teachers learned new instructional practices when they engaged in conversations reflecting on and re-thinking their own ideas about what supports student learning. For Claire, teachers demonstrated their learning to her when they articulated what they did, why they thought it supported the development of student ideas, and what further development of tools, activity and/or curriculum would be needed to further push these science ideas.

ASSERTION 4: Teacher's interpretations of reform are situated in the context of their work, in classrooms with their own students. Unless they are regularly asked to reflect on the relationships between their changes in practice to the larger principles of the reform vision, there is little that will compel them to do that kind of sense-making.

In this study, we saw how a district attempted to support teachers in learning reform-related instructional practice. The Science Academy embodied most of what research has identified as "best practice" when supporting teacher learning new instructional practice. However, despite participating in a high-quality, job-embedded professional development

program, none of the teachers in the program could initially articulate how their learning was related to NGSS.

The NGSS was built from a vision of classroom science learning that is articulated in the *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (NRC, 2012). However, the NGSS and Framework do not articulate teaching practices. The Ambitious Science Teaching Framework is a core set of instructional practices that support teachers in learning to plan and enact instructional practice that is aligned with the big-picture goals of the NGSS and *A Framework for K-12 Science Education*. The AST framework is a vehicle that allows teachers to inquire into their primary instructional tools (i.e. curriculum) and instructional strategies (e.g. supporting the development of student talk using disciplinary practices, etc.) to help all students construct and revise evidence-based explanations for why natural science phenomena occur. The teachers in this study were capable and comfortable (for the most part) with trying out the new reform-related practices and instructional tools. These teachers knew that they were attempting instructional practice that fostered the development of a more student-centered and student-engaged learning environment where students were trying to inquire deeply about how and why certain science phenomena happen. They experimented with Ambitious Science Teaching—every individual. When asked about why they were using particular instructional strategies or using instructional tools, all of them articulated responses that were implicitly aligned to the big-picture vision for science instruction articulated in the Framework.

However, when teachers were specifically asked throughout the year how their new instructional practices and curricular tools were supporting them in implementing the NGSS, none of them seemed to know. Teachers reported hearing about the standards, but they did not

have a conceptual understanding about what NGSS was or how the reform was related to their instructional practice. Even though these teachers attempted to enact reform-related practice they did not necessarily know how what they were doing was part of the reform program. This finding suggests a bigger question: *Why is it that teachers participating in a high-quality professional development program, aligned to a reform, can't readily articulate the nature of the reform underlying this work?* One possible explanation relates to the nature of the Next Generation Science Standards. The NGSS can appear as content standards. The Framework can appear to articulate a vision merely for which content students should learn and why. Neither policy document articulates what teachers' instructional practices should be. The image of instruction in the Framework is several layers removed from the reality of classroom practice. Neither document suggests to teachers what they are supposed to do differently to create a new kind of science learning environment.

The teachers in this study initially learned about reform in the context of how it impacted their day-to-day work with students, rather than at the level of generalizations about practice that may be part of reform rhetoric. When teachers were learning about new pedagogical approaches, they were not trying to make sense out of the reform as an abstraction. They were trying to make sense of implementation and of what instructional coaches were telling them to do with students. Teachers are rarely asked to step back from the organized chaos of practice and make sense of reforms in broad, generalizable ways. The teachers in the Science Academy were focused on learning a core set of high-leverage instructional practices that encompassed most of what we know that supports students learning science. While learning to use new instructional moves set a foundation for developing the kind of classroom environment depicted in the Framework

document, it did not mean that teachers needed to understand the NGSS as a system of new ideas or be able to articulate the role of the standards for changing practices in meaningful ways.

Conclusion

Instructional coaches are influential actors in school systems when supporting the implementation of large-scale standards-based reforms. In their role, they frequently mediate between high-level rhetorical messages of reform and the actual working lives of the teachers who implement the reform. Coaches develop multiple interpretive lenses that operate together when making sense out of new reform messages. They then re-represent reform to teachers, emphasizing certain parts of it, creating tools consistent with that vision, and taking up particular practices for professional learning. The literature is clear about sense-making frameworks being important to teacher interpretation of reform, but there has been little about sense-making frames that coaches bring to their work. Understanding how varying interpretations of reform in teacher classroom practice appears rooted in the intersection of teacher and coach sense-making frames during professional learning.

I acknowledge that there are many factors at work within the system that can influence teacher and coach decision-making about practice (e.g. time pressures, familiarity with content, messages from principals, existing school-level initiatives, prior experiences by teachers and enduring instructional habits—productive or unproductive.). Additionally, observing teacher practice for one year may not be a long enough time frame to see sustained shifts in teacher practice as a result of coaching experience. I also acknowledge that this study only looked at two coaches, whose coaching role was primarily devoted to working with teachers in the classroom. I acknowledge that not all coaches have their time devoted to the kind of work that Sara and Claire were doing and limit any claims about the relationship between coaches and teachers to coaches

who are dedicated to working at least half-time with teachers. Rather than making generalizable statements about all coaches, this study attempts to generalize to a workable theory of how reforms translate to action in classrooms. A major question that arises from this study is, what are the opportunities for coaches' learning? We cannot assume, naively, that they will simply learn on the job. Teachers and coaches can both gain experience on the job. However, if reform asks both of these groups to teach in ways that are not traditionally a part of every-day practice, then other kinds of learning experiences have to be put into play. For example, there could be a professional learning community among coaches in districts where they examine practice, their work with teachers, and even student outcomes. It seems important that districts or educational service providers should focus part of their work on supporting instructional coach learning of the practices that make them so instrumental in advancing classroom teaching.

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Appendix A

Teacher Sense-making and Perceptions Observational Rubric

	1	2	3	4
Conversations about Science	Science is an unproblematic method for finding out about the world. Science skills such as systematic procedures and data collection techniques are of central importance.	Science is a well-known body of knowledge that is codified in texts and experts. Scientific knowledge takes the form of facts and assertions.	Science is a complex set of ideas that explain phenomena. Ideas are well-known and accepted by those in the science community. Ideas may not be self-evident for novice observers.	Science is problematic and under construction. Science happens by building, evaluating, and refining theories and models. Scientific ideas and methods of observation and experimentation can be negotiated.
Conversations about Student Learning	Learning happens through engagement in activities. Engagement in tasks such as “hands on” science and frequent “lab” activities is expected to result in learning.	Learning happens through acquiring and processing information. Learning is demonstrated by reporting information accurately in response to verbal or written questions.	Learning happens through conceptual change from naïve misconceptions to scientifically correct understanding. Learning is aided by guidance from a more knowledgeable person.	Learning happens gradually by building, refining, and testing emerging understandings within a social group. Learning requires sense-making, puzzlement, and reasoning.
Conversations about Classroom Teaching	Teachers support student work through science activities and scientific methods. Teaching is about organizing activities and keeping students “on task.”	Teachers provide access to information through texts and media, confirmatory/ discovery activities, and direct instruction. Teaching is about making information accessible and clear.	Teachers pre-assess students’ misconceptions & provide key science activities/ information to help change their understanding. Teaching is about correcting students’ misconceptions and serving as a knowledgeable guide.	Teachers support sense-making through discussions, activities, and “just in time” instruction in response to students’ unfolding ideas. Teaching is about connecting students’ ideas to each other and to additional science ideas.
Conversations about socio-professional culture	Working with other teachers is for polite “sharing” of ideas, resources, and strategies. Talk consists of individual contributions without connecting to other talk.	Working with other teachers is for collaboration and “picking up” additional strategies. Talk consists of linked, generally additive, contributions building off of another person’s talk (usually chains).	Working with other teachers is for comparing, contrasting, evaluating, and critiquing practice. Talk consists of linked, sometimes argumentative, contributions creating “webs” of interactions. Disagreements are seen as acceptable and sometimes necessary.	Working with other teachers is for critiquing, analyzing, and improving practice. Talk consists of questions, counter-arguments, or alternate interpretations in “webs” of interactions. Arguments seen as productive opportunities launching future teaching experiments.

Appendix B

Teacher Practice Classroom Observation Rubric

	1	2	3	4
1. Big Ideas	**Focus on topic or "things"** Teacher selects concrete or abstract entities (things) to learn about in varying degrees of detail. Students asked to describe, name, label, identify, using correct vocabulary.	**Focus on observable processes** Teacher selects as focus "what is changing" in a system or how conditions affect a naturally occurring event.	**Explanatory model focus** Teacher focuses on *unobservable* processes, events, or entities, or the relationships among science concepts. Teacher links these to important *observable* natural phenomena in order to develop an explanatory model that students will make sense of over time.	
2. Attending to Student's Ideas	**Monitoring and re-teaching ideas** Teacher starts by presenting information, then monitors language students use to see if students are developing "correct" conceptions (whether students "get it" or not). Teacher engages in 1-on-1 tutoring or uses IRE in whole class conversations to present more correct conceptions to students (perhaps using a different modality).	**Eliciting students' initial & unfolding understandings** Teacher elicits students' initial and on-going hypotheses, questions, or conceptual frameworks about a scientific idea.	**Referencing students' ideas & adapts instruction** Teacher elicits students' initial conceptions of a scientific idea by posing a rich open-ended task or puzzling event related to the big idea of the unit. Teacher listens for partial understandings as well as alternative conceptions (without presuming students need to precisely replicate the teacher's line of thinking). Teacher uses students' language and partial understandings as building blocks to shape the direction of classroom conversations. Teachers engineer productive classroom conversations or pursue students' lines of thinking by weaving students' lines of reasoning together with scientifically coherent ideas across multiple lessons.	
3. Choosing activities and framing intellectual work	**Primarily focusing on procedure** Teacher asks students to describe procedures for activities or experimental set-ups. Science concepts are played down to allow time to talk about designing experiments. Talk with students is about how to do an activity or about error, validity, reliability, recording data.	**Discovering or Confirming Science Ideas** Teacher has students "discover" science concepts for themselves OR has students use an activity as a "proof of concept." Science is about acquiring accepted facts, principles, or laws. Students collect information to recognize or prove patterns.	**Linking concepts within and across investigations** Teacher first seeds students' thinking with new science concepts (not explanations) and asks students to use these ideas to makes sense of an investigation. Science ideas are up for discussion. Students derive explanatory language from activity and use it to solve new problems. Public representations of students' ideas change in response to findings from each day.	**Model-Based Inquiry focus** Teacher highlights tentative or partial explanatory models as the basis for multiple investigations. Teacher asks students to use evolving model as a reference before, during and after each inquiry. Teacher builds in background knowledge of underlying (unobservable) science ideas and models before, during, and following an inquiry, but without doing the reasoning for the students. Science is about revising and testing models to synthesize ideas and explain problems.
4. Pressing for Explanation	**No press for a scientific explanation** Teacher does not ask students to provide any form of explanation; or teacher uses "explain" to mean "justify" as in justify the existence of an entity or accepted fact. There is no event or process that is subject to explanation.	**"What happened" explanation** Teacher asks students to describe relationships between variables, differences between experimental groups, trends over time, or qualitative observations. "Explain what you see in the data."	**"How/ partial why" something happened explanation** Teacher asks students to hypothesize about reasons for relationships among variables or observations, and how these predict the ways some natural system will behave.	**Causal explanation** Teacher has students use unobservable events, processes, and entities to construct a causal story of why something happened. (may mean first supporting students through "what" and "how explanations" with goal of working toward "why explanations") Teacher unpacks learning about the nature of scientific explanations with students, and about "what counts" as evidence.

Appendix C

Teacher Interview Protocol #1

Interview Questions:

1) Tell me a little about how you became/decided to become a teacher?
2) What is important to you in your classroom about science instruction?
3) Could you draw a diagram and explain the network in which you operate your job as a teacher?
    - Who do you work with? Teachers? Administrators? Coaches?
    - Who do you regularly interact with?
    - Who do you collaborate with?
    - Who do you share information with? What kind of information do you share?
4) What problems do you think the NGSS will solve in science education?
    - What are the key messages that you've heard about the NGSS?
    - Who gives you these messages?
5) Could you describe to me what science instruction looks like in your classroom? What do the NGSS look like in your classroom?

Appendix D

Teacher Interview Protocol #2

Interview Questions:

1. How do you think your practice has changed this year?
    - What has become routine in their classrooms this year either in terms of tools or routines that they use?
    - What do you think has influenced these changes?
2. Were there certain aspects about your practice that you tried to work on and felt you were not successful at?
    - Could you define what you think successful is? Looks like?
3. What parts of the Science Academy were most valuable to your learning (summer institute, studio days, after school PD, in classroom coaching)?
    - Why?
4. What challenges/problems did you run in to over the course of the year?
    - Were there other challenges/problems in your school that impacted what you were trying to do in your classroom? (i.e. your principal?)
5. How do you think this professional development has helped prepare you to address NGSS? In what way?
    - What else do you think you need to learn about the NGSS?

Appendix E

Individual Semi-structured Lesson Debrief Interview

INDIVIDUAL DEBRIEF: Teachers can choose to do lesson debriefs individually (one-on-one) with researchers or in groups. If the teacher chooses to do lesson debriefs individually, the following questions will be used. The Individual Debrief will be recorded.

Purpose: This interview is designed to uncover teacher's moment-to-moment decision-making process during attempts at responsive science discourse.
Frequency: This lesson debrief semi-structured interview will last between 30-45 minutes for each participant after each science lesson observation (6-8 observations per school year). Video clips from the video-recorded lesson and copies of student work will be used as artifacts for the interview.
Questions posed to teachers about lesson: Our debrief session today will be focused around science talk, what opportunities students had to talk and if or how these were used by students or not.
General Reflection:

1. So how did today's science lesson go? Tell me about how it went for you and the students.
2. How do you think students engaged with the related NGSS? (Read NGSS identified in curriculum guide or lesson plan.)

Student Role:

1. How was student participation similar or different to what you intended or predicted in your lesson planning?
2. Please describe something noteworthy, interesting, or surprising that students said during today's science talk Prompt: Is there a particular moment today where students said something that surprised you? How did you respond to the students' contribution? Is there a particular moment today where students participated and it aligned or fulfilled your intent for the lesson? What were you listening for? How did you react to their participation?
3. What did science ideas did you hear today from students? Prompt (I also observed lesson so I can use examples): So when Jim said X, I thought he might be thinking about Y, what did you notice about Jim or other's ideas about Y?

Teacher role:

1. I've selected some brief clips from today's lessons. As we watch, I'd like to hear about what you were thinking in the moments when you were listening to students' contributions. Feel free to stop and replay parts and tell me what you were thinking about.
2. Based on this exchange, what do these students think about the subject matter? How does this relate to NGSS identified in the curriculum guide?
3. How do you think the way you responded influenced the thread of science talk? What happened after this exchange? (Watch video if necessary)

Teacher Learning:

1. What is one thing you can take away from our talk today to influence future teaching?

Appendix F

Coach Interview Protocol #1

Interview Questions

1. What are the key messages about the NGSS? Where/who gives you these messages?
   - From the district? Other administrators? State? Other?
   - Could you describe to me what your goals are as a principal/coach in the context of these messages?

2. What problems do you think the NGSS will solve in science education?
   - Will it solve something in teacher practice? Student learning?

3. What is important to your school/district around science instruction?
   - Instruction? Raising test scores? Uniform instruction? Teacher autonomy?

4. Could you describe to me an example of a teacher that you know or work with who exemplifies "best practices" in science teaching?
   - If you can't identify one specific teacher, what are some "best practices" that you have seen in the field of teachers that you work with?
   - How do these "best practices" relate to what is required by the NGSS?

5. Could you describe any concerns that you have about implementing the NGSS?
   - Implementing concerns? Evaluation concerns? Planning concerns?

6. What sorts of supports will teachers need to implement the NGSS? What support will you be able to provide to these teachers?
   - Could you describe an example of how you would support a teacher?

Appendix G

Coach Interview Protocol #2

Interview Questions

1. How did you work with teachers throughout the year?
    - What was your focus?
    - What did you want teachers to learn? Pay attention to?
2. What do you think teachers in the Science Academy learned this year?
    - How do you think they learned it?
    - Is there anything from your experiences with teachers this year that help you understand how teachers learn to "shift their practice"?
    - What do you think helped teachers learn to shift practice?
    - What changes did you see in teacher practice over the course of the year?
        - Evidence?
3. How are the Science Academy Teachers leaders of NGSS?
    - How do you envision using them/positioning them as leaders? What does that mean?
4. What does Ambitious Science Teaching have to do with NGSS?
    - What opportunities did you give teachers to learn about NGSS?
        - What were you trying to focus their learning about NGSS on?
    - Ex: I noticed in some of the PD, you used the same slides to introduce or talk to teachers about NGSS. How do you think teachers were learning about NGSS in those instances?
5. What challenges/problems did you run in to over the course of the year?
    - Were there challenges/problems in your district or in schools that influenced how you interacting with teachers?
6. For Sara: Earlier in the year, you told me that you didn't think teachers should write curriculum—that you didn't think they were qualified to do so. Do you still think that? Why? Why not?

VITA
Kat Laxton

EDUCATION

2011-2016 Doctor of Philosophy, College of Education, Curriculum & Instruction, Science Education, University of Washington, Seattle, Washington

Dissertation:
Implementing the NGSS: How Instructional Coaches Mediate New Standards-Based Educational Reform to Teacher Practice

Committee Members: Mark Windschitl (Chair), Ken Zeichner, Meredith Honig, Michael Blake

2004-2005 Master of Education, Science Education, Louisiana State University
Baton Rouge, LA
Concentration: Earth Science

2000-2004 Bachelor of Science, Elementary Education, Louisiana State University
Baton Rouge, LA

AWARDS, HONORS, & GRANTS

2015-Present Math-Science Partnership Grant
Applied for and was awarded full funding to design and manage the Partnership for Ambitious Science Teacher Leaders.

2013 CADRE Fellowship
CADRE is a network for STEM education researchers funded by the National Science Foundation's Discovery Research K-12 program. I was awarded participation in this highly selective group of early career researchers and developers in STEM education research to gain exposure to and collaborate with STEM education research across the United States.

2011-2014 Doctoral Scholarship to the University of Washington
Awarded full tuition funding for Ph.D. by the University of Washington College of Education

2010 Evolution in the Fossil Record
Awarded funding and participation in a summer workshop to learn in-depth content knowledge about relationships between genetics and paleontology in evolution

2010 Iceland GeoVentures Series: Plate Tectonics Live
Awarded travel grant from The Kinkaid Foundation to participate in a field study

of plate tectonics, geothermal energy and geology in Iceland.

2008 Houston Heights Association Science Grant
Applied for and was awarded classroom money to support instruction

2000-2004 Undergraduate Scholarship to Louisiana State University
Awarded out-of-state tuition waver due to maintaining academic excellence.

PUBLICATIONS

Refereed journals

Thompson, J., Hagenah, S., Lohwasser, K. & Laxton, K. (2015) Problems without ceilings: Mentoring communities' engagement around ambitious and equitable teaching and learning. (Under review, *Journal of Teacher Education*).

PRESENTATIONS

(*invited)

Colley, C. and Laxton, K. (2013). *Learning, developing and sustaining ambitious and equitable science teaching practice.* Presented at the annual Teaching and Learning Symposium at the University of Washington, Seattle, WA.

*Laxton, K. (2015). *Understanding policy implementation: Making sense of the Next Generation Science Standards*. Structured poster session at the annual meeting of NARST, Chicago, IL.

Laxton, K. (2013). *Tools to teach novice teaches ambitious teaching practices*. Presented at the annual meeting of CADRE Fellows, Boston, MA.

Thompson, J., Hagenah, S., Lohwasser, K. & Laxton, K. (2014). *Problems without ceilings: mentoring communities' engagement around ambitious and equitable teaching and learning.* Structured poster session conducted at the annual meeting of the American Educational Research Association, Vancouver, Canada.

PROFESSIONAL EXPERIENCE

2014 – Present Regional Science Coordinator & K-12 Science Program Manager
Puget Sound Educational Service District
Renton, WA

2011-2014 Teaching Assistant, College of Education, University of Washington

2011-2014 STEP Content Coach, School of Education, University of Washington

2008-2011	Science Teacher, The Kinkaid School, Houston, TX Taught 6th & 7th Grade Integrated Science Cross Country & Swimming Coach
2007-2008	Science Teacher, Alexander Hamilton Middle School Houston Independent School District, Houston, TX 8th Grade Integrated Science
2005-2007	Science Teacher, Two Rivers Middle School Metro Nashville Public Schools, Nashville, TN 7th Grade Integrated Science Science Department Chair Founder of Outdoor Adventure Science Club
Spring 2005	Student Teacher, Broadmoor Elementary School Baton Rouge School District, Baton Rouge, LA 1st Grade
Fall 2004	Student Teacher, Sherwood Middle School Baton Rouge School District, Baton Rouge, LA 6th & 8th Grade Integrated Science
Spring 2004	Student Teacher, McKinley Middle Magnet School Baton Rouge School District, Baton Rouge, LA 7th Grade Science and Math
Fall 2003	Student Teacher, Highland Elementary School Baton Rouge School District, Baton Rouge, LA 4th Grade
Spring 2003	Math Tutor, Nicholson Elementary School Baton Rouge School District, Baton Rouge, LA 2nd Grade
Spring 2002	Teaching Assistant, School for the Visual and Performing Arts Baton Rouge School District, Baton Rouge, LA 2nd Grade